STATUS OF WETLANDS IN BANGALORE

REFERENCE

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PREFACE

Wetlands are among the most productive and biologically diverse but very fragile ecosystems They are vulnerable to even small changes in their biotic and abiotic factors In recent years, there has been concern over the continuous degradation of wetlands due to shortsighted developmental activities. The principle objective of the book is to provide the present status of wetlands and strategies for their conservation The first section gives an overview of the status of wetlands

One of the important benefits provided by wetlands in improving water quality is by filtering sediments and nutrients from surface water. Wetlands act as natural purification mechanisms, enhancing the water quality in the vicinity Swamps and marshes are particularly good at filtering sediments and nutrients, which are the major causes for wetland degradation Wetland vegetation plays a major role in removing 90% of dissolved nutrients such as nitrogen and phosphorus and to some extent heavy metals In addition to functioning as a purification mechanism, they also play a valuable role in reducing turbidity of floodwaters (as runoff and surface water passes through, wetlands remove or transform pollutants through physical, chemical, and biological processes)

In this report, we discuss these aspects and strategies for monitoring, which include physical, chemical and biological aspects Commonly monitored parameters have been discussed in detail, which include the detailed methodology for analysing various physico-chemical and biological (plankton, fish, avifauna, macroinvertebrates) parameters The methods adapted for characterisation of wetlands are illustrated with case studies This helps in evolving overall strategies for characterisation of wetlands.

REFERENCE

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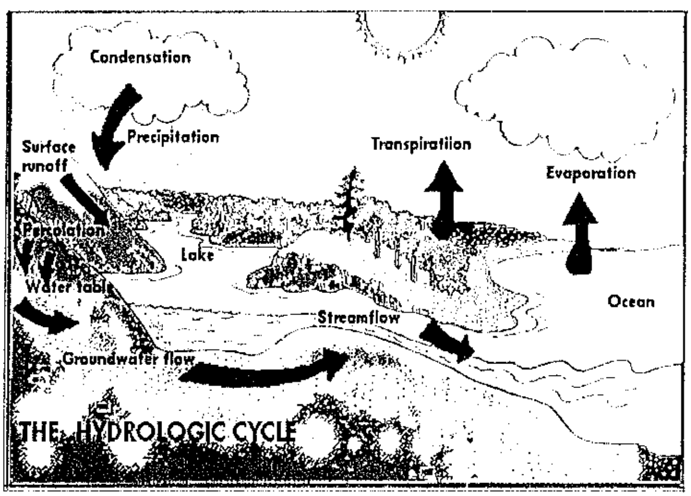
STATUS OF WETLANDS IN BANGALORE

Wetlands are one of the most productive ecosystems, comparable to tropical evergreen forests in the biosphere and play a significant role in the ecological sustainability of a region They are an essential part of human civilisation meeting many crucial needs for life on earth such as drinking water, protein production, water purification, energy, fodder, biodiversity, flood storage, transport, recreation, research-education, sinks and climate stabilisers The values of wetlands though overlapping, like the cultural, economic and ecological factors, are inseparable. The geomorphological, climatic, hydrological and biotic diversity across continents has contributed to wetland diversity Across the globe, they are getting extinct due to manifold reasons, including anthropogenic and natural processes Burgeoning population, intensified human activity, unplanned development, absence of management structure, lack of proper legislation, and lack of awareness about the vital role played by these ecosystems (functions, values, etc) are the important causes that have contributed to their decline and extinction With these, wetlands are permanently destroyed and lose any potential for rehabilitation This has led to ecological disasters in some areas, in the form of large-scale devastations due to floods, etc.

Figure 1: The Hydrological Cycle



The hydrological cycle (Fig 1) is one of the key elements in the aquatic environment Water (moisture) constantly revolves between the ocean, sky, land and the ocean again Water in the oceans evaporates into the atmosphere, and falls back on the earth as precipitation, some of which after wetting the foliage and ground, run off over the surface to lakes and rivers Excess water causes floods and erosion. Precipitation that soaks into the ground is available for growing plants and evaporation It also reaches the deeper zones and slowly percolates and seeps out to maintain the water level in the streams during dry periods. The global water cycle unifies the subsystems consisting of state variables (precipitable water, soil moisture, etc) and fluxes (precipitation, evaporation, etc.).

Wetland ecosystems depend on constant, recurrent or shallow inundation at or near the surface of the substrate and characterise the presence of physical, chemical, and biological features (grade continuously from aquatic to terrestrial), identified by hydric soils and hydrophytic vegetation Water, modified substrate and distinct biota thus are the essential constituents of these ecosystems

Wetlands form the transitional zone between land and water, where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in and on it (Cowardian et al., 1979). They are usually formed in the depressions (subjected to flooding) and groundwater seeps Wetland type is determined primarily by local hydrology and the unique pattern of water flow through an area In general, there are two broad categories of wetlands: coastal and inland Enhanced appreciation of wetlands in the recent past has led to the signing of many international agreements for protecting them, among which the Ramsar convention is the most important

The Ramsar Convention on Wetland[1] in 1971, in Iran, (http://www.ramsar.org) characterised wetlands as

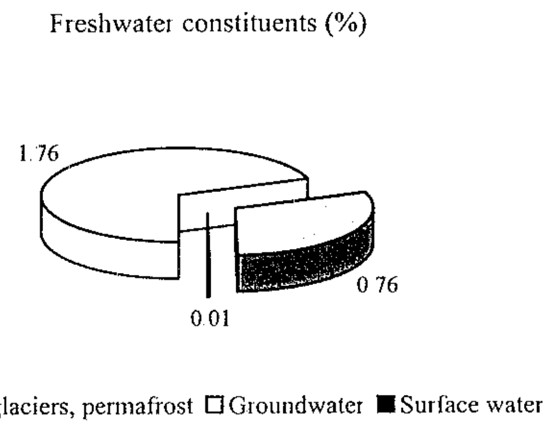
> '... *areas of marsh, fen, peatland, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt including areas of marine water the depth of which at low tide does not exceed six meters* '

In addition, the Convention (Article 2 1) proposes that wetlands:

> "may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands "

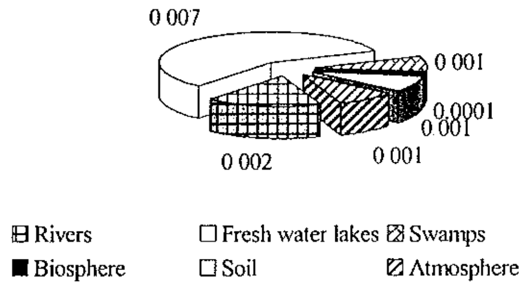
As a result of these provisions, the coverage of the Convention extends to a wide variety of habitat types, including rivers and lakes, coastal lagoons, mangroves, peatlands, coral reefs and man made wetlands (such as fish and shrimp ponds, farm ponds, irrigated agricultural land, salt pans, reservoirs, gravel pits, sewage farms, and canals)

Figure 2: Graph showing water distribution on earth

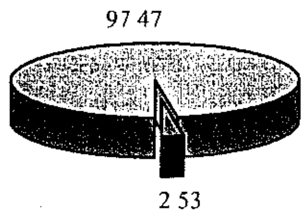


[1] Mission Statement: 'The Convention's mission is the conservation and wise use of wetlands by national action and international cooperation as a means to achieving sustainable development throughout the world' (Brisbane. 1996) (http://ramsar.org)
The Ramsar Convention is an intergovernmental treaty, which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources There are presently 127 contracting parties to the Convention, with 1085 wetland sites totaling 82 2 million hectares, designated for inclusion in the Ramsar List of Wetlands of international importance

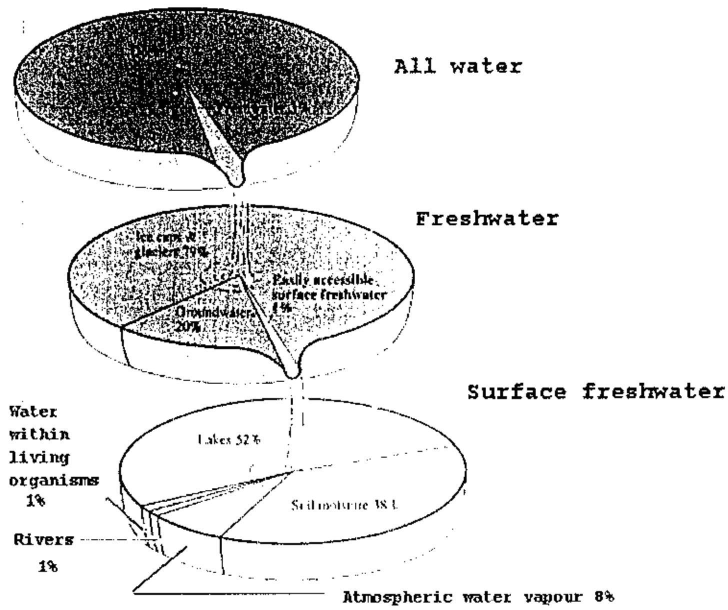
Surface water constituents (%)



Distribution of World Water



Distribution of World's Water



Two-thirds of the earth is surrounded by water and appears blue (the planet of water) from space (UNEP, 1994). Lakes and rivers, the most important freshwater resources, account for 2.53% of the total water found on earth (Figure 2) Of the total water in the hydrosphere (4 x 10^8 cubic kilometres), 97 5% is deposited in the oceans that cover 71% of the earth's surface. Wetlands are estimated to occupy nearly 6 4% of the earth's surface, 30% of which is made up of bogs, 26% fens, 20% swamps, about 15% flood plains, etc (IUCN, 1999). The amount of fresh water on earth is very small compared to seawater, of which 69 6% is locked away in the continental ice, 30 1% in underground aquifers, and 0 26% in rivers and lakes. Lakes in particular occupy less than 0 007% of the world's fresh water. The distribution of the world water resources compiled from various sources is listed in Table 1 and the continent wise distribution of fresh water resources is listed in Table 2 (UNEP 1994).

Table 1: Distribution of world water resources

Water resource	Area (million sq. km)	Volume (million cu. km)	% total water	% fresh water
Ocean	361	1338	97 47	
Fresh water	-	35	2 53	
Ice	16	24	1 76	69 1390
Ground water	-	10 5	0 76	30 0710
Wetlands (marshes, swamps, lagoons, flood plains, etc ,)	2 6	0 1	0 0001	0 0039
Lakes (excluding saline lakes)	1 5	0 09	0.007	0 2769
Rivers	--	0.02	0.0002	0.0079

Table 2: Distribution of fresh water resources by continents

Fresh water type	Africa	Europe	Asia	Australia	North America	South America
Lakes*	30,000	2,027	27,782	154	25,623	913
Rivers*	195	80	565	25	250	1,000
Reservoirs*	1,240	422	1,350	38	950	286
Ground water*	5,500,000	1,600,000	7,800,000	1,200,000	4,300,000	3,000,000
Wetlands**	341,000	-	925,000	4,000	180,000	1,232,000

* Refers to volume in cu. km.

** Refers to sq km.

Wetlands with a share of 0 0001 % among the global water sources include swamps, marshes, bogs and similar areas and are an important and vital component of the ecosystem (IUCN, 1996) A wide variety of wetlands exist across the continents because of regional and local differences in hydrology, vegetation, water chemistry, soils, topography, climate and other factors. At the earth's surface, fresh water forms the habitat of large number of species These aquatic organisms and the ecosystem they live in represent a substantial sector of the earth's biological diversity.

FUNCTIONS OF WETLANDS:

The various beneficial functions of wetlands like sustaining life processes, water storage (domestic, agricultural and industrial usage), protection from storms and floods, recharge of ground water, water purification, storehouse for nutrients, erosion control and stabilisation of local climate (such as temperature and rainfall), help maintain the ecological balance.

FLOOD STORAGE:
In their natural condition, most wetlands store floodwaters temporarily, protecting downstream areas from flooding. By checking the floods, they maintain a constant flow regime downstream, preserve water quality and increase the biological productivity of the aquatic communities. This function becomes increasingly important in urban areas, where developmental activities (such as breaching of wetlands for residential, commercial, and industrial activities, paving of surfaces in catchment areas, etc) have increased the rate and volume of surface water run-off and the potential for flood damage. This necessitates the protection of wetlands, an important means of minimising flood damages in the future.

GROUND WATER RECHARGE:
Periodically inundated wetlands are very effective in storing rainwater and have innate capacity to recharge the ground waters. Ground water recharge occurs through mineral soils found primarily around the edges of wetlands The extent of groundwater recharge depends on the type of soil and its permeability, vegetation, sediment accumulation in the lakebed, surface area to volume ratio and water table gradient.

WATER SUPPLY:
Wetlands have a tremendous ability to meet the water requirement in the surrounding areas. Natural wetlands are underlain by aquifers with a high potential for water supply

SHORELINE STABILISATION AND EROSION CONTROL:
Wetland vegetation can reduce shoreline erosion in several ways, including –

- Increasing durability of the sediment through binding (with stilt / plank root structure)
- Dampening waves through friction
- Reducing current velocity through friction, improving water quality.

Coastal wetlands particularly mangroves help in shoreline stabilisation and storm protection by dissipating the force by reducing the damage of wind and wave action

WATER QUALITY:
Wetlands play an important role in improving the water quality by filtering sediments and nutrients from surface water Aquatic vegetation helps in removing 90% of the dissolved nutrients like nitrogen and phosphorus and also in adsorption of heavy metals. Dissolved materials may be retained in wetlands and the water quality may vary seasonally or from year to year Removal of sediment load is also valuable because sediments often transport absorbed nutrients, pesticides, heavy metals and other toxins that pollute the water.

NUTRIENT CYCLING:
Wetlands, transition zones between land and water are efficient in filtering sediments They can intercept run-off from land before it reaches the water and help in filtering nutrients, wastes and sediments from floodwaters In certain wetlands, plants are so efficient in removing wastes that artificial wastewater treatment systems use aquatic plants for the removal of pollutants from water. Wetlands remove nutrients (especially nitrogen and phosphorus), particulates and total biological oxygen demand from flooding waters for plant growth and help prevent eutrophication or over-enrichment of other forms of natural waters (Nixon & Lee, 1986). However, overloading a wetland with nutrients, beyond its threshold, impairs its ability to perform basic functions

ECOLOGICAL BENEFITS:
Wetlands being one of the most biologically productive natural ecosystems are vital for the survival of diverse flora and fauna, including many threatened and endangered species by providing shelter, food, etc , and forming a part of the complex food-web It is estimated (Wetlands in Asia, 1997) that about 20% of the known species of life rely directly or indirectly on wetlands for their survival, as they are their primary and important seasonal habitats.

WETLAND PRODUCTS:
Wetland products include fish, timber, housing materials such as reeds, medicinal plants, the provision of fertile land for agriculture (sediments), water supply for domestic, arable, pastoral or industrial purposes, energy resource (fuelwood, etc), transport, recreation, tourism, etc By supporting diverse human activities, large wetlands play a particularly important role in the subsistence and development of thousands of people

In economic terms, these could be categorised into direct and indirect benefits

- Direct economic benefits include water supply, fisheries, agriculture, energy resource, wildlife resource, transport, recreation and tourism, supporting a vast diversity of flora, fauna and cultural heritage.
- Indirect benefits are improved water quality (including drinking water) by intercepting surface runoff and removing or retaining its nutrients, processing organic wastes, reducing sediment before it reaches open water, and cultural aspects.

THREATS AND LOSS OF WETLANDS:

Wetlands represent dynamic natural environments that are subjected to both human and natural forces Natural events influencing wetlands include rising sea level, natural succession, hydrologic cycle, sedimentation, and erosion. The rise in sea level, for example, both increases and decreases the wetland's spatial extent depending on local factors.

Wetlands are under increasing stress due to the rapidly growing population, technological development, urbanisation and economic growth. Additional pressures on wetlands from natural causes like subsidence, drought, hurricanes, erosion etc., and human threats coming from over exploitation, encroachment, reclamation of vast wetland areas for agriculture, commercial and residential development, and silviculture have altered the rate and nature of wetland functions particularly in the last few decades. The primary pollutants causing degradation are sediments, nutrients, pesticides, salinity, heavy metals, weeds, low dissolved oxygen, pH and selenium (USEPA, 1994)

Wetland loss may be defined as "the loss of wetland area, due to conversion of wetland to non-wetland areas as a result of human activity" and wetland degradation is "the impairment of wetland functions as a result of human activity". About 50 % of the world's wetlands have been lost in the last century, primarily through drainage for agriculture, urban development and water system regulations. It has been estimated that nearly one hectare of the world's wetlands is getting degraded at the tick of every minute of the clock (Narayanan, 1992).

Wetlands have been degraded and lost in ways that are not as obvious as direct physical destruction or degradation. Other threats include chemical contamination, excess nutrients, and sediment from air and water. On a global scale, climate change could also affect wetlands through increased air temperature; shifts in precipitation; increased frequency of storms, droughts, and floods; increased atmospheric carbon dioxide concentration; and sea level rise (Table 3) The loss of wetlands can be mainly attributed to natural and anthropogenic activities.

Table 3: Contribution of various sectors to pollution of wetlands

Anthropogenic Activities	**Industrial**	**Domestic**	**Agriculture**	**Urbanization**
Discharges to Wetlands	✓	✓	✓	✓
Non-point Source Pollution	✓	✓	✓	✓
Air pollutants	✓	X	X	✓
Toxic chemicals	✓	✓	✓	X
Deposition of fills material	✓	✓	✓	✓
Construction	X	✓	X	✓
Tilling for crop production	X	X	✓	X
Pest species of plants and animals	X	✓	✓	X
Siltation	✓	✓	✓	✓
Changing nutrient levels	✓	✓	✓	X
Tourism and recreational activities	X	X	X	✓
Water regime and physical modification	✓	✓	✓	✓

Apart from pollution, the other major problems include hydrologic manipulations of wetlands in the form of flow alterations and diversions, disposal of dredged or fill material, sewage inflows, and construction of levees or dykes leading to alterations in:

- Water currents, erosion or sedimentation patterns;
- Natural water temperature variations;
- Chemical, nutrient and dissolved oxygen regime of the wetland;
- Normal movement of aquatic fauna;
- pH of the wetland; and
- Normal water levels or elevations.

All of these impacts affect the wetland quality, species composition and functions.

Some activities do however create wetlands Construction of farm ponds and in some cases, reservoirs and irrigation projects may increase wetland spatial extent, although valuable natural wetlands may be destroyed in the process

Wetlands near urban centres are under increasing developmental pressure for residential, industrial and commercial facilities. Increasing population and economic growth create high demand for real estate in sub-urban localities. As suitable upland becomes exhausted, pressure intensifies to develop wetlands for residential housing, manufacturing plants, business office complexes and similar uses. They are often the final refuge for wildlife in an increasing urban environment and support many upland animals displaced by development With accelerating development of adjacent uplands, the role of urban wetlands in flood protection and water quality maintenance becomes critical. Urban and industrial development increases the amount of surface water run-off from the land after rainfall. This raises flood heights and increases the flow rate of rivers, increasing the risks of flood damage. Increased run-off brings with it various substances that degrade water quality, such as fertiliser chemicals, grease and oil, road salt, sediment, etc. Effluents from some sewage treatment plants built to handle the needs of growing communities also reduce water quality. But, passing through wetlands, cleansing action takes place as many pollutants are removed, retained or utilised by the wetlands Urban wetlands in certain instances function as recharge areas. This is especially true in communities where ground water withdrawals are heavy. Thus, urban wetlands are essential for preserving public water supplies

In many cases, they represent the last large tracts of open land and are vulnerable to development for several reasons including the following:

- Increased population in metropolitan areas has raised land values and demand for real estate
- Interstate highways have improved access to many areas, which has increased development opportunities.
- Wetlands may be zoned for light industry or residential housing by local governments.
- The lack of any comprehensive wetland protection policy measures for inland wetlands in most states

CONSEQUENCES OF LOSING OR DEGRADING WETLANDS:

The dominant features underlying wetland loss are population growth and subsequent anthropogenic developmental activities, which impose great pressure on water resources. Lack of appreciation of wetland values, their products, functions and attributes has led to conversion of wetlands for other purposes

The unsustainable use of wetland resources may be considered to be a combination of information, market and policy or intervention failures. The information failure refers to the widespread lack of appreciation of the economic values of conserved wetlands The market failure is the external problem whereby wetlands are damaged by economic activities without accounting for direct and indirect benefits of these ecosystems

The loss or degradation of wetlands can lead to serious consequences, including increased flooding; species decline, deformity, or extinction; and decline in water quality. These losses, as well as degradation, have resulted in greatly diminishing the wetland resources across all continents of which the loss of fish diversity is conspicuous Besides, wetlands are also important as a genetic reservoir for various species of plants including rice, which is a staple food for $3/4^{th}$ of the world's population The spatial loss of wetlands means broader ramifications to life on earth through loss in food chain links

The quality of water flowing into wetlands may be impaired indirectly, by alterations to the water regime or by different types of polluting activities. Pollution of inland waters is mainly due to the discharge of domestic sewage, industrial wastewaters and agricultural operations Pollution can be classified as point source (emanating from an identifiable source) or non-point pollution (emanating from a diffuse source). The wastewater coming from point sources are easier to treat than that from non-point sources The effects of diffuse pollutants are cumulative and can adversely affect wetlands even at some distance Lower water quality results in degradation or destruction of wetlands.

Decline in wetland quality results in increased undesirable growth of weeds and algal blooms. When these algal blooms decompose, large amounts of oxygen are used up, depriving fish and other aquatic organisms of oxygen resulting in their death

The extraordinary productivity of water ecosystems means that many different stakeholders or users have easy access to and use of wetland resources The overexploitation of these resources entails intense cropping, overgrazing, over fishing and excess hunting pressure The cumulative impacts of these activities threaten biodiversity.

Water plays an important role in the development of a country In India, where majority of the population is agrarian, quantity and quality of aquatic resources play a major role in the ecological and economic sustenance of the people

STATUS OF WETLANDS IN INDIA

India is blessed with water resources in the form of numerous rivers and streams. By virtue of its geographical position and varied terrain and climatic zones, it supports a rich diversity of inland and coastal wetlands. Wetlands distributed from the cold arid Trans-Himalayan zone to wet Terai regions of Himalayan foothills and Gangetic plains extend to the floodplains of Brahmaputra and swamps of northeastern India including the saline expanses of Gujarat and Rajasthan. Along the east and west coasts they occur in the deltaic regions to the wet humid zones of Southern peninsula and beyond, to the Andaman and Nicobar and Lakshadweep Islands India also shares several of its wetlands with Ladakh and the Sunderbans deltas with Bangladesh. These wetland systems are directly or indirectly associated with river systems of the Ganges, Brahmaputra, Narmada, Tapti, Godavari, Krishna and Cauvery. Southern peninsular India has very few natural wetlands, although there are a number of man-made water storage reservoirs constructed virtually in every village known as 'tanks' providing water for human needs and nesting sites for a variety of avifauna

DISTRIBUTION OF WETLANDS IN INDIA

India has totally 67,429 wetlands, covering an area of about 4.1 million hectares [Ministry of Environment and Forests (MoEF), 1990] Out of these, 2,175 are natural and 65,254, man made. Wetlands in India (excluding rivers), account for 18 4% of the country's geographic area, of which 70% is under paddy cultivation

A survey conducted by the Ministry of Environment and Forests (MoEF) in 1990 showed that wetlands occupied an estimated 4.1 million hectares of which 1 5 million hectares were natural and 2.6 million hectares manmade (excluding paddy fields, rivers and streams) and mangroves occupying an estimated 0.45 million hectares. About 80% of the mangroves were distributed in the Sunderbans of West Bengal and Andaman and Nicobar Islands, with the rest in the coastal states of Orissa, Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Goa, Maharashtra and Gujarat. According to the *Directory of Asian Wetlands* (1989), wetlands occupy 58.2 million hectares or 18.4% of the country's area (excluding rivers), of which 40 90 million hectares (70%) are under paddy cultivation (Figure 3). A preliminary inventory by the Department of Science and Technology, recorded a total of 1,193 wetlands, covering an area of about 3,904,543 ha, of which 572 were natural (Scott and Pole, 1989). The Directory of Indian Wetlands published by WWF and Asian Wetland Bureau in 1995 records 147 sites as important of which 68 are protected under the National Protected Area Network by the Wildlife Protection Act of 1972. State-wise distribution of wetlands in India (Chatrath, 1992) is given in Table 4

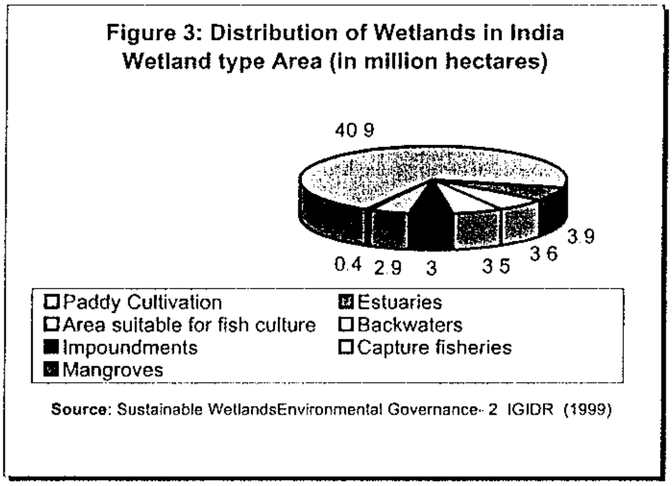


Table 4: Distribution of wetlands in India

Sl.No	State	Natural		Artificial	
		Nos.	Area (ha)	Nos.	Area (ha)
1	Andhra Pradesh	219	1,00,457	19,020	4,25,892
2	Arunachal Pradesh	2	20,200	NA	NA
3	Assam	1394	86,355	NA	NA
4	Bihar	62	2,24,788	33	48,607
5	Goa	3	12,360	NA	NA
6	Gujarat	22	3,94,627	57	1,29,660
7	Haryana	14	2,691	4	1,079
8	Himachal Pradesh	5	702	3	19,165
9	Jammu and Kashmir	18	7,227	NA	21,880
10	Karnataka	10	3,320	22,758	5,39,195
11	Kerala	32	24,329	2,121	2,10,579
12	Madhya Pradesh	8	324	53	1,87,818
13	Maharashtra	49	21,675	1,004	2,79,025
14	Manipur	5	26,600	NA	NA
15	Meghalaya	2	NA	NA	NA
16	Mizoram	3	36	1	1
17	Nagaland	2	210	NA	NA
18	Orissa	20	1,37,022	36	1,48,454
19	Punjab	33	17,085	6	5,391
20	Rajasthan	9	14,027	85	1,00,217
21	Sikkim	42	1,107	2	3
22	Tamil Nadu	31	58,068	20,030	2,01,132
23	Tripura	3	575	1	4,833
24	Uttar Pradesh	125	12,832	28	2,12,470
25	West Bengal	54	2,91,963	9	52,564
	TOTAL	2167	14,58,580	65,251	25,87,965

Sl.No	Union Territories	Natural		Artificial	
		Nos.	Area (ha)	Nos.	Area (ha)
1	Chandigarh	-	-	1	170
2	Pondicherry	3	1,533	2	1,131
	TOTAL	3	1,533	3	1,301
	GRAND TOTAL	**2,170**	**14,60,113**	**65,254**	**25,89,266**

Table 5: Distribution of mangroves in India

Sl No	States / Union Territories	Area in sq. km
1	Andaman and Nicobar Islands	1190
2	West Bengal	4200
3	Orissa	150
4	Andhra Pradesh	200
5	Tamil Nadu	150
6	Karnataka	60
7	Goa	200
8	Gujarat	260
9	Maharashtra	330
	TOTAL	**6,740**

India accounts for 16% of the world's population in 2.42% of the earth's surface. About 74% of human population is rural (HDR, 1999) and subject wetlands to stress from various anthropocentric activities. Human communities in India are closely associated with wetlands since the Indus valley civilization, which flourished along the banks of river Indus. The water bodies and their resources have been an integral part of the social and cultural ethos of human societies. Currently about 170 million people constituting 17% of India's total population in more than 3,800 coastal villages are scattered along the 7,500 km coastline. Communities living close to wetlands follow the natural cycle of floods and adjust to the seasonal movements of the fish and harvest them based on changing water levels. The coastal villages, due to poor resource base and livelihood insecurity force an unsustainable dependence on coastal wetlands and change their characteristics leading to their destruction. Marine fisheries in the Arabian Sea and the Bay of Bengal, export approximately 307,337 tons of fish annually and about two thirds of this export is made up of shrimp (Ministry of Fisheries, 1999). In addition to the various ecological and economic values, wetlands also provide cultural value to societies. Most of the Indian villages are settled around dependable water sources for drinking, etc.

IMPACTS AND STATUS OF WETLANDS IN INDIA

Wetlands have been drained and transformed by anthropogenic activities like unplanned urban and agricultural development, industrial sites, road construction, impoundment, resource extraction, and dredge disposal causing substantial long-term economic and ecological loss. Of the total aerial extent of 58.2 million ha, nearly 40.9 million ha is under paddy cultivation. About 3.6 million ha is suitable for fish culture, while approximately 2.9 million ha is under capture fisheries (brackish and freshwater). Mangroves, estuaries and backwaters occupy a spatial extent of 0.4, 3.9 and 3.5 million ha respectively. Man-made impoundments contribute about 3 million ha. Rivers, including main tributaries and canals, occupy nearly 28,000-km. Canal and irrigation channels contribute to 113,000-km.

Though accurate results on wetland loss in India are not available, the Wildlife Institute of India conducted a survey on these aspects and revealed that 70 – 80 percent of individual fresh water marshes and lakes in the Gangetic flood plains have been lost in the last five decades. At present, only 50 percent of India's wetlands remain. They are being lost at a rate of 2 to 3% every year. Indian mangrove areas have been halved almost from 700,000 hectares in 1987 to 453,000 hectares in 1995 (Sustainable Wetlands, Environmental Governance-2, 1999).

The Directory of Indian Wetlands published by the World Wide Fund for Nature (WWF)-India and Asian Wetland Bureau in 1995 records 147 wetland sites. About 32% of these sites were lost primarily through hunting and associated disturbances, while 22% were lost to human settlements, 19% to fishing and associated disturbances, and 23% through drainage for agriculture Removal of vegetation in the catchment leads to soil erosion and siltation that is estimated to contribute to over 15 % of wetland loss Nearly 20 % of wetlands have been lost mainly due to pollution from industries (WCMC, 1998). The recent estimate based on remote sensing shows only 4000 sq km area of mangrove resource in India. The current rate of wetland loss in India could lead to serious consequences as large populations are dependent on these wetlands (World Development Report, 1994)

Some of the major threatening factors influencing wetland destruction in India include:

Hydrologic alteration

Wetlands consist of multiple linked paths (waterways, habitat types, biodiversity on the site) that interact through energy flows, chemicals and physical transfers, moving biota, and water flows. Watershed conditions and downstream wetlands are linked as they influence the soil and hydrologic regime of the downstream areas. India's entire land surface has been altered through long-term human use and manipulations (e.g., intensive cropping, deforestation, intensive grazing and alteration of water flows) Anthropogenic alteration of the hydrological regime has further led to the alterations in natural drainage (Gopal, 1982). For example, map analysis of different periods by Rao & Sadakata (1993) showed sediment split 30 km long at the mouth of the northernmost river tributaries of Godavari in South India. Rivers continue to be isolated from their neighbouring floodplains leading to lowered water tables, loss of ground-water recharge, human development in flood prone areas and increased flooding potential downstream due to faster flood-water drainage. The changes in land use due to direct deforestation of wetlands has led to loss in valuable resources as fishes, shell fish, fuel, fodder, medicine, honey and beeswax and chemicals for tanning leather (Mitchell Beazley, 1993). Besides these economic losses, changes in land-use result in accelerated water leading to soil erosion, siltation of river courses and wetland filling with entrained sediments Further construction of canals and diversions of streams and rivers to transport water to lower arid regions for irrigation has altered the drainage pattern and significantly degraded the wetlands of the region For instance, the Indira Gandhi Canal Project across the river Sutlej in Gujarat removes water from the river as it drains from the western Himalayan mountains and diverts it via a canal system to the desert region of the state and neighbouring Rajasthan providing irrigation to cash crops This has led to changes in the physical and chemical conditions of the soil, ecological problems, invasion of exotic plant varieties, salinisation, regional desertification and elimination of culturally sustainable life styles. This has further led to overdrawing of water leading to groundwater depletion in the area to as much as 1.5-2.0 m. Soil erosion resulting from this change in hydrological conditions has indirectly eliminated many wetlands by filling them as observed in many parts of urban India. Over withdrawal of ground water has led to salinisation threatening to reduce the economic benefits the society can derive from wetlands. Cumulatively this altered hydrology can dramatically change the character, functions, values and appearance of wetlands in the region

Agricultural activities

The conversion of wetlands, deltas and floodplains of most rivers in India to paddy fields is rampant, following '*Green revolution*' of the early 70's It is an ecological irony that as a result of this, the gross spatial extent of wetlands in the Indian subcontinent is greater today than it was 3000 years ago (Lee Foote et al, 1996) owing to increased paddy fields treated as wetlands. The rich Gangetic floodplains, with easy access to water, constitute one of the most intensively cultivated regions of the world and Kolleru lake in Andhra Pradesh has lost some 34,000 hectares of natural wetlands to agriculture (Anon, 1993). This was followed by profound changes in the irrigation pattern in India The irrigated land increased from 3044 km^2 (in 1970) to 4550 km^2 (in 1990), showing 49% increase in the area (Anon, 1994). The demand for water to irrigate crops has increased dramatically over the last few decades resulting in the construction of a large number of reservoirs, canals and dams significantly altering the hydrology of the associated wetlands. In India, currently there are more than 1,500 large reservoirs covering 1.45 million hectares and more than 100,000 small and medium reservoirs covering 1.1 million hectares (Gopal, 1994). Reservoir construction has to a certain extent helped in justifying the beneficial effects in terms of economic benefits, especially the fishing communities and farmers in the vicinity But these impounding waters also significantly alter the catchments causing long-term costs in terms of ecological and social impacts (which are often overlooked in most of the hydrological projects) This kind of adhoc planning strategies do have serious environmental and ecological consequences which is evident from development activities in Saurashtra region, where over exploitation of ground water has led to steep fall in the water levels (up to 1 5 to 2 0 m per year) and also to salinisation (Lee Foote et al, 1996)

The demand for shrimps and fishes has provided economic incentives to convert wetlands and mangrove forests to develop pisciculture and aquaculture ponds (Jhingran, 1982) Both rice fields and fishponds come under wetlands and seldom function as natural wetlands However, such systems greatly alter the resident biota by altering the flow of detritus and soluble soil nutrients that initiate the food web, hampering ecosystem equilibrium

Pollution

The degradation of water quality is a direct consequence of population growth, urbanisation and industrialisation. Unrestricted dumping of sewage with toxic chemicals has polluted many freshwater wetlands, making them unfit for drinking, fishing or bathing in most parts of India. According to the study conducted by Chopra (1985), more than 50,000 small and large lakes in India are polluted to the point of being considered 'dead'. The natural coastal wetlands are also polluted to the extent that their fishery and recreational values are lost. The prime sources of pollution are domestic and industrial sewage as point source besides agricultural runoff and the more insidious atmospheric pollution contributing to the non-point source pollution. Studies suggest that 70% of the 3,100 cities and towns (population >100,000) in India have no sewage treatment facilities (Gopal, 1994)

Legal-policy failures

Wetlands jurisdiction is diffused and falls under various departments like agriculture, fisheries, irrigation, revenue, tourism, water resources and local bodies For instance, all mangroves in the country fall under the direct control of forest department. The lack of a comprehensive wetland policy, with each department having its own developmental priorities, works against the interests of conservation of wetlands resulting in intended or unintended 'spill-over' further aggravating the problem. For example, the various subsidies and cross-subsidies given to irrigation, fertilizers - pesticides, land use policies, etc , have negative impact on wetlands. The divergence of wetlands and its benefits between the private and social, and lack of awareness in appreciating the full economic benefits on the part of policy makers have led to its market failure. At policy level, wetlands are too often taken for granted and are considered as wastelands and targeted for development to other immediate uses. A survey conducted by WWF-IUCN covering some of the important wetlands in India identified wildlife poaching (38%), pollution (37%), grazing pressure, alteration to other land uses, over-fishing and siltation as some of the major threats The developmental policies of the government encourage large-scale aquaculture, pisciculture and salt manufacturing as in Chilka lake and west coast mangroves or pisciculture in Kolleru lake

Direct deforestation in wetlands

Mangroves are specialised, flooding and salt-tolerant shrubs and trees that grow along the coasts in the tropics In India, mangrove forests are valued for production of fish and shell-fish, live-stock fodder, fuel and building materials, local medicine, honey and bees-wax and for extracting chemicals used in tanning leather (Ahmad, 1980). Alternative land-uses of farming and fisheries production have replaced many mangrove areas and continue to pose threats to the forests The loss of wetland forests, coastal or riverine, reduces the ability of wetlands to slow water and trap suspended sediments.

Inundation by dammed reservoirs

There are currently more than 1550 large reservoirs covering more than 1 45 million ha, and more than 100,000 small and medium reservoirs covering 1 1 million ha in India (Gopal, 1994). Due to erratic alterations of impounded water levels, the potential for shoreline wetlands to develop and mitigate the losses of river bottom and riparian zones is minimal. As a result of variable dam releases for power generation, the wetted area does not follow a predictable seasonal pattern, precluding development of a stable wetland flora and wildlife community

Degradation of water quality

More than 50,000 small and large Indian lakes are polluted to the point of being considered 'dead' (Chopra-1985). The primary sources of pollution are human sewage, industrial pollution and agricultural runoff that may contain pesticides, fertilisers and herbicides. Pollution of lakes makes the water unsuitable for drinking, fishing or bathing. Extreme organic pollution levels from sewage can be put to constructive use in some situations. But, the unrestricted dumping of industrial wastes into the sewage stream threatens this situation. India's wetlands have been given a respite in terms of agricultural runoff

Global climate change effects

Wetlands both contribute to and suffer from climate change. They are the single largest source of methane; a gas that is a major contributor to the atmospheric trapping of heat which leads to global warming. Unlike most regions of the world, the population of India has been high enough to cause change in the landscape. Continued degradation of water and wetland resources means that extensive regions will be marginalized or rendered less habitable by people and domestic animals if a warming and drying cycle of change affects India's climate.

Ground-water depletion

Demand for water to irrigate crops has increased dramatically in the last 20 years. Between 1980 and 1983 the rapid depletion of ground-water left over 60,000 villages in rural India with no source of drinking water (Chopra 1985). Water pumping continues to reduce ground-water level by 1.5 to 6 m per year in some areas, and the beds of rivers that once flowed continuously are now dry for much of the year.

Introduced species - extinction of native biota

Indian wetlands are threatened by exotic plant species such as water hyacinth and salvinia. These free-floating nuisance plants were introduced in India and pose problems by clogging waterways and competing with native vegetation. As habitats are changed, exotic plants may be favoured over native plants. When wetlands lose native species of animals and plants, they are thought to be of lower value making it harder to justify their defence.

WETLANDS OF KARNATAKA

Karnataka is situated between 11° 31 and 18° 45' north latitudes and 74° 12' and 78° 40' east longitudes. It is blessed with numerous rivers, lakes and streams. Its length (north to south) is about 750 km and width (from east to west) about 400 km. The state covers an area of 1,92,204 sq. km, which is 5.35 % of the total geographical area of the country, with a coastline of about 320 km. There are nineteen districts in the state. The provisional population of Karnataka after the conclusion of 2001 census is a little over 52.7 million, of which, males accounted for 26.8 million while the female population was 25.8 million (Shashidhar, H, 2001). In 1991, of the total population of 44.9 million, males were 22.9 million and females 22 million (Rege, et al., 1996). The state now ranks ninth in population size and shares 5.13 per cent of the country's total population (Shashidhar, H, 2001).

Southwest and northeast monsoons contribute to a major portion of the rainfall. Annual rainfall varies from 3932.9 mm (Dakshina Kannada) to 142.4 mm (Bijapur). There is also negligible quantity of rainfall during summer and winter. Temperature is lowest in early January, increasing gradually at first and rapidly after mid-February to early March. The warmest month in major parts of the state is May when maximum temperature is recorded. It reaches 43°C in Gulbarga - Raichur region. In Bidar, Gadag and Bellary, it exceeds 40°C. In the coastal area it is about 35°C to 36°C. Over the southern maidan, it is about 36°C to 38°C. It is 32°C to 34°C in the Western Ghats and Malnad area.

Distribution of wetlands

Wetlands of Karnataka are classified into inland and coastal wetlands, both natural and man-made. Inland natural wetlands include lakes, ox-bow lake and marsh/swamp; inland man-made wetlands include reservoirs, tanks, and waterlogged plains. Coastal-natural wetlands include estuary, creek, *kayal*, mudflat, mangroves and marsh vegetation; coastal man-made wetlands include saltpans. Wetlands cover about 2 72 Mha of the total geographical area of Karnataka, of which inland wetlands cover 2 54 Mha and coastal wetlands 0 18 Mha.

Totally, 682 wetlands are scattered throughout Karnataka covering about 271840 ha. Out of these, seven wetlands are inland natural (581.25 ha), 615 inland man-made (253433.75 ha), 56 coastal natural (16643 75 ha) and four coastal man-made (1181.75 ha). The inland wetlands cover 93.43 % (254015 ha) of the total wetland area, while coastal wetlands cover only 6.57 % (17825.5 ha) Tanks (561) rank first in the number of wetlands and account for 79087 50 ha. Reservoirs come next in number (53) with an area of about 174290 ha. Lakes are fewer in number (5) covering 437.5 ha Mangroves in Karnataka cover 550 ha. Karnataka has the basins of Krishna (58 9 %), Cauvery (18 8%), Godavari (2.31%), North Pennar (3.62 %), South Pennar (1.96%), Palar (1.55 %) and west flowing rivers (12.8%) draining 1,91,770 sq km (Rege, S N et al, 1996). As per 1996 statistics, there were nineteen districts in the state and wetlands distributed in different proportions in all of them. Table 6 gives the district-wise distribution of wetlands (Rege, et al, 1996)

Table 6: District–wise distribution of wetlands in Karnataka

Wetland Type / District	INLAND WETLANDS				COASTAL WETLANDS				No	Total Area (ha)
	Oxbow lake	Swamp / Marsh	Reservoirs	Tanks	Estuary	Man-groves	Salt marsh /pans	Others		
Bangalore			2	48					50	10512
Belgaum			3	8					11	19733.25
Bellary			4	35					39	35300
Bidar	1		1	2					5	887.50
Bijapur			4	25					29	12993.75
Chick-magalur			1	15					16	19775 5
Chitradurga			4	51					55	13087.50
Kodagu			1	-					1	462.50
Dharwad			1	35					36	4400
Gulbarga		1	5	21					27	4625
Hassan			2	29					31	9843.75
Kolar			-	58					58	1029.4
Mandya			-	25					27	3312.5
Mysore			6	49					56	26450.6
Uttara Kannada			3	2	4	2	9	14	34	28131 25
Raichur			1	27					29	3099.5
Shimoga			11	10					21	45756.75
Dakshina Kannada			-	-	7	5	1	13	27	4375.00
Tumkur			4	121					125	18249.5

IMPACTS AND STATUS OF WETLANDS IN KARNATAKA

Deforestation and other anthropogenic activities have accelerated soil erosion causing increased sedimentation resulting in shrinkage of area under wetlands Some reservoirs and other waterbodies in Karnataka are facing the problem of siltation The number of wetlands in Karnataka has halved during the last century

Turbidity

It is a significant parameter in determining the opaqueness of water that helps photosynthetic processes and fish life. It mainly depends on particulate matter present in the water. Wetlands in Karnataka are classified in to low, medium and high based on the turbidity values. Among 620 surveyed wetlands, about 200 wetlands have low turbidity. 222 moderate and 198 high turbidity Under the wetland categories, tanks (161) have the lowest turbidity, followed by reservoirs (36), lakes/ponds (2) and ox-bow lakes (1) Under moderate classification, tanks (212) again rate first followed by reservoirs (9) and lakes (1). Nearly 188 tanks have high turbidity followed by reservoirs (8) and lakes (2).

Aquatic vegetation status

Wetlands usually support diverse aquatic vegetation. Aquatic weeds are generally used as indicators of eutrophication. These are ideal habitats for fish and migratory birds. On the basis of vegetation, Karnataka is divided into four zones namely completely vegetated (CV), partially vegetated (PV), vegetation on fringes (VF) and no vegetation (NV). Of the 682 wetlands in Karnataka, 517 do not have vegetation, out of which 417 are tanks. Eighty-three tanks show partially vegetated condition, 54 have vegetation on fringes and 7 are completely vegetated.

Seasonal variation in water spread of wetlands

The total water spread area in pre-monsoon is 204053 74 ha while in post monsoon it is 246643.00 ha Out of 682 wetlands in the state, 71 have shown water spread less than 56 25 ha (Rege, S N et al 1996) The water-spread area of lakes/ponds in post monsoon is about 437 50 ha while in pre monsoon it is about 368 75 ha Reservoirs have shown considerable variations from post monsoon (167268 ha) to pre monsoon (138684 25 ha) Tanks also vary from 46975.25 ha in post monsoon to 60912 25 ha in pre monsoon. The coastal wetlands, which are under constant influence of the sea have not shown any variations and remained unchanged in terms of water spread area in all seasons. Most of the tanks dry up during pre-monsoon seasons

Wetlands of Karnataka have already been lost in the process of urban development and over population. The peripheral areas of wetlands in the state have been encroached for settlements. A large number of wetlands in the state are subjected to inflows of domestic sewage, solid waste and industrial effluents, responsible for decline in their quantity and quality. Fertiliser and pesticide run-off from agricultural lands has also aggravated the pollution load These threats have degraded species diversity and the productivity of the wetlands.

BANGALORE SCENARIO

Bangalore district is located in the heart of South Deccan of Peninsular India It is situated in the south-eastern corner of Karnataka state (12°39' – 13°18' N latitude and 77°22' – 77°52' E longitude) with a geographical area of about 2,191 sq km and an average elevation of 900 m above the mean sea level The climate of the district enjoys an agreeable temperature range from the highest mean maximum of 36 2° C in April to lowest mean maximum of 11 4° C in January. It has two rainy seasons from June to September and from October to November coming one after the other but with opposite wind regime, corresponding to south-west and north-east monsoons The mean value of the rainfall of about 900-mm with standard deviation of 18 7 mm was recorded from the year 1875 to 1976 (Srinivasa et al, 1996)

Bangalore city once sported a large number of lakes, ponds and marshy wetlands, which ensured a high level of ground water table and pleasant climate It is a great pity that many lakes and ponds have already disappeared due to various anthropogenic activities and pressures due to unplanned urbanisation and expansion Surviving lakes are reduced to cesspools due to direct discharge of industrial effluents and unregulated dumping of solid wastes.

DISTRIBUTION OF LAKES IN BANGALORE

Wetlands of Bangalore occupy about 4 8% of the city's geographical area (640 sq km) covering both urban and rural areas (Krishna et al , 1996). Bangalore has many man-made wetlands but no natural wetlands They were built for various hydrological purposes to serve the needs of irrigated agriculture Totally there were 262 lakes coming within the green belt area of Bangalore City. Bangalore Metropolitan Area is divided into 7 taluks Table 7 gives the distribution of tanks by taluks in Bangalore (Chakrapani, 1996)

Table 7: Distribution of tanks by taluks

Sl. No.	Name of the Taluk	No. of tanks
1	Bangalore North	61
2	Bangalore South	98
3	Hoskote	23
4	Anekal	44
5	Magadi	11
6	Nelamangala	13
7	Devanahalli	12

The number of tanks in Bangalore has fallen from 262 in 1960 to 81 at present (Lakshman Rau, 1986) These 81 lakes have been classified in to four categories depending on the spatial extent (Table 8)

Table 8: Distribution of 81 live lakes based on area

Area	No. of lakes
Area < 10 ha	49
Area between 11 and 20 ha	16
Area between 21 and 50 ha	14
Area > 50 ha	2
Total	81

Table 9: Spatial extent of some 17 existing lakes

Sl No	Lake	Area (ha)
1	Vasanthapura	2 0
2	Dorekere	11 29
3	Moggekere	6 06
4	Madivala	114 20
5	Agaram	56 67
6	Puttenahalli	32.89
7	Doddabegur	32 86
8	Ulsoor	49.80
9	Bellandur	361.30
10	Narasipura-1	3.62
11	Narasipura-2	6 12
12	Doddabommasandra	40 90
13	Nagavara	22 46
14	Lalbagh	96 00
15	Kempambudhi	14.84
16	Hebbal	76.87
17	Hulimavu	49.70
	TOTAL	977.58

IMPACTS AND STATUS OF WETLANDS IN BANGALORE

Status of wetlands in Bangalore is a direct measure of status of management of anthropogenic activities, management of land, solid waste collection and disposal, disposal of used water and also attitude of the people at large In Bangalore wetlands are being lost due to:

- Anthropogenic stress
- Increasing population and growing economy leading to unplanned urban development that has put greater pressure on the land resources
- Lack of governmental commitment, cohesive academic research on wetland in understanding the importance and essence of conservation and management owing to financial constraints and lack of infrastructure and required expertise
- Deficiency in proper management of non point source of pollution like storm water and agricultural runoff, and unregulated land use management have also led to the steady increase in problems of pollution, eutrophication, invasion of exotic species, toxic contamination by heavy metals, pesticides and organic compounds (Kiran, R and Ramachandra, T V, 1999)

The lakes are unique features of the ecology of the city. Bangalore supports no natural wetlands, the present one's were built mainly for various hydrological purposes and to serve the needs of irrigation and drinking water supply. The vast majority of the wetlands in Bangalore occur on the outskirts of the city, in the rural fringe. Studies on lakes of Bangalore during the past decade, show that 35% tanks were lost owing to various anthropogenic pressures. Converting wetlands for residential, commercial and agricultural purposes has also been a part of the mosquito eradication program of the Bangalore Development Authority (Deepa et al., 1997) Remaining lakes are dying fast, as they are filled with solid waste materials and sewage. The present trends in decrease in the water quality and number of water bodies are the result of unplanned development of the city, resulting in vast tracts of wetlands being cleared Recent studies on lakes of Bangalore show that nearly 40 % of lakes are sewage fed, 13 % surrounded by slums and 35% showed loss of catchment area The major problems of the city's tanks are lack of government records and sewerage entering them (65 are sewage fed, 16 are breached) Lakes situated outside the city's limit face the problem of brick kiln contributing to the declining water quality.

The number of man-made wetlands has fallen from 379 in 1973 to 246 in 1996 and further reduced to 81 at present (Lakshman Rau, N et al., 1986) About 133 water bodies have been lost in North (42) and South (91) taluks during a period of two decades. Table 10 gives the percentage loss of number of tanks in North and South taluks (Kiran R and Ramachandra T V, 1999)

Table 10: Region-wise spatial extent and status of tanks

Region	Area in sq. km	No. tanks (1973)	No. tanks (1996)	Percentage loss (No. of tanks)
North	506 87	138	96	30 43
South	594.96	241	150	37.75
Total	1101.8	379	246	34.09

Earlier investigations have revealed that nearly 30 % of lakes are used for irrigation. Fishing is being carried out in 25 % of the lakes surveyed About 36 % of lakes are used for washing purposes and only 3% are used for drinking. Agriculture along the margins is practiced in 21% of the lakes Approximately 35% of lakes are used for grazing by cattle Mud lifting was recorded in 30 % of the lakes and brick making in 38 % of the lakes (Srinivasa, 1996)

- Lake structure status - As the city expands, more and more lakes are being walled up to restrict the water spread

- Water level status – The level of water in wetlands or any water body is significant in determining the waterfowl population and diversity. Nearly 23% of lakes were dry due to lack of rains in the past two years while 25% had little water (Srinivasa, 1996)

- Status of lakes due to sewage and effluents – The presence of sewage and varied degree of eutrophication were recorded from 28% of lakes in 1996, while it was about 10% in 1989, 13% in 1992 and 16 % in 1995 About 25% of lakes (1996) have suffered from green waters as compared to 8% in 1989. Approximately 8 % of the lakes had other effluents It is disheartening to see that nearly 30% of vegetables are grown with these untreated waters (Srinivasa, 1996)

- Encroachment and reclamation status - Nearly 30% of the lakes was encroached for mud lifting and 38% for brick making processes About 30% of the lakes were drained either for residential sectors in their ornamental borders or converted to layouts Nearly 22% of the lakes were encroached for agricultural purposes, slums surround 13% of the lakes and unauthorised buildings (Srinivasa, 1996) In some cases, land filling and walling of the lake margin has been observed. For instance, Miller tank was converted into a housing layout, Shulay tank was filled up and a football stadium constructed, Akkithimmanahalli tank near Langford road was converted in to a housing layout with a hockey stadium built on the site and the Domlur tank converted into a BDA layout Sampangi tank has given way for the construction of a sports stadium and the corporation now maintains a small replica of this tank in the grounds.

- Poaching of birds and species diversity - Water birds, in particular larger ones like ducks, geese, storks, ibises and cormorants are hunted to a large extent Poaching of water birds increases during October and April Poaching was recorded in eight lakes, which increased from 7.5 % of total area in 1996 while the corresponding amount in 1989 was about 35% Reduction in the percentage has occurred mainly due to the fact that the number of dry lakes in 1996 was much more than in 1989 (Krishna, et al , 1996) Over 330 species of birds have been recorded in Bangalore. Out of these nearly 40% occur in or near wetlands. These represent 19 different families Nearly 91,000 birds were identified in 1996 as compared to about 52,000 birds in 1995 (Krishna, 1996)

- Phytoplankton and Zooplankton diversity - Microcystis species accounted for about 68%, and Phormidium species 55% of the lakes *Aphanizomenon*. *Anabaena* *Oscillotaria*, *Spirulina* *Coelosphaerium*, *Nostoc* and *Lyngbya* species were also recorded during the two surveys of lakes in and around Bangalore Totally 72 lakes were surveyed in 1989 and about 56 phytoplankton forms were observed. But within 6 years, the number of phytoplankton forms had increased to 66 including 8 unidentified forms in 60 lakes (Chakrapani, 1996) Totally, 62 forms of zooplankton including 5 unidentified forms were recorded during the survey of 1995, which was less in number (54 forms with about 9 unidentified forms) when compared to the survey of 1989 (Chakrapani, 1996)

- Quality status - The colour of the polluted waterbodies was mostly greenish indicating eutrophication mainly due to algal blooms followed by the contribution of effluents from domestic and industrial sources Nearly 23% of lakes are suffering from eutrophication due to inflow of sewage (Chakrapani, et al, 1996)

The pollution has resulted in "significant degradation" to the aquatic ecosystem evident from frequent fish kills (Benjamin et al, 1996) with significant adverse effects on:

1) Human health or welfare, including effects on municipal water supplies as noticed in few tanks as Kamakshipalya and Kempambudhi tanks
2) Life stages of aquatic life and other life forms dependent on aquatic ecosystems, such as decreased population of birds (Krishna M.B.et al, 1996), fish, etc.
3) Ecosystem diversity, productivity and stability, including loss of fish and wildlife habitat or loss of the capacity of a wetland to assimilate nutrients, purify water, etc , and
4) Recreational, aesthetic, and economic values

The disappearance of the tanks which play a vital role in the microclimate of the region, especially during summer, mitigating the heat, has reflected changes in terms of the air, water and ground water quality, and rainfall and temperature patterns of the city

- Turbidity in the cleaner waterbodies ranged from 1.0-25.0 NTU (Nephlometeric Turbidity Units) and 70 0-362 0 NTU in polluted waterbodies, primarily due to silt, suspended and organic matter and autochthonous sources (mainly planktons). The sources are mainly the stormwater and agricultural runoff, and effluents from industrial and domestic sectors, which in turn restrict the penetration of light, giving rise to reduced photosynthesis and aesthetically unsatisfactory odours (Kiran, R and Ramachandra, T V, 1999).

- The pH values ranged from 7-9.3 in urban areas and 7.3-8.7 in non-urban areas. Kamakshipalya recorded 6.0 - 6.6 during the entire study period (Kiran et al, 1999). pH values above 9 (alkaline) were recorded at Yediur, Puttenahalli and Ulsoor tanks (Chakrapani, et al., 1996).

- The COD values ranged from 27 mg/L in unpolluted waters to a high of 621 mg/L in Kamakshipalya, as a result of pollution that is largely determined by the various organic and inorganic materials [calcium, magnesium, potassium, sodium etc] (Kiran, R and Ramachandra, T.V 1999).

- The dissolved oxygen concentration of the analysed waterbodies ranged from 1.2 mg/L in Kamakshipalya lake to 11.1 mg/L in Ulsoor and Yediur lakes largely due to photosynthetic activity (Kiran et al., 1999). The recommended dissolved oxygen concentration for a healthy and ideally productive lake waterbody is 8 mg/L (Wetzel, 1973).

- The level of phosphates was found to range from 0.06 mg/L to a high of 4.2 mg/L, the higher values were seen in Kamakshipalya lake (Kiran, R and Ramachandra, T.V, 1999). Phosphates have the tendency to be precipitated by many cations and accumulate at the bottom of the lake becoming temporarily inaccessible to productive organisms. The nitrate concentration was found to range from 0.1 to a very high level of 2.7 mg/L in view of the standard level for inland surface water fixed at 0.1 mg/L (NEERI, 1988). This parameter is very significant in relation to algal productivity (algal blooms) in lakes, which mainly leads to eutrophic condition (Kiran, R and Ramachandra, T.V 1999).

- Dissolved solids ranged from 30-301 mg/L in less polluted lakes like Bannergatta and Sankey and 430.0-1024.0 mg/L in highly polluted lakes such as Kamakshipalya and Yediur. The suspended solids ranged from 52.2 mg/L to a high of 278.3 mg/L as a result of silt and suspended nutrients (Kiran, R and Ramachandra, T.V, 1999).

- Among the heavy metals, iron and lead were present in higher quantities and the other two parameters zinc and chromium were in traces (Kiran et al, 1999). The permissible limit for iron is 0.3 mg/L (NEERI, 1988) for drinking water. Above this value, iron imparts bitter astringent taste (Chakrapani et al, 1996).

Investigations revealed that most of the analysed parameters for the lakes in Bangalore (e.g. Ulsoor, Hebbal, Yediur, Kamakshipalya and Madivala) exceeded the limits set by Indian Standards for industrial and sewage effluents discharge [IS 2490 -1982] (Kiran and Ramachandra, T V, 1998)

The high level of dependency on wetlands and its poor quality calls for immediate restoration of degraded lakes and appropriate measures for restoration and management in order to maintain ecological balance in the region. This subsection provides an overview of wetland status - global and India with primary focus on Bangalore.

In U.S.A, nearly 54% of the 87 million hectares of wetlands have been lost, primarily through agricultural activities. Twenty-two of the lower 48 states have lost at least 50 % of their original wetland area. Indiana, Illinois, Missouri, Kentucky and Ohio have lost more than 80 %, while California and Iowa have lost nearly 99 % (USEPA, 1995). Conversion of the wetland for agriculture was responsible for 54 % of the loss; drainage for urban development - 5 % and planned development - 41 %. These wetlands are threatened by air and water pollutants, and hydrologic alterations (USEPA, 1994b). In New Zealand, about 90 % of wetlands have been lost over the last 150 years through land drainage and development. In Ireland, only 23,000 hectares of bogs (7.5 %) out of the original 3,11,000-hectares remain (Chatrath, 1992) and about 51 % of wetlands have been lost to forestry and peat mining during the last 3 decades. An average of 61% of wetlands has been lost in six countries (Netherlands, France, Germany, Spain, Italy and Greece) as estimated by the European Commission in 1995. It was noticed that nearly 67 % of mangrove forests was lost in the Philippines over the last 60 years. In Netherlands, only 3.6 % of the original bogs remain. Wetland area has drastically reduced in Belgium, Chile, South America and Africa, mainly due to significant anthropogenic activities that include intensive agricultural activity, drainage etc. In Japan, only 19,200 (nearly 60 %) out of 32,000 coastal wetlands remain. Similar situations apply to the wetlands of U.K and Norway too (Clare Shine et al., 1999).

Almost 95 % of the wetland coral reefs have been damaged primarily through excess fishing, using dynamites and other poisonous materials. About 20 % of the world's fresh water fishes were found to be endangered, mainly due to disturbance to their habitat (IUCN, 1994). Fresh water fishes comprise about one-third of all fish species. The diversity of fish species is threatened, since lakes are semi-closed systems and fishes have no means of escaping from lake deterioration, becoming vulnerable to ecosystem disturbances. Table 11gives the number of threatened fresh water fish species data (The1996 IUCN Red List of Threatened Animals) for 21 selected countries.

Table 11: Number of threatened fresh water fishes

Country	Total species	% threatened
USA	822	15
Mexico	384	20
Australia	216	13
South Africa	94	27
Croatia	64	31
Turkey	174	11
Greece	98	16
Madagascar	41	32
Papua New Guinea	195	6
Hungary	79	14
Canada	177	6
Spain	50	22
Romania	87	13
Italy	45	20
Moldova	82	11
Portugal	28	32

Bulgaria	72	11
Sri Lanka	90	9
Germany	68	10
Slovakia	62	11
Japan	150	4

In several countries, 20–30 % of the fish species are threatened at present, with about 81 fish species recorded to have become extinct during the past century. Globally, pollution and habitat modification are the most widespread and pervasive factors known to cause decline in fisheries.

Totally, 93 lakes were sampled in five continents (Africa, Asia, Central and South America, Australia and Europe). It was found that nearly 55 lakes have declined in terms of quality, particularly those in Asia. Table 12 gives the changes in the lake quality for the five selected continents.

Table 12: Changes in lake condition

Country	Number in sample	Worse condition	Better condition	No change in quality
Africa	20	8	1	11
Asia	24	16	1	7
Central and S America	9	7	0	2
Australia	3	1	0	2
Europe	37	23	1	13
Total	93	55	3	35

Globally, large and long-lived lakes have been known to support high diversity of fishes, molluscs, crustaceans and several invertebrates. Table 13 gives the biodiversity features of major long-lived lakes

Table 13: Biodiversity features of major long-lived lakes

Lake	Country	Biodiversity	
		Total animal species	Endemic
Baikal	Russia	1,825	982
Tanganyika	Burundi, Tanzania, Zambia, Zaire	1,470	632
Victoria	Kenya, Tanzania, Uganda	290	270
Malawi	Malawi, Mozambique, Tanzania	640	600
Titicaca	Bolivia, Peru	533	61
Biwa	Japan	595	54
Ohrid	Albania, Macedonia	17	2

Approximately one third of Wullar lake of Kashmir is degraded due to siltation and encroachment, which have also affected many other lakes in India, especially Chilka lake in Orissa (the largest brackish water lagoon in south-east Asia), Kolleru lake (Andhra Pradesh) and Sukhna lake, a man made wetland in Chandigarh. Most of these lakes have lost their water holding capacity in just two decades. Eutrophication (nutrient enrichment) and weed infestation threaten Srinagar's Dal lake, which is situated in the heart of Kashmir Valley.

Water hyacinth is spreading at an alarming rate in Harike lake (Punjab), having infested 75% of the wetland area. This lake is important for migratory waterfowl and attracts over 20,000 ducks during winter. Nearly 210 species of birds were found in this wetland, out of which three duck species, the bronze-capped teal (*Anas falcata*), scaup duck (*Aytha marila*) and white-headed stifftailed duck (*Oxyura leucocephala*) are rarely seen elsewhere in India (WWF, 1992). Extensive fishing throughout the year has caused considerable disturbance to the aquatic life (especially birds) in this lake

Loktak lake, the largest natural lake in eastern India (in the southern part of Manipur valley), is seriously threatened on account of unplanned land use practices and over exploitation of the available resources in its catchment. These improper planning approaches have led to unsustainable economic development. Much of the lake is choked with weeds, silted (due to catchment conditions) and encroached from all sides. These anthropogenic activities have resulted in shrinkage in size, pollution and loss of rich biodiversity and other biological resources.

Kaliveli (in South Arcot district of Tamil Nadu) is one of the largest semi-permanent water bodies of India that has suffered from shrinkage of its water-spread area, mainly due to encroachment by paddy fields. A wide variety of water bird species, including pelicans, storks and flamingos, is poached for meat. This has resulted in the migration of the entire bird population (upto 40,000) of Kaliveli

Kolleru Lake (Andhra Pradesh) has lost 34,000 hectares of water spread to agriculture. Deepar beel (Assam), Hokarsar Lake (Kashmir) and the Pyagpur and Sitadwar Jheels (near Lucknow, Uttar Pradesh) are just a few of the many wetlands that have shrunk on account of reclamation for agriculture.

Aftab Alam et al (1996) studied the presence of plankton, and the dynamics and effects of varying dominant biota on the plankton population in four freshwater ponds receiving pollutants. The study involved both qualitative and quantitative estimation of plankton by drop count method, and they were identified using standard monographs of Edmondson (1959) and Pennak (1980). 'A' pond, which received detergent pollutants, showed less plankton with 13 genera of phytoplankton and 7 genera of zooplankton, the dominant phytoplankton being *Microcystis*, *Tetrapedia*, *Nostoc*, *Selenestrum*, *Euglena*, *Phacus* and certain diatom species and zooplankton such as *Branchionus*, *Filinia*, *Hexarthra*, *Euchlanis*, *Monia*, *Cyclops* and *Diaptomus*. The poor results for pond 'A' compared to ponds 'B' (showed 24 species of phytoplankton and 15 species of zooplankton) and 'D' (30 species of phytoplankton and 17 species of zooplankton) was attributed to the influx of phosphorus into the water body by washing activities and dominance of certain planktivorous insects. Also, the presence of certain pollution tolerant species of phytoplankton - *Oscillatoria*, *Scenedesmus* and *Euglena* indicated high degree of organic pollution. The study concluded that both eutrophication and macrophytic infestation are responsible for plankton richness of ponds and the dominant biota affected other biota, bringing changes in the biotic composition with few others interfering directly with the biotic community

S. K. Khatavkar et al (1995) studied the short-term effect of phosphorus on phytoplankton primary production in two tropical fresh water bodies situated in the Western Ghats region of Maharashtra. The study involved measurements of important physico-chemical parameters. The results showed no significant change in the production after adding phosphorous, except for a marginal increase on few occasions. It was felt that the primary production during short-term exposure might be influenced by the planktonic density rather than absorption of nutrients as P and N. Addition of nutrients in short-term exposure can stimulate phytoplanktonic growth rate only where the phytoplanktons are in the starving condition. However, such conditions occur often in deep, temperate and oligotrophic lakes, where turnover period is longer

Kaur H et al (1996) studied the biotic components of a fresh water pond in Patiala, which revealed its eutrophic condition. Plankton analyses were done on monthly basis for six months following the methods of Mellanby and Tonapi. The protozoan fauna consisted mainly of *Diffugia* sp., while *paramecium* sp., varied seasonally. Nine species of rotifers were observed as the most abundant of all the planktonic population present, indicating their tolerance to organic pollution. They included *Lecane* sp., *Brachionus* sp., *Notholca* sp., *Anuraea* sp., *Rattulus* sp., *Cathypna* sp., *Trichotoria* sp., and *Notops* sp.

Large tracts of the Sunderban 'mangals' have been axed in the last two or three hundred years, reducing the forested area by half. A part of Pichavaram mangroves of Tamil Nadu has been drained and certain mangrove species such as *Sonneratia* and *Xylocarpus* have been extensively felled, restricting some areas to pure coppices of *Avicennia*, severely depleting the species diversity. 75 % of Little Andaman is deforested. The increase in sewage and industrial effluent in mangrove estuaries has also led to the disappearance of many species of flora and fauna. The increase in industrialisation in coastal areas, off-shore mining, dredging, construction, and oil transport have greatly increased the vulnerability of coral reefs in India. It has been estimated that 50–70 % of the coral life of the Gulf of Kutch has been destroyed as a consequence of mining In the Andamans, widespread and uncontrolled deforestation has resulted in soil erosion and massive siltation in the fringing reef habitats (WWF, 1992)

Hunting and poaching of waterfowl and other animals prevalent in many parts of the country mainly threaten wetland faunal species It is estimated that about 50% of the ducks visiting the Manjhaul chaur near the Bihar-Bengal border are poached by duck-trappers. Poachers kill about 15,000 – 20,000 waterfowl each year in Chilka lake (Orissa). Poaching of wetland dependent species, in particular, hunting of the endangered Indian rhinoceros in Assam's Manas and Kaziranga National Parks, while the collection of gharial eggs in Satkoshia Gorge Sanctuary (near Cuttack, Orissa) has greatly depleted the wild populations.

Jebanesan et al (1994) paper deals with physico-chemical analysis, metallic and non-metallic pollution of the Cooum river at 9 stations in the vicinity of Madras for a period of three years from June 1985 to May 1988 in an attempt to find the present status of pollution in the river by analysing the chemical factors responsible and the relative abundance of aquatic macrophytes The results of the various physico-chemical parameters showed heavy pollution due to industrial and domestic sewage at the downstream than at the upstream. The results are expressed as a range at all the 9 stations for the various parameters such as pH, DO, BOD, COD, heavy metals, etc

L.L Sharma et al (1992) studied the diurnal fluctuations in some limnological parameters in relation to plankton in Lake Fatehsagar in Rajasthan For diurnal variation studies, sampling was done on three occasions in the deepest part of the lake The parameters selected for the study were visibility, air and water temperature, pH, DO, carbon-di-oxide, carbonates and bicarbonates While comparing data on physico-chemical parameters with planktonic density, it was evident that phytoplankton had higher density at noon coinciding with reduced level of carbon-di-oxide and increased pH, DO and carbonate in the surface waters *Microcystis flosquae*, a dominant plankter had maximum density at 15 00 hrs and many rotifers were found on the surface during night In general, maximum number of zooplankters coincided with the higher concentration of carbon-di-oxide in the bottom waters, decreased pH and lack of sunlight during late night hours

Someswara Rao et al (1994) studied the quality of ambient air and drinking water in the port town of Kakinada, Andhra Pradesh The water of river Godavari was analysed before and after treatment (at both the treatment plants constructed by the side of each reservoir) 60 samples across the Godavari river and along the canals were also analysed The river water was found to be generally soft but turbidity and iron were found to be high in the post-monsoon season Nitrites were also high indicating pollution due to organic matter and DO was found to be in the range of 5 1-6 5mg/L Residual chlorine at the tap end was sometimes found to be as high as 0.4 to 0 5ppm (optimum level-0 1ppm) and sometimes, it was absent. Some parts of Kakinada have saline and hard ground water They reported that the above-said effect could be due to seawater intrusion since the concentration of chloride, magnesium, sulphate and sodium were found to be high near the sea and reduced as one moved away from the sea The ground water table was found to be at a depth of 1-2.5m, which could lead to pollution of ground water, by sewage inflow High levels of nitrite and low levels of DO strengthened this claim Fe, Cu and Zn were found to be in concentrations much higher than the desirable limits

Ajai Pillai et al (1996) studied the physico-chemical property of drinking water of Durg Municipality Samples for analysis were collected from utility points (municipality taps). Raw water and treated water were also collected; the samples were analysed for their chemical and biological characteristics following standard methods (APHA-1985). They reported higher values for the chemical parameters at Police Line and Sindhiya Nagar The TDS concentration at this place was above the limit (150-10,500) The total hardness was also found to be higher. The fluoride content was found to be much lower than 0 5mg/L and hence there was a deficiency in fluoride. They reported a high coliform (MPN/100ml) indicating a poorly maintained supply system with a possibility of sewage mixing with water supply.

V.N R Rao et al (1987-90) studied sewage pollution in the high altitude Ooty lake, its causes and concern. The sampling programme consisted of a series of fortnightly water quality and biological surveys for one year from Nov-87 to Oct-88 and monthly surveys from Nov-88 to Oct-90. Four sampling points were chosen The physico-chemical and biological characteristics of the waters were estimated according to

Standard methods (APHA, 1981) except ammonia, which was determined, by phenol-hypochlorite method outlined by Solarzano (1969). The alkalinity and hardness of the lake was reportedly high. Nitrate-nitrogen fluctuated seasonally and ranged between 0.03-3.07 mg/L, nitrite-nitrogen between 0.01-1.23 mg/L and ammoniacal-nitrogen between 0.01-8.31 mg/L. Phosphate-phosphorus was very high throughout the study period, highest value being 4.97 mg/L (lakes with or above 20 mg/L of phosphate-phosphorus are called eutrophic lakes according to Dillon-1975). The concentrations of metals in the water were low to be considered hazardous. Concentration of DDT in the waters (1.37-3.7ug/l) far exceeded its solubility level suggesting the presence of rich organics in the surface waters. a, B, r and d isomers of HCH were detected in the waters. Carbofuran was observed in the lake and the concentration ranged from 14.22-32.4ug/l. Chlorophyll a concentration in the surface water ranged between 24.7 and 196.8mg/m^3. Blue-green algal blooms were observed in summer that indicated eutrophic conditions of the lake. The dominant species of phytoplankton in the lake were *Chlorophyceae. Scenedesmus. Chlorella, Crucigenia, Oocystis, Chlorococcum, Pediastrum, Schroederia. Tetrastum* and *Ankistrodesmus*. Total and faecal coliforms were high at the inlet points and gradually increased towards the outlets of the lake. Prevention of entry of raw sewage, dredging the lake and removal of *E.crassipes* will enhance the self-purifying capacity of the lake

Gupta S et al (1992) conducted a preliminary investigation on physico-chemical factors, periphyton and invertebrate communities in a protected water work of Shillong, Meghalaya, to assess the drinking water quality and major environmental changes of the incoming stream water as it passes through the water supply system. High levels of DO, low levels of suspended solids and the absence of molluscs and tubifields indicated high natural water quality of the reservoir

Nag.J K. et al (1993) studied trace metal levels in drinking water of Hoogly district. Water samples were collected from 55 locations from tube wells and other ground-water sources used as drinking water in the district of Hoogly, West Bengal. In all samples Hg was absent, Na, Ca, Cr, Pb, As, K (except in one) and Mg (except in two) were under maximum admissible concentration or guide level (GL) recommended by WHO. But the serious cause of concern was the presence of Zn in >65% water samples with a maximum of 33 times more compared to WHO recommended GL. Other heavy metals like Cu and Cd were also found in several samples.

Pandey D.K (1993) evaluated the water quality of Nainital lake (lentic ecosystem) of Central Himalaya at bimonthly intervals. The study was conducted to determine the impact of seasonal variation on physico-chemical and microbial characteristics of Nainital lake water of Central Himalayan region. Various characteristics of water were evaluated at bimonthly intervals from Sep 1990 to Jan 1991. All the parameters except DO of the lake water observed were maximum during the month of September and minimum in the month of January. DO content on the other hand was maximum in Jan and minimum in Sep. samplings. The study showed high pollution load in this water ecosystem at all times.

H Kaur. et al (1996) studied the abiotic and biotic components of a fresh water pond of Patiala (Punjab). The Sirhindi Gate Pond lies close to thickly populated localities and thus has become a dump for domestic wastes. This pond is located at Vikas colony, a thickly populated locality lying opposite the Sirhindi Gate of Patiala City. Water samples were collected once a month over a period extending from July-1992 to December-1992. Temperature, pH and DO were taken on the spot while the other physico-chemical parameters like alkalinity, chlorides, nitrates, hardness and iron were estimated in the laboratory as per APHA (1989) procedures.

The pH value ranged from a minimum of 7.4 in September to a maximum of 8.4 in August. The alkalinity values fluctuated between 220 mg/L in December to 350 mg/L in August. Total hardness varied from 110 mg/L (July) to 220 mg/L (Dec). The chloride content varied from 200-280 mg/L (permissible limit = 250 mg/L). The Fe content varied from 0-0.7 mg/L and was totally absent in September. The protozoan fauna of the pond was *Paramecium* species, *Difflugia* species, *Copromonas* species, *Oxytricha* species and *Spirostomum* species. Nine species of rotifers and 2 species of annelids were present. Crustaceans and insects were abundant in July and August.

M. Parvateesam and Sudha Gupta (1994) studied the physicochemical characteristics of a lake receiving effluents from textile mills in Rajasthan. Drainage of wastes from textile mills alters the physicochemical characters of freshwaters Hamir lake situated near the industrial area of Kishangarh near Ajmer was chosen for the study. The chemical analyses of the water samples were carried out following the methods recommended by Golterman et al (1978) and APHA (1989) Temperature ranged from 18.3-34.6 ^{0}C, pH from 6 5-8 8 units, conductivity from 1.75-4.0x10^{-3} u/cm, total alkalinity from 101-654 mg/L, TDS from 772-1770 mg/L, chlorides from 51.2-161 mg/L, DO from 0 04-12 35 mg/L, dissolved carbon-di-oxide from 0-26 3 mg/L, ammonia-nitrogen from 1 1-3 9 mg/L, nitrate-nitrogen from 0.24-0.84 mg/L, phosphate-phosphorus from 0.9-8.6 mg/L, dissolved organic matter from 280-480 mg/L and BOD from 100-160 mg/L These values indicate that the lake is polluted. Dissolved organic matter is accumulated in the lake due to textile wastes and oxidation of dead aquatic flora and fauna

Baruah B K. et al (1996) studied the effect of paper mill effluent on the water quality of receiving wetland The Nagaon Paper Mill, located at Jagiroad in Central Assam, employs bamboo as raw material, various chemicals like alkali, sodium sulphate, chlorine etc. and water for the manufacture of paper. The mill releases effluents at the rate of 2100 m^3 per hour containing numerous organic and inorganic chemicals, polluting a wetland called Elenga Beel. The analysis of effluent flowing out of the ETP and Beel water was carried out as per Standard methods of APHA (1985) and Trivedi and Goel (1986) The paper mill effluent revealed that most of the parameters and components of the effluent had crossed the standard permissible limits, specifically in respect to pH, DO, BOD, COD, hardness, alkalinity, chlorides, sulphates, Ca and residual chlorine The Elenga Beel water quality before confluence with the effluent showed normal values of the water parameters The pH of Beel water after confluence recorded high in pre-monsoon season. Further study revealed absence of DO and high BOD and COD Analysis further revealed that the high load of alkalinity, hardness, chlorides, Ca, Mg, Na, K and sulphate of the effluent caused remarkable increase in values of all these parameters in the Beel water The findings clearly indicated that Nagaon Paper Mill effluent has extremely polluted the Elenga Beel

Sabu Thomas and Abdul Azis P.K (1996) studied the spatial and temporal distribution of nutrients in the Peppara reservoir-a man-made ecosystem in the Western Ghats. Water samples were collected from 4 stations that were monitored and analysed following techniques and procedures (Golterman 1969; Jhingran et al 1988) The concentration of nitrate-nitrogen in the reservoir ranged from 0-1ug/l at the surface and 0.08-0 85ug/l at the bottom. Maximum value was observed in Jan at the intermediate zone of the reservoir Phosphate-phosphorus concentration ranged from 0-1 51ug/l Silicate concentration ranged from 1ug/l to 36.95ug/l for surface and bottom water. The major supply of phosphorus in the reservoir comes from agricultural areas and plantations in the watershed of the reservoir When the nutrient values in the present study were compared with those from other reservoirs in Kerala, it was found that the concentrations of nitrates, nitrites and phosphates were almost the same and that of silicate was higher

H C Kataria et al (1995) carried out an assessment of water quality of Kolar reservoir in Bhopal (M.P) The samples were selected from 6 sampling stations at different stations of the Kolar dam The samples were analysed according to APHA (1985), Trivedi and Goel (1986) and NEERI (1986) Temperature, pH, turbidity, electrical conductivity, total solids, suspended solids, nitrites, nitrates, phosphates, chlorides, total alkalinity, total hardness, calcium hardness and magnesium hardness were analysed on the same day BOD was determined by dilution and incubation method Temperature varied from 22 4 to 33 ^{0}C and pH ranged from 7.5 to 8.1 Turbidity ranged from 6.0 to 38.2 NTU Nitrite ranged from 0 002 to 0.080ppm and nitrate ranged from 0 026 to 0 840ppm due to organic pollution and use of fertilisers and industrial effluents mixing into the dam water by run-off water Phosphate concentration varied from 0 006 to 1 2ppm. Phosphate concentration was found to be higher in summer and lower in winter Chloride content ranged from 22 2 to 34.8ppm Total hardness ranged from 112 to 136, 86 to 102 and 26 to 42ppm, respectively in different sampling points of the dam. BOD and COD ranged from 2.0 to 3.6 and 18 2 to 92.8ppm respectively. Fluoride ranged from 0.030 to 0.123ppm Sulphate ranged from 38.4 to 72ppm These results show that the reservoir is severely affected by various domestic and industrial effluents flowing into the dam at various points

H F Mogal and H C. Dube (1990-92) studied the distribution of faecal indicator bacteria in mud and water at Dandi Sea coast Mud and water samples were collected aseptically at bi-monthly intervals from June 1990 to April 1992 Both types of samples were serially diluted for the enumeration of *E coli* by pour plate method on eosin methylene blue (EMB) agar medium The examination of coliforms was done by the multiple-tube-fermentation procedure as a most probable number (MPN) index It was determined by consulting the PMN chart (APHA, 1985). Using azide dextrose broth, a presumptive test was performed to enumerate faecal streptococci (APHA, 1985) The total coliform population builds up from June onwards reaching a maximum in April *E. coli* was present in least numbers in June and the highest counts were obtained in December The faecal streptococci were also at their lowest in June and rose steadily reaching highest numbers in December. The study showed that the total coliforms outnumbered the *E. coli* and faecal streptococci The faecal pollution of human origin noted in the mud and water can be safely ascribed to sewage effluents having coliform bacteria.

Bangalore – Case studies

Hebbal lake, situated on NH-7, has been severely affected by sewage and industrial effluents from BEL factory and Vidyaranyapura. The lake was eutrophic due to excessive sewage inflow. High chlorides, sulphates, COD, phosphate and solids damage the quality of water. The preliminary socio-economic survey carried out in the region surrounding Hebbal lake through Contingency Valuation Method showed high level of dependency on wetlands for ground water, food, fodder, fuel, etc. The lake has been restored now. The lake, even in its present state, supports irrigation and acts as a source of fodder to the livestock in the surrounding areas (Ranjani and Ramachandra, T.V, 1999).

Madivala lake, a perennial tank located in south eastern part of Bangalore City, has been reduced from 114 ha to around 100 ha due to encroachment by the BDA for a road and illegal development of private layouts. Direct discharge of domestic sewage from parts of Jayanagar and J.P Nagar has increased the pollution of the lake. Low DO, high alkalinity, hardness, coliform bacteria, and predominance of *Microcystis*, pollution indicating algae, are deteriorating the water quality (Ayesha Parveen and Ramachandra, T.V, 1998)

Ulsoor lake, one of the important lakes of Bangalore, has very broad and deep feeder channels through which sewage and sullage flow in The runoff and discharges from Commercial Street, automobile workshops, aeronautical industries and Lakshmi talkies affect the lake Fishy odour, high TSS, alkalinity, hardness, phosphates, coliform population and predominance of *Microcystis*, damage the quality of water (Priyadharsini and Ramachandra, T.V, 1998)

Amruthalli lake, situated in Bangalore north taluk, has now attained eutrophic condition due to excessive input of nutrients and organic matter through sewage, storm water, industrial effluents and dumping of organic waste matter from surrounding areas. The lake water is severely polluted by phosphates, TSS, alkalinity, hardness, odour, weed infestation and low DO. Socio-economic survey showed the economic dependency of people residing around the wetland to be about Rs 20/day The lower value was due to the lake being eutrophic and unusable (Rajinikanth and Ramachandra, T.V, 2000)

Rachenahalli lake, situated in Bangalore North and South taluks, has been polluted due to discharge of wastewater from nearby institutions and dumping of organic waste materials from the surrounding areas (mainly poultry wastes) Its quality has been affected by parameters like nutrients, alkalinity and hardness. Socio-economic survey showed the economic dependency of people in the surrounding villages to be about Rs 10,435/day [during cropping and fishing season] (Rajinikanth and Ramachandra, T.V, 2000)

Kiran. R, et al (1998) carried out a comparative water quality assessment of Yediyur and Bannergatta lakes of Bangalore. A periodic monitoring for 12 months (once a month) was done. The physical parameters analysed were colour, odour, temperature, transparency and turbidity The chemical parameters were pH, electrical conductivity, solids, hardness-Ca and Mg, nitrates, phosphates, potassium, sulphates, dissolved oxygen, BOD, COD, free carbon-di-oxide, fluorides, Na and heavy metals like Cu, Pb, Fe, Cd, Ni and Cr A qualitative assessment of plankton was also carried out The study revealed high degree of pollution in Yediyur lake as indicated by high values of COD (84-378 mg/L), BOD (14-32 mg/L), chlorides (96-109.8 mg/L) and higher values of solids In its present condition, the lake acts as a breeding ground for mosquitoes On the contrary, Bannergatta lake has no major source of pollution and the major parameters like COD, BOD, pH and chlorides were found to be within the permissible limits prescribed by the Central Pollution Control Board for surface waters. This lake satisfies the drinking water quality standards also

Decline in the number of water bodies has a serious impact on ground water level. This is evident from a recent study that the level of ground water table has decreased from 35-40 feet to 250-300 feet in 20 years due to disappearance of lakes (Deepa et al, 1997).

Wetlands are currently degraded by both natural and anthropogenic activities, which deteriorate their quality, and push them to the brink of extinction in the process of unplanned development, giving rise to the need for suitable conservation strategies Unfortunately, over the years, less attention has been given to wetland losses world over, including Bangalore. The degradation of the wetlands has altered their functions, affecting the ecological balance The present study of water bodies in Bangalore attempts to:

1. Assess the water quality of selected water bodies through physico-chemical parametric studies. Generally, wetland functions directly relate to their physical, chemical and biological integrity. Water quality evaluation for wetlands leads to information about their misuse by indicating the pollution status. Gale et al (1993) define water quality objectives as the overall direction and purpose of the project, and furthermore define goals as milestones to be met during the course of a project Since the quality of aquatic life depends on water quality, a thorough assessment of the same becomes an integral part of wetland evaluation. The assessment of the chemical criteria of the water body helps in:
   - Evaluating the chemicals that cause toxicity to aquatic life.
   - Studying the long-term effects on the ecosystem
   - Conducting the status and monitoring of wetland resources by studying their physico-chemical and biological parameters.
2. Designate uses that protect the structure and function of wetlands for protection of fish, birds, wildlife, and recreation.

   The baseline values attached to wetlands in terms of designating the viable usage of these water bodies based on established standards protecting their functions is also attempted
3. Analyse the qualitative and quantitative aspects of plankton population of the water bodies.

   The biological integrity of the wetlands is the driving force for their sound ecological functioning. Wetlands that support a vast diversity of fish, birds, mammals, etc., depend directly on it by supporting vast and diverse forms of plankton providing a nutrient base and a complex food-web. In many cases, planktons also act as the biological indicators of pollution being very sensitive to changes in water quality.

Water is a dynamic medium and its quality varies spatially and temporally. In order to characterise any water body, studies on the major components, hydrology, physico-chemical and biological characteristics, should be carried out

Hydrological features:

A thorough knowledge of the hydrological properties of the water body must be acquired before an effective water quality monitoring system is established. Each of the inland water body is characterised by the following unique hydrological features.

- Rivers: characterised by uni-directional current with relatively high average velocity (0.1 – 1.0 m/S). In general, thorough and continuous vertical mixing is achieved in rivers due to the prevailing currents and turbulence
- Lakes: characterised by low, average current (0.001 to 0.01 m/S) giving higher residential time for water Currents within a lake are multi-directional with mixing regulated by the climatic conditions and lake depth
- Ground water: characterised by a steady flow pattern both in direction and speed that is largely governed by the porosity of the geological material as a result of which the mixing is poor
- Reservoirs: intermediate between rivers and lakes

  Large variations in the water residence time occur in different types of inland water bodies. The hydrodynamic characteristics of each type of water body are highly dependent on the size of the water body, climatic conditions and the drainage pattern associated with it Ground water greatly depends on the recharge regime i e infiltration through unsaturated aquifer zone, that allows renewal of the groundwater

Physical, chemical and biological properties:

The physical and chemical properties of a freshwater body are characteristic of the climatic, geochemical, geomorphological and pollution conditions (largely) prevailing in the drainage basin and the underlying aquifer. The biota in the surface water is governed entirely by various environmental conditions that determine the selection of species as the physiological performance of the individual organisms. The primary production of organic matter, in the form of phytoplankton and macrophytes is more intense in lakes and reservoirs than in rivers. In contrast to the chemical quality of waterbodies, which can be measured by suitable analytical methods, biological quality is a combination of both qualitative and quantitative characterisation This can be carried out in two levels:

- Response of individual species to changes in their environment
- Response of biological communities to changes in their environment

SAMPLING

The sample collected should be small in volume, enough to accurately represent the whole water body The water sample tends to modify itself to the new environment It is necessary to ensure that no significant changes occur in the sample and preserve its integrity till analysed (by retaining the same concentration of all the components as in the sample) The essential objectives of water quality assessment are to:

- define the status and trends in water quality of a given water body
- analyse the causes for the observed conditions and trends
- identify the area specific problems of water quality and provide assessments in the form of management to evaluate alternatives that help in decision making

Sampling strategies

The sampling strategies may be as follows:

Stratified random sampling: Here, the sample sites are selected randomly within the areas related to the more homogenous components of an otherwise heterogeneous variable. For example, sampling can be done within the epilimnion, thermocline and hypolimnion of a stratified lake or reservoir as mere sampling of the surface water will not give a true picture of the water quality. Instead sampling can be done at deep water and littoral zones of an aquatic habitat

Systematic sampling This sampling method is considered most satisfactory as it gives a more representative sample for water quality assessment Sample sites are chosen at appropriate locations so as to cover the entire water body. Sampling is carried out at regular depths so as to get various depth profiles. The sampling locations are also decided on the basis of pollution loads entering the river and other important events in the water body like organised bathing, sewage entry points and tributary entry points.

Rapid sampling This sampling is carried out when there is constraint of time for detailed sampling A rapid assessment of the water quality can be done by mixing equal volumes of water from different locations of water body However, this method cannot give detailed assessment of various habitats of the water body.

Site selection

Sampling sites for the water body/lake are selected to represent the water quality at different points and depths Generally sampling test sites selected for monitoring include:

- *Inlet*: the point where the principal feeder opens into the lake
- *Centre*: the point that gives the general water quality of the lake.
- *Outlet*: the place where the overflow occurs.

Types of samples

Generally three types of water samples are collected

- *Grab or Catch samples* the sample is collected at a particular time and place that represents the composition of the source at that particular point and time
- *Composite samples* a mixture of grab samples is collected at the same sampling point at different time intervals
- *Integrated samples* a mixture of grab samples collected at different points simultaneously

Sampling frequency

The quality of water varies with time in a water body due to various natural and human induced factors The monitoring has to be done in a way that records all the changes in the quality The sampling frequencies generally adopted in monitoring are:

- Weekly sampling for one year
- Consecutive days sampling during the study period.
- Hourly sampling for 24 hours.
- Monthly sampling at predefined time

Variations in water quality are mainly due to changes in the concentrations of the components of the water flowing into the water body. These variations can be man-made or natural and can either be cyclic or random

- *Random variations*: due to spasmodic. often unpredictable events such as accidental oil spills, sewage leaks, overflows, etc.
- *Cyclic variations*. may be a result of regular seasonal changes triggering certain natural processes such as rainfall, snowmelts and seasonal temperature changes, altering the ecosystem. Seasonal growth and decay of vegetation will also rise due to cyclic changes in the composition of water

In lakes, the mass of water and good lateral mixing provide inertia against any rapid modifications due to inputs and outputs

Sampling container

The sampling container should not react with the sample. be of adequate capacity to store the sample and be free from contamination

Sampling method

To characterise the water quality of wetlands in Bangalore, seven tanks were selected based on their location and the source of pollution. They were Bannergatta, Hebbal, Kamakshipalya, Madivala, Sankey, Ulsoor and Yediur. Grab sampling was done at the inlet, centre and outlet in most of the waterbodies studied to assess their physical and chemical qualities at monthly intervals, except during some seasons when the centre of the lake was not accessible due to excessive growth of water hyacinth. The samples were collected in thoroughly cleaned 2 5-litre inert plastic containers, which were rinsed with distilled and lake/tank water before collection.

The sampling time for respective tanks was as follows:

Sl. No	TANK	TIME
1	Madivala	8.00-10.00 A.M
2	Bannergatta	10.30-12.00 A.M
3	Kamakshipalya	10.30-12.00 A.M
4	Hebbal	10.00-11.30 A.M
5	Sankey	9.00-10.30 A.M
6	Yediur	10.00-11.00 A.M
7	Ulsoor	10.30-12.00 A.M

Note:

Water samples were collected in a sampling bottle avoiding floating materials. The stoppers of the sample containers were closed properly to prevent outside contamination. The container was labelled describing the name of the water body, date, time, sampling-point, and conditions under which it was sampled.

Preservation of the sample

Between the time a sample is collected and analysed in the laboratory, physical, chemical and biochemical reactions may take place in the sample container leading to changes in the intrinsic quality of the sample, making it necessary to prevent or minimize these changes with suitable preservatives such as alcohol and mercuric chloride. Highly unstable parameters such as pH, temperature, transparency, free carbon-di-oxide, dissolved oxygen, etc., are measured at the sampling site.

The preservation procedure includes keeping the samples in the dark, adding chemical preservative (Table 14), lowering the temperature to retard reactions or combinations of these

Table 14: Preservation Methods

EXPERIMENT	PRESERVATIVE	Max. holding time
BOD	Cool, 4°C	4 hours
Calcium	Cool, 4°C	7 days
Chloride	Cool, 4°C	7 days
COD	Cool, 4°C	24 hours
Dissolved Oxygen	Fix on site	6 hours
Fluoride	Cool, 4°C	7 days
Magnesium	Cool, 4°C	7 days
Nitrate + Nitrite	Cool, 4°C	24 hours
PH	None	6 hours
Phosphorus		

Dissolved	Filter on site using 0.45µm filter	24 hours
Inorganic	Cool, 4°C	24 hours
Ortho	Cool, 4°C	24 hours
Total	Cool, 4°C	1 month
Potassium	Cool, 4°C	7 days
Specific conductance	Cool, 4°C	24 hours
Sodium	Cool, 4°C	7 days
Cadmium	2 ml conc. Nitric acid/L sample	6 months
Chromium	2 ml conc. Nitric acid/L sample	6 months
Copper	2 ml conc. Nitric acid/L sample	6 months
Iron	2 ml conc. Nitric acid/L sample	6 months
Lead	2 ml conc. Nitric acid/L sample	6 months
Nickel	2 ml conc. Nitric acid/L sample	6 months
Zinc	2 ml conc. Nitric acid/L sample	6 months

(Source: Analytical Methods Manual, Water quality branch, Environment Canada, 1981)

PARAMETRIC ANALYSES

The parametric analyses carried out to assess the water quality are broadly divided into:

- **Physical parameters:** Colour, Temperature, Transparency, Turbidity and Odour
- **Chemical parameters:** pH, Electrical Conductivity (EC), Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Hardness, Calcium Hardness, Magnesium Hardness, Nitrates, Phosphates, Sulphates, Chlorides, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Fluorides, Free Carbon-di-oxide, Potassium and Sodium
- **Heavy metal:** Lead, Chromium, Zinc, Iron, Nickel, Cadmium and Copper
- **Biological parameters:** The biological parameters involved the qualitative analyses of planktons (zooplankton and phytoplankton).

Field measurement: The field parameters measured include pH, conductivity, dissolved oxygen, temperature and transparency

Physical parameters

COLOUR

In natural water, colour is due to the presence of humic acids, fulvic acids, metallic ions, suspended matter, plankton, weeds and industrial effluents. Colour is removed to make water suitable for general and industrial applications and is determined by visual comparison of the sample with distilled water

Visual comparison: About 20ml of the sample and 20ml of distilled water are taken in two separate wide mouthed test tubes. The results are tabulated (as clear, greenish, greyish, brownish, blackish, etc) by comparing the colour of the sample with distilled water

TEMPERATURE

Impinging solar radiation and atmospheric temperature brings about spatial and temporal changes in temperature, setting up convection currents and thermal stratification. Temperature plays a very important role in wetland dynamism affecting the various parameters such as alkalinity, salinity, dissolved oxygen, electrical conductivity etc. In an aquatic system, these parameters affect the chemical and biological reactions such as solubility of oxygen, carbon-di-oxide, carbonate-bicarbonate equilibrium, increase in metabolic rate and affects the physiological reactions of organisms, etc. Water temperature is important in relation to fish life. The temperature of drinking water has an influence on its taste

Apparatus required: Thermometer- 0.1° C division

Procedure: Temperature measurement is made by taking a portion of the water sample (about 1litre) and immersing the thermometer into it for a sufficient period of time (till the reading stabilizes) and the reading is taken, expressed as °C

TRANSPARENCY (LIGHT PENETRATION)

Solar radiation is the major source of light energy in an aquatic system, governing the primary productivity Transparency is a characteristic of water that varies with the combined effect of colour and turbidity It measures the light penetrating through the water body and is determined using Secchi disc

Apparatus required: Secchi disc, a metallic disc of 20cm diameter with four quadrats of alternate black and white on the upper surface. The disc with centrally placed weight at the lower surface is suspended with a graduated cord at the centre

Procedure: Transparency is measured by gradually lowering the Secchi disc at respective sampling points. The depths at which it disappears (X_1) and reappears (X_2) is noted. The transparency of the water body is computed as follows

$$\text{Transparency (Secchi Disc Transparency)} = (X_1 + X_2)/2$$

Where, X_1 = Depth at which Secchi disc disappears
X_2 = Depth at which Secchi disc reappears

TURBIDITY

Turbidity is an expression of optical property, wherein light is scattered by suspended particles present in water (Tyndall effect) and is measured using a nephelometer Suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms cause turbidity in water. Turbidity affects light-scattering, absorption properties and aesthetic appearance in a water body Increase in the intensity of scattered light results in higher values of turbidity

Apparatus required: Nephelometer (it detects scattered light at 90° to the incident beam of light It consists of a light source for illuminating the sample One or more photoelectric detectors with a display unit indicate the intensity of light scattered at 90° to the path of incident light), sample cells, lab glassware and Monopan balance

Principle: Nephelometric measurement is based on comparison of the intensity of scattered light of the sample with the intensity of light scattered by a standard reference suspension (Formazin polymer) under similar conditions

Reagents:

- **Distilled water and Stock primary Formazin suspension:**
  - **Solution 1:** 1 0 g Hydrazine sulphate is dissolved in 100ml of distilled water
  - **Solution 2:** 10 0g of Hexamethylenetetramine is dissolved in distilled water and made up to 100ml in a volumetric flask
- **Stock Turbidity Suspension:** 5ml of solution 1 and 2 are mixed in a volumetric flask and allowed to stand for 24 hrs at about $25^\circ C$ ($\pm 3^\circ C$) and diluted to 1000ml with distilled water to give a 400 NTU suspension
- **Standard Turbidity Suspension:** 10ml of the stock solution was diluted to 100ml with distilled water to give a standard solution of 40 NTU

Procedure: The nephelometer is calibrated using distilled water (Zero NTU) and a standard turbidity suspension of 40NTU The thoroughly shaken sample is taken in the nephelometric tube and the value is recorded

Turbidity (NTU) = (Nephelometer readings) (Dilution factor*)

* If the turbidity of the sample is more than 40 NTU, then the sample is diluted and the dilution factor is accounted in final calculations

Chemical parameters

pH:

The effect of pH on the chemical and biological properties of liquids makes its determination very important. It is one of the most important parameters in water chemistry and is defined as -log $[H^+]$, and measured as intensity of acidity or alkalinity on a scale ranging from 0-14 If free H^+ are more it is expressed as acidic (i e pH<7) and if OH^- ions are more then it is expressed as alkaline (i e pH> 7)

In natural waters, pH is governed by the equilibrium between carbon dioxide/bicarbonate/carbonate ions and ranges between 4 5 and 8 5 although mostly basic It tends to increase during day largely due to the photosynthetic activity (consumption of carbon-di-oxide) and decreases during night due to respiratory activity. Wastewater and polluted natural waters have pH values lower or higher than 7 based on the nature of the pollutant

(* The colorimetric indicator method can be used only for approximate pH values)

Apparatus required:

- **pH indicator (BDH) method:** BDH Indicator (Universal Indicator) and test tubes.
- **Electrometric method:** Glass electrode, reference electrode (mercury/calomel or silver/silver chloride) and pH meter.

Procedure:

- **Colorimetric method:** About 10ml of the sample is taken in a wide mouth test tube, 0.2ml of BDH indicator is added, and shaken gently. The color developed is matched with the chart and the pH is noted
- **Electrometric method:** pH is determined by measuring the Electro Motive Force (E.M.F) of a cell comprising an indicator electrode (an electrode responsive to hydrogen ions such as a glass electrode) immersed in the test solution and the reference electrode (usually a mercury/calomel electrode). Contact between the test solution and the reference electrode is usually got by means of a liquid junction, which forms a part of reference electrode. E.M.F of this cell is measured with pH meter, that is, a high impedance voltmeter calibrated in terms of pH. The electrode is allowed to stand for 2 minutes to stabilize before taking reading for reproducible results (at least ±0.1 pH units).

ELECTRICAL CONDUCTIVITY

Conductivity (specific conductance) is the numerical expression of the water's ability to conduct an electric current. It is measured in microSiemens per cm and depends on the total concentration, mobility, valence and the temperature of the solution of ions. Electrolytes in a solution disassociate into positive (cations) and negative (anions) ions and impart conductivity. Most dissolved inorganic substances are in the ionised form in water and contribute to conductance. The conductance of the samples gives rapid and practical estimate of the variation in dissolved mineral content of the water supply. Conductance is defined as the reciprocal of the resistance involved and expressed as mho or Siemen (s)

$$G = \frac{1}{R}$$

G – Conductance (mho or Siemens) and R - Resistance

Apparatus required: Conductivity meter

Procedure: The electrode of the conductivity meter is dipped into the sample, and the readings are noted for stable value shown as mS/cm.

TOTAL SOLIDS:

Total solids is the term applied to the residue left in the vessel after evaporation of the sample and its subsequent drying in an oven at a temperature of 103-105 °C. Total solids include Total Suspended Solids (TSS) and Total Dissolved Solids (TDS).

Principle: A known volume (50 ml) of well-mixed sample is evaporated in a pre-weighed dish and dried to constant weight in an oven at 103-105 °C. The increase in weight over that of the empty dish gives the total solids.

Apparatus: Evaporating dishes - 100ml porcelain dish, steam bath, drying oven, desiccator, Monopan balance and measuring jars

Procedure: A known volume of the well-mixed sample (50ml) is measured into a pre-weighed dish and evaporated to dryness at 103 °C on a steam bath. The evaporated sample is dried in an oven for about an hour at 103-105 °C and cooled in a desiccator and recorded for constant weight

Calculation:

$$\text{Total solids (mg/L)} = \frac{(W_1 - W_2)(1000)}{\text{Sample volume (ml)}}$$

W_1 = Weight of dried residue + dish
W_2 = Weight of empty dish

TOTAL DISSOLVED SOLIDS

Dissolved solids are solids that are in dissolved state in solution. Waters with high dissolved solids generally are of inferior palatability and may induce an unfavourable physiological reaction in the transient consumer.

Principle: The difference in the weight of total solids and the total suspended solids expressed in the same units gives the total dissolved solids

Apparatus: Glass-fiber filter disks, membrane filter funnel, filtration apparatus, suction flask and pump, drying oven and Grooch crucible

Procedure: The difference in the weights of Total Solids (W_1) and Total Suspended Solids (W_2) expressed in the same units gives Total Dissolved Solids (TDS)

Calculation:

$$\text{Total Dissolved Solids (mg/L)} = \frac{(W_1 - W_2) \times 1000}{\text{Sample volume (ml)}}$$

W_1 = Weight of total solids + dish
W_2 = Weight of total suspended solids

TOTAL SUSPENDED SOLIDS

Suspended solids are the portions of solids that are retained on a filter of standard specified size (generally 2 0 μ) under specific conditions. Water with high-suspended solids is unsatisfactory for bathing, industrial and other purposes.

Principle: A well – mixed sample is filtered through a weighed standard glass fibre filter and the residue that is retained on the filter is dried to a constant weight at 103-105 °C. The increase in the weight of the filter determines the total suspended solids

Apparatus: Porcelain dish (100ml capacity), glass fiber filter disk, suction pump and flask, measuring jar, membrane filter funnel, oven and filtration apparatus

Procedure: The known volume of vigorously shaken sample (50ml) is filtered into a pre-weighed glass fibre filter disk fitted to suction pump, and washed successively with distilled water. The filter is carefully removed from the filtration apparatus and dried for an hour at 103-105 °C in an oven, cooled in dessicator and weighed for constant weight

Calculation:

$$\text{Total Suspended Solids (mg/L)} = \frac{(W_1 - W_2)(1000)}{\text{Sample volume (ml)}}$$

W_1 = Weight of dried glass fibre filter + residue
W_2 = Weight of glass fibre filter disk before filtering

TOTAL HARDNESS

Hardness is predominantly caused by divalent cations such as calcium, magnesium, alkaline earth metal such as iron, manganese, strontium, etc. The total hardness is defined as the sum of calcium and magnesium concentrations, both expressed as $CaCO_3$ in mg/L. Carbonates and bicarbonates of calcium and magnesium cause temporary hardness. Sulphates and chlorides cause permanent hardness.

Table 15: Hardness Chart ***(for drinking water)***

Soft	0 – 60 mg/L
Medium	60 –120 mg/L
Hard	120 - 180 mg/L
Very Hard	> 180 mg/L

Principle: In alkaline conditions, EDTA (Ethylene-diamine tetra acetic acid) and its sodium salts react with cations forming a soluble chelated complex when added to a solution. If a small amount of dye such as Eriochrome black-T is added to an aqueous solution containing calcium and magnesium ions at alkaline pH of 10.0 ± 0.1, it forms wine red colour When EDTA is added as a titrant, all the calcium and magnesium ions in the solution gets complexed resulting in a sharp colour change from wine red to blue, marking the end point of the titration Hardness of water prevents lather formation with soap rendering the water unsuitable for bathing and washing It forms scales in boilers, making it unsuitable for industrial usage. At higher pH>12.0, Mg^{++} ion precipitates with only Ca^{++} in solution. At this pH, murexide indicator forms a pink color with Ca^{++} ion When EDTA is added, Ca^{++} gets complexed resulting in a change from pink to purple indicating end point of the reaction

Apparatus required: Lab glassware - burette, pipette, conical flask, beakers, etc

Reagents:

- **Buffer solution:** 16.9 g of ammonium chloride, 1.25g of magnesium salt of EDTA is dissolved in 143ml of concentrated ammonium hydroxide and diluted to 250ml with distilled water.
- **Eriochrome black-T indicator:** 0.5 g of Eriochrome black-T indicator is dissolved in 100g of triethanolamine
- **Standard EDTA titrant:** 0.01M or Ng AR grade EDTA is dissolved in distilled water and diluted to 1000ml and is standardised against standard calcium solution, 1ml = 1mg $CaCO_3$
- **Standard Calcium solution:** 1.0g of AR grade $CaCO_3$ is weighed into a 250ml conical flask, to which 1+1 HCl is added till all $CaCO_3$ is dissolved completely. 200ml of distilled water is added and boiled to expel carbon-di-oxide. Dilute to 1000ml 1ml = 1mg $CaCO_3$

Procedure: Exactly 50ml of the well-mixed sample is pipetted into a conical flask, to which 1ml of ammonium buffer and 2-3 drops of Eriochrome black -T indicator is added. The mixture is titrated against standard 0.01M EDTA until the wine red colour of the solution turns pale blue at the end point.

Calculation:

$$\text{Total hardness (mg/L)} = \frac{(T)(1000)}{V}$$

Where, T = Volume of titrant

V = Volume of sample

CALCIUM HARDNESS

The presence of calcium (fifth most abundant) in water results from passage through or over deposits of lime stone, dolomite, gypsum and other calcium bearing rocks. Calcium contributes to the total hardness of water and is an important micro-nutrient in aquatic environment and is especially needed in large quantities by molluscs and vertebrates. It is measured by EDTA titrimetric method Small concentration of calcium carbonate prevents corrosion of metal pipes by laying down a protective coating. But increased amount of calcium precipitates on heating to form harmful scales in boilers, pipes and utensils

Principle: When EDTA (Ethylene-diamine tetra acetic acid) is added to the water containing calcium and magnesium, it combines first with calcium. Calcium can be determined directly with EDTA when pH is made sufficiently high such that the magnesium is largely precipitated as hydroxyl compound (by adding NaOH and iso-propyl alcohol). When murexide indicator is added to the solution containing calcium, all the calcium gets complexed by the EDTA at pH 12-13 The end point is indicated from a colour change from pink to purple.

Apparatus required: Burettes, pipette, conical flask, beakers and droppers.

Reagents:

- **Sodium hydroxide (8%):** 8g of sodium hydroxide is dissolved in 100ml of distilled water
- **Murexide indicator (ammonium purpurate):** 0.2 g of murexide is ground well with 100g of sodium chloride thoroughly
- **Standard EDTA titrant, 0.01M:** 3.723 g of EDTA (disodium salt) is dissolved in distilled water and made up to 100ml with the same.

Procedure: A known volume (50ml) of the sample is pipetted into a clean conical flask, to which 1ml of sodium hydroxide and 1ml of iso-propyl alcohol is added. A pinch of murexide indicator is added to this mixture and titrated against EDTA until the pink color turns purple.

Calculation:

$$\text{Calcium as Ca (mg/L)} = \frac{T \times 400.5 \times 1.05}{\text{Sample taken, ml}}$$

Where, T= volume of titrant, ml

$$\text{Calcium hardness (mg/L as } CaCO_3) = \frac{T \times 1000 \times 1.05}{\text{Sample taken, ml}}$$

MAGNESIUM HARDNESS

Magnesium is a relatively abundant element in the earth's crust, ranking eighth in abundance among the elements It is found in all natural waters and its source lies in rocks, generally present in lower concentration than calcium. It is also an important element contributing to hardness and a necessary constituent of chlorophyll Its concentration greater than 125 mg/L can influence cathartic and diuretic actions

Principle: Magnesium hardness can be calculated from the determined total hardness and calcium hardness.

Calculation:

$$\text{Magnesium (as Mg, mg/L)} = (T - C) \times 0.243$$

where, T = Total hardness mg\L as $CaCO_3$
C = Calcium hardness mg\L as $CaCO_3$

High concentration of magnesium proves to be diuretic and laxative, and reduces the utility of water for domestic use while a concentration above 500 mg/L imparts an unpleasant taste to water and renders it unfit for drinking Chemical softening, reverse osmosis and electro dialysis or ion exchange reduces the magnesium hardness to acceptable levels

NITRATES

Nitrates are the most oxidized forms of nitrogen and the end product of the aerobic decomposition of organic nitrogenous matter The significant sources of nitrates are chemical fertilizers from cultivated lands, drainage from livestock feeds, as well as domestic and industrial sources Natural waters in their unpolluted state contain only minute quantities of nitrates The stimulation of plant growth by nitrates may result in eutrophication, especially due to algae. The subsequent death and decay of plants produces secondary pollution. Nitrates are most important for biological oxidation of nitrogenous organic matter Certain nitrogen fixing bacteria and algae have the capacity to fix molecular nitrogen in nitrates. The main source of polluting nitrates is the domestic sewage let into water bodies Nitrates may find their way into ground water through leaching from soil and at times by contamination. They can be measured by the phenoldisulphonic method

Principle: Nitrates react with phenoldisulphonic acid and produce a nitrate derivative, which in alkaline solution develops yellow colour due to rearrangement of its structure. The colour produced is directly proportional to the concentration of nitrates present in the sample.

Apparatus required: Nessler's tube, pipettes, beakers, spectrophotometer, cuvettes, measuring jar and hot water bath

Reagents:

- **Phenol disulphonic acid:** 25 g of phenol was dissolved in 150 ml of concentrated sulphuric acid, 85ml of sulphuric acid was further added and heated for about 90 min on a water bath and stored in dark bottles upon cooling.
- **Sodium hydroxide:** About 50g of sodium hydroxide is dissolved in 150-200 ml of water and cooled
- **Conc. Ammonium hydroxide**
- **Nitrate solution:**
  - **Stock nitrate solution:** 721.8 mg (0.722g) of AR potassium nitrate is dissolved in distilled water and made up to 100ml for stock solution
  - **Standard nitrate solution:** Standard nitrate solution is prepared by evaporating 50ml of the stock solution to dryness in the water bath The obtained residue is dissolved in 2ml of phenol disulfonic acid

and diluted to 500ml, to give 1ml = 10 µg. The solution of various strengths ranging from 0.0 (blank) to 1.0 mg/L at intervals of 0.2 mg/L is prepared by diluting stock solution with distilled water.

Procedure: A known volume (50ml) of the sample is pipetted into a porcelain dish and evaporated to dryness on a hot water bath. 2ml of phenol disulphonic acid is added to dissolve the residue by constant stirring with a glass rod. Concentrated solution of sodium hydroxide or conc. ammonium hydroxide and distilled water is added with constant stirring to make it alkaline. This is filtered into a Nessler's tube and made upto 50ml with distilled water. The absorbance is read at 410nm using a spectrophotometer after the development of colour. The standard graph is plotted by taking concentration along X-axis and the spectrophotometric readings (absorbance) along Y-axis. The value of nitrate is found by comparing absorbance of sample with the standard curve and expressed in mg/L.

Calculation:

$$\text{Nitrates (as } NO_3 \text{ mg/L)} = \frac{\text{Absorbance of sample X Conc of std X 1000}}{\text{Absorbance of Std X Sample taken}}$$

The high concentration of nitrate in water is indicative of pollution.

PHOSPHATES

Phosphates occur in natural or wastewaters as orthophosphates, condensed phosphates and naturally found phosphates. Their presence in water is due to detergents, used boiler waters, fertilizers and biological processes. They occur as detritus in the bodies of aquatic organisms. They are essential for the growth of organisms and a nutrient that limits the primary productivity of the water body. Inorganic phosphorus plays a dynamic role in aquatic ecosystems and is one of the most important nutrients when present in low concentration, but in excess along with nitrates and potassium, causes algal blooms. It is calculated by the stannous chloride method.

Principle: In acidic conditions orthophosphate reacts with ammonium molybdate forming Molybdophosphoric acid, reduced further to molybdenum blue by stannous chloride. The intensity of the blue colour is directly proportional to the concentration of phosphate. The absorbance is noted at 690nm using spectrophotometer.

Apparatus required: Spectrophotometer, lab glassware, hot plate and Nessler's tube.

Reagents:

- **Ammonium molybdate reagent:** 25g ammonium molybdate is dissolved in 175ml distilled water. 280ml concentrated sulphuric acid is added to 400ml distilled water and cooled. Molybdate solution is added and the mixture diluted to 1000ml.
- **Stannous chloride reagent:** 2.5g fresh stannous chloride is dissolved in 100ml glycerol, heated on water bath and stirred with the glass rod to hasten dissolution.
- **Standard phosphate solution:** 219.5 mg of dried AR potassium hydrogen phosphate is dissolved in distilled water and made up to 1000ml, where 1ml = 50.0 µg of phosphate. 10ml of the stock solution is made up to 1000ml to give 1ml = 0.05 mg. Standards of strength ranging from 0 (blank) to 0.05mg/L at intervals of 0.01mg is prepared by diluting the stock with distilled water.

Procedure: To 50ml of the filtered sample, 4ml of ammonium molybdate reagent and about 4-5 drops of stannous chloride reagent is added. After about 10 min but before 12 min, the colour developed is measured photometrically at 690nm and calibration curve is prepared. A reagent blank is always run with same treatment with distilled water as sample. The value of phosphate is obtained by comparing absorbance of sample with the standard curve and expressed as mg/L.

Calculation:

$$\text{Phosphates (as P mg/L)} = \frac{\text{Absorbance of sample X Conc. of std X 1000}}{\text{Absorbance of Std X Sample taken}}$$

High phosphorus content causes increased algal growth till nitrogen becomes limiting, although blue green algae continues to dominate because of its ability to utilize molecular nitrogen. Besides sedimentation, high uptake by phytoplankton is one of the reasons for fast depletion of phosphorus in water.

SULPHATES

Sulphates are found appreciably in all natural waters, particularly those with high salt content. Besides industrial pollution and domestic sewage, biological oxidation of reduced sulphur species also add to sulphate content. Soluble in water, it imparts hardness with other cations. Sulphate causes scaling in industrial water supplies. and odour and corrosion problems due to its reduction to hydrogen sulphide. It can be calculated by turbidometric method

Principle: Sulphate ions are precipitated in acetic acid medium with barium chloride to form barium sulphate crystals of uniform size. The scattering of light by the precipitated suspension (barium sulphate) is measured by a Nephelometer and the concentration is recorded

Apparatus required: Nephelometer, magnetic stirrer, Nessler's tubes and lab glassware

Reagents:

- **Conditioning reagent:** 50 ml of glycerol was mixed in a solution containing 30 ml of conc. hydro chloric acid, in 300ml distilled water (10% HCl), 100 ml of 95% ethyl alcohol or isopropyl alcohol and 75g NaCl.
- **Barium Chloride**
- **Standard sulphate solution:** 147.9mg of AR grade sodium sulphate was dissolved in distilled water and made up to 1000ml, to give 1ml = 100mg sulphate.

Procedure: 100ml of the sample is filtered into a Nessler's tube containing 5ml of conditioning reagent. About 0.2g of barium chloride crystals is added with continued stirring. A working standard is prepared by taking 1ml of the standard, 5ml of conditioning reagent and made up to 100ml, to give 100 NTU. The turbidity developed by the sample and the standards are measured using a Nephelometer and the results are tabulated

Calculation:

Sulphate (as SO_4 mg/L) = (Nephlometric reading) (0.4) (Dilution Factor)

CHLORIDES

The presence of chlorides in natural waters can mainly be attributed to dissolution of salt deposits in the form of ions (Cl^-). Otherwise, high concentrations may indicate pollution by sewage or some industrial wastes or intrusion of sea water or other saline water. It is the major form of inorganic anions in water for aquatic life. A high chloride content has a deleterious effect on metallic pipes and structures, as well as agricultural plants. They are calculated by Argentometric method

Principle: In alkaline or neutral solution, potassium chromate indicates the endpoint of the silver nitrate titration of chlorides. Silver chloride is quantitatively precipitated before the red silver chromate is formed

Apparatus required: Lab glassware.

Reagents:

- **Potassium chromate indicator solution:** 50g of potassium chromate is dissolved in minimum amount of distilled water and silver nitrate is added drop wise till a red precipitate is formed. The mixture is allowed to stand for about 12 hours and diluted to 1000ml with distilled water
- **Silver nitrate solution (0.014N):** 2.395g of silver nitrate is dissolved in distilled water and made up to 1000ml

Procedure: A known volume of filtered sample (50ml) is taken in a conical flask, to which about 0.5ml of potassium chromate indicator is added and titrated against standard silver nitrate till silver dichromate ($AgCrO_4$) starts precipitating

Calculation:

$$\text{Chlorides } (Cl^-) = \frac{(A-B)\,(N)\,(35.45)}{\text{Sample taken in ml}}$$

Where,

A - Volume of silver nitrate consumed by the sample

B - Volume of silver nitrate consumed by the blank

N - Normality of silver nitrate (Standard methods, APHA, 16th edn, pp 286-88)

DISSOLVED OXYGEN

Oxygen dissolved in water is a very important parameter in water analysis as it serves as an indicator of the physical, chemical and biological activities of the water body. The two main sources of dissolved oxygen are diffusion of oxygen from the air and photosynthetic activity. Diffusion of oxygen from the air into water depends on the solubility of oxygen, and is influenced by many other factors like water movement, temperature, salinity, etc Photosynthesis, a biological phenomenon carried out by the autotrophs, depends on the plankton population, light condition, gases, etc Oxygen is considered to be the major limiting factor in waterbodies with organic materials Dissolved oxygen is calculated by many methods

Method 1: Membrane electrode method

Principle: The membrane electrode has a sensing element protected by an oxygen-permeable plastic membrane that serves as a diffusion barrier against impurities Under steady conditions, the electric current read is directly proportional to the D O concentrations (electric current is directly proportional to the activity of molecular oxygen)

Apparatus required: Oxygen-sensitive membrane electrode and lab glassware

Procedure: The calibrations are carried out following the manufacturer's calibration procedure The electrode is dipped into the sample, and the reading noted

Method 2: Winkler's method

Principle: Oxygen present in the sample oxidizes the dispersed divalent manganous hydroxide to precipitate as a brown hydrated oxide after addition of potassium iodide and sodium hydroxide Upon acidification, manganese reverts to its divalent state and liberates iodine from potassium iodide, equivalent to the original dissolved oxygen content of the sample The liberated iodine is titrated against N/80 sodium thiosulphate using fresh iodine as an indicator

Apparatus required: BOD bottles- 300ml capacity, sampling devices, lab glassware - measuring cylinder, conical flasks, etc., and Bunsen burner

Reagents:

- **Manganese sulphate:** 480g of manganous sulphate tetrahydrate was dissolved and made up to 1000ml with distilled water (Discard if it changes colour with starch)
- **Alkaline iodide-azide reagent:** 500g of sodium hydroxide and 150g of potassium iodide along with 10g of sodium azide (NaN_3) was dissolved and made up to 1000ml with distilled water
- **Conc. sulphuric acid**
- **Starch indicator:** 0 5g of starch was dissolved in distilled water and was boiled for few minutes.
- **Stock sodium thiosulphate:** 24 82g of sodium thiosulphate pentahydrate ($Na_2S_2O_2$ $5H_2O$) was dissolved in distilled water and made upto 1000ml
- **Standard sodium thiosulphate (0.025N):** 250ml of the stock sodium thiosulphate pentahydrate was made upto 1000ml with distilled water to give 0 025N

Procedure: The samples were collected in BOD bottles, to which 2ml of manganous sulphate and 2ml of potassium iodide were added and sealed This was mixed well and the precipitate was allowed to settle down. At this stage 2ml of conc sulphuric acid was added, and mixed well until all the precipitate dissolved 203ml of the sample was measured into the conical flask and titrated against 0 025N sodium thiosulphate using starch as an indicator The end point is the change of colour from blue to colourless

Calculations:

203ml because (200) (300)/ (200-4) = 203ml

1ml of 0 025N Sodium Thiosulphate = 0 2mg of Oxygen

$$\text{Dissolved Oxygen (as mg/L)} = \frac{(0.2)\,(1000\text{ ml of Sodium Thiosulphate})}{200}$$

(Water analysis, APHA, 16th edn, pp 423-17)

BIOLOGICAL OXYGEN DEMAND

Biological Oxygen Demand (BOD) is the amount of oxygen required by microorganisms for stabilizing biologically decomposable organic matter (carbonaceous) in water under aerobic conditions The test is used to determine the pollution load of wastewater, the degree of pollution and the efficiency of wastewater treatment methods. 5-Day BOD test being a bioassay procedure (involving measurement of oxygen consumed by bacteria for degrading the organic matter under aerobic conditions) requires the addition of nutrients and maintaining the standard conditions of pH and temperature and absence of microbial growth inhibiting substances

Principle: The method consists of filling the samples in airtight bottles of specified size and incubating them at specified temperature (20° C) for 5 days. The difference in the dissolved oxygen measured initially and after incubation gives the BOD of the sample.

Apparatus required: BOD bottles - 300ml capacity, air incubator - to be controlled at 20°C -\+ 1° C, oximeter and magnetic stirrer

Reagents:

- **Preparation of dilution water:** To 1000ml of water, 1ml each of phosphate buffer, magnesium sulphate, calcium chloride and ferric chloride solution is added, before bringing it to 20° C and aerating it thoroughly.

Procedure: The sample having a pH of 7 is determined for first day DO. Various dilutions (at least 3) are prepared to obtain about 50% depletion of D.O. using sample and dilution water. The samples are incubated at 20° C for 5 days and the 5th day D.O is noted using the oximeter. A reagent blank is also prepared in a similar manner.

Calculation:

$$\text{BOD, mg/L} = \frac{(D_1 - D_2) - (B_1 - B_2) \text{ X } f}{p}$$

D_1 - 1st day D.O of diluted sample, mg/L
D_2 - 5th day D.O of diluted sample, mg/L
P - decimal volumetric fraction of sample used
B_1 - 1st day D.O of control, mg/L
B_2 - 5th day D.O of control, mg/L

(Water analysis, APHA, 16th edn)

CHEMICAL OXYGEN DEMAND

Chemical oxygen demand (COD) is the measure of oxygen equivalent to the organic content of the sample that is susceptible to oxidation by a strong chemical oxidant. The intrinsic limitation of the test lies in its ability to differentiate between the biologically oxidisable and inert material. It is measured by the open reflux method

Principle: The organic matter in the sample gets oxidized completely by strong oxidizing agents such as potassium dichromate in the presence of conc. sulphuric acid to produce carbon-di-oxide and water. The excess potassium dichromate remaining after the reaction is titrated with Ferrous Ammonium Sulphate (FAS) using ferroin indicator to determine the COD. The dichromate consumed gives the oxygen required for the oxidation of the organic matter

Apparatus required: Reflux apparatus, Nessler's tube, Erlenmeyer flasks, hot plate and lab glassware

Reagents:

- **Standard potassium dichromate solution (0.250M):** 12.25g of potassium dichromate dried at 103° C for about 2 hours was dissolved in distilled water and made upto 1000ml
- **Standard ferrous ammonium sulphate (FAS) 0.25N:** 98g of FAS was dissolved in minimum distilled water to which 20ml of conc. sulphuric acid was added and made upto 1000ml using distilled water to give 0.25N of ferrous ammonium sulphate
- **Ferroin indicator:** 1.485g of 1,10-Phenanthroline monohydrate and 695mg of ferrous sulphate were dissolved in 100ml of distilled water
- **Conc. sulphuric acid**
- **Silver sulphate crystals**
- **Mercuric sulphate crystals**

Procedure: 15ml of conc. sulphuric acid with 0.3g of mercuric sulphate and a pinch of silver sulphate along with 5ml of 0.025M potassium dichromate are taken in a Nessler's tube. 10ml of sample (thoroughly shaken) is pipetted out into this mixture and kept for about 90 minutes on the hot plate for digestion. 40ml of distilled water is added to the cooled mixture (to make up to 50ml) and titrated against 0 25M FAS using ferroin indicator, till the colour turns from blue green to wine red indicating the end point A reagent blank is also carried out using 10ml of distilled water

Calculation:

$$\text{COD (mg/L)} = \frac{(\text{Blank reading} - \text{Sample reading}) \times N \times F \times 1000}{\text{Sample taken, ml}}$$

To calculate F,

$$F = \frac{10000}{\text{Titrant value of blank}}$$

FLUORIDE

Fluorides have dual significance in water supplies High concentration causes dental fluorosis and lower concentration (<0 8 mg/L) causes dental caries. A fluoride concentration of approximately 1mg/L in drinking water is recommended. They are frequently found in certain industrial processes resulting in fluoride rich wastewaters Significant sources of fluoride are found in coke, glass and ceramic, electronics, pesticide and fertiliser manufacturing, steel and aluminium processing and electroplating industries It is calculated by SPADNS method

Principle: The colorimetric method of estimating fluoride is based on the reaction of fluorides (HF) with zirconium SPADNS solution and the 'lake' (colour of SPADNS reagent), which is greatly influenced by the acidity of the reaction mixture Fluoride reacts with the dye 'lake', dissociating (bleaching) the dye into a colourless complex anion (ZrF_6^{2-}) As the amount of fluoride increases, the colour produced becomes progressively higher or of different hue.

Apparatus required: Spectrophotometer and lab glassware.

Reagents:

- **Standard fluoride solution.**
- **Stock:** 221 0mg of AR grade sodium fluoride was dissolved in distilled water and made up to 1000ml to give 1ml = 100 μ g of F^-
- **Working Standard:** 100ml of the stock fluoride was diluted to 1000ml to give 1ml = 10 μg of flouride
- **SPADNS Solution:** 958mg of SPADNS is dissolved in 500ml of distilled water [1]
- **Zirconyl-acid reagent:** 133mg zirconyl chloride octahydrate ($ZrOCl_2$ $8H_2O$) was dissolved in about 25ml of distilled water. 350ml of conc. HCl was added and diluted to 500ml with distilled water.
- **Acid zirconyl-SPADNS reagent:** Equal volume of SPADNS and zirconyl acid reagent was mixed

Procedure: A standard graph was prepared by using fluoride concentrations ranging from 0.005mg/L to 0 150mg/L at 570nm. A reference solution was prepared by adding 4ml of acid zirconyl-SPADNS reagent to 21ml of distilled water. A known volume of filtered sample (21ml) was taken in a test tube, 4ml of acid zirconyl-SPADNS reagent was added to the sample along with a reference solution The mixture was left for about 30 min for complete colour development and the optical density was read at 570nm

Calculation:

$$F^- \text{ mg/L} = \frac{(\text{O D sample}) (\text{Conc of the Standard}) (1000)}{(\text{O.D Standard}) (\text{sample taken})}$$

FREE CARBON-DI-OXIDE

The important source of free carbon-di-oxide in surface water bodies is mainly respiration and decomposition by aquatic organisms It reacts with water partly to form calcium bicarbonate and in the absence of bicarbonates gets converted to carbonates releasing carbon-di-oxide.

[1] * SPADNS - Sodium 2-(parasulfophenylazo)-1,8-dihydroxy-3, 6-naphthalene disulfonate

Principle: Free carbon-di-oxide reacts with sodium carbonate or sodium hydroxide to form sodium bicarbonate The completion of the reaction is indicated by the development of pink colour, characteristic of phenolphthalein indicator at an equivalent pH of 8.3

Apparatus required: Lab glassware - measuring jar, pipette, conical flask, etc.

Reagents:

- **Sodium hydroxide solution (0.22N):** 1g of sodium hydroxide was dissolved in 100ml of distilled water and made up to 1000ml to give 0 22N
- **Phenolphthalein indicator**

Procedure: A known volume (50ml) of the sample was measured into a conical flask 2-3 drops of phenolphthalein indicator was added and titrated against 0 22N sodium hydroxide till the pink colour persisted indicating the end point[2](*)

Calculation:

$$\text{Free } CO_2 \text{ (mg/L)} = \frac{(V_t)(1000)}{V_s}$$

Where, V_t - volume of titrant (ml)
V_s - volume of the sample taken (ml)

POTASSIUM

Potassium ranks seventh among the elements in order of abundance, behaves similar to sodium and remains low Though found in small quantities (<20mg/L) it plays a vital role in the metabolism of fresh water environment.

Principle: Trace amount of potassium can be determined by direct reading of flame photometer at a specific wavelength of 766 5nm by spraying the sample into the flame The desired spectral lines are then isolated by the use of interference filters or suitable slit arrangements. The intensity of light is measured by the phototube.

Working principle of Flame photometer: The emission of characteristic radiations by alkali and alkaline earth metals and the correlation of the emission intensity with the concentration of the element form the basis of flame photometry The principle of the flame photometer depends on the "Emission Spectroscopy" in which the electrons of the metals after absorbing energy get excited from ground state to higher energy level and return back to the ground state with emission of light The sample under test is introduced into flame in solution by means of atomizer The radiation from the flame enters a dispersing device and isolates it (radiation) from the flame to the desired region of the spectrum The photo tube measures the intensity of isolated radiation, which is proportional to the concentration of the element present in the sample

Apparatus required: Flame photometer, lab glassware and Whattman filter paper

Reagents:

- **Deionised distilled water.**
- **Stock potassium solution:** 1 907g of dried potassium chloride, was dissolved in 1000ml of distilled water, to give 1ml = 1mg of potassium.
- **Working potassium solution:** Working standards of suitable strengths were prepared from the stock solution.

Procedure: The filter of the flame photometer is set at 766.5nm (marked for Potassium, K) and the flame is adjusted for blue colour The scale is set to zero and maximum using the highest standard value. A standard curve of different concentration is prepared by feeding the standard solutions The sample is filtered through the filter paper and fed into the flame photometer. The concentration is found from the standard curve or as direct reading

SODIUM

Sodium is one of the most abundant elements and is a common constituent of natural waters The sodium concentration of water is of concern primarily when considering their solubility for agricultural uses or boiler feed water. The concentration ranges from very low in the surface waters and relatively high in deep ground waters and highest in the marine waters It is calculated by flame photometric method.

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2 (*) If the pink color appears on adding phenolphthalein it indicates the absence of free carbon-di-oxide

Reagents:

- **Deionised water**
- **Stock sodium solution:** 2.542g of sodium chloride dried (at 140° C) was dissolved in 1000ml distilled water to give 1ml = 1mg of sodium
- **Working potassium solution:** Working standards of suitable strengths were prepared from the stock solution

Procedure: The filter of the flame photometer is set to 589nm (marked for Sodium, Na). By feeding distilled water the scale is set to zero and maximum using the standard of highest value. A standard curve between concentration and emission is prepared by feeding the standard solutions. The sample is filtered through filter paper and fed into the flame photometer and the concentration is found from graph or by direct readings

Apparatus required: Flame photometer, lab glassware and Whattman filter paper

Heavy metals

Heavy metals are elements (properties of metals satisfied) of high atomic numbers. They have high utilities in industrial applications from papers to automobiles, by their very characteristic properties. They are found in the deep bowels of the earth as ores (complexes of mixtures). The metals are segregated from these ores, leaving behind the tailings that find their way into the environment as toxic pollutants. They get into the water bodies directly from point sources as sewage, and non-point sources as runoff and more insidiously as atmospheric deposition pollutants transported from long distances. Heavy metals affect every level of the food web, from producers in the trophic levels to the highest order carnivore by residing in the system and magnifying at every trophic status.

Atomic absorption spectrophotometer (AAS)

Working principle: Atomic absorption spectrophotometer's working principle is based on the sample being aspirated into the flame and atomized, when the light beam from AAS's is detected through the flame into the monochromator, and onto the detector that measures the amount of light absorbed by the atomized element of the flame. Since metals have their own characteristic absorption wavelength, a source lamp composed of that element is used, making the method relatively free from spectral or radiational interferences. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

Procedure: The sample is thoroughly mixed by shaking, and 100ml of it is transferred into a glass beaker of 250ml volume, to which 5ml of conc. nitric acid is added and heated to boil till the volume is reduced to about 15-20ml, by adding conc. nitric acid in increments of 5ml till all the residue is completely dissolved. The mixture is cooled, transferred and made upto 100ml using metal free distilled water

Operations for analysing heavy metals:

- **Lamp selection:**
  - Lamp for the element to be detected is selected
  - Operating current is suitably adjusted.
  - The lamp is aligned for the visible beam to fall on the slit of the monochromator
- **Wave length selection and slit adjustment:**
  - Appropriate wavelength for the element to be detected is selected. The wavelength controller is moved clockwise or anti-clockwise slowly to get maximum percentage of transmittance
  - The slits are adjusted to get closest to the required wavelength and avoid excess stray light
- **Flame adjustment:**
  - On selecting suitable wavelength, the acetylene-air mixture is lit at the recommended pressure.
  - The burner level is so adjusted that the beam from the cathode crosses 1cm from the top of the burner and the beam is stabilized
- **Analysis:**
  - A calibration graph is obtained by feeding the standard solutions of suitable concentration
  - The samples are aspirated by feeding them through the capillary and the readings are noted. (Distilled water is aspirated between samples)

Apparatus required: AAS and lab glassware

Reagents:

- **Air-Acetylene flame**

- **Metal free water**
- **Standard metal solutions**

LEAD

Lead is relatively a minor element in the earth's crust but is widely distributed in low concentrations in uncontaminated soils and rocks. Lead concentration in freshwater is generally much higher High concentration of lead results from atmospheric input of lead originating from its use in leaded gasoline or from smelting processes Industrial processes such as printing and dyeing, paint manufacturing, explosives, photography and mine or smelter operations may contain relatively high values of lead Lead is toxic to aquatic organisms

Principle: Lead can be determined at a wavelength of 283 3 nm by AAS with aspiration of the sample into the oxidising air-acetylene flame When the aqueous sample is aspirated, the sensitivity for 1% absorption is 0 5 mg/L and the detection limit is 0 05 mg/L.

Standard lead solution: 1 598g of lead nitrate was dissolved in about 200ml of water containing 1 5ml of conc nitric acid and diluted to 1000ml of metal free water to give 1ml = 1mg lead A series of standards ranging from 1mg to 5mg were prepared from the stock and a standard graph was made

COPPER

Copper is a widely distributed trace element because most copper minerals are relatively insoluble and are sorbed to solid phases, hence only low concentrations are normally present in natural waters. Because of the presence of sulphide, copper would be expected to be even less soluble in anoxic systems The presence of higher concentrations of copper can usually be attributed to corrosion of copper pipes, industrial wastes or particularly in reservoirs, where copper is used as algaecides Copper is an essential trace element in the nutrition of plants and animals including man. It is required for the function of several enzymes and is necessary in the biosynthesis of chlorophyll High levels are toxic to organisms but the response varies greatly with species

Principle:

Copper can be determined at a wavelength of 324 7 nm by AAS with aspiration of the sample into an oxidising air-acetylene flame When the aqueous sample is aspirated, the sensitivity for 1% absorption is 0 1 mg/L and the detection limit is 0 01 mg/L.

Standard copper solution: 1g of copper salt is dissolved in 15ml of 1+1 nitric acid and diluted to 1000ml to give 1ml = 1mg copper. A series of standards ranging from 1mg to 5mg were prepared from the stock and a standard graph was prepared.

NICKEL

Nickel is present in less than 1 mg/L in surface waters Nickel is relatively a non-toxic element. It is essential for animal nutrition. Certain nickel compounds have shown to be carcinogenic in animal experiments. However, soluble nickel compounds are not currently regarded as either human or animal carcinogens, but higher concentrations of nickel can react with DNA (deoxy ribonucleic acid), resulting in the damage of DNA

Standard nickel solution: 1.273g of nickel oxide was dissolved in a minimum quantity of 10% HCl and diluted to 1000ml with distilled water to give 1ml = 1mg of nickel. A series of standards ranging from 1mg to 5mg were prepared from the stock and analysed

IRON

Iron is an abundant element in the earth's crust, but exists generally in minor concentrations in natural water systems Iron is found in the +2 *(ferrous)* and +3 *(ferric)* states depending on the oxidation-reduction potentials of the water. The ferric state of iron imparts orange strain to any settling surface, including laundry articles, cooking and eating utensils, and plumbing fixtures

Principle:

Iron can be determined at a wavelength of 248 3 nm by AAS with aspiration of the sample into an oxidising air-acetylene flame Under standard conditions, iron produces 1% absorption at 0 12 mg/L and a linear response up to about 5 mg/L.

Standard iron solution: 1g of iron was dissolved in 50ml of 1+1 nitric acid and diluted to 1000ml with distilled water to give 1ml = 1mg of iron A series of standards ranging from 1mg to 5mg were prepared from the stock and analysed.

CHROMIUM

The concentration of chromium in natural waters is usually very low Elevated concentrations of chromium can result from mining and industrial processes Chromate compounds are routinely used in cooling waters to control erosion Chromium in water supplies is generally found in the hexavalent form

Principle:
Total chromium can be determined at a wavelength of 357 9 nm by atomic absorption with aspiration of sample into a reducing air-acetylene flame Under standard concentrations, chromium produces 1 % absorption at 0 25 mg/L and is detectable down to 0 003 mg/L

Standard chromium solution: 2 828g of AR grade potassium dichromate was dissolved in about 200ml of distilled water, with 1.5ml of conc nitric acid and made up to 1000ml with the same to give 1ml = 1mg of chromium A series of standards ranging from 1mg to 5mg were prepared from the stock and analysed

CADMIUM

Cadmium is largely found in nature in the form of sulphide, and as an impurity of zinc - lead ores The abundance of cadmium is much less than that of zinc. Cadmium may enter the surface waters as a consequence of mining, electroplating plants, pigment works, textile and chemical industries. Cadmium is toxic to man There is evidence that cadmium affects reproductive organs in humans and is also a potential carcinogen. A specific disease called "itai-itai" has been observed in Japan due to excess cadmium. In addition, due to bioaccumulation, certain edible organisms may become hazardous to the ultimate consumer

Principle: Cadmium can be determined at a wavelength of 228 8 nm by atomic absorption with aspiration of sample into an oxidising air-acetylene flame. When the aqueous sample is aspirated, the sensitivity for 1 % absorption is 25 μg/L and the detection limit is 2 μg/L

Standard cadmium solution: 1 000g of cadmium metal was dissolved in minimum volume of 1+1 HCl and made upto 1000ml with distilled water to give 1ml = 1mg of cadmium A series of standards ranging from 1mg to 5mg were prepared from the stock and analysed

ZINC

Zinc is an abundant element in rocks and ores and is present in natural waters only as a minor constituent The main industrial use of zinc is in galvanizing and may enter the drinking waters from galvanized pipes. Another important use is in the preparation of alloys, including brass and bronze It is an essential element in human nutrition with food being the main source of zinc to the body. Zinc may be toxic to aquatic organisms but the degree of toxicity varies greatly depending on water quality characteristics as well as the species being considered

Principle: Zinc can be determined at a wavelength of 213 9 nm by AAS aspiration of the sample into an oxidizing air-acetylene flame When the aqueous sample is aspirated, the sensitivity for 1% absorption is 20 μg/L and the detection limit is 5 μg/L.

Standard zinc solution: 1 000g of zinc metal was dissolved in 20ml of 1+1 HCl and diluted to 1000ml in distilled water, to give 1ml = 1mg of zinc A series of standards ranging from 1mg to 5mg were prepared from the stock and analysed

Sl. No	Element	Wavelength (in nm)
1	Lead	283.3
2	Copper	324.7
3	Iron	248.3
4	Chromium	357.9
5	Cadmium	228 8
6	Zinc	213.9
7	Nickel	231.6

Biological parameters

PLANKTON ANALYSIS:

The physical and chemical characteristics of water affect the abundance, species composition, stability and productivity of the indigenous populations of aquatic organisms The biological methods used for assessing water quality include collection, counting and identification of aquatic organisms; biomass measurements; measurements of metabolic activity rates; toxicity tests; bioaccumulation; bio magnification of pollutants; and processing and interpretation of biological data. The work involving plankton analysis would help in:

1. Explaining the cause of colour and turbidity and the presence of objectionable odour, tastes and visible particles in waters;
2. The interpretation of chemical analyses
3. Identifying the nature, extent and biological effects of pollution
4. Providing data on the status of an aquatic system on a regular basis

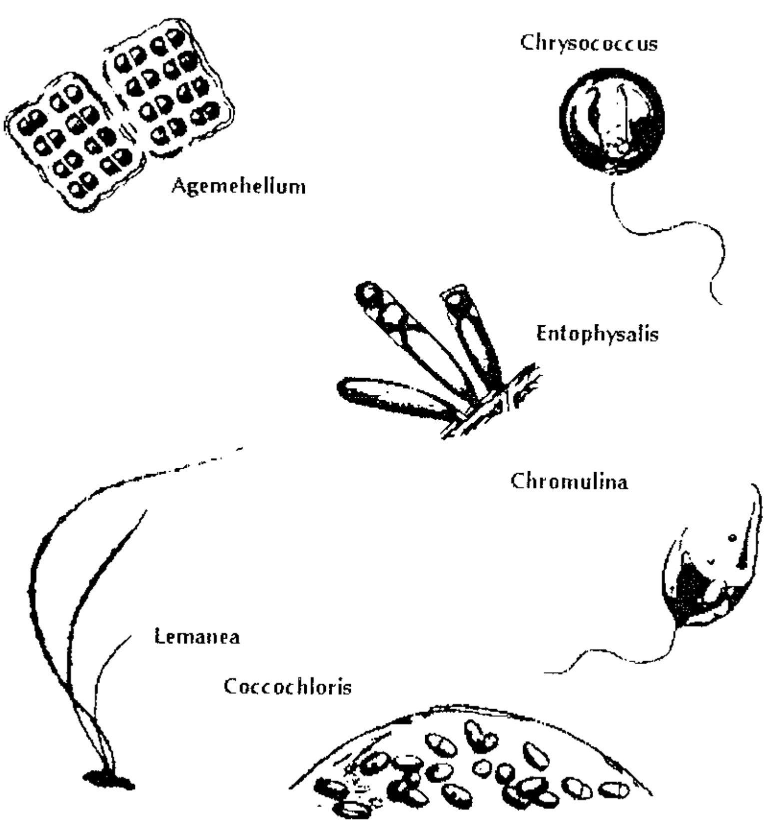
Plankton: A microscopic community of plants (phytoplankton) and animals (zooplankton), found usually free floating, swimming with little or no resistance to water currents, suspended in water, non-motile or insufficiently motile to overcome transport by currents, is called "Plankton"

Phytoplankton (microscopic algae) usually occurs as unicellular, colonial or filamentous forms and is mostly photosynthetic and grazed by zooplankton and other organisms occurring in the same environment. Zooplankton principally comprises of microscopic protozoans, rotifers, cladocerans and copepods. The species assemblage of zooplankton also may be useful in assessing water quality

The structure of photosynthetic populations in the aquatic ecosystems is dynamic and constantly changing in species composition and biomass distribution. An understanding of the community structure is dependent on the ability to understand the temporal distribution of the different species. Changes in species composition and biomass may affect photosynthetic rates, assimilation efficiencies, and rates of nutrient utilization, grazing, etc.

Plankton, particularly phytoplankton, has long been used as an indicator of water quality. Because of their short life spans, planktons respond quickly to environmental changes. They flourish both in highly eutrophic waters while a few others are very sensitive to organic and/or chemical wastes. Some species have also been associated with noxious blooms causing toxic conditions apart from the tastes and odour problems (Figure 4-6).

Figure 4: Clean Water Algae



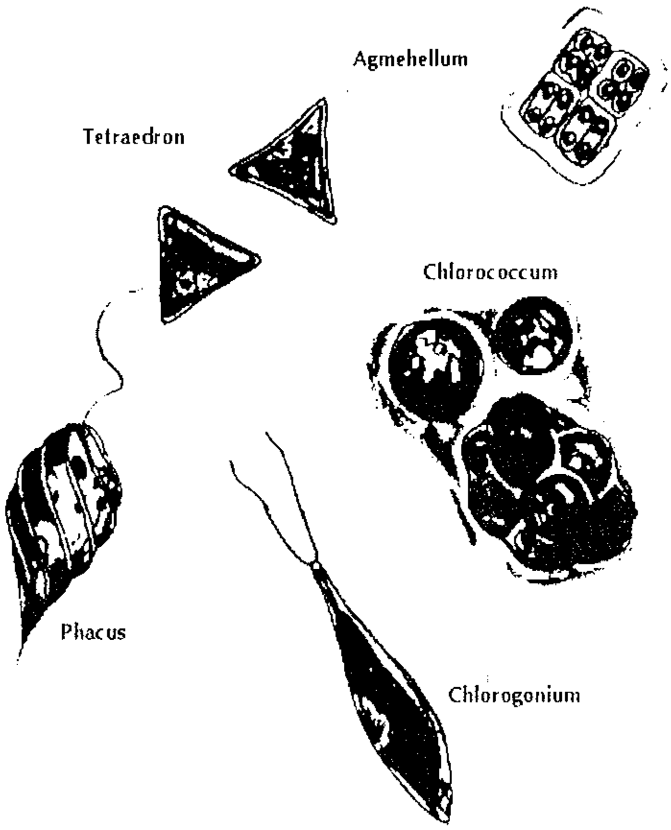


Figure 5: Polluted Water Algae

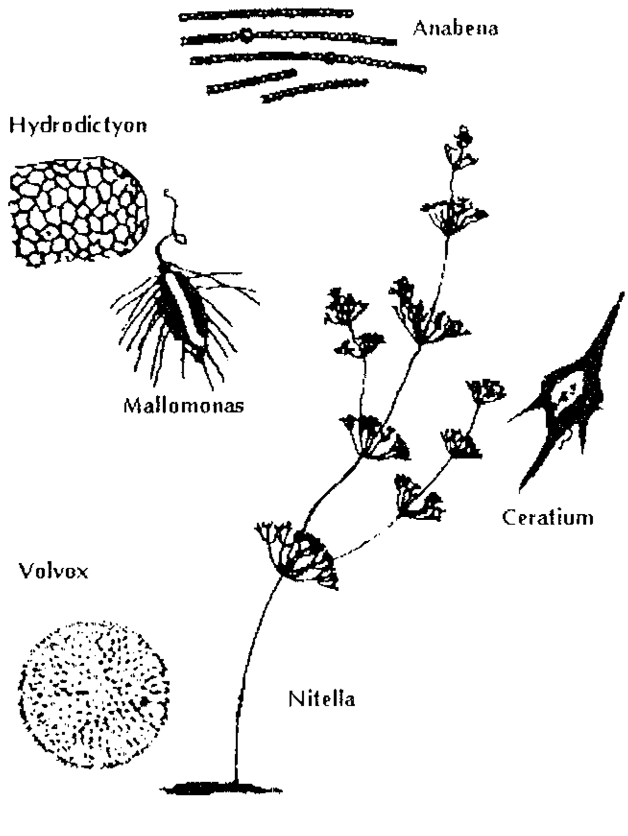


Figure 6: Taste and Odour Algae

Plankton net: The plankton net is a field equipment used to trap plankton. It has a polyethylene filter of a defined mesh size and a graduated measuring jar attached to the other end. A handle holds the net. The mesh size of the net determines the size range of the plankton trapped. The mesh number 30 of size 60 mm was used for collecting samples

Sampling Procedure: The manner in which sampling is done should conform to the objectives of the study. The "surface samples" (samples collected from the surface) were collected as close to the water surface as possible, mostly towards the centre of the lake at regular monthly intervals. A known volume of the sample, 5L to 50 L, is filtered and planktons are filtered and preserved for further analysis.

Labels: The sample label had the date, time of sampling, study area-lake name and the volume measured pasted on the containers of 50ml capacity

Preservation: The samples collected into the 100ml polyethylene vials were preserved by adding suitable amounts of 1ml chloroform to act as the narcotizing agent and 2ml of 2% formalin for preservation and analyses.

Concentration technique: The plankton nets were used to collect samples for the qualitative and quantitative estimation of the plankton, by filtering a known volume of water (5-50 liters) through the net depending on the plankton density of the tanks

Qualitative and quantitative evaluation of plankton: Detailed analyses of phytoplanktonic populations were done by estimating the numbers in each species. The phytoplankton consisting of individual cells, filaments and colonies were counted as individual cells. When colonies of species were counted, the average number of cells per colony was counted, and in filamentous algae, the average length of the filament was determined

Sedimentation and enumeration by microscope Preserved samples in bottles were mixed uniformly by gentle inversion and then exactly 1ml of the sample was pipetted out into the S-C cell for analysis

Microscope:

Compound microscope.

A monocular compound microscope was used in the counting of plankton with different eyepieces such as 10X, 15X and 20X. The microscope was calibrated using plankton counting squares

Counting:

Counting cell: Sedgwick-Rafter (S-R) cell:

The Sedgwick-Rafter cell is a devise used for plankton counting and is about 50mm long by 20mm wide and 1mm deep. The cell is covered by a relatively thick cover-slip and is calibrated to contain exactly 1.0 ml

Method:

Filling the cell

The cover slip is placed diagonally across the S-R cell and filled with the sample carefully without air bubbles with a large bore pipette. The sample is allowed to settle for about 5 minutes before the actual counting begins

Note: Since the configuration of the S-R cell does not allow the use of high power microscope objectives, the identification of organisms smaller than 10 – 15 mm is difficult or impossible, limiting the usage to only larger forms of relatively dense populations

Strip counting:

A "strip" is the length of the cell that constitutes a volume approximately 50 mm long, 1-mm deep accounting to 25mm^3 or 1/40 (2.5%) of the total cell volume. By moving the mechanical stage from left to right, the organisms can be examined in a systematic manner. By knowing the surface area of the portion counted in relation to that of the total, a factor was determined to expand the average counts of the plankton to the total area of the counting surface. This total area represents the number of organisms present per given volume of the sample. This volume expanded to an appropriate factor yields the organisms per litre of water for the lake.

The total number of planktons in the S-R cell is obtained by multiplying actual count in the strip by the number (enumeration factor) representing the portion of the S-R cell counted. The number of the strips counted is a function of the precision desired and the number of units (cells, colonies) for the strips measured In this study, 500 cells were counted for estimation

The plankton count in the S-R cell was got from the following,

$$\text{Number/ml} = \frac{C \times 1000\ \text{mm}}{L \times D \times W \times S}$$

Where:

C = number of organisms counted
L = Length of each strip (S-R cell length) in mm
D = Depth of a strip (S-R cell depth) in mm
W = Width of a strip in mm
S = number of strips counted

or

$$V_1 = (50)(1)(W)$$
$$= mm^3$$

The plankton counts per strip are then determined by multiplying the actual count by the factor representing the counted portion of the whole S-R cell volume

$$\text{No /ml} = (C)\ (1000\ mm^3)\ /\ (L)\ (D)\ (W)\ (S)$$

Where

C = Number of organisms counted.
L = Length of each strip in mm (of S-R cell)
D = Depth of the strip in mm (S-R cell)
W = Width of the strip in mm (Whipple grid image width)
S = Number of strips counted.

Phytoplankton Counting Units: Some plankton are unicellular while others are multicellular (colonial), posing a problem for enumeration For analysis, a colony of plankton was accounted as a single count The large forms that cross two or more boundaries of the grid were counted separately at lower magnification and their number included in the total count

BIOMONITORING OF WATER BODIES

The quality of water affects species composition, abundance, productivity and physiological conditions of the aquatic community. The structure and composition of these aquatic communities is an indicator of the water quality. Bio-monitoring methods, which involve the use of plants and animals to assess periodic changes in environmental quality; can be used to assess the water quality Some of the advantages of using bio-monitoring techniques are as follows:

(i) Biological communities reflect overall ecological integrity (i e , chemical, physical and biological integrity). Therefore bio-monitoring results directly assess the status of a water body
(ii) Biological communities integrate the effects of different pollutant stressors and thus provide a holistic measure of their impact.
(iii) Routine monitoring of biological communities can be relatively inexpensive, particularly when compared to the cost of assessing toxic pollutants either chemically or with toxicity studies.
(iv) Where criteria for specific ambient impact do not exist (e.g , non-point source impacts that degrade habitat), macroinvertebrates may be the only practical means of evaluation.

The methods useful in bio-monitoring include the collection, identification and counting of bioindicator organisms, biomass measurements, measurements of metabolic activity rates, and investigations on the bioaccumulation of pollutants The communities that are useful in bio-monitoring are plankton, periphytes, macrophytes, fishes, macroinvertebrates, amphibians, aquatic reptiles, birds and mammals These organisms reflect a certain range of physical and chemical conditions. Some organisms can survive a wide range of conditions and are tolerant to pollution. Others are very sensitive to changes in conditions and are intolerant to pollution These organisms are called bioindicators (EPA, 1989).

Macroinvertebrates as bioindicators of water quality

Macroinvertebrates are invertebrates visible to the naked eye Adults of this group are larger than 0 5 mm. These are an ecologically important group in any aquatic system, more so in freshwater habitats Some examples of organisms that are sensitive to pollution are mayflies, stoneflies and some caddis flies Examples of pollution tolerant organisms are sludge worms, leeches and midge larva.

Advantages of using benthic macroinvertebrates are:

- They are a highly diverse group of organisms
- They are abundant in freshwater.
- Macroinvertebrate communities are good indicators of localised conditions: Because many benthic macroinvertebrates have limited migration patterns or sessile mode of life, they are particularly well suited for assessing site-specific impacts.
- Macroinvertebrate communities integrate the effects of short-term environmental variations. Most species have a complex life cycle of approximately one year or more Sensitive life stages will respond quickly to stress; the overall community will respond more slowly
- Macroinvertebrates are relatively easy to identify, at least up to the order level, and in some cases up to the family level Most of them are sedentary in nature and hence reflect very well the environmental conditions of the place where they are captured

Ecological Importance:

Macroinvertebrates convert and transport nutrients from one part of the water body to another, influencing nutrient cycling. This process is important for keeping the general health of a water body They convert organic matter such as leaf litter and detritus into food in their body They in turn become the main source of food for higher aquatic organisms such as fish, forming a basic link between organic matter and higher aquatic animals in the food web They are sensitive to changes in habitat and pollution, especially to organic pollution Because of this, they are considered to be important indicators of water quality

Habitat:

Freshwater provides a wide range of micro-habitats for these organisms such as stones, organic debris, clay and plants Based on the microhabitat, the organisms can be broadly classified into the following:

Sediment living: These animals live on or in sediment such as gravel, cobbles, silt, clay, rocks and sand Since most organisms are bottom dwellers they are called as benthic organisms.
Vegetation living: These organisms cling to the stems and leaves of plants, which give shelter, and a range of foods for many types of organisms. Water plants include algae and moss

Food Habits:

Based on their food and feeding habits, macroinvertebrates may be divided into shredders, collectors, scrapers (grazers) and predators

- Shredders feed on coarse organic matter such as leaves and algae. They are omnivorous and feed on bacteria, fungi and protozoans present along with coarse organic matter These animals break the coarse material into finer material in their body and then excrete them as faeces Some examples of shredders are stonefly nymphs and caddisfly larvae.

- Collectors feed on decomposing finer organic matter including the faecal matter released by shredders They also feed on coarse organic matter along with bacteria and fungi. Animals, which strain minute particles transported by the flowing water, are called filter collectors and are generally found in high velocity flows, for example caddisfly larvae Animals, which feed on organic matter deposited at the bottom, are called gathering collectors; for example, mayfly nymphs and beetles

- Scrapers feed essentially on plants including algae They are also known as grazers Some examples are mayfly nymphs and caddisfly larvae

- Predators feed on other aquatic insects and their body parts are adapted to capture live prey, for example, scoop like jaws in damselfly and spear like mouth parts in water striders

Even though there is an overlap among the feeding habits of the organisms, it helps to understand the organisms in relation to organic resource availability. The composition of the macroinvertebrates changes based on the availability of food. As one moves downstream, the number of grazers declines and that of collectors increases

Sampling Sites:
The composition and population of macroinvertebrates are influenced by water flow velocity, volume of water and substrates including vegetation, food, and water temperature pattern. Therefore, the sample should be collected from different microhabitats to get a representative picture. The sampling points of macroinvertebrate collection should be close to water sampling points (collected for physico-chemical analyses). The sampling sites should be longitudinal to the flowing water systems. In case of any disturbance or pollution in the water body, the samples are taken from 3 sites – area before disturbance, area immediately after disturbance and area away from the disturbance. This is decided on site based on factors such as type of pollution, load of pollution, flow velocity and similarity in microhabitat. The samples are collected once every season or at least twice a year, in March-April and late October. For quantitative sampling, an area of 3feet x 3feet is generally recommended.

Types of Sampling:
Sampling can be either qualitative or quantitative. In quantitative sampling, the number of individuals of each species is counted and the area sampled is measured. This is expressed as numbers per unit area of the water body. In qualitative sampling, different types (species) of macroinvertebrates are identified. Here, the area sampled is not measured. This sampling is useful for pollution monitoring. Comparative studies can also be done in the sampling site over a period of time (Sunil Kumar M and Shailaja Ravindranath, 2001).

Substrata to be sampled are boulders, large stones, gravel, gravel-sand, sand or mud and various parts of water plants including patches of algae. Various devices are available for sampling invertebrates. Most of the devices use nets, with the mesh size varying from 0.125 to 0.25 mm. This is because some of the insect stages (nymph/larva) are smaller than 500 micrometers and do not meet the conventional definition of macroinvertebrates. However, they are considered important water quality indicators

Types of samplers:

Qualitative samplers:

D frame net: This is mainly used to sample gravel or cobble substrata and soft sediments. The net is dragged on the substrata to collect samples

Kick screens: They are used to sample riffle areas and a large area can be sampled then with a D frame net. The kick screen is held upright with the base touching the river bottom and remaining open upstream. After disturbing the streambed i.e., brushing the surface of the stones to dislodge any organisms present, the net is held so as to catch the dislodged organisms. The net is removed to prevent the organisms from escaping

Quantitative samplers:

Square foot sampler: This has a square (1ftx1ft) frame hinged to another frame of the same size. The cloth sides on the frames help the water to flow into the net. During sampling, the frame is pushed into the substrate and the substrate area is disturbed within by rubbing the rocks. The dislodged organisms are carried into the cloth net by the flowing water.

Grab sampler: They are so called as they are used to grab a sediment sample. There are various grab samplers, out of which the most commonly used is Ekman grab sampler. The Ekman grab sampler is useful in sampling silt and sludge in deep waters with little current. The grab is made of stainless steel and has two jaws, which help in collecting the samples. The jaws of the device are kept open before the sampling.

Scoop: This device is shaped as a dust pan, with a wire screen at the bottom and back

Artificial substrate samplers:
They provide for the colonisation and collection of organisms along the rivers, lakes, canals and tanks where it is difficult to collect benthic animals due to strong currents and deep waters. Various types of artificial samplers are available, the most common being Hester Dendy and Basket samplers.

Data Analysis:
The level of pollution can be found by using any one of the following indices

Diversity index
Biotic index
Biological water quality evaluation system

Diversity Index:

Diversity here refers to the number of different species found in the community Greater the number more is the diversity. Diverse communities tend to be more stable than less diverse ones. Due to pollution and habitat degradation, the number of species in the community is reduced by the elimination of the species sensitive to water and habitat changes. The community then has a reduced number of species but a great proportion of pollution tolerant species

Two main types of Diversity indices are commonly used They are:

(i) Sequential Comparison Index (SCI): The SCI is a measure of the distribution of individuals among groups of organisms. It is based on the theory of runs. A run is the count of similar organisms in successive picks A run ends when a dissimilar organism is encountered and a new run begins when an organism picked up from a sample looks different from the previous one. This test does not require the knowledge of identification of macroinvertebrates

PROCEDURE:

On a white metal or plastic tray, straight parallel lines are drawn with a distance of 1 or 1.5 inches between the lines. The container with benthic organisms is shaken and the contents poured over the tray. Pouring water over the tray separates the clumps of organisms. Now, each organism is moved using forceps to the nearest drawn line If the organisms are between two lines, it is moved to either one of the lines. In the end, all the organisms should be associated with any one of the lines Now the organisms are carefully observed If similar organisms occur successively, it is considered as one run. If an organism is not similar to the previous one, it is considered as a new run The number of runs and the total number of organisms after going through the entire sample is recorded

Calculation

SCI = number of runs / total number of organisms picked

Interpretation: The SCI has a range of 0-1 with the following water quality ratings

SCI value	Water quality
0 -0.3	Poor
0.3 – 0.6	Fair
0.6 – 1.0	Good

(ii) Shannon Weiner index: The index is widely used for several biological communities It can also be used for the evaluation of stresses to benthic macroinvertebrate populations due to changes in water quality. Weiner and Shannon independently developed the index and hence the name.

The Shannon Weiner diversity index (H) is given by

$$H = -\sum_{1}^{s} n_i/N \log_2 n_i/N$$

Where

s = number of species in a sample,

N = total number of individuals in a sample,

n_i = number of individuals in each species.

The relationship between the Shannon-Weiner index (H) and the quality of water is as follows

H	**Quality of water**
>3	Clean
1-3	Moderately polluted
<1	Heavily polluted

Biotic index:

Biotic index is a measure to find the level of pollution using bioindicators present in water. This concept is based on the fact that each species has varying degree of tolerance to organic pollution Some species are sensitive to pollution and may not survive in such conditions. Others are tolerant and hence survive in a wide range of situations Biotic index using macro invertebrates is calculated based on animal scores, which range from 1 to 10 Sensitive taxa are given higher scores while tolerant ones are given lower scores. Lower scores therefore indicate poor water quality. Animal scores for the major macroinvertebrates found in a waterbody are given in table 16

Table 16: Animal scores for the major macroinvertebrates found in a waterbody

Macroinvertebrates	*Scores*
Mayfly nymph	10
Stonefly nymph	10
Caddisfly larva	10
Lobster	8
Dragonfly nymph	8
Damselfly nymph	8
Freshwater Limpet	8
Freshwater mussel	6
Shrimps	6
Prawn	6
Water bugs	5
Water beetles	5
Flat worms	5
Water mites	4
Snails	3
Leeches	3
Rat tailed maggot	3
Midge larvae	2
Segmented worms	1

This is based on the Biological Monitoring Working Party (BMWP) score system. If there are different scores for the same animal group, the score that has maximum number of families is considered.

The level of pollution can be ascertained from the above table as follows:
The scores for each animal in the list are found out. The scores are added and the total score is divided by total number of species. This gives the biotic index, which indicates the average pollution tolerance of the taxa. Higher the index, less polluted is the water. Comparison of the biotic index can be made between micro habitats / sampling area in the same water body.

Biological water quality evaluation system:
This is based on the classification of indicator macroinvertebrates based on their sensitivity and tolerance to organic pollution. The indicator organisms are divided into 5 classes representing different degrees of water quality. Table 17 can be used to evaluate the water quality

Table 17: Indicator organisms and water quality

Macroinvertebrates	Abundance	Expected BOD levels	Water quality	Class
Ephemeroptera (e g , May fly nymph) Trichoptera (e g , caddisfly larvae) Plecoptera (e.g., stonefly nymph)	C-D	1 or < 1	Clean	I
Odonata (e.g., Dragonfly and Damselfly nymph) Hemiptera (e.g., water bugs)	A-E	1-5	Slightly polluted	2
Coeloptera (e g , water beetles) Crustacea (e.g., prawn)	A - E	5-10	Moderately polluted	3
Annelida (leech in particular) Diptera (e.g., rat tailed maggot) Mollusca (e.g., snails and mussels)	A - E	1-15	Highly polluted	4
Annelida (True worms in particular e.g., sludge worm) Diptera (e.g., red worms, rat tailed maggot)	A -E	20-30	Excessively polluted	5

Table 18: Classification based on abundance of the individual macroinvertebrates

Abundance	No of individuals	Grouping
A	1	Single
B	2-10	Scarce
C	11-50	Common
D	51-100	More than common
E	101-1000	Dominant
F	1001 -10000	Excessive
G	More than 10,000	Only this species

Indicator Information (Sunil Kumar M and Shailaja Ravindranath, 2001)

1 Flat worms (Phylum Platyhelminthes)

Flat ribbon like worms with elongated body; segments are absent or no true segments; carnivorous; found in ponds and flowing water, for example, Planaria.

2 Segmented worms (Phylum Annelida)

Segmented worms; elongated body with a definite head

* ***Leeches (Class Hirudinea)*** - Flattened body with suckers at both ends, found in shallow waters under stones/rocks where there is a lot of vegetation; parasites on aquatic birds, fish and molluscs; active during night (nocturnal). They can live without oxygen for several days.
* ***Sludge worms (Class Oligocheata)*** - Round body with many segments; live in mud or in high organic debris; feed on detritus.

3 Arthopods (Phylum Arthropoda)

Animals with jointed legs; largest phylum in the animal kingdom consisting of about 75% of animal species.

* ***Crustaceans (Class Crustacea)***

Its body is protected by a crust (hard chitinous skin); many are carnivores, but some are herbivores. They also feed on detritus. Most species are less tolerant to pollution. They are mainly filter feeders.

Freshwater Prawn (Order Decapoda)

Front pair of legs have pincers, long, thread - like pair of antennae and a laterally compressed body.

Freshwater Lobster (Order Decapoda)

Front pair of pincers is huge.

Freshwater Shrimp (Order Decapoda)

Long, thin, laterally compressed body with slender legs, depressed crust and small extension of head (rostrum)

* ***Water mites (Class Arachnida)***

Animals with 8 legs; fairly pollution tolerant; resemble spiders; small animals with nearly round shaped body; carnivores; easy to identify

* *Insects (Class Insecta)*

Animals with 6 legs; largest class in animal kingdom. Adult insects are rare in water bodies. Land living (terrestrial) insects pass through their earlier life cycle stages (metamorphosis) in freshwater. Some insects undergo incomplete metamorphosis passing through 3 stages namely, egg, nymph and adult. The nymph looks almost like the adult except that its wings are not completely developed. Some examples are: Mayfly and Dragonfly. Others undergo complete metamorphosis, passing through 4 stages: egg, larva, pupa and adult. The larva looks entirely different from the adult. In the pupa stage it becomes inactive. The nymph and the larva stages are active and live longer than the adult form. Hence they are good water - quality indicators

Mayfly nymph (Order Ephemeroptera)

They are grazers and collectors; gills present on either side of the abdomen; found in highly oxygenated waters; about 2.5 cms in length.

Stonefly nymph (Order Plecoptera)

Similar to Mayfly nymphs; gills are rarely found around the base of their legs; live in well - oxygenated water; herbivores or detritivores, some are even carnivores; size 2.5 cms

Dragonfly nymph (Order Odonata)

Robust nymphs with pointed abdomen; predator, easily eat up a tadpole or small fish; found generally in ponds and slow moving water bodies; often covered with algae and organic debris; indicate low organic pollution.

Damselfly nymph (Order Odonata)

Nymphs slender with 3 plate like fill filaments; predators; found mainly in ponds and slow moving waters; covered with algae or organic debris; indicate low organic pollution

Water Bug nymph (Order Hemiptera)

Surface dwellers; found in ponds and flowing waters; head is prolonged with a beak-like structure which helps in sucking fluids from plants/animals; largely predators.

Caddisfly larva (Order Trichoptera)

They form a large benthic community. Some live in hollow cases made up of small stones, gravel, leaves, twigs, sand, while others are free-living. They have a cylindrical body and hard-shelled head capsules; the last segment bears 3 small hooks; grow up to 4 centimetres, generally carnivores

Beetle (Order Coleoptera)

Many species of beetles are found in water. Some are surface dwellers, while others are submerged species. Wings form a rigid cover on the abdomen; many are carnivores; some eat detritus and algae

Truefly larva (Order Diptera)

One of the largest order of aquatic insects; includes many families They are the most common indicators of highly polluted waters They have pseudopodia in one or more segments. They have less than 15 segments; resemble worms; many are detritivores; some are carnivores Some examples are, rat tailed maggot, mosquito larva and species of midge larva such as red worm

4 Molluscs (Phylum Mollusca)

Benthic animals, having a soft body covered with a hard calcareous shell secreted by the body Some are tolerant to pollution while others are sensitive. They generally feed on algae, higher plants and detritus

Freshwater Snails (Class Gastropoda)

They have one spiral shell They are usually found everywhere Some snails are tolerant to conditions of oxygen depletion In these snails, the shell spirals to the right. Others are sensitive to oxygen depletion; in these animals the shell spirals to both right and left.

Freshwater limpets (Class Gastropoda)

The shell is a small cone. They are susceptible to pollution and are found in well-oxygenated waters

Freshwater mussels (Class Bivalva)

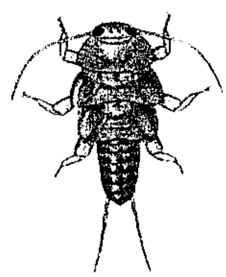
They have a shell with 2 halves connected by a hinge. They are less tolerant to pollution

Indicators of Good Water Quality (http://mason.gmu.edu/)

I) Insects

(A) Stonefly nymphs (Order Plecoptera)

Roach-like stonefly nymphs (Family Peltoperlidae)

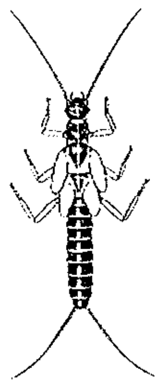


Measures 8-15mm in length.
Two tails
Two sets of wing pads
Brown in colour.
They consume living and decaying plant material.

Common stonefly nymph (Family Perlidae)

Measures 8-15mm in length.
Two tails.
Two sets of wing pads.
Yellow to brown in colour
They are not tolerant to low dissolved oxygen levels
Therefore, they prefer cold swift moving streams.

Slender Winter Stonefly nymph (Family Capniidae)



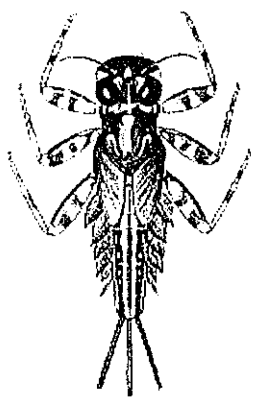
Measure up to1/2 inch in length.
Two tails
Two sets of wing pads.
Small, slender and cylindrical.
Often darkly coloured.
Habitat ranges from small to medium sized streams.

(B) Mayfly nymphs (Order Ephemeroptera)

Brush Legged Mayfly nymph (Family Oligoneuridae)

Mature larvae measure ¾ inch in length.
Two rows of long hairs present inside of the front legs
Two or three tails.
Slender antennae
The hairs in the front legs are used to filter the food particles from water.

Flat headed Mayfly nymph (Family Heptageniidae)



Measure ¾ inch in length.
Nymphs are flattened with sprawling legs and a horizontally oriented head.
Plate like gills are present on abdominal segments
Abdomen terminates in two or three tails
Often coloured yellow to dark brown
They are common in aquatic habitats, found clinging to rocks, where they graze on algae and other organic material associated with stream bottom.

Burrowing Mayfly nymph (Family Ephemeridae)

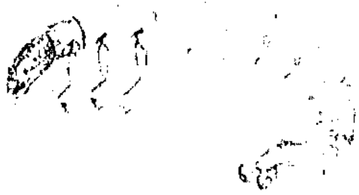
Measure to an inch in length
Conspicuous dorsal gills
Three tails.
Burrow in silt or sand in rivers, streams, lakes and ponds.
Most species feed on organic matter associated with the substrate.

(C) Caddisfly Larvae (Order Trichoptera)

Netspinning Caddisfly larva (Family Hydropsychidae)

Larvae measure ¾ in length
Three pairs of legs.
Body is caterpillar-like and strongly curved
Colour varies from bright green and dark brown
Gill tufts on lower surface of the body.
Three hard plates on dorsal thorax
They are widespread and abundant in poor quality streams. As their name suggests they construct a silken mesh net, which they use to filter organic particles from the water.

Fingernet Caddis larva (Family Philopotamidae)



Larvae measure ½ inch in length
Abdomen curved and without gills
Colour varies white to orange to grey
They spin a tube like net with which they filter animal and plant material from water.

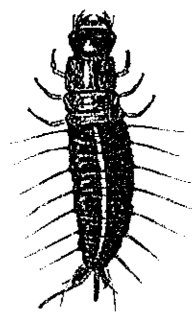
Case-making Caddis larva (various families)

Up to one inch in length.
Build distinct cases made of sticks, rocks, sand, plant material and/or other debris.
Three pairs of legs and antennae reduced and inconspicuous.

Free living Caddis larva (Family Ryacophilidae)

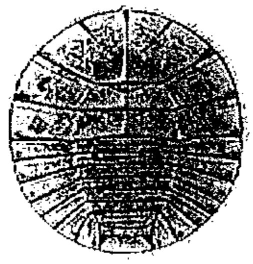
Measure ¾ or 1 inch in length
Abdomen has deep constrictions between segments
Often whitish to green in colour.
Found in clean cool streams.
Most species are active predators.

(D) Dobsonfly (Order Megaloptera, Family Corydalidae)



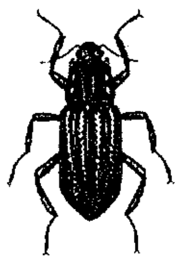
Commonly called as hellgrammites.
Measure ¾ - 4inches in length.
Body is elongated and somewhat flattened
Large pinching jaws.
Lateral appendages along the length of the abdomen.
Cotton like gill tufts on underside of abdomen.
Short inconspicuous antennae.
Feed on other aquatic insects
They are usually found on the underside of rocks in cool slow moving streams.

(E) Water Penny (Order Coleoptera, Family Psephenidae)



Measures ¼ inch in length.
Flat disk like body.
Head and legs concealed from above
Six gills and branched legs on underside
Prefers cold running water. Their smooth flattened bodies enable them to resist the pull of current.
They are usually found attached to smooth rocks where they graze on attached algae.

(F) Riffle Beetle (Order Coleoptera, Family Elmidae)



Measure approximately 1/16 to ¼ inch in length.
Body small, usually oval.
Legs are long and antennae are usually slender.
They walk slowly in the underwater, they do not swim on the surface.

II) Others:

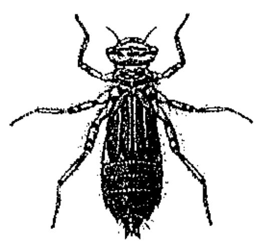
Gilled Snail (Order Gastropoda, Family Viviparidae)

Shell usually opens on right. Shell opening covered by a thin plate (operculum)

Indicators of Moderate Water Quality:

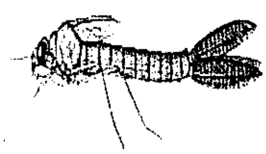
I) Insects

(A) Dragonfly nymph (Order Odonata, suborder Anisoptera)



Measure 0.5 to 2.0 inches in length.
Large eyes.
Two pairs of wing pads.
Large round or oval abdomen, which terminates in three small pointed structures.
Has a large jaw modified for grasping and covers the underside of the head
Prefer cool still water, often found among vegetation and leaf packs and burrowed in sediments.

(B) Damselfly nymph (Order Odonata, Suborder Zygoptera)

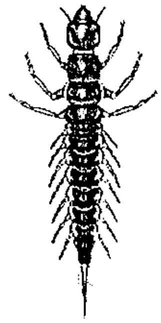


Measure ½ to 1 inch in length.
Large eyes.
Three broad flattened gills at the end of abdomen
Underside of head covered by a large jaw modified for grasping.

(C) Watersnipe fly larva (Order Diptera, family Athericidae)

Measure 12 – 18 mm in length
Colour varies from pale to green
Widespread in well oxygenated streams
Some species burrow in sediments.

(D) Alderfly larva (Order Megaloptera, Family Sialidae)



Measure 1 inch in length
Abdomen terminates in a single tail
Lateral filaments along the abdomen
Often pale to deep reddish brown in colour.

(E) Cranefly larvae (Order Diptera, Family Tipulidae)

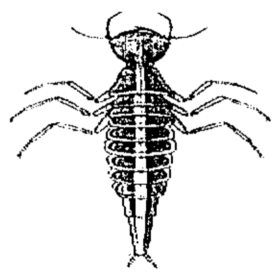
Measure 1/3 – 2 inches in length
Head is usually retracted into the body
Milky green to brown colour
Four finger like lobes at back end of body.

(F) Beetle larvae (Order Coleoptera)

Whirligig Beetle larva (Family Gyrinidae)

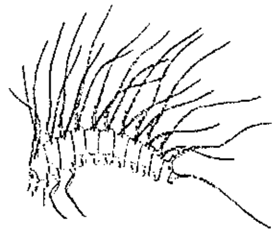
Measures up to 1 ¼ inches in length
Abdominal segments have lateral filaments
Usually pale whitish to yellow in colour
Abdomen terminates in four small hooks.

Predaceous diving beetle larva (Family Dysticidae)



Measure up to 2 inches in length
Six long and slender legs
Abdomen strongly tapered in the posterior region
They are voracious predators consuming a variety of small aquatic animals including fish.

Crawling water beetle larva (Family Haliplidae)



Measure 2- 6 mm in length
Usually small and elongate
Many species have conspicuous filaments covering the abdomen.
Larvae are omnivorous and usually found among aquatic vegetation and debris.

(II) Others

Scuds (Order Amphipoda, Family Gammaridae)

Measure 5-20 mm in length
Clear whitish to pink in colour
Laterally flattened (top to bottom)
Seven pairs of legs, the first two are made for grasping
Found in shallow fresh water springs, streams, lakes and ponds
Most species feed on detritus
Scuds are an important source of food for many fishes.

Sow bugs (Order Isopoda, Family Asellidae)

Measure 5 – 20 mm in length
Clear whitish to pink in colour
Dorso ventrally flattened.
Seven pairs of legs, the first two are modified for grasping
Found in shallow freshwaters on rock or detritus.

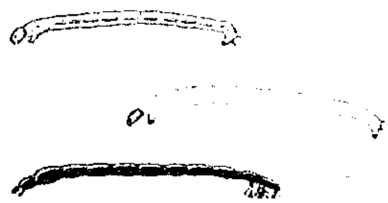
Crayfish (Order Decapoda, Family Cambaridae)

Measure up to 6 inches in length
Have 5 pairs of walking legs, the first pair with large pinchers.
Crayfish are usually active only during the night
During the day, they hide in burrows or under rocks.
Crayfish are omnivorous, eating both plants and animals.

Indicators of Poor Water Quality

(I) Insects

(i) Midge larva (Order Diptera, Family Chironomidae)



Measure upto ½ inch in length.
Body small, cylindrical and slightly curved.
Occasionally deep red in colour, otherwise variously coloured.
Frequently found in sediments of lakes, streams, and ponds where they feed on deposited organic material.

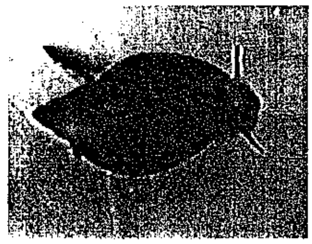
(ii) Black fly larva (Order Diptera, Family Simulidae)

Measure ½ inch in length.
Body cylindrical and widest in the posterior
Abdomen terminates in an attachment disc
Head usually possesses fan like appendages
They prefer cold, running water and are usually found attached by the end of their abdomen to rocks, woody debris or vegetation in the currents of rivers and streams.

(II) Others:

(i) Pouch snail (Order Gastropoda, Family Physidae)

Tolerant to pollution
The breathing is through lungs (gets air at the surface of water)
The adults measure upto 12mm
It feeds on algae and plants
Their shells open on the left when the point is upwards.

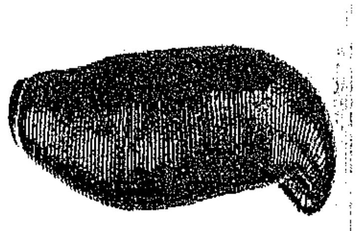


(ii) Planorbid snail (Order Gastropoda, Family Planorbidae)

Size small, discoidal, adults seldom exceeding 4 mm in length
They are restricted to freshwater.
Shell keeled or strongly angular at the periphery
The shell is drab coloured and spiralled
The pouch snail is usually more tolerant to pollution than other snails.

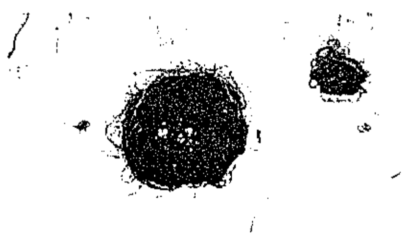
(iii) Leech (Class Hirudinea)

Measure 1-5 cm in length.
Typically dorso ventrally flattened.
Always have 34 segments.
Suckers at both the ends.
They are common in warm protected waters of ponds, lakes, streams and marshes.
They avoid light by hiding under rocks and among aquatic vegetation Silty substrates are unsuitable for them as they cannot attach properly.



(iv) Aquatic Worm (Class Oligochaeta)

Measure 1- 30 mm in length, but sometimes 100 mm in length.
Clear whitish to pink in colour.
Tolerant to low dissolved oxygen
Found in silty substrates and among debris or detritus in ponds, lakes, streams and rivers Usually found in organically polluted lakes.



Fish census techniques

Introduction:

Fish are the most abundant, widespread and diverse group of vertebrates, comprising 22, 000 species with various forms, size and habits Sampling fish requires high level of resources (e g , time, labour, and cost of equipment), and this increases with the size of the habitat (e.g , pond versus the sea) To census fish in the largest aquatic systems, data can be gathered from commercial catches, where available, or by visiting markets where fish are landed.

Methods of capturing fish fall into two categories namely: passive methods, which rely on the fish swimming into a net or a trap, and active methods where fish are pursued The fact that fish are poikilothermic influences the choice of method and timing of sampling. There are very few truly quantitative techniques, so statistics such as catch per unit effort are used commonly to generate indices of abundance. Variability in swimming speed, seasonality as a result of migration, diurnal and patchiness of distribution all influence how catchable a species is. It is vital to have at least some knowledge of the ecology and behaviour of fish in the habitat to be sampled Factors such as depth, clarity, presence of vegetation or the speed of the current have to be considered. A hydrographical survey prior to sampling may be required (William Sutherland, 1996).

Seasonality for Fish Collections:

Seasonal changes in the abundance of fish community primarily occur during reproductive periods and (for some species) summer and winter migratory periods. Generally, the preferred sampling period is from mid to late summer Although some fish species are capable of extensive migration, fish populations and individual fish tend to remain in the same area during summer. The stream fish assemblages are stable and persistent for 10 years, recovering rapidly from droughts and floods indicating that substantial population fluctuations are not likely to occur in response to purely natural environmental phenomena. However, comparison of data collected during different seasons is discouraged, as are data collected during or immediately after major flow changes (EPA, 1989)

Fish Sampling Methodology

Although various gear types are routinely used to sample fish, electrofishing equipment and seines are the most commonly used collection methods in fresh water habitats Each method has advantages and disadvantages. However, electrofishing is recommended for most fish field surveys because of its greater applicability and efficiency. Local conditions may require consideration of seining as an optional collection method. Advantages and disadvantages of each gear type are presented below

Electrofishing:
It involves passing an electric current through water via electrodes which stuns nearby fish, leading to their disorientation and easy capture Power is supplied by a generator and is converted to the required form by an electrofishing unit or box. Several types of current maybe used, each producing slightly different effects The most commonly used is DC, because it attracts fish to the anode and causes fewer harmful effects to the fish than AC

Advantages of Electrofishing:
Electrofishing allows greater standardization of catch per unit of effort Electrofishing requires less time and a reduced level of effort than some sampling methods (e g , use of ichthyocides). Electrofishing is less selective than seining (although it is selective towards size and species) If properly used, adverse effects on fish are minimized Electrofishing is appropriate in a variety of habitats

Disadvantages of Electrofishing:
Sampling efficiency is affected by turbidity and conductivity Although less selective than seining, electrofishing is size and species selective Effects of electrofishing increase with body size Species specific behavioral and anatomical differences also determine vulnerability to electro shocking Electrofishing is a hazardous operation that can injure field personnel if proper safety procedures are ignored.

Seine netting:
A seine net is a wall of net fitted with floats at the top (float line) and a weighted line (lead line) on the bottom, and generally with a bulging section at the back of the net to hold the catch The first step in seine netting is to encircle a known area of water. To do this, the net is generally fixed at one end, which can be a shore, a boat or buoy or by walking when in very shallow water, in an arc or semi circular fashion and returning to the fixed point In shallow waters, they can be dragged through the water by two people, one at each end towards a fixed point.

Advantages of Seining:
Seines are relatively inexpensive. They are lightweight and are easily transported and stored. Seine repair and maintenance are minimal and can be accomplished onsite Seine use is not restricted by water quality parameters. Effects on the fish population are minimal because fish are collected alive and are generally unharmed.

Disadvantages of Seining:
Previous experience and skill, knowledge of fish habitats and behaviour, and sampling effort are probably more important in seining than in the use of any other gear. Sample effort and results for seining are more variable than sampling with electrofishing Use of seines is generally restricted to slower water with smooth bottoms, and is most effective in small streams or pools with little cover. Standardization of unit of effort to ensure data comparability is difficult.

Bankside counts:
It is possible to census fish without catching them. Bankside count is a good technique in shallow, slow-moving and clear waters with minimal vegetation, such as streams or even lakeshores. The stretch of water is divided into continuous and non-overlapping sections. The sections should be small enough such that all fish can be counted from a single vantage point Fish density can be calculated by measuring the area surveyed Shore based visual counts are easy, fast and inexpensive, and appropriate when the water is shallow. But any disturbance from humans will reduce the accuracy of visual counts. Fish in deep waters, turbid waters or dense habits maybe overlooked

Trawling:
Trawling involves towing a cone-shaped net along the bottom or through the water at a specific depth. For mid water or surface trawls, the mouth of the net is to be fitted with floats at the top (head rope) and lead at the bottom (ground rope) to keep it open For the trawls, the net is deployed from the stern or side of the boat. The net must be towed at a faster rate than the fish can swim. Trawling is a semi-quantitative method for estimating numbers and biomass. Trawling helps in censusing large water bodies where large areas can be covered in a short time. Trawling is limited to waters free of obstructions It needs expensive equipment and is time consuming (William Sutherland, 1996).

Lift, throw and push netting:
Lift nets fall into two types namely hand held scoop nets and buoyant nets. Hand held scoop nets are inserted below the water surface and brought up sharply whereas the buoyant nets are allowed to lie at the bottom for a fixed period before taking it up abruptly to the surface Cast nets are circle nets that are deployed from a boat or bank. They consist of a central line, which is retained, in the hand for hauling the net after casting Push nets have a pocket-shaped net attached to a triangular or D shaped frame, which keeps the mouth of the net open These techniques are appropriate for small fishes in shallow waters or near the surface for deeper waters. This type of netting is fairly cheap and used extensively in developing countries, but a major disadvantage is that little is known about their selectivity and efficiency

Hook and Lining:
This technique relies on catching fish with a baited hook attached to a line. The bait maybe worms or pieces of meat, fish etc. The line maybe short and held by hand or maybe longer and attached to a pole. The line is then cast into the water either from the boat or the shore When a fish bites the hook, the line becomes tensed and is pulled up It is a cheap and good method to census large and predatory fish, which occur at low density. It is inappropriate to monitor entire fish communities as a result of its high selectivity The fish is inevitably damaged and subjected to considerable stress.

Trapping:
Traps for censusing fish fall into three categories namely: pot gear, fyke nets and trapping barriers (weirs) The fish pass through an entrance hole, but are confused by the blind trappings within the net and are trapped Fyke nets have a succession of fish, which concentrates the fish in the final section Pot traps and fyke nets are usually set temporarily whereas the weirs are more permanent, mostly used along rivers to catch migratory species

Trapping is one of the most versatile fish censusing methods. It is used in a wide range of habitats from fast flowing rivers to lakes and wetlands dominated by vegetation to estuaries It is effective to catch species that are active by night. But trapping may be labour intensive In highly vegetated areas the traps may be damaged (William Sutherland, 1996)

Gill netting:
It is a passive technique and relies on the fish trying to swim through diamond shaped apertures in a net set vertically in the water column The apertures are large enough to allow the fish's head but not the body and fish become trapped Gill nets usually have a head line along the bottom edge and a float line along the top. By varying

the length of the head line, gill nets can be made to sink to the bottom or stay at the surface of water, allowing the capture of fishes at various depths.

Gill netting is a low cost method for censusing fish Gill nets are relatively cheap and long lasting They are most effective in lakes and rivers with little current when the target species is highly mobile The major disadvantage is that the fish in gill nets often die, especially if the net was set for too long or too many fishes are caught

Sampling Representative Habitat:

Fish sampling Processing and Enumeration:

Effort should be made when sampling to avoid regionally unique natural habitat. Samples from such situations, when compared to those from sites lacking the unique habitat, will appear different, i.e , assess as in either better or worse condition, than those not having the unique habitat. This is due to the usually high habitat specificity that different taxa have to their range of habitat conditions; unique habitat will have unique taxa Thus, all sampling is focused on sampling of representative habitat (EPA, 1989)

Composite sampling is the norm for investigations to characterize the reach, rather individual small replicates. However, a major source of variance can result from taking too few samples for a composite Therefore, each of the protocols (i.e , for periphyton, benthos, fish) advocate compositing several samples or efforts throughout the stream reach Replication is strongly encouraged for precision evaluation of the methods

When sampling wadeable streams, rivers, or waterbodies with complex habitats, a complete inventory of the entire reach is not necessary for bioassessment However, the sampling area should be representative of the reach, incorporating riffles, runs, and pools if these habitats are typical of the stream in question Midchannel and wetland areas of large rivers, which are difficult to sample effectively, may be avoided. Sampling effort may be concentrated in near-shore habitats where most species will be collected. Although some deep water or wetland species may be undersampled, the data should be adequate for the objective of bioassessment.

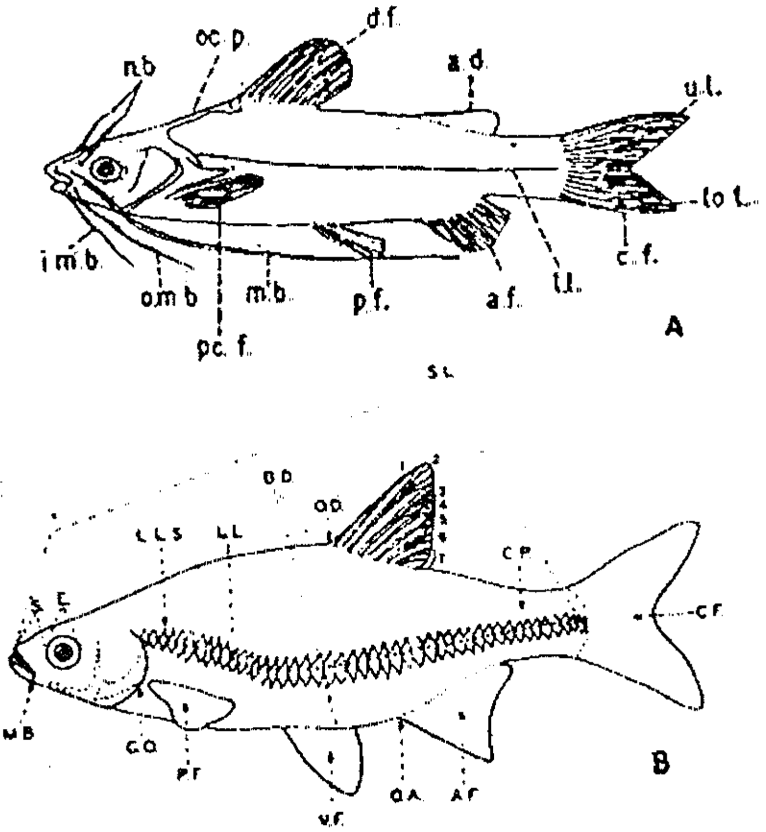
Processing of the fish biosurvey sample includes identification of all individuals to species, weighing and recording incidence of external anomalies. It is recommended that each fish be identified and counted. The data from the counted and weighed sub sample is extrapolated for the total.

Fish Environmental Tolerance characterisations:

Responses of individual species to pollution vary regionally and according to the type of pollutant. Tolerance characterisation of fishes is presented in a Table in the annexure (EPA, 1989)

IDENTIFICATION OF FISHES

Scientific identification of fishes is based mainly on external characters such as body shape, length, depth, mouth and nature of fish spines, scales, etc. The best way to collect fish for a scientific or taxonomic study is to catch them alive through a fishing net, trap or any other device locally adopted except poisoning with toxic chemicals (Jayaram K C , 1996).



Outline lateral view diagrams of A) a non-scaled catfish and B) a scaled fish showing body parts

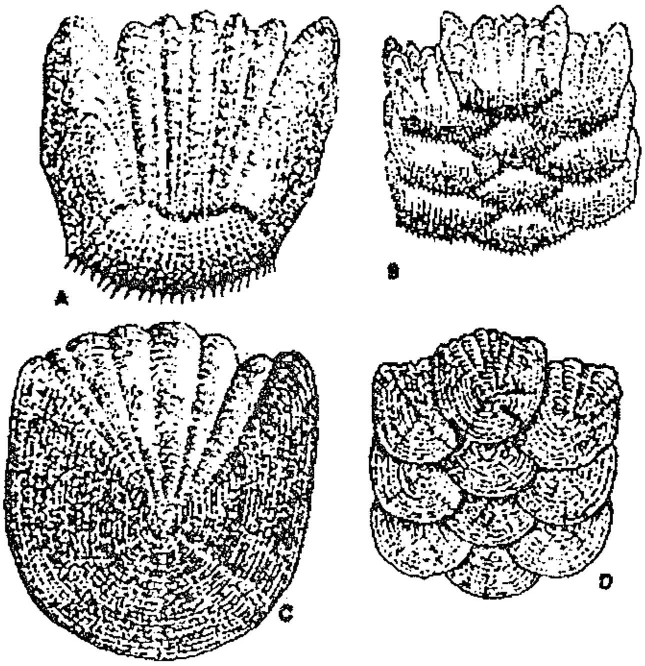
A Non-scaled catfish
a d. = adipose dorsal fin
a f. = anal fin
c.f. = caudal fin
d f. = dorsal fin
i.m.b. = inner mandibular barbell
l.l = lateral line
lo l. = lower lobe of caudal fin
m.b. = maxillary barbell
n b. = nasal barbell
oc.p. = occipital process
o.m.b = outer mandibular barbell
p f. = pelvic fin
pc.f = pectoral fin
u.l. = upper lobe of caudal fin

B Scaled fish
A F. = anal fin
B D = body depth
C F = caudal fin
C P = caudal peduncle
E = length of eye
G O = gill opening
L L = lateral line
L L S. = lateral line scales
M B = maxillary barbell (in terminal position)
O A = origin of anal fin
O D = origin of dorsal fin
P F. = pectoral fin
S = length of snout
S L = standard length
V F. = pelvic fin
1 to 7, dorsal fin rays (note that two very small rays at the front end of this fin are not counted and that the last fin ray is divided to its base

Fish have different ecological preferences and inhabit waters best suited to them Environmental factors influence the predominance of certain species of fish. For instance, river fishes prefer riffle or quiet areas; a hill stream with fast flowing water over rocky bed may not have large sized carps, while dimly lit, shallow swampy pools may have cat fishes, mussels, eels and may not have fishes like rohu, mrigal etc

The fishes caught are segregated mainly based on the presence or absence of scales on the body. When scales are present, they are further separated based on body shape, number and length of fins In the case of fishes without fins, they are separated according to the total number of barbels. After the segregation, they are identified according to the keys (Jayaram K C., 1996)

Classification of fishes for scientific study is done through taxonomy or systematics. Under this, each fish is given a name of two words; the first one is generic name and the second specific name, followed by the name of the author who described it first. There may be many fishes under the first word, which is called *Genus*. This indicates the affinity of the fish grouped under the same genus due to common features. Similarly, a number of *Genera* (plural of genus) are grouped under the term *Family*, while a number of families are put under an *Order*. Many orders come under a *Class*. The characters differentiating orders and families are distinct, but down the hierarchy, they become insignificant. For identification, the fishes are first grouped under orders, then families, genera and species. Identification keys are available for all orders, families and genera.



Different kinds of scales

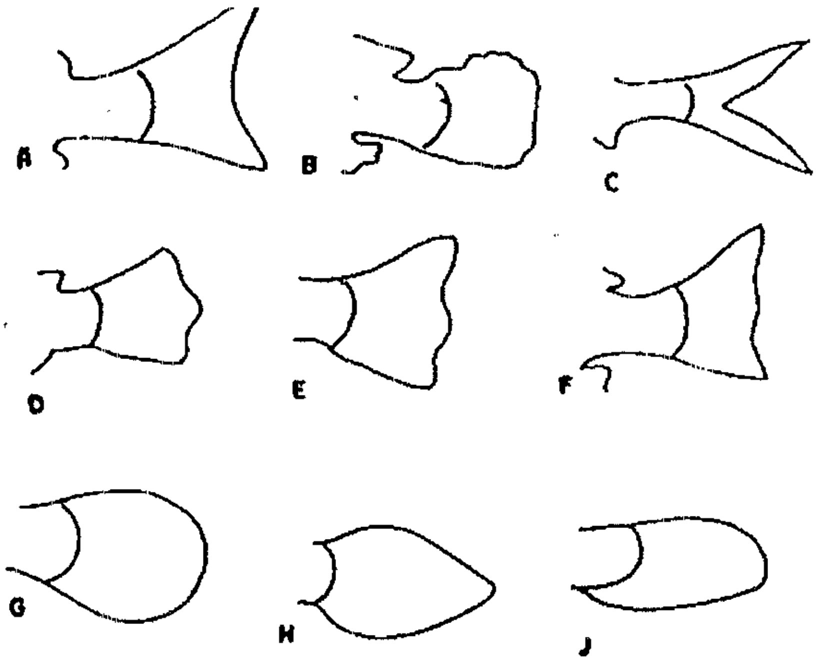
A,B, Ctenoid C,D, Cycloid.

Glossary of terms for identification of fish:

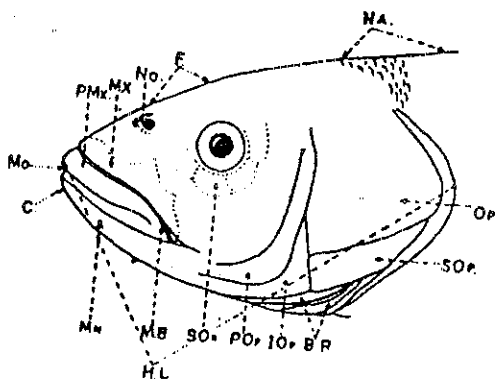
Adipose fin: A short fleshy fin, without rays behind the dorsal fin mainly on the back of catfishes
Antrorse: Pointing forward or towards anterior direction especially in pectoral spine.
Axilla: Space behind base of a fin.
Axillary: Pertaining to the axilla.
Barbel/s: Slender, tactile whisker-like projection extending from the head of some fishes; functioning primarily as a sensory organ for locating food and locations.
Base: The part where a fin joins body, as in length of dorsal/anal fin base.
Branchial: As referred to gills
Branchiostegeal rays: Numerous tiny thin bones arranged fanwise from the lower edge of the opercle to the ventral surface of the head and covered by the branchiostegeal membrane
Breast: Ventral part of the body situated between head and pectoral fins.
Caudal peduncle: The narrow posterior part of the fish's body between anal and caudal fin.
Ctenoid scale: Scales with rough, comb-like or toothed margin
Cycloid scale: Scales that are smooth-edged, more or less circular with concentric striations.
Depth of body: The greatest vertical height of fish.
Dorsal: The back or upper part of the body
Fin rays:
All paired and median fins in teleosts have long, mobile filament like prolongations called rays. The movements of the fins are due to the action of muscles, the movements possible due to the articulations and often flexibility of these rays. The term "ray" also applies to spines, whether they are included within the membrane of a fin or not.
The chief types of fin rays encountered are:

- Hard rays: a number of soft rays united solidly to form hard rays, which are rigid and sharply pointed. These are formed of cartilage. The outermost caudal fin ray called the principal ray is also a hard ray.
- Spinous rays: are made of bone tissues and are harder and stronger than rays. These are usually not flexible and they are commonly found in catfishes.

- Simple ray: It is either soft or hard but without any branching at its tip or elsewhere.
- Branched ray: It is branched either from the base or middle or tip of the ray.



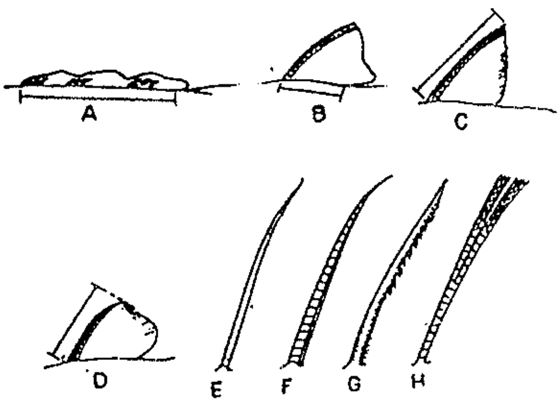
Different caudal fin shapes
(A-slightly emarginated or furcate, B-rounded with wavy margins, C-forked, D-wedge or paddle shaped, E-notched, F-truncate or cut square, G-rounded, H-lanceolate and J-ovate)



BR-branchiostegeal ray, C-chin, F-forehead, HL-head length, OP-interopercule, MB-maxillary barbell, MN-mandible, MO-mouth, MX-maxillary, NA-nape, NO-nostrils, OP-opercule, PMX-premaxillary, POP-preopercule, SOP-subopercule and SOR-suborbital

Gills: The respiratory apparatus of fishes, found within the gill openings.
Gill archers: The bony supports to which the gill rakers are attached.
Gill opening: The opening situated generally on either side of the head; the water used for breathing enters by the mouth and is expelled through gill-openings.
Gill rakers: These are thin needle like prolongations on the gill arches
Gill slit: Each of the narrow spaces between the gill arches.
Gular plate: A hard plate covering the under part of the throat, often present in some fishes.
Isthmus: The fleshy interspace below the head and between the gill openings.
Nare, Naris, Nostril: On the snout of fishes the opening of the olfactory or organ of smell; in fishes these are usually a pair of nostrils on either side of head

Opercule or operculum: The gill cover.
Opercular flap: A fleshy extension of the rear edge of opercule.
Origin of fin: The point where the first ray is inserted into the body of the fish.
Pectoral fins: The paired fins attached to the shoulder girdle
Pelvic fins: The paired fins placed behind or below the pectoral fins.
Scale: One of the thin, bony or horny plates covering the whole or part of the body of most fishes. Scales can be macroscopic as on eel, small as on Chela and large as on Tor. A fish may have no scales as the catfishes



Different types of fins and rays
A-long dorsal fin, B-short dorsal fin, C-high dorsal fin, D-low dorsal fin, E-simple unbranched ray, F-thick ray, G-antrorsely serrated dorsal ray and H-branched ray

Waterfowl Census Techniques:

Birds are the easiest of all animals to census as they are often brightly coloured, relatively easy to see and highly vocal. The bird census and monitoring is an extremely cost-effective way of monitoring the overall health of the ecosystem. The censusing methods are broadly of two types: those for censusing species that are evenly distributed across the landscape and those for species that are highly clumped in distribution

Water birds are broadly defined as: "birds ecologically dependent on wetlands" and include traditionally recognised groups popularly known as wildfowl, waterfowl and shorebirds and waders. In addition to these groups there are other species that are dependant on wetlands such as kingfishers, passerines, etc

Wetland and water birds make use of a variety of conditions, from dry zones and meadows bordering lakes to open water zones. On the basis of their size, the availability of food and suitable foraging conditions, different birds can occupy different parts of the lake. Generally there are five major groups of water birds found based on the wetland zones they frequent. They are: (i) Open water birds, (ii) Waders and shoreline birds, (iii) Meadow and grassland birds, (iv) Birds of reed bed and other vegetation, and (v) Birds of open air space above wetlands (Krishna M B , 1996)

Ducks, geese, grebes, cormorants, kingfishers, terns, gulls and pelicans represent the open water birds. Stilt, greenshank, sandpipers, storks, ibises, spoonbill, herons and egrets tend to frequent shallow waters. Rails, bitterns, coots, jacanas, moorhens, snipe, painted snipe etc, represent the vegetated portions of the wetland. The following section is adapted from "Shorebird Study Manual" (Howes and Blackwell, 1989)

Counting water birds:

Counts should either be written immediately into a field notebook or dictated into a hand-held tape recorder. All counts should be transcribed onto the count forms as soon as possible. Water bird numbers can either be counted accurately or estimated, this decision depends on several factors:

- The time period available;
- The site conditions i e , are the birds a long distance from the observer? Are they difficult to see amongst vegetation?
- The size of the site. Should the count area be divided into smaller sub-sites?
- The behaviour of the birds i e , are they flying? Are there disturbances which may disrupt a count?
- Weather conditions i e , is there a heat haze, strong winds or rain?

- The overall approximate numbers of birds present When counting, maximum accuracy should be aimed for, sometimes this is best achieved by counting each bird individually, sometimes by estimating numbers.

Bird by bird counts should be made when:

- small numbers (less than 3000) birds are present. This decision, based on total numbers present, will depend on the observer's experience;
- there is limited movement of the birds, i.e., they are stationary, feeding or roosting;
- there is little or no disturbance, e.g. by people or birds of prey, which may force the birds to fly often; or
- the birds are scattered and are in an open area (e.g. resting in open water, or foraging on a wide intertidal mudflat)

Numbers are usually estimated when:

- there is a large number of birds present (3000+);
- birds are continually in flight, i.e. large flocks moving to a roost site;
- there is much disturbance, and therefore the birds are continually moving, taking prolonged observation on the ground difficult;
- when birds are tightly packed together at a roost site and not all birds are wholly visible; or
- when the identification of species is not possible due to poor light conditions (e.g. viewing into the sun) or the distance between the observer and the birds is large

Methods for accurate counting

To count a water bird flock accurately, the counter can either write counts directly in a notebook, dictate numbers and species into a hand-held recorder or to another person to write down or use a tally counter. A tally counter is a small, hand-held instrument which records and adds numbers at the press of a button. This facilities fast counting and if the person counting is distracted, ensures that the number counted will not be forgotten. Tally counters can also be used for estimating numbers of birds using blocks (see below) where for each block size the counter is pressed once.

Accurate counts can be made using the following techniques:

- Closely viewing individual birds, either with binoculars or telescope, and counting 1,2,3,4,5,6,7, ... etc.
- Counting small groups of birds within a scattered flock and noting down each total, e.g. 3,7,4,2,11,17,3, etc Totals for each group are added to form the final total.
- Counting flocks in multiples i.e., 2,4,6,8,10,12, etc. This method is faster than counting individually

Methods for estimating numbers

An easy and accurate method for estimating numbers of birds present in the 'Block Method'. This can be used for large flocks, densely packed flocks or distant flocks, either in flight or on the ground This method involves counting or estimating a "block" of birds within a flock. Depending on the overall flock size a "block" can be 10, 100 or 1,000 birds The "block" is then used as a model to measure the remainder of the flock. Some examples are given below.

It is very important to gain as much experience as possible by practicing counting and estimating large flocks of birds. In time it will become easier to estimate large flocks of water birds accurately and using the block method will become the obvious choice.

Field techniques for counting

Counts can be made by a single observer or by a two-men team A single observer may find it difficult to count and record large numbers of birds without the aid of a hand-held tape recorder or tally counter. However, it can be done by using gaps in the flock or markers such as rocks, bushes, fishing stakes or posts as breaks in counting when numbers can be written down in a notebook

A two-men team can divide activities, one observing (using binoculars and telescope), identifying, counting (or estimating), and dictating data to the second who records this in a field note book or on a prepared count form. A two men team allows discussion on numbers estimated and species identification.

Counts by either a single observer or a two-men team can be made in two ways:

- a species by species count i.e., count all of one species then another etc, starting with the most abundant and finishing with the least abundant. This ensures that even if the flock flies away during counting an estimate of the least abundant species can be made using the completed counts, e.g. there were 613 Dunlin and there were roughly half as many Terek Sandpipers, therefore the Terek Sandpiper count can be recorded as ca. 300 This method is fairly slow but is best when birds seem settled and unlikely to fly.

- an all species count, i.e., observing a flock and counting Coot, 2; Mallard, 1; Pintail, 3; Wigeon, 4; etc. until all birds have been counted. This method is fast to use and is best for widely spaced flocks or in areas where birds are often moving

Techniques are outlined below for counting at high tide and low tide.

Counting high tide roosts
High tide roosts are usually formed in areas adjacent to intertidal areas Birds in non-tidal areas may also gather at roosts during the evening. Counting birds at a roost is a very effective method of identifying the species composition and overall abundance and fluctuations of species within an area, provided it is used by the majority of birds present within the area In many cases a high tide roost will contain a larger number of waterbirds from the adjacent intertidal area

The following method can be used to count waterbirds at a high tide roost.
- scan the area with binoculars to see where the main concentrations of birds are.
- count or estimate the overall flock size using the binoculars, e g 2,000 birds.
- mount telescope on a tripod.
- scan flock in one direction, i.e., left to right, with the telescope and make a note of all species seen
- make an assessment of the dominant species present e.g Lesser Sand plover 40%, Dunlin 10% etc Completing these steps ensures that even if the roost is now disturbed and birds leave, some data have been collected
- where possible, accurate counts of individual species can now be made Using the telescope, move slowly through the flock counting each species.

Counting birds flying into a roost
Once a roost site is known, a simple method of counting the birds using it is to count the birds as they fly. Flying flocks (such as large numbers which are packed closely together and change direction often) may be difficult to count accurately, so estimates need to be made and the most abundant species identified. In some cases, flocks can be counted and species identified relatively easily (small flocks or flocks which fly in lines or small groups). When counting a flying flock either begin at the front of the flock and move towards the back (in this way birds can be counted as they fly 'through' the field of view of the binoculars) or begin at the back and move towards the front (in this way it is possible to regulate the speed of the birds passing through the field of view) Try both methods to see which suits you best.

An observer must position himself suitably before high tide and wait for the arrival of the birds. This can also be carried out by two men, each in a different position. Each man independently counts the flocks of incoming birds and identifies as many species as possible When all birds have arrived at the roost the two observers can compare their counts and agree on a count figure. Both men can then observe the roost and identify and count the different species present They will, therefore, have totals of three different counts and an accurate picture of the roost numbers and species composition. A single observer should count the roost several times to get comparative counts and ultimately a maximum count.

Counting foraging birds
Counts of this nature will either take place in an intertidal area or freshwater marsh/ rice field/lake shore, etc In most cases the distances between the observer and the feeding birds will be great and the landscape flat.

A simple method, as given for counting at high tide roosts can be used to count birds widely scattered on the feeding area

Counting foraging birds can be made easier if they can be divided using markers Good markers are fishing stakes or traps, which are often left permanently in the mud flats and also physical features such as small bays, headlands or channels, etc Count the birds between the markers and add to get the total.

In some cases the feeding area used by waterbirds will be too large to accurately survey (on the ground) on a regular basis. If this is the case it will be necessary to select a small area (i e. less than 25 ha), which can be marked.

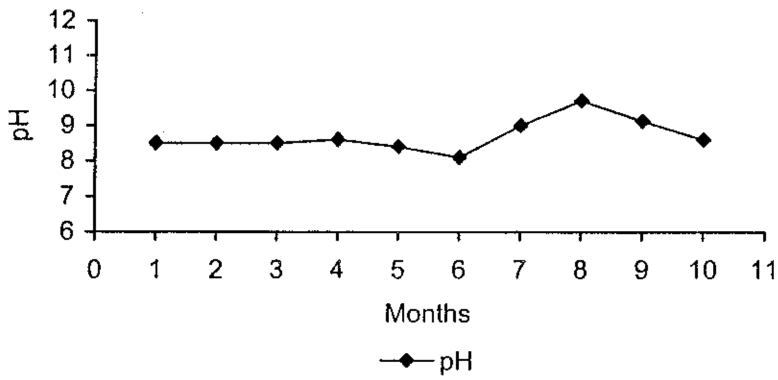
To characterise the wetlands in Bangalore, seven tanks were selected based on their location and the source of pollution-Bannergatta, Hebbal, Kamakshipalya, Madivala, Sankey, Ulsoor and Yediyur Grab sampling was done at the inlet, centre and outlet in most of the waterbodies studied to assess their physical and chemical qualities at monthly intervals, except during some seasons when the centre of the waterbody was not accessible. Variability of physico-chemical parameters in these lakes is discussed in the following section.

BANNERGATTA TANK

The Bannergatta tank (Deepakanalla), situated in Bannerghatta National Park, is in the southern part of the city. Amidst thick forest, covering an area of about 2 hectares, it serves as a source of drinking water for the wild animals. The tank provides habitat for Indian crocodiles, many forms of fishes and variety of birds (egrets, kingfishers, etc). The tank with no major source of pollution and located close to the nature camp was chosen for water quality assessment, which was done for ten months at a point towards the outlet (boating is not done in the tank).

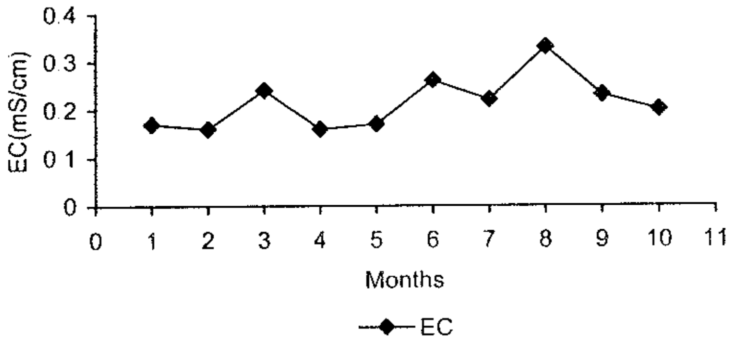
Water was clear with non-objectionable odour throughout the study period, with temperature ranging from 21-29°C (26 1± 2 6°C) and transparency of 30-50 cm showing the clarity of the water body. The low turbidity values further illustrate the clean status of the water-body.

Figure7.1: pH



pH: pH of the water-body is the measure of acidity or alkalinity in the aquatic system, which determines the various chemical and biological interactions occurring within The water samples were found to be alkaline throughout the study period with pH ranging from 8.1 to 9.7, which could be attributed to the dissolved alkaline substances (Figure 7.1)

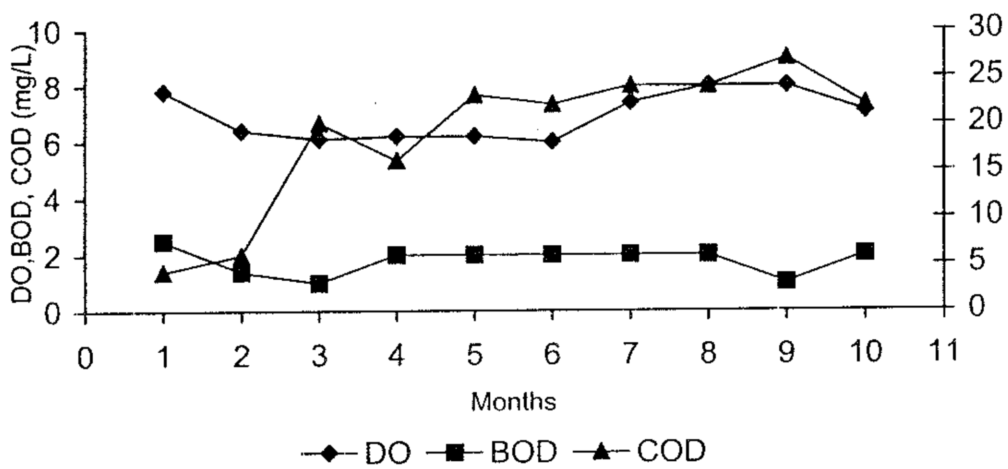
Figure 7 2: EC



Electrical Conductivity: The electrical conductivity (EC) was in the range of 0 20±0 06 milli Siemens/cm indicating less dissolved solids and no major source of pollution (Figure 7 2)

Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD): The important parameters that determine the water quality of the lake are DO, BOD and COD DO ranges from 6 0-7.8 mg/L showing the healthy status of the water body (Welsh, 1957) The BOD and COD values ranging from 2 ± 0 79 mg/L and 19.4±7 2 mg/L respectively, further supplement the non-pollution of the water-body (Figure 7 3)

Figure 7.3 :DO, BOD, COD



Total solids (TS), Total dissolved solids (TDS) and Total suspended solids (TSS): The suspended solids ranged from 20-132 mg/L The high values noticed during July-Sept 1997 might be due to rain Similar trends were noticed with total solids, ranging from 78-242 mg/L The total dissolved solids were found to be 93 8 ± 27 7 mg/L, well within the WHO, Aesthetic Quality Guidelines (that suggest 1000 mg/L as the limit) The low value of solids indicates that water is not polluted (Figure 7 4)

Figure 7.4: TS,TDS,TSS

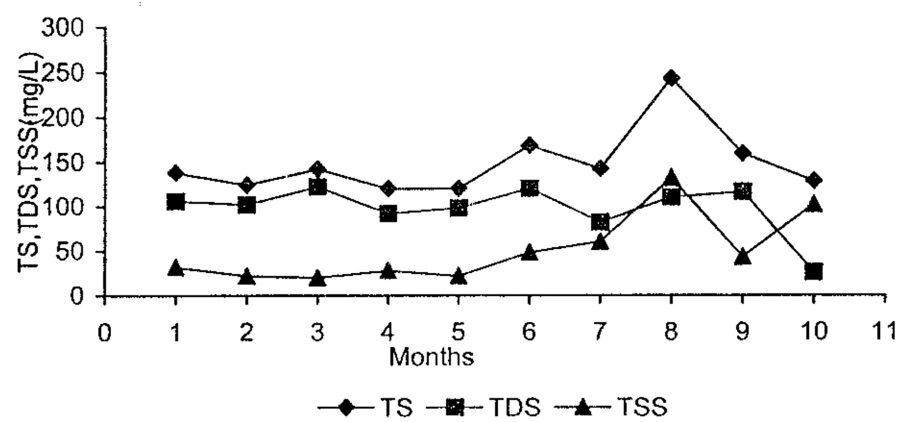
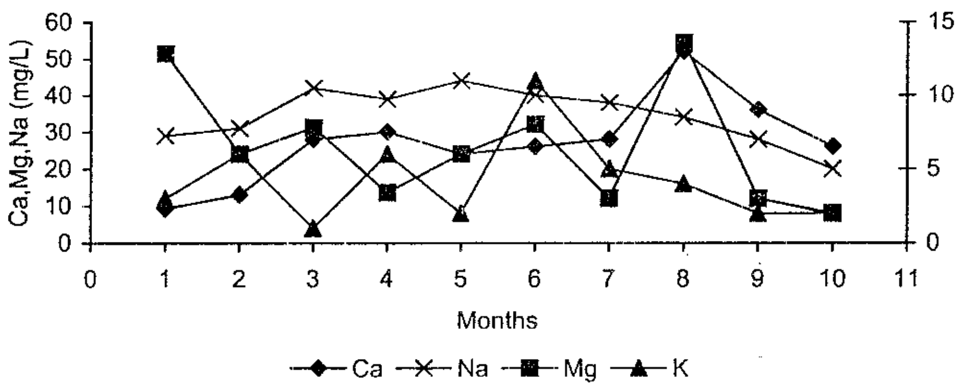


Figure 7.5: Ca, Mg, K, Na



Cations: The major cation (Ca, Mg, K, and Na) analyses showed low values Calcium was found to be 25.2 ±12 25 mg/L, magnesium 6 54 ±3.69 mg/L, potassium 4 0 ±2 7 mg/L and sodium 34.5±7 1 mg/L, indicating no source of either domestic or industrial pollution The relatively higher values of calcium and sodium could be due to the geomorphology of the area (Figure 7 5)

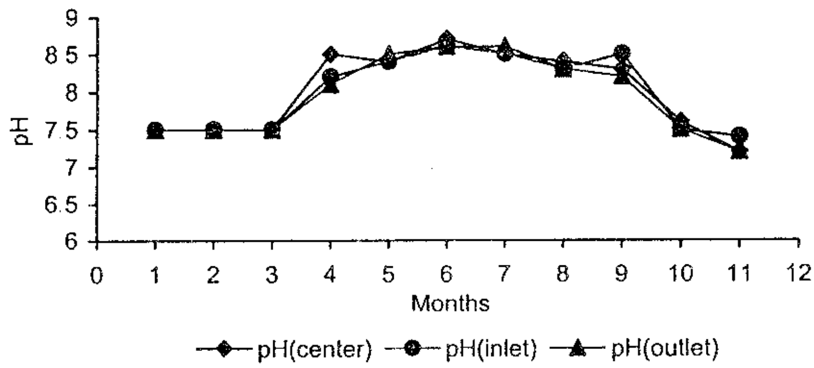
Heavy metals: The various heavy metals that included copper, lead, iron, zinc, nickel, cadmium and chromium were found at non-detectable levels.

SANKEY TANK

During the latter half of the 19th Century, Col Sankey constructed a tank in the Western part of the city, between Malleswaram and Sadashivanagar areas, to meet the drinking water demand The tank has a well-maintained park and a corporation swimming pool at the southern part, and a nursery towards the north, adjacent to the tank It also attracts large populations of migratory birds apart from small time fishing activities The tank presently has no major source of pollution except for some washing activities towards the southern and western parts of the tank. The water is presently used for watering plants by the forest department The tank serves the recreation requirement of the region and has a boat club run by the Karnataka State Tourism Development Corporation (KSTDC) The monthly water samples were collected at three points (inlet, centre and outlet) for twelve months, for evaluating the physico-chemical and biological parameters The water was clear throughout the study period with non-objectionable odour

Temperature of the water body ranged from 21 to 30 °C The clarity of water is indicated by low turbidity values ranging from 6 to 14 NTU and high transparency of over 25 cm.

Figure 8.1: pH



pH: The pH of the water samples during the study period was mostly neutral at all points ranging from 7.2-8.4 The standard pH range for unpolluted natural water bodies lies between 6.0-9.0 (Figure 8 1)

Figure 8.2: TDS

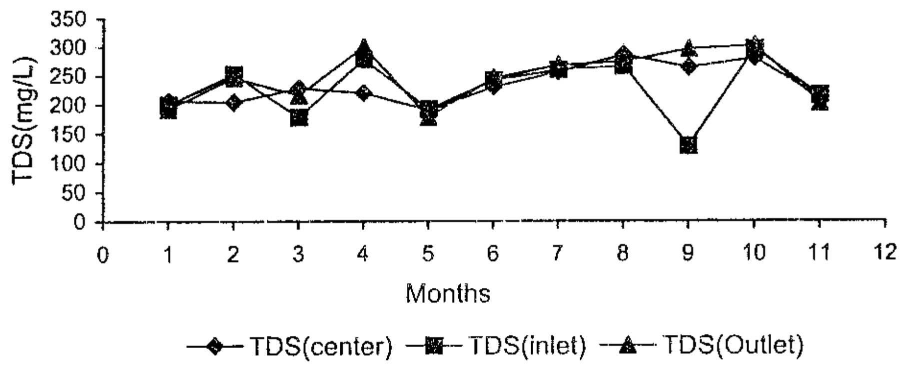
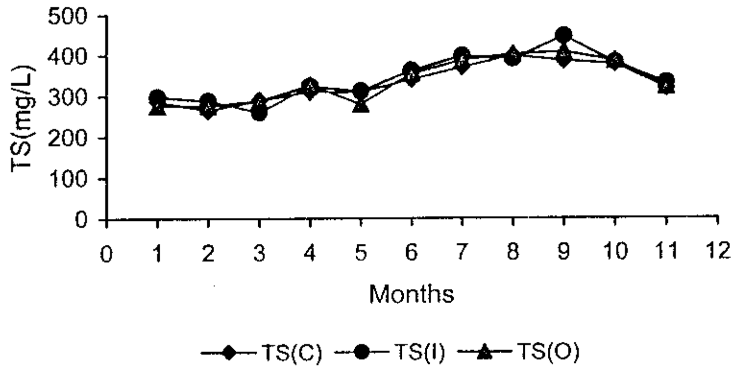


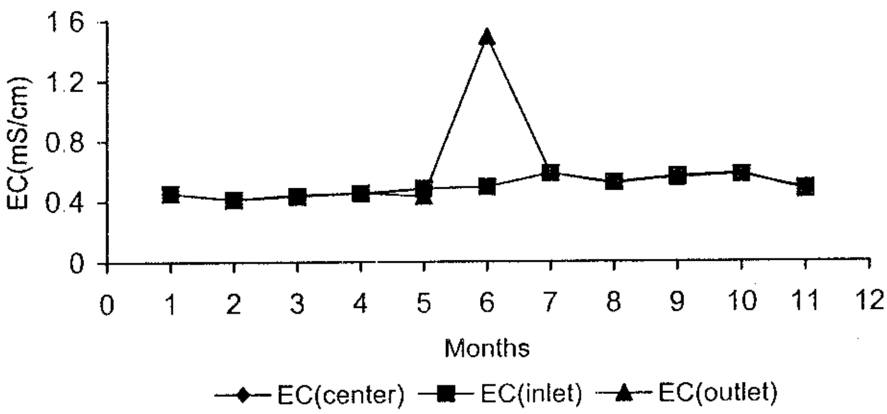
Figure 8.3: TS



Solids: The water samples showed lower concentration of solids during the study period. Lower TDS values of 228±47.75, 234.18±30.97, 247.2±42.8 mg/L were found at inlet, centre and outlet respectively (Figure 8.2). The TS ranged from 260-446 mg/L towards inlet, 264-398 mg/L at centre and 276-408 mg/L at outlet (Figure 8.3) Similarly low TSS values at all sample points indicate that the tank has less plankton density and pollution load

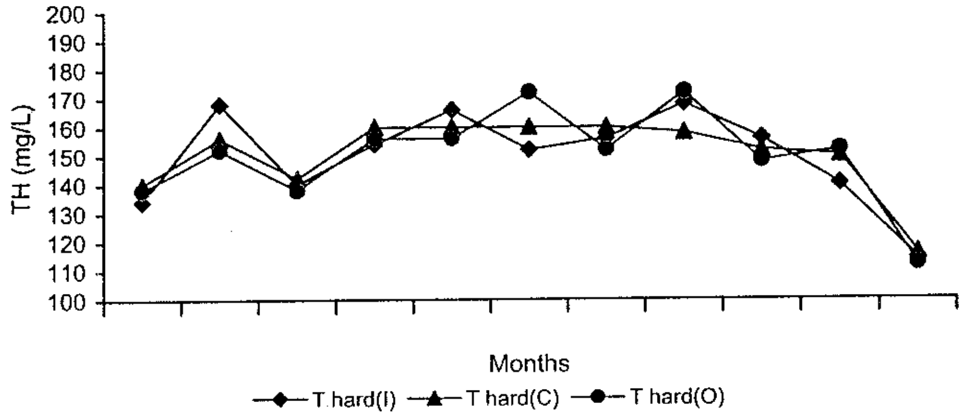
Electrical Conductivity (EC): The electrical conductivity of water samples at centre and outlet was 0.49±0.05, and 0.55±0.29 mS/cm towards inlet. Lower value of EC suggests that the tank has no major source of pollution. The high value of EC noted during April 1997 at outlet was due to inflow from the nursery side (Figure 8.4).

Figure 8.4: EC



Total Hardness (TH): The dissolved salts of carbonate and bicarbonates of divalent cations (such as calcium and magnesium) cause the hardness in water. Relatively higher value of about 150 mg/L of total hardness was found at inlet, which may be due to runoff from the nursery (Figure 8.5) (which uses hardness-inducing substances such as lime)

Figure 8 5: TH



Dissolved Oxygen (DO): The DO values of the lake are 6 6±0.9 mg/L, 6.7±0.9 mg/L and 6 6±1 0 mg/L at inlet, centre and outlet of the tank respectively. The DO at all sample points of the lake showed nearly similar values throughout the study period (Figure 8.6).

Figure 8 6: DO

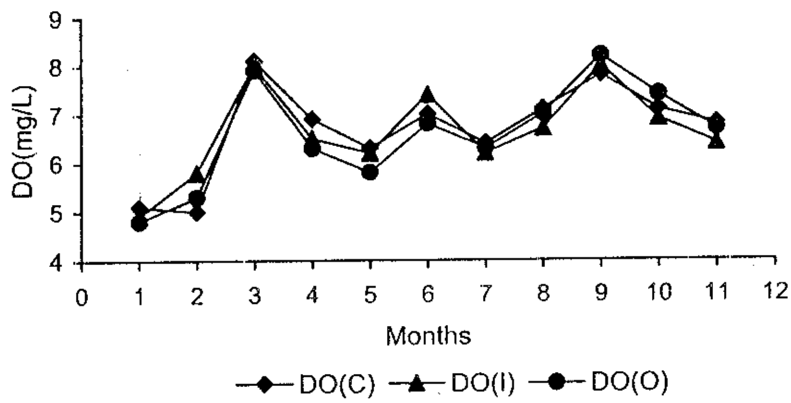
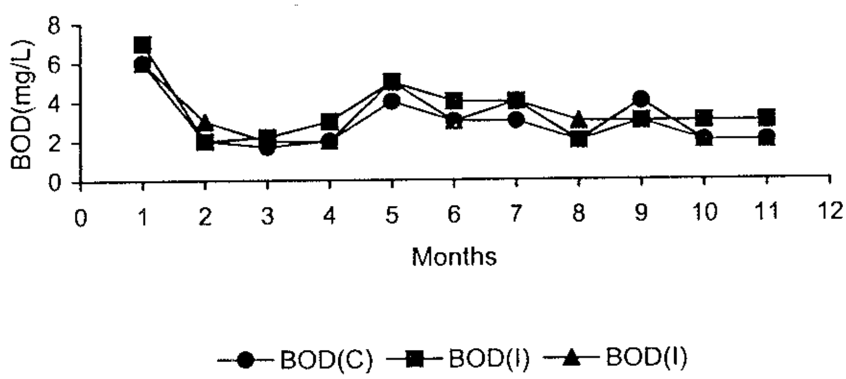
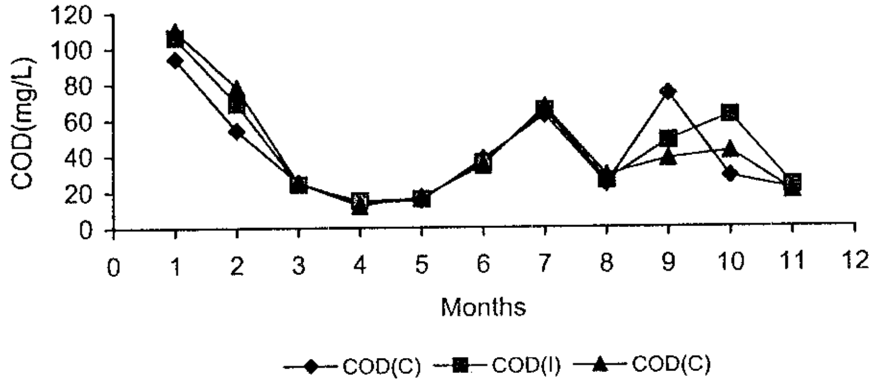


Figure 8.7: BOD



Biological Oxygen Demand (BOD): Low BOD values ranging from 1.7-7.0 mg/L were noticed at all points in the lake, indicating low degree of pollution (Figure 8.7).

Figure 8.8: COD



Chemical Oxygen Demand (COD): Low values of COD ranging from 15-105mg/L at inlet, 14-94mg/L and 12-112 mg/L at inlet, centre and outlet respectively clearly shows the water in this lake is relatively less polluted (Figure 8.8).

Figure 8.9: Ca,Mg,K,Na(I-San)

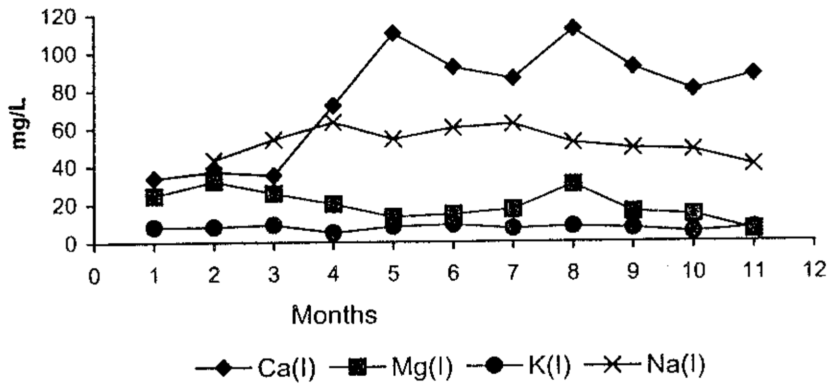


Figure 8.10: Ca,Mg,K,Na

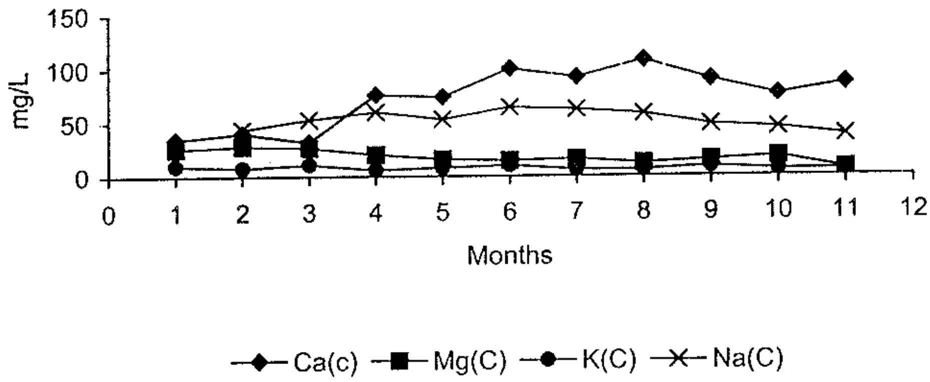
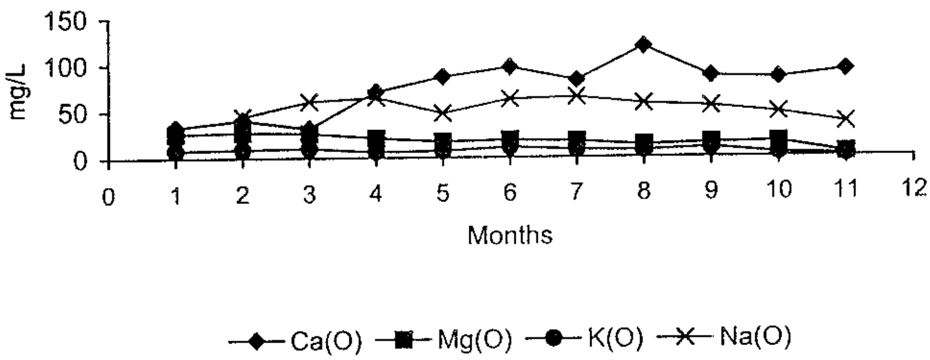


Figure 8.11: Ca,Mg,K,Na

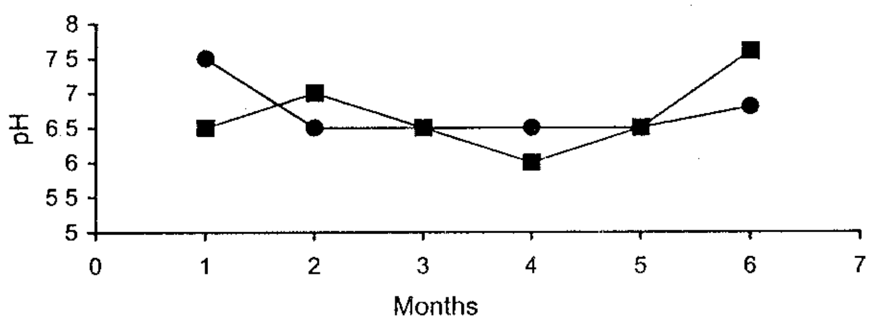


Cations: The cations showed little variations with time during the study Calcium varied from 31.0 - 118 0 mg/L at various points measured in the tank. Low values of potassium ranged from 2 0-11 0 mg/L and similar trends were noticed for all cations measured at all sampling points (Figure 8 9 – 8 11)

KAMAKSHIPALYA TANK

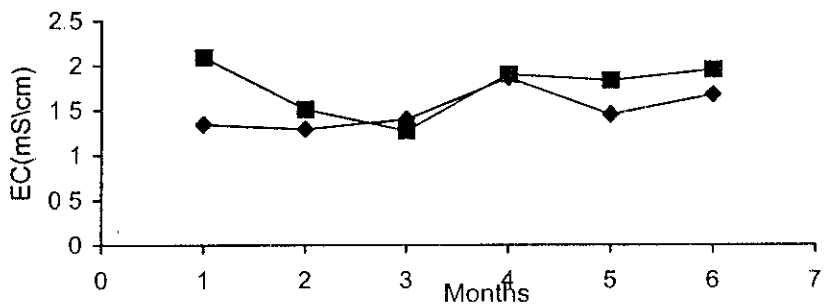
The Kamakshipalya tank situated in the western part of the city covers a small area, less than a hectare. The tank is encroached on all the sides by slums. A number of small-scale industries located in the vicinity manufacture plastic products and undertake electroplating (chromium), etc. The tank once a source of drinking water (till the late 80's) receives direct effluents from both industries and the surrounding residential areas of Basaveshawaranagar, Saligrama, Kamakshipalya, etc The water quality was monitored for a period of six months at two points towards the periphery of the tank (as no boating facility was available to carryout water sampling at the centre). Sampling points chosen were (a) behind the slums and (b) towards the outlet, where effluents from neighbouring dye industries enter the tank Colour of the water was blackish, with high turbidity and obnoxious odour throughout the study period Turbidity of the water body was high, ranging from 28 to 362 NTU (Nephelometric Turbidity Units). The tank due to its poor water quality has become a breeding ground for mosquitoes, and due to poor management, is a cesspool for pollutants, supporting negligible biodiversity.

Figure 9.1: pH



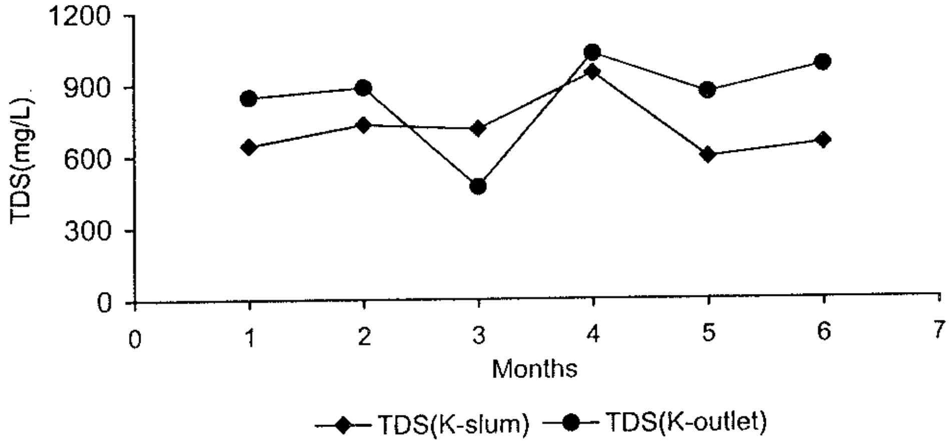
pH: The pH of the lake during the study period was acidic, ranging from 6.5-7.5 This could be due to the decay and decomposition of the accumulated organic matter (Figure 9.1)

Figure 9.2: EC



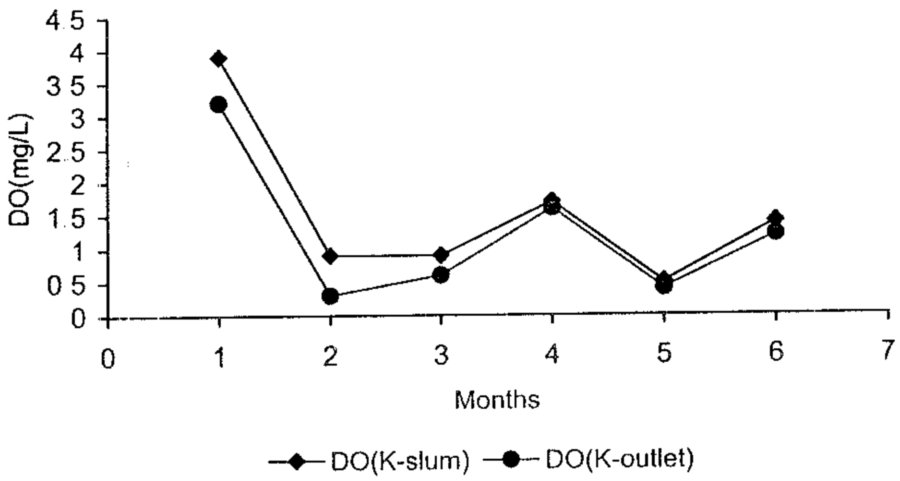
Electrical Conductivity (EC): The EC ranges from 1.27-2.09 milli Siemens/cm, indicating high amount of dissolved solids (Figure 9.2).

Figure 9.3: TDS



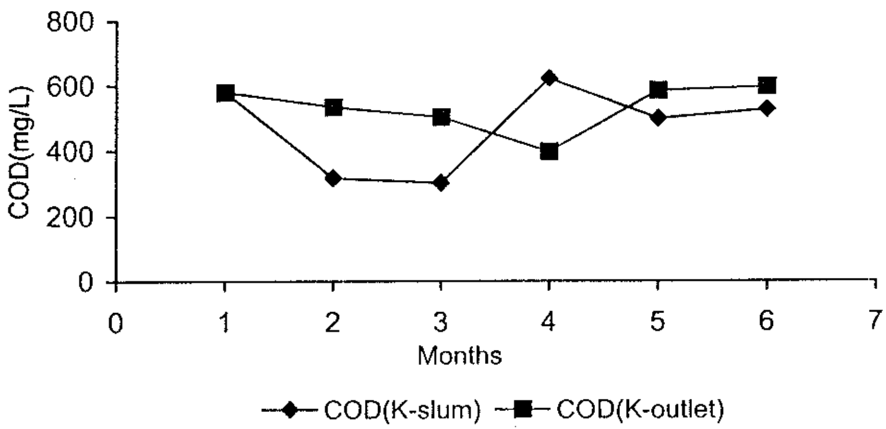
Total Dissolved Solids (TDS): Total dissolved solids of the water body were found to be 710.3 ±114.2 mg/L at the point behind the slum and 843.3 ±179 2 mg/L towards the outlet, indicating a high level of pollution (Figure 9 3)

Figure 9 4: DO



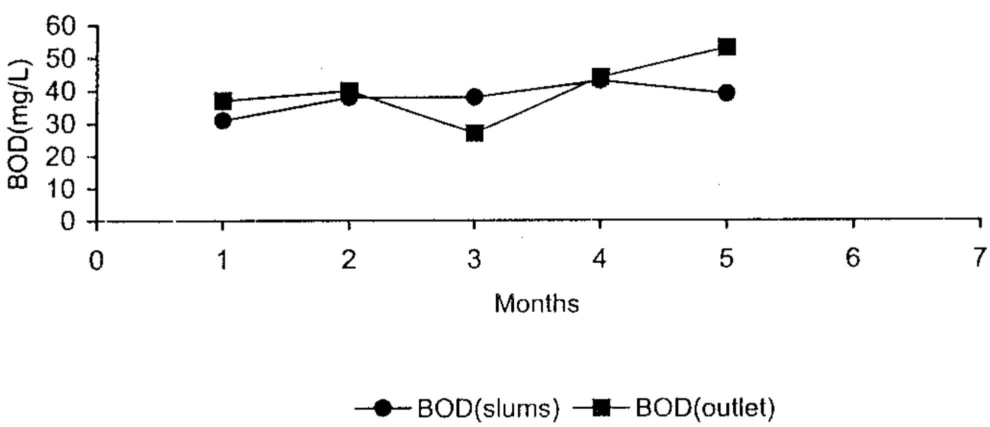
Dissolved Oxygen (DO): DO ranged from 0 5 to 3 9 mg/L, due to the presence of high amounts of organic substances leading to biological activities such as respiration and decay processes within the system. This lower DO value reflects the septic condition of the lake (Figure 9.4).

Figure 9.5: COD



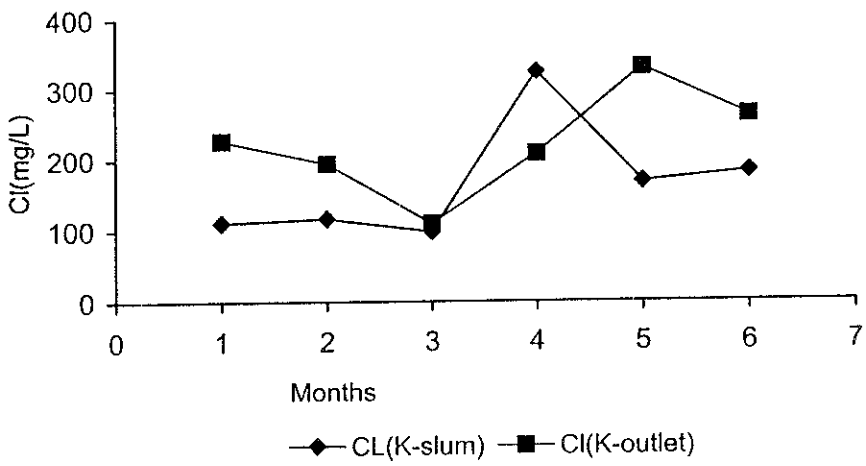
Chemical Oxygen Demand (COD): COD value ranges from 170 to 621 mg/L. High values were observed during much of the study period (over 300mg/L), indicating severe chemical pollution due to sewage load. Rains during January 1997 lowered the COD value due to dilution. The permissible limit for inland surface water is 250 mg/L (Central Pollution Control Board - CPCB Standards) (Figure 9.5)

Figure 9.6: BOD



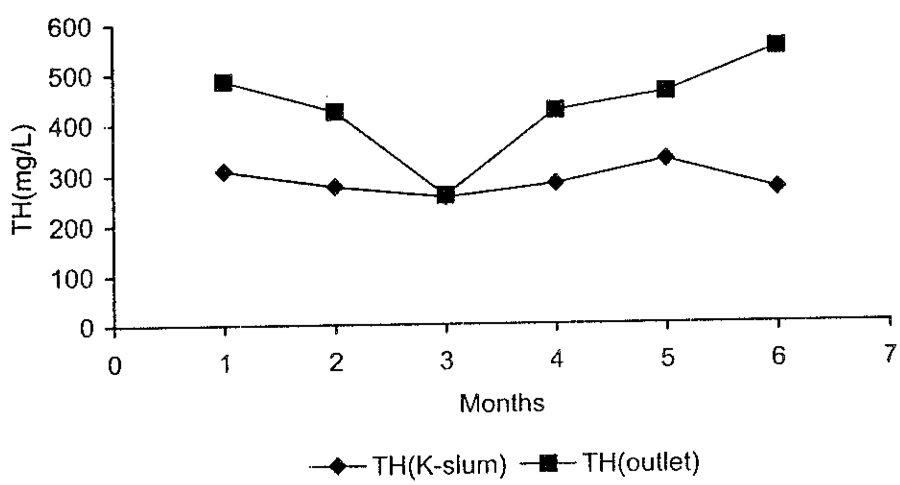
Biological Oxygen Demand (BOD): BOD is a very important parameter that estimates the amount of oxygen required for biodegrading organic substances present in the lake. BOD ranges from 27 to 192 mg/L, indicating oxygen demand for various biological activities (Figure 9.6). Higher BOD values noticed in samples collected behind slums are due to dumping of organic wastes

Figure 9.7: Cl



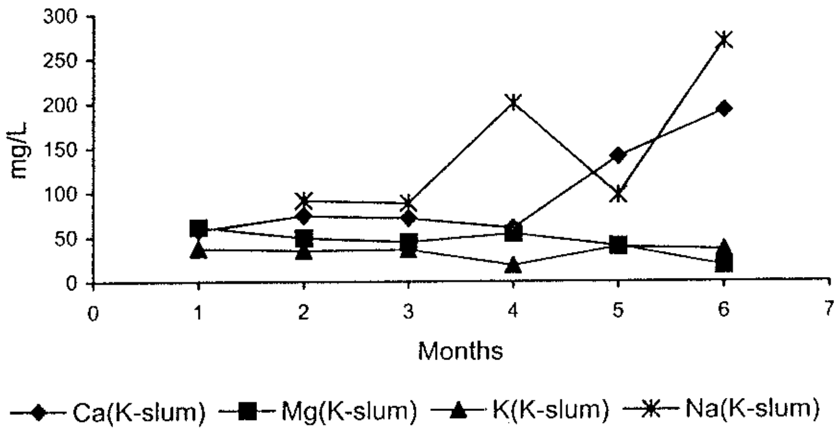
Chlorides: The chloride value of samples was 166.4±76 898 mg/L at the point behind the slum and 221 7±67 1 mg/L at the outlet. These high values observed reflect pollution due to effluents of both domestic and industrial sectors (Figure 9 7)

Figure 9.8: TH



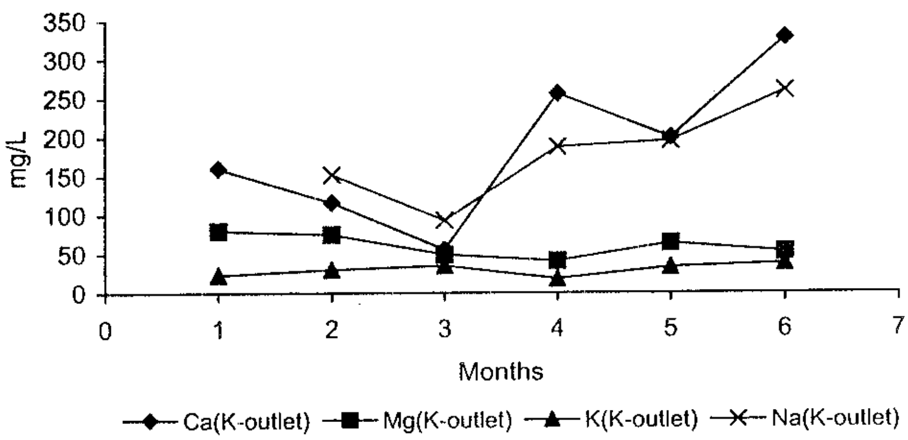
Total Hardness: The samples showed high values of hardness ranging from 254 to 548 mg/L. The major source of hardness, detergents, get into the water body from the dye industries situated adjacent to the tank and from the residential colonies (Figure 9.8)

Figure 9.9: Ca, Mg, K, Na (K-slum)



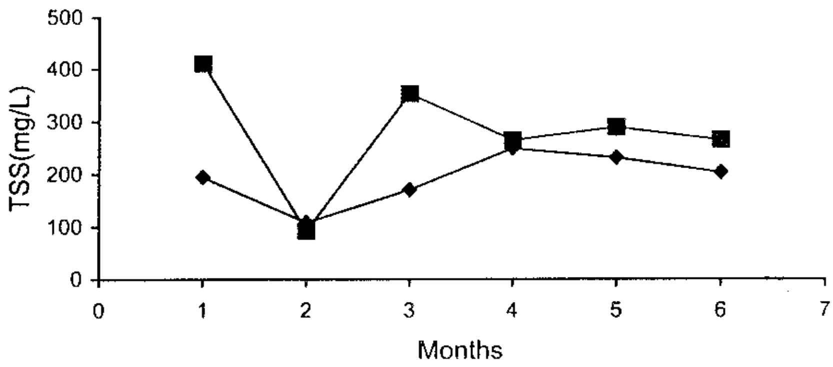
Ca, Mg, K, Na: Higher sodium concentration was found to be 149 ± 73.2 mg/L suggesting pollution by domestic sewage and high calcium ranging from 57.2 to 192.0 mg/L, which could be due to detergents washed into the water body (Figure 9.9).

Figure 9.10: Ca, Mg, K, Na (K_outlet)



Higher values of cations were noticed towards the outlet. The high sodium concentration ranging from 93 to 260 mg/L suggests pollution by domestic sewage. The drop in the calcium concentration during January 1997 is due to dilutions because of rain during the season (Figure 9.10)

Figure 9.11: TSS



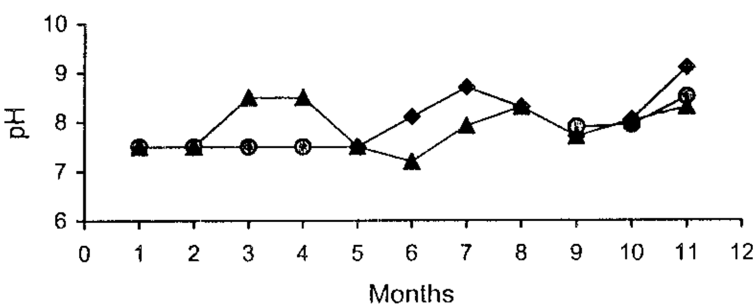
—◆— TSS(K-Slum) —■— TSS(K-outlet)

Total Suspended Solids: Higher values of suspended solids were noticed during the study period ranging from 108 to 410 mg/L (the tolerance limit for inland surface water is 100 mg/L) which is due to influx of sewage (Figure 6.11) High amount of suspended solids leads to depletion in DO (especially if it is organic) apart from imparting high turbidity (Figure 9.11)

MADIVALA TANK

Madivala tank is the second biggest in Bangalore, after Bellandur tank The tank is situated in B T M. layout between Bannergatta and Hosur roads, covering an approximate area of about 115 hectares This tank has a park and a boating club run by KSTDC for recreational purpose It receives voluminous amounts of untreated sewage of both domestic (mainly) and industrial sectors from surrounding areas of Jayanagar, B T M. layout, Madivala and from other localities The tank gets detergents from washing and other domestic effluents from a '*Dhobighat*' (washing clothes at large scale by washer men) and an associated slum The pollution status of the tank was evaluated by analysing the various physico-chemical and biological parameters at the inlet, centre and outlet of the tank The tank was covered with water hyacinth for 4 months of the study period during which time sampling at the centre of the tank was not done The color of the water was found green for much of the study period, mainly due to higher plankton density During Sept-Oct 1997, water was clear due to dilution on account of rain The water temperature was between 21°C (during Dec 1996 – Jan 1997) to 29°C (Apr-May 1997).

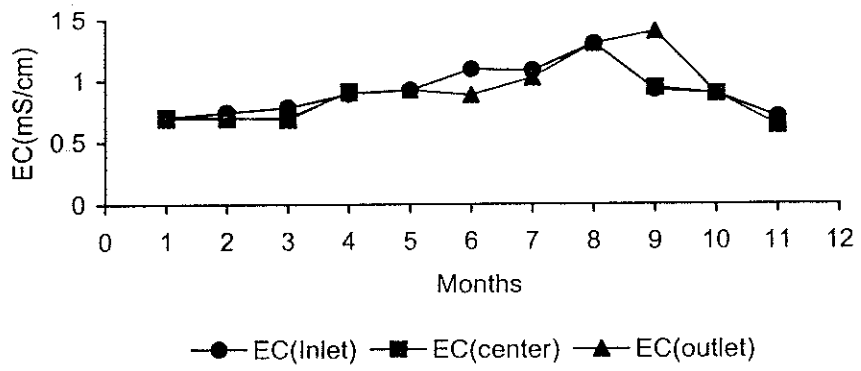
Figure 10.1: pH



—◆— pH(inlet) —●— pH(center) —▲— pH(outlet)

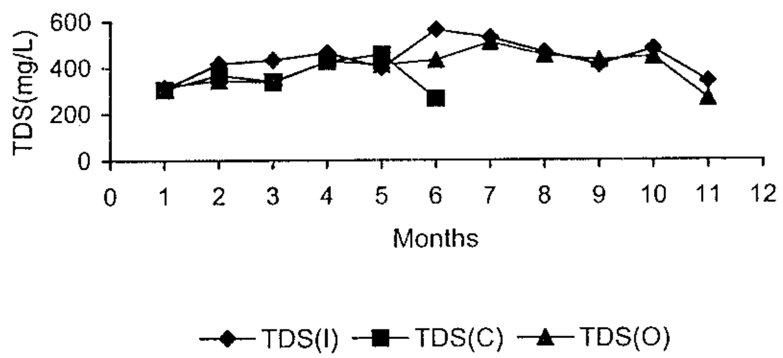
pH: The pH range for inland surface water is 6.0 - 9.0 (Welch, 1952) The pH of the water samples of Madivala tank ranged from 7.2 to 9.1 showing alkalinity, which is due to the using up of the available free carbon-di-oxide on account of plankton activity and sewage (Figure 10.1)

Figure 10 2: EC



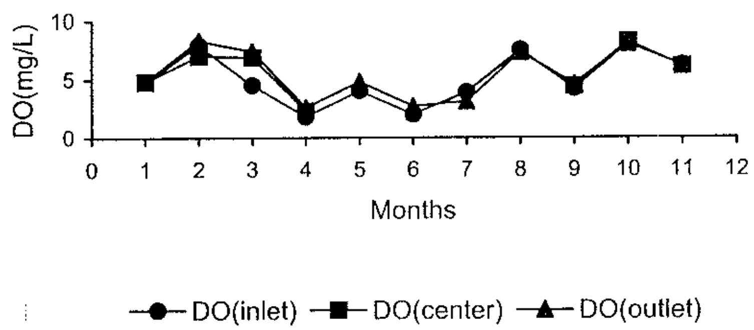
Electrical Conductivity: EC varied from 0 7-1 3 mS/cm at the inlet and 0 63-1.4 mS/cm at the outlet, due to higher dissolved solids from the sewage (at inlet) and washing activities that bring in dissolved salts at outlet. The values at the centre ranged from 0 63-0.79 (Figure 10.2).

Figure 10.3: TDS



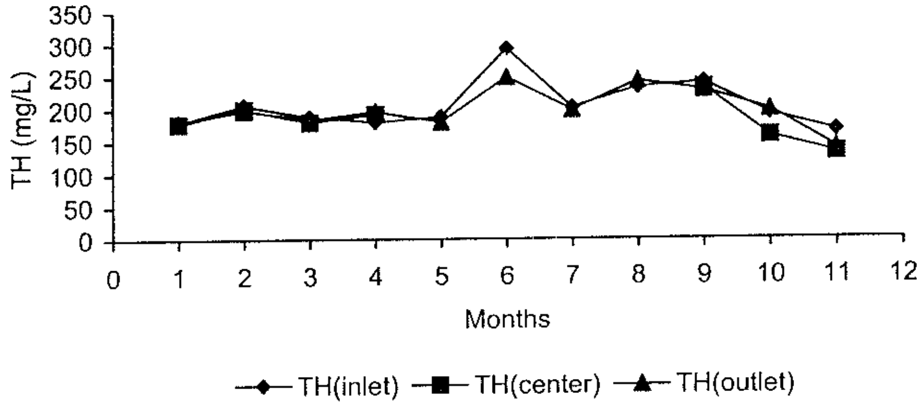
Total Dissolved Solids: The total solids averaged at 464.3 mg/L (S.D 71 5) at inlet, 396.9 (S.D 68 9) at outlet, and 321.4 (S D 112) at centre of the lake. Higher values of TDS were noticed at both outlet and inlet during Apr-May 1997 due to decreased water level (Figure 10 3)

Figure 10.4: DO



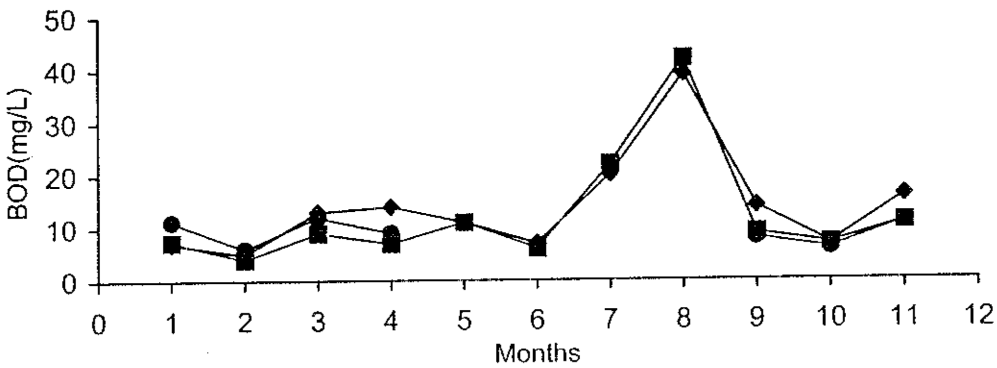
Dissolved Oxygen: The DO concentration throughout the study period did not vary much from one station to another, ranging from 1.8 to 8.0 mg/L, 2.3 to 8.2 mg/L and 2.6 to 8.3 mg/L at inlet, centre and outlet respectively. DO values of the lake showed to be a limiting factor for the lake's health. Low DO values during Feb-Apr 1997 were due to water hyacinth (Figure 10.4).

Figure 10.5: TH



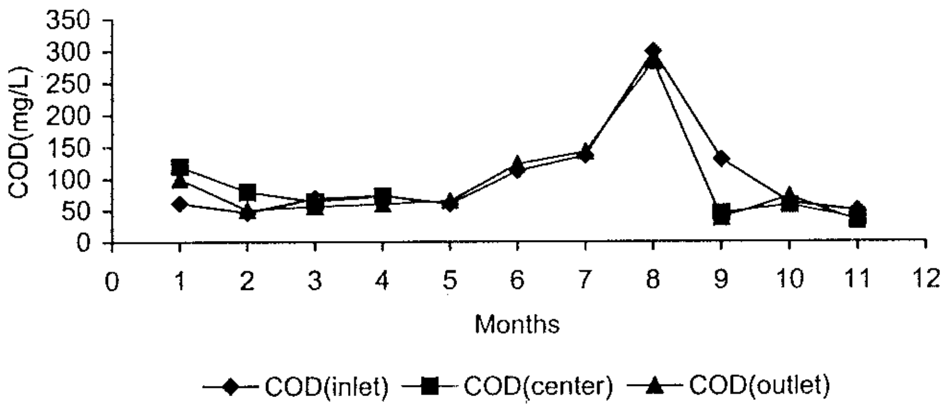
Total Hardness: Total hardness of water samples were 206±34.4 mg/L at inlet, 181.7± 29.3 mg/L at centre and 199.3±29.4 mg/L at outlet during the study period. This high value of hardness is due to domestic sewage and washing activities that take place on the tank bed (Figure 10.5).

Figure 10.6: BOD



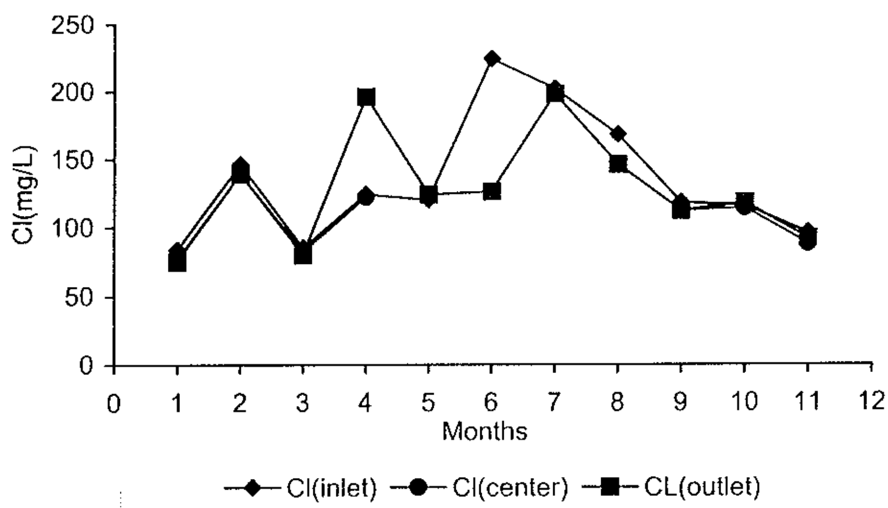
Biological Oxygen Demand: The BOD values of water samples vary from 4.0 to 42.0 mg/L towards the outlet and inlet. The higher values noticed during May-Jul 1997 were due to water hyacinth blooms, sewage and precipitation runoff (Figure 10.6)

Figure 10 7: COD



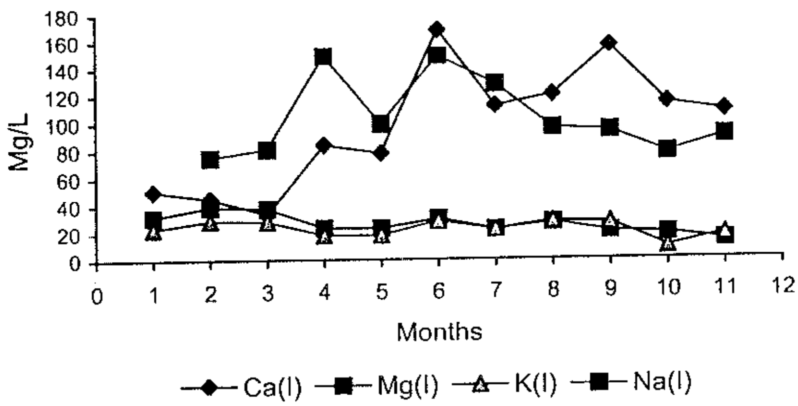
Chemical Oxygen Demand: Organic and inorganic chemical pollution in water samples are reflected by high values of COD The values in Madivala lake ranged from 46 2 to 282 0 mg/L Higher values of COD noticed during May-July 1997 could be due to sewage and surface runoff towards the inlet and detergents from washing by washer-men at the outlet (Figure 10.7)

Figure 10 8: Cl



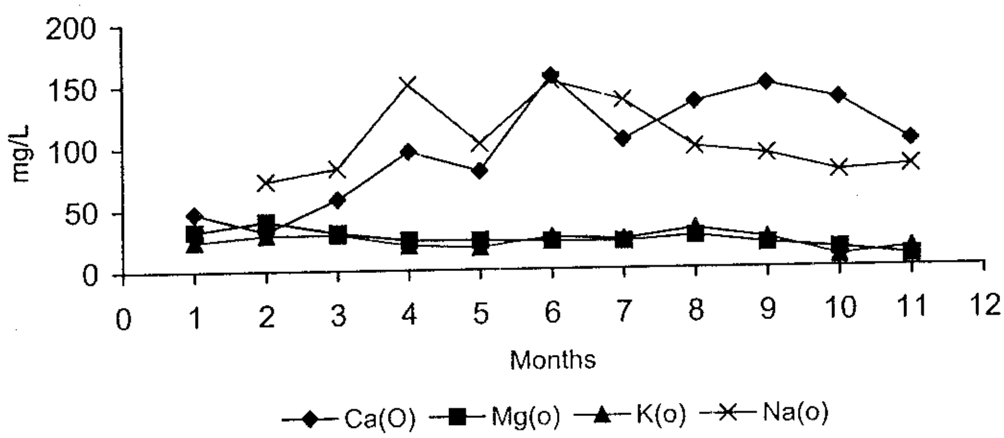
Chlorides: The high chloride contents of 134.8 mg/L noticed at the inlet is an evidence of organic pollution from domestic pollutants (Kataria, H C., et al 1996) and 127 8 mg/L at the outlet, which is mainly due to detergents (Figure 10 8).

Figure 10.9: Ca, Mg, K, Na (I)



Cations: The calcium content of the water sample indicated a decrease from 50.5 to 33.6 mg/L during Nov 1996-Jan 1997 and increased during Feb-Apr 1997. Potassium and magnesium are 22.5±6.0 mg/L and 26.1±7.4 mg/L respectively. The fluctuations in sodium values can be attributed to sewage (Figure 10.9).

Figure 10.10: Ca,Mg,K,Na



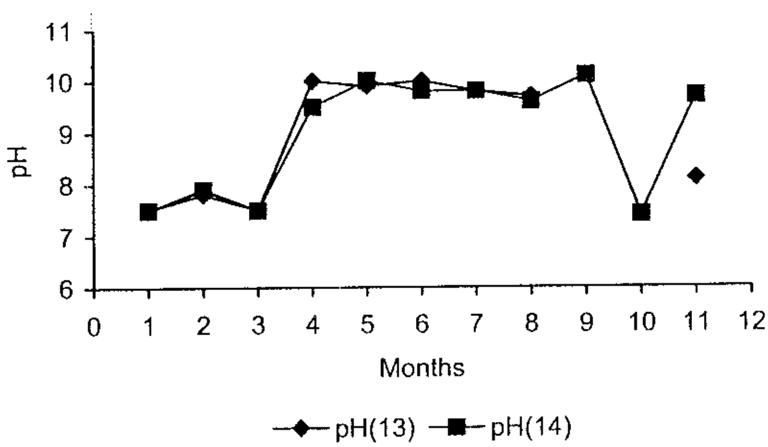
Similar trends in the Ca, Mg, K, and Na values were noticed towards the outlet of the tank (Figure 7.10)

YEDIYUR TANK

The Yediyur tank situated on the Kanakapura road in Jayanagar area of the city covers an area of about a hectare. The tank has a park and residential layout in its vicinity. It receives both industrial and domestic sewage apart from solid wastes dumped across the periphery of the tank. It is heavily infested with plankton, mainly microcystis, indicating pollution. The tank serves as a breeding ground for mosquitoes and acts as a cesspool leading to obnoxious odour. It has two major inlets and two outlets. In order to assess the level of pollution and to suggest restoration measures, water quality of the tank was monitored for a period of about twelve months at two points, one towards the centre of the tank and the other towards the major inlet point.

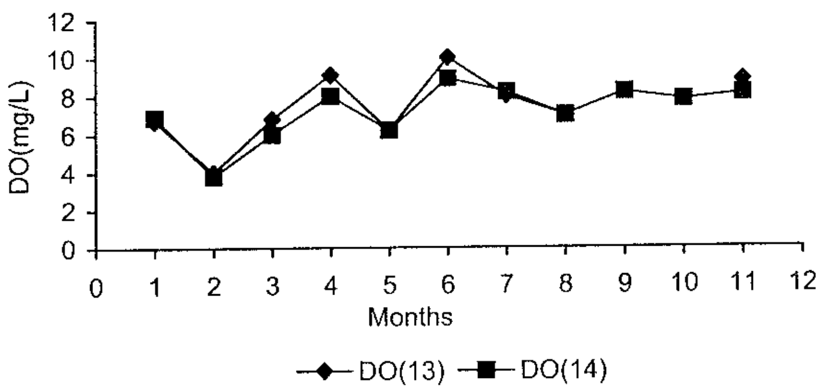
The tank water was greenish owing to high plankton density. High turbidity noticed is due to plankton and sewage. Transparency of 5-14 cm indicates low light penetration. The temperature of the water measured during sampling time (10-11 am) varied from 23-29°C.

Figure 11.1: pH



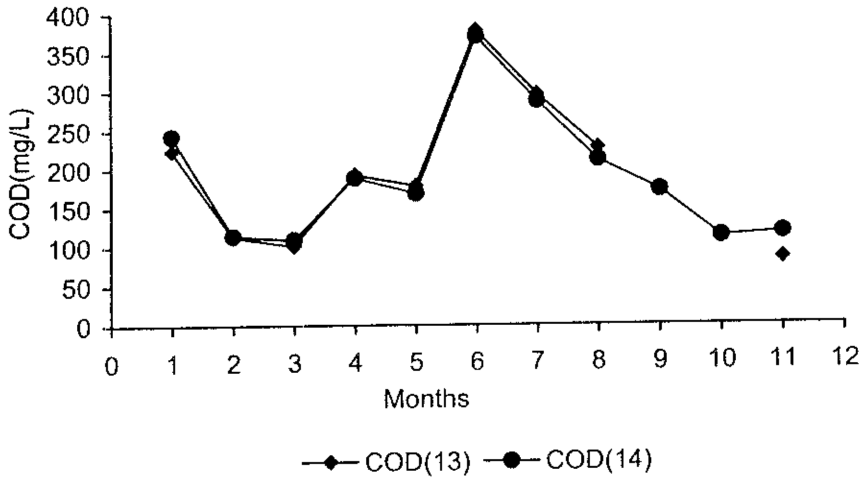
pH: The pH is affected not only by the reaction of carbon-di-oxide but also by the presence of organic and inorganic solutes in the water. The pH at both the sample points was mostly towards alkalinity ranging from 7.5 to 10.1. The decrease in pH during the monsoons may be due to decreased photosynthetic activity and the inflow of storm water. Maximum values in summer may be due to increased photosynthetic activity by algal blooms. The alkaline pH could also be due to untreated domestic sewage getting into the water body (Figure11.1)

Figure 11.2: DO



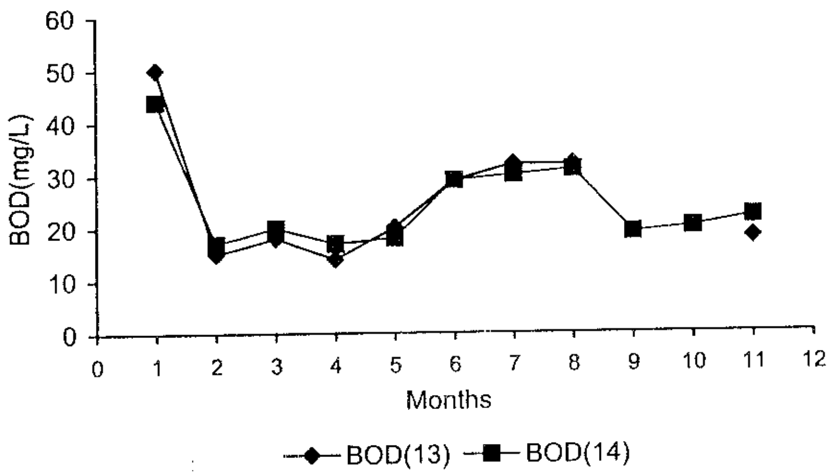
Dissolved Oxygen: Dissolved oxygen is important for all living organisms. The main source of dissolved oxygen in aquatic system is either direct diffusion from air or from photosynthetic activity of the autotrophs. It is an important parameter indicating the health status of the water body. DO ranged from 4.0 to 10.0 mg/L at the centre and 3.8 to 8.9 mg/L towards the inlet. Relatively lower values at the inlet were due to sewage and solid waste preventing air-water interaction and decomposition of organic matter leading to decreased/low dissolved oxygen. The higher values noticed at the centre may be due to higher planktonic density resulting in higher photosynthetic activity (Figure 11.2)

Figure 11.3: COD



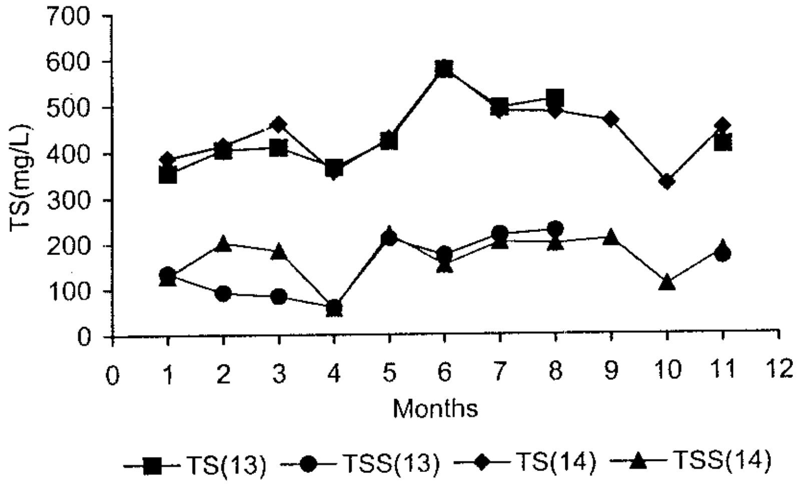
Chemical Oxygen Demand: COD is an important measure of pollution in an aquatic ecosystem to estimate the carbonaceous factor of the organic matter. The COD values ranged from 84 mg/L in Oct 1997 to a high of 378 mg/L during Apr 1997 at the centre and 112 mg/L in Sept 1997 to a high of 370 mg/L during Apr 1997 towards the inlet. During April 1997, high values of COD were noticed, which may be due to less volume of water (after evaporation) and continued inflow of sewage. The lower values during Sept-Oct 1997 were due to inflow of catchment runoff resulting in dilution (Monsoon) (Figure 11.3)

Figure 11.4: BOD



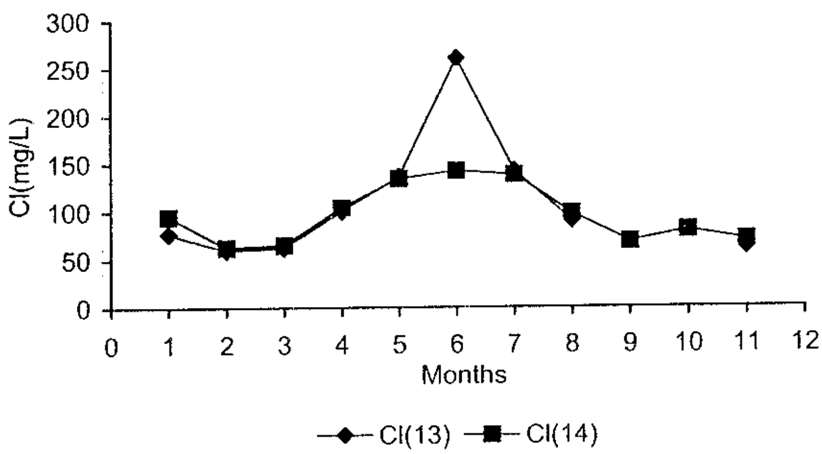
Biological Oxygen Demand: BOD is the amount of oxygen required by microorganisms while stabilizing the biologically decomposable organic matter under aerobic conditions. It is used as a measure of organic pollution. The BOD values ranged from 14-32 mg/L towards the centre of the lake and 17-31 mg/L towards the inlet where there was high influx of pollutants. Higher values of BOD, exhibited during summer, may be due to increased temperature and sewage (Figure 11.4).

Figure 11.5: TS,TSS



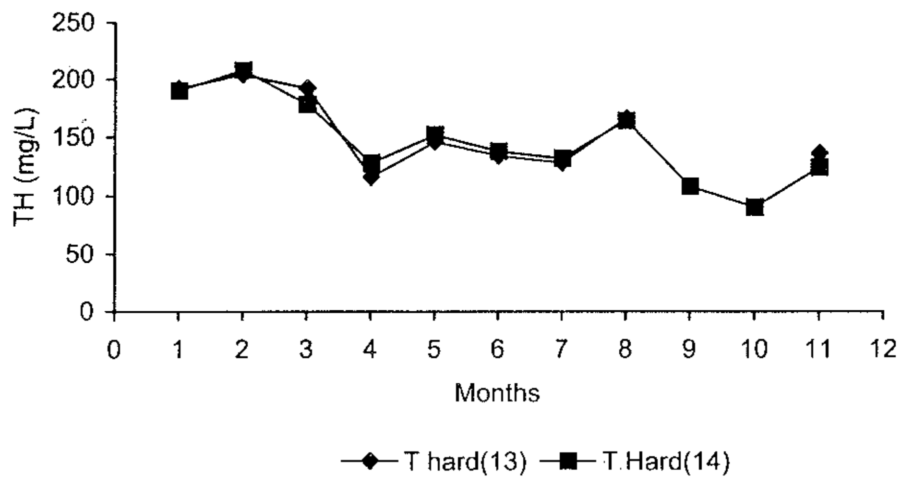
Total Solids (TS) and Total Suspended Solids (TSS): The TS in the lake was about 151 8 (avg)±58 6(Sd) mg/L towards the centre and 167 5 (avg)±48 2(Sd) mg/L towards the inlet The high TSS noticed during summer may be due to algal blooms resulting in higher plankton density towards the centre and sewage at the inlet Maximum total solids were noticed both at inlet and at the centre (Figure 11 5) This may be due to decreased water depth and inflow of sewage.

Figure 11.6: Cl



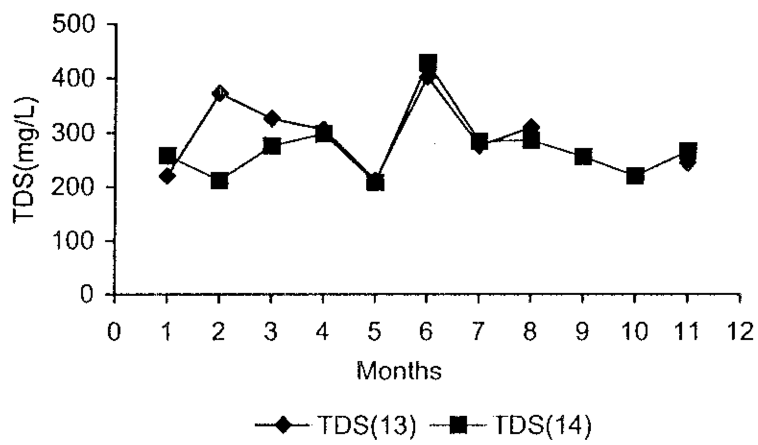
Chlorides: High concentration of chlorides is an indicator of pollution due to high organic wastes of animal or industrial origin. In the present study, high values of chlorides were noted at an average of 109 8 mg/L at centre and 96.0 mg/L towards the inlet (Figure 11.6)

Figure 11.7: TH



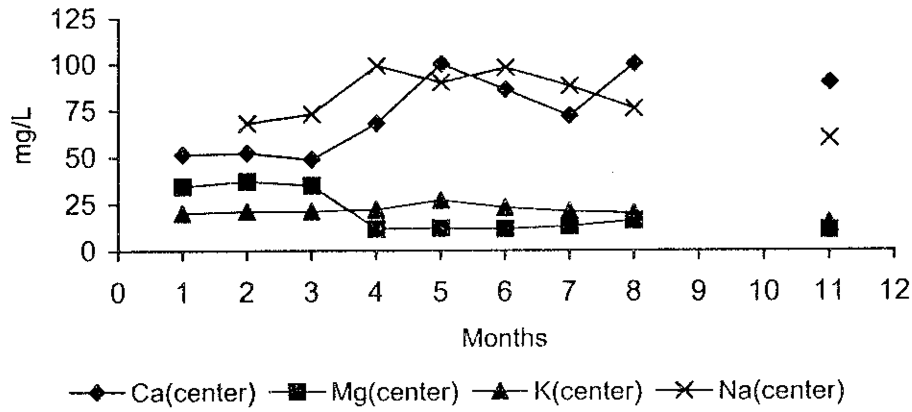
Total Hardness: The main cause of hardness in natural water is due to calcium and magnesium salts combined with carbonates and bicarbonates. The value of total hardness ranges from 157.1± 30.5 at centre to 146.5 ± 34.1 mg/L at inlet. The main source of hardness is domestic and industrial washing flowing into the lake (Figure 11.7).

Figure 11.8: TDS



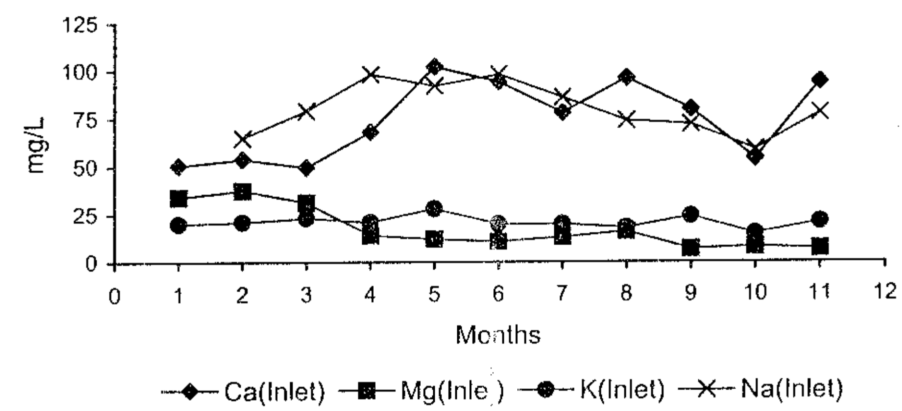
Total Dissolved Solids: The Total Dissolved Solids (TDS) include anions and cations in dissolved form. High TDS indicates pollution. The study showed that dissolved solids were higher towards the inlet ranging from 208-428 mg/L at an average of 272.0 mg/L, which is attributed to the inflow of sewage. Similarly, the TDS ranges from 212 to 402 mg/L at an average of 296.4 mg/L in the centre, due to transport of pollutants from the inlets. Dissolved solids were noticed to be more during summer at both points, which may be due to lowered water level (Figure 11.8).

Figure 11.9: Ca,Mg,K,Na



Cations: The major cations calcium, magnesium, potassium and sodium showed noticeable variation. Calcium, magnesium and sodium are 74.2±19.5, 20.2±10.9 and 80.1± 12.6 mg/L respectively, and the higher range can be attributed to pollution from domestic and industrial sources (such as detergents, food wastes, etc) (Figure 11.9 – 11.10).

Figure 11.10: Ca, Mg, K, Na



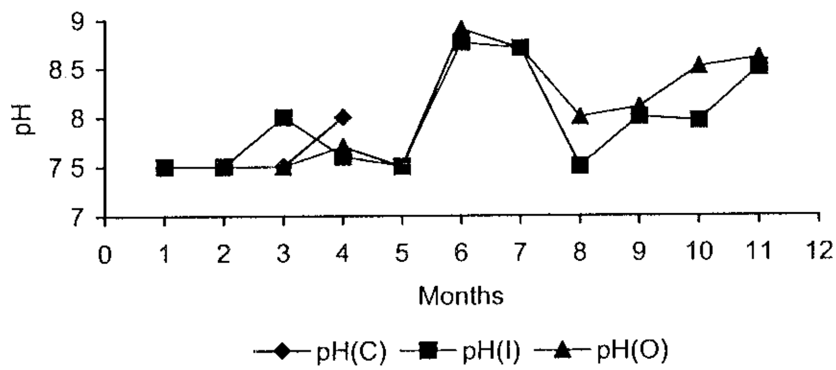
Similar results of the higher values of cations obtained at inlet, indicate pollution by domestic and industrial sewage

HEBBAL TANK

Hebbal tank is situated in the northern part of the city covering an area of about 75 hectares, one of the biggest tanks in Bangalore. It supports agriculture and small-scale fishing and serves as a water source for the forest nursery nearby. The tank receives untreated domestic sewage from H E L layout, Vidyaranyapura, Hebbal and surrounding areas apart from vehicular pollution due to heavy traffic on the adjoining highway (NH-7). It is infested with water hyacinth for much of the year. The tank is ecologically important as it supports a large population of migratory birds, which includes egrets, cranes, coots, kingfishers, etc. Once a major drinking water source to the surrounding areas, it is on the verge of death due to pollution. Samples collected at the inlet, centre and outlet (sampling at centre was done based on the availability of a boat and absence of water hyacinth) were analysed for physico-chemical and biological characteristics on a monthly basis.

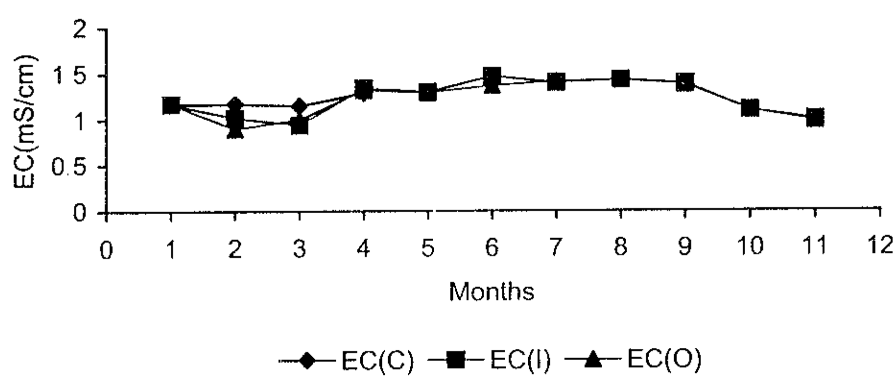
The colour of the water body was dark grey towards the inlet (due to sewage), greenish towards centre and outlet (as a result of plankton) Higher values of turbidity were noticed at the centre and inlet due to plankton and sewage. Transparency ranges from 9.0-21.5 cm at various points in the tank indicating low light penetration. Temperature of the water during sampling time (10-12 am) was in the range of 20-30°C.

Figure 12.1: pH



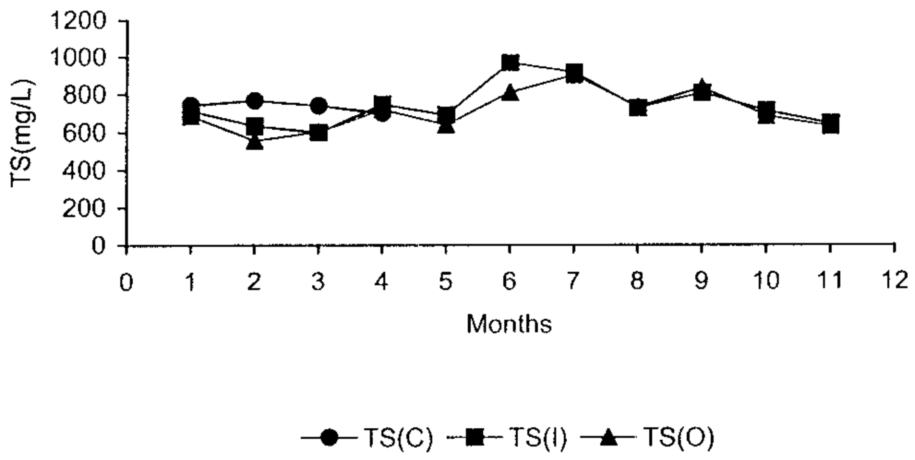
pH: pH is a dynamic parameter in an aquatic ecosystem varying with changes in physical and chemical properties over a period. pH of the tank was found mostly in the alkaline range from 7.5 to 8.9 at sample points of the lake. The high pH noticed could be attributed to characteristics of the incoming sewage and plankton activity. Plankton activities increase pH by making use of the available carbon-di-oxide (Figure 12.1)

Figure 12.2: EC



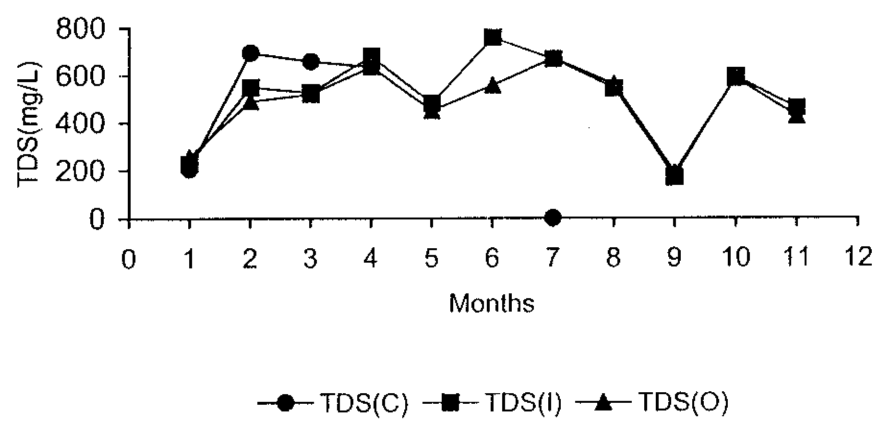
Electrical Conductivity: The electrical conductivity noticed during the study period was high, varying from 1.2 to 1.5 mS/cm. Higher EC values were noticed during Apr-Jul 1997, which could be due to high dissolved solids from sewage and reduced volume of water due to evaporation. The decreased EC during Sept-Oct 1997 could be attributed to dilution on account of runoff due to rains (Figure 12.2)

Figure 12.3:TS



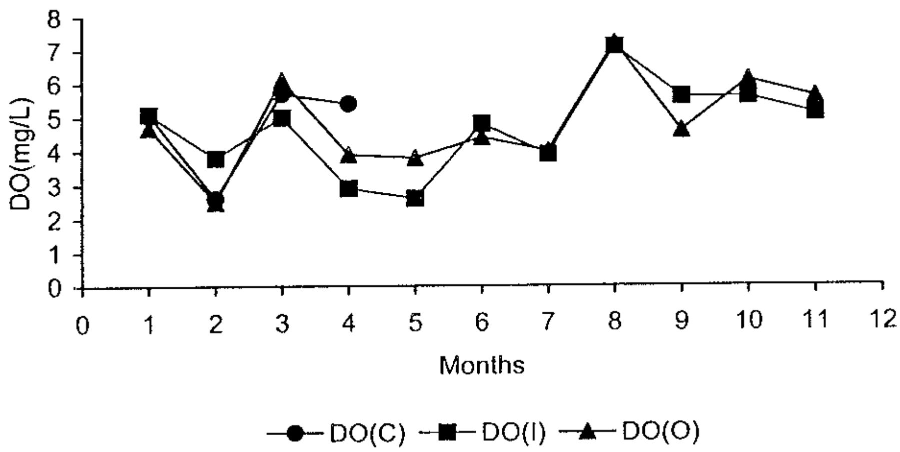
Total Solids: The main source of total solids to Hebbal tank is inflow of sewage and surface runoff. TS showed higher values at centre during Nov 1996 – Feb 1997 (737 5 ±22 9 mg/L) compared to average values of outlet and inlet, which is due to high plankton density. TS were found to range from 600-968 mg/L at inlet, 702-766 mg/L at centre and 556-902 mg/L at outlet. A high value at inlet was mainly due to sewage and agricultural run-off (Figure 12 3)

Figure 12.4: TDS



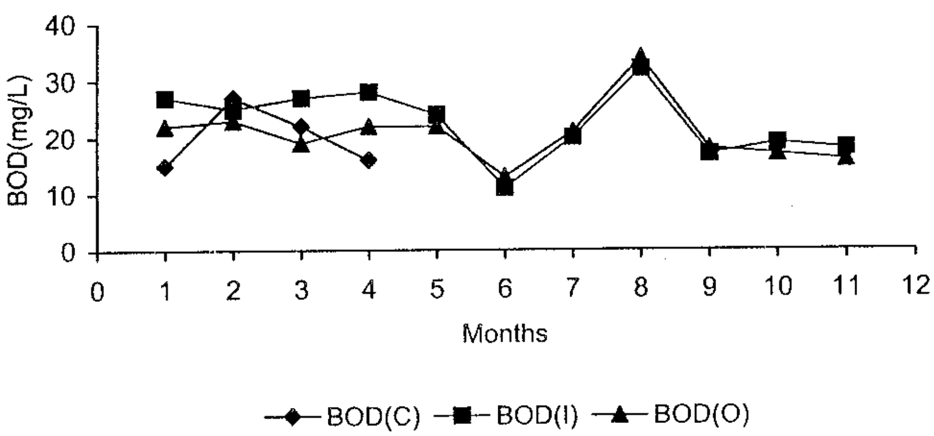
Total Dissolved Solids: The dissolved solids showed higher values of 514.5±172 I mg/L, 548±199.7 mg/L, and 485 6±143.6 mg/L at inlet, centre and outlet respectively. The steep fall in the values of TDS during Aug 1997 was due to increased water levels from rain and may be due to sampling done towards the periphery of the tank (owing to non-availability of a boat) (Figure 12.4).

Figure 12.5: DO



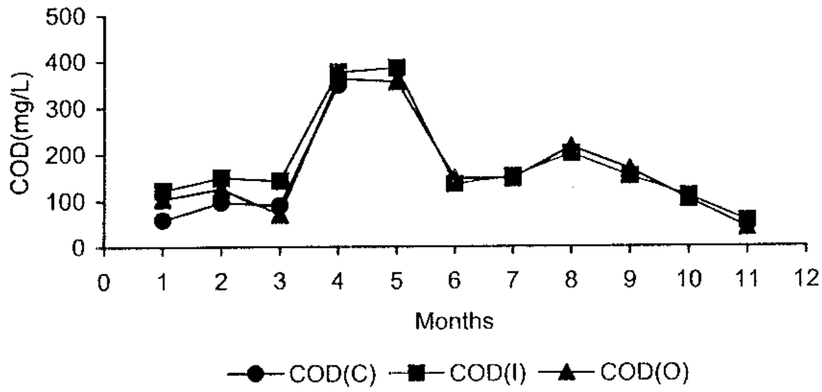
Dissolved Oxygen: Throughout the study period, low values of dissolved oxygen were noticed at the inlet (2.6-7 1 mg/L) compared to the outlet (2.5-7.3 mg/L). Low dissolved oxygen at the inlet is due to sewage getting into the tank. The higher DO during July 1997 at both points was due to sampling time (done at noon, when photosynthetic activity by the phytoplankton is maximum, releasing oxygen) (Figure 12 5)

Figure 12.6: BOD



Biological Oxygen Demand: The BOD observed at inlet, centre and outlet was 22.5±5 8 mg/L, 20 0±4 8 mg/L and 20 6±5.2 mg/L respectively. The BOD at the inlet was understandably high (11.0-32 0 mg/L) due to sewage entering the tank there (Figure 12 6)

Figure 12.7: COD vs months



Chemical Oxygen Demand: The COD values of the tank range from a low value of 56.0 mg/L during Oct 1997 due to rains, to a high of 386.0 mg/L during Mar 1997 at inlet, 58.3 to a high of 348 mg/L at centre and 41.0 to 362.0 mg/L towards the outlet. The higher values noticed during Feb-Mar 1997 could be due to sewage entering during the sampling time and increased chemical concentration due to reduced volume of water during summer (Figure 12.7).

Figure 12.8: Ca,Mg,K,Na(I)

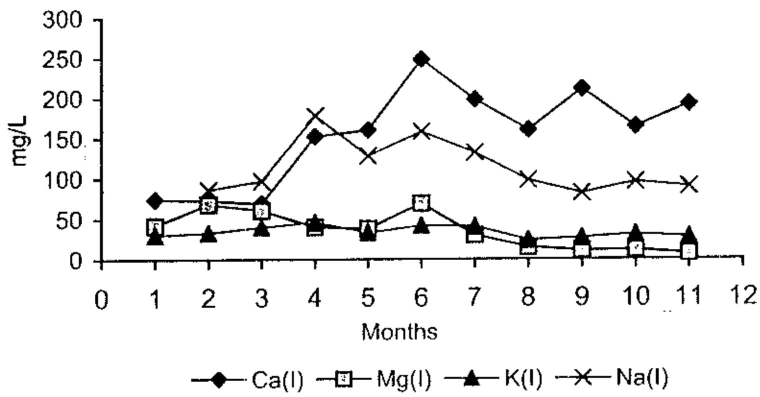


Figure 12.9: Ca,Mg,K,Na(C)

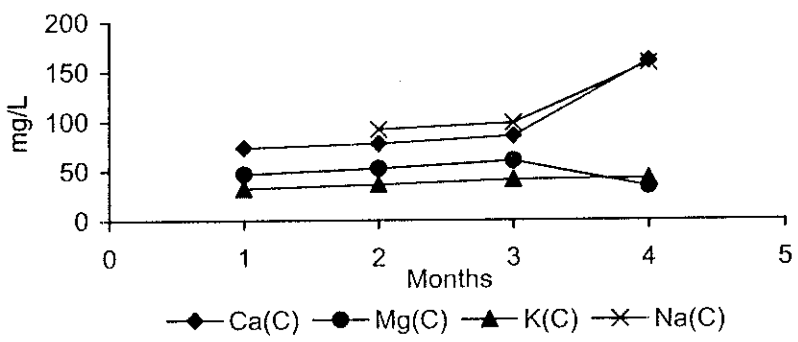
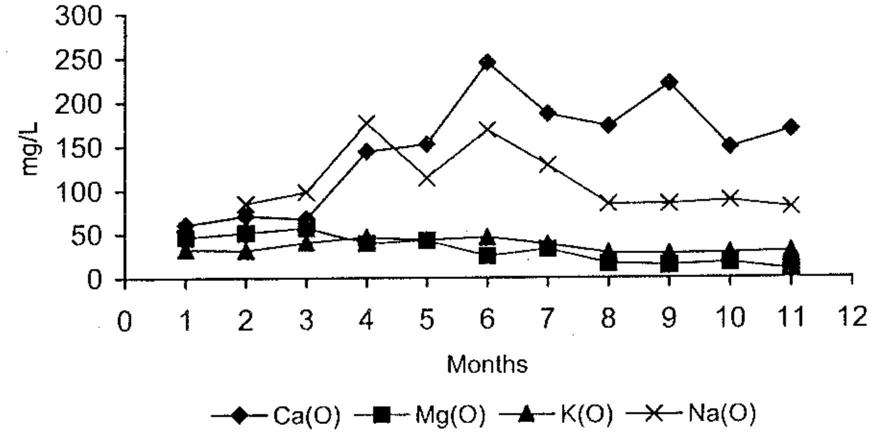


Figure 12.10: Ca,Mg,K,Na(O)

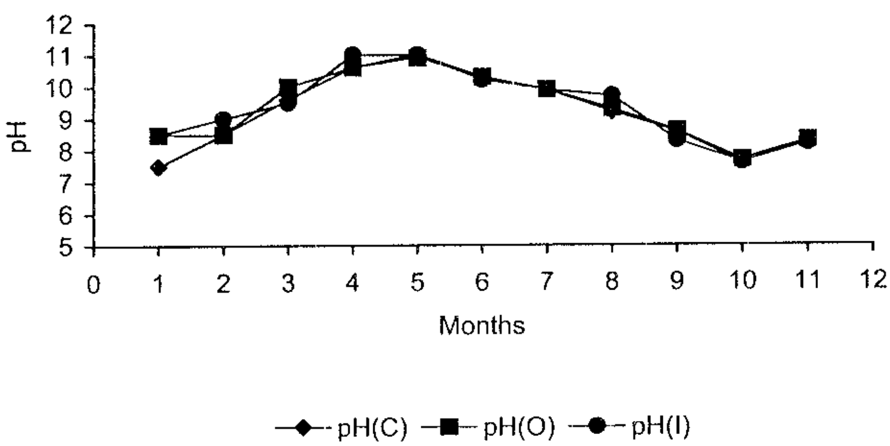


Cations: The various cations analysed showed higher values at all the points within the tank (Figure 12 8 – 12.10). *Calcium*: The values of calcium ranges from 68 9 to 248.0 mg/L at inlet, 73.2 to 160.0 mg/L at centre and 60 6 to 244 0 mg/L at outlet The high values could be attributed to domestic sewage, which has detergents in it
Sodium The high values of sodium ranging from 92 to 176 mg/L were observed at different points in the lake. High values could be due to domestic sewage getting into the tank Nitrates, phosphates and potassium analysed to evaluate the eutrophic condition of the lake ranged from ND to 4.0

ULSOOR TANK

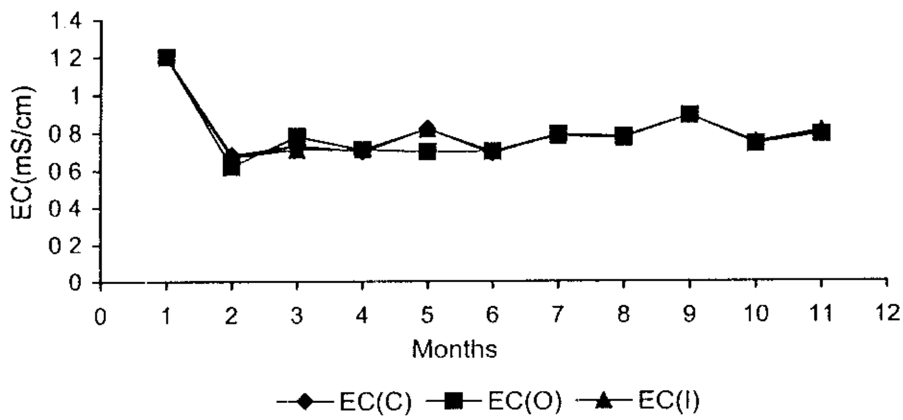
Ulsoor tank, situated in the eastern part of the city, is spread over an area of about 50 hectares It has three islands and receives direct industrial and domestic effluents from the surrounding areas of Tannery road, Ulsoor, etc It has a park in its vicinity, a corporation swimming pool adjacent to the tank and a boat club run by KSTDC (Karnataka State Tourism Development Corporation) for recreational purpose Madras Engineering Group (MEG) uses the tank for boat training The colour of the water is greenish, with objectionable (fishy) odour The temperature of the lake during sampling periods ranged from 22-31°C with low transparency (4.5-16 cm) and high turbidity (68-290 NTU).

Figure 13.1: pH



pH: The pH of the monthly water samples was found mostly towards alkalinity ranging from 7.5-11.0 The high pH observed might be due to high plankton activity (which makes use of the available carbon-di-oxide) and sewage (Figure 13.1)

Figure 13 2: EC



Electrical Conductivity: EC values ranged from 0.6-1.2 mS/cm The high values of EC were due to high dissolved solids (Figure 13.2) High EC would affect plant life of the surrounding ecosystems and the aquatic biological food chain and ecology adversely (Ramakrishna Parma et al, 1990)

Figure 13.3: TS

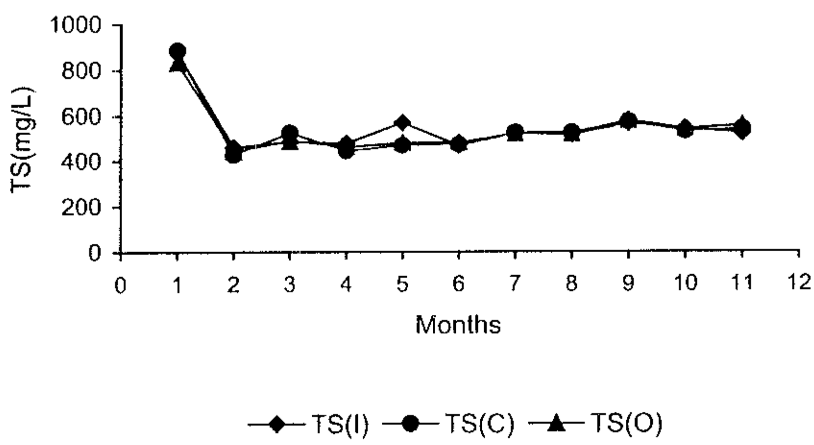


Figure 13.4: TSS

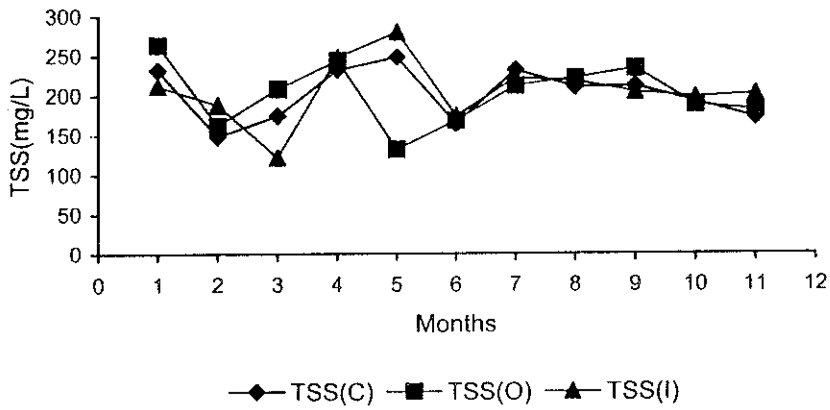
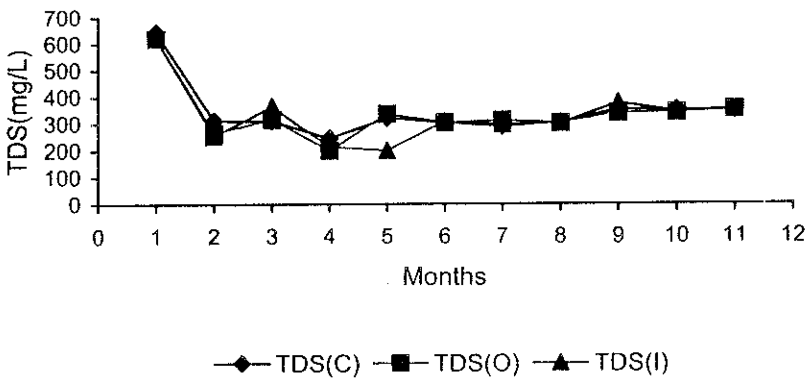
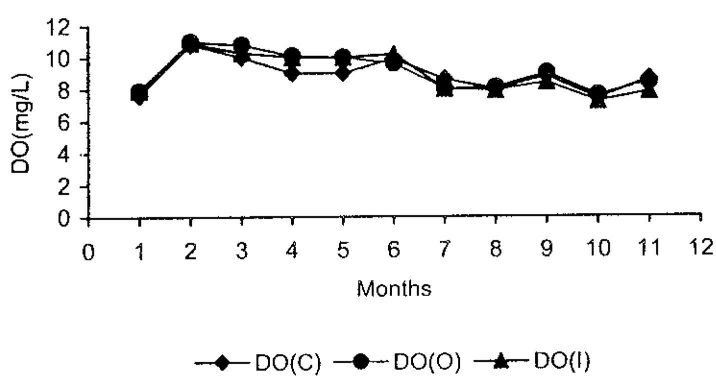


Figure 13.5: TDS



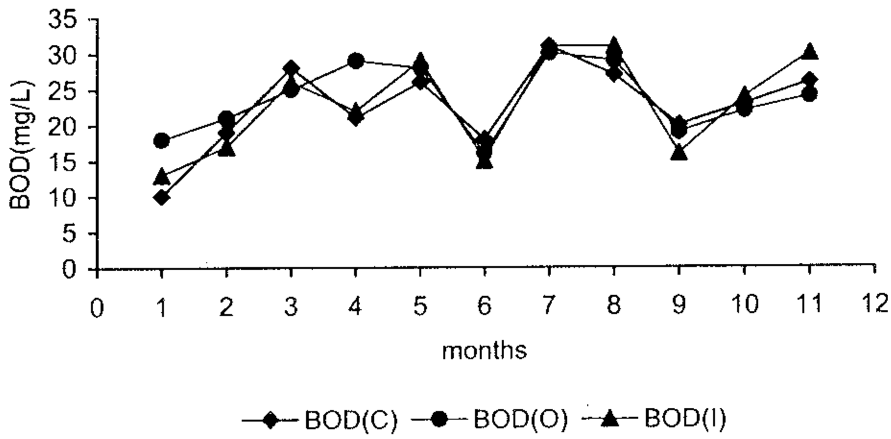
Solids: Total solids ranged between 460-884 mg/L and suspended solids were about 200 mg/L at all sampling points in the lake during the study period. The high values of suspended and dissolved solids (246-644 mg/L) are a result of high plankton density (Figure 13.3-13.5).

Figure 13.6: DO



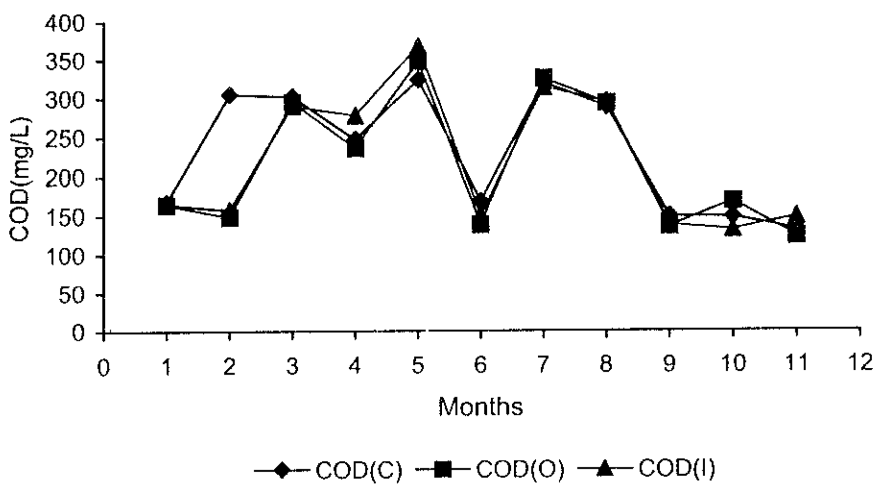
Dissolved Oxygen: DO content was found to be 6 9±1 2 mg/L at inlet, 9 1±1 0 mg/L at centre and 9 0±1.2 mg/L at outlet. High dissolved oxygen content of Ulsoor tank indicates high plankton activity at the time of sampling (10-12 am) (Figure 13.6)

Figure 13.7: BOD



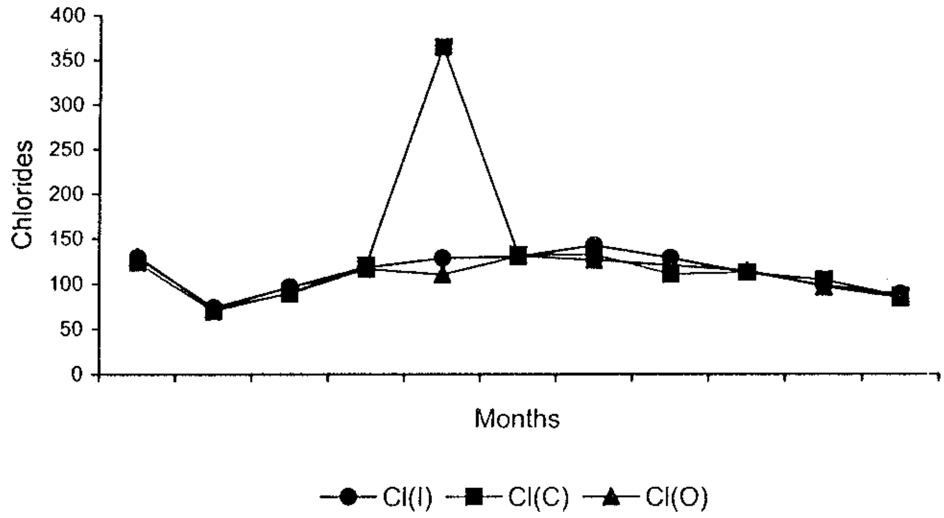
Biological Oxygen Demand: The BOD values of the tank ranged from 10.0 to 31 0 mg/L with higher values (avg 22 6 mg/L) at inlet, which receives influx of sewage The permissible limits for BOD for irrigation water are 150 mg/L (Figure 13.7)

Figure 13.8: COD



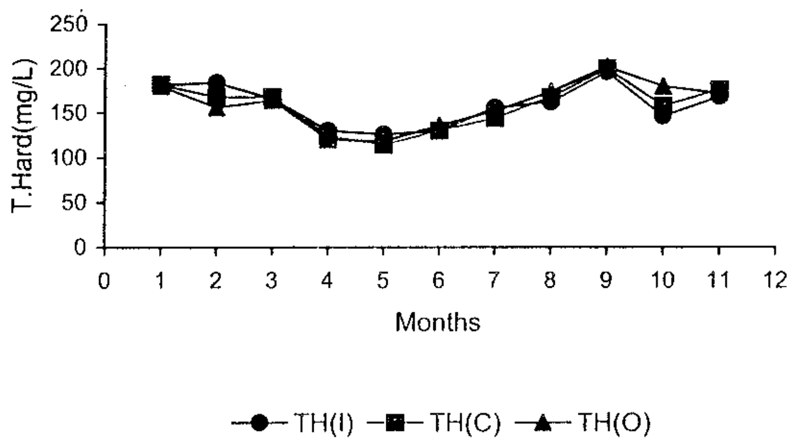
Chemical Oxygen Demand: The COD values were found to be 231.4 mg/L, 216 mg/L and 221.3 mg/L at inlet, centre and outlet respectively The high values of COD are a result of pollution from both industrial and domestic sectors (Figure 13.8).

Figure 13.9: Cl



Chloride: The study showed high concentrations of chlorides at 131 4 mg/L at inlet, 108.0 mg/L at centre and 113.0 mg/L at outlet High concentration of chlorides is considered to be an indicator of pollution due to high organic wastes of animal and industrial origin (Figure 13 9)

Figure 13.10: TH



Total Hardness: Hardness of the water samples ranged from 126-196 (avg 159 5) mg/L at inlet, 114-200 (avg 157.5) mg/L at centre and 118-202 (158 7) mg/L towards the outlet The high values could be mainly attributed to the inflow of sewage (Figure 13 10)

Figure 13.11: Ca,Mg,K,Na

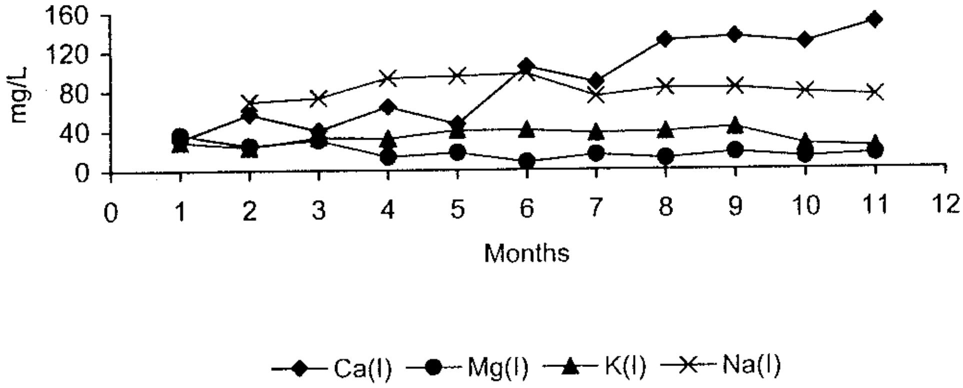
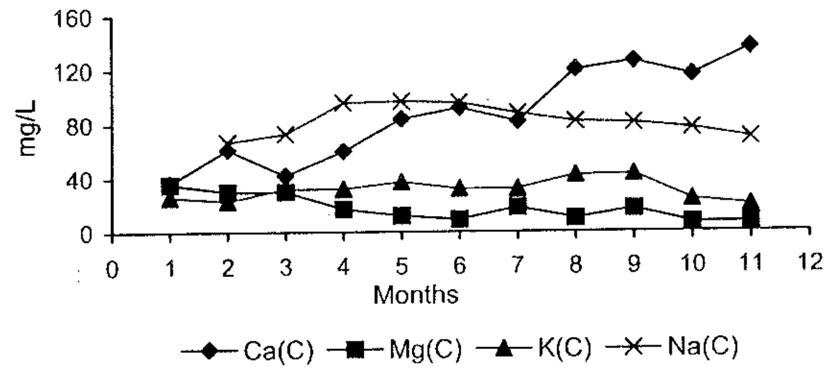


Figure 13.12: Ca,Mg,K,Na



Cations: The various cations analysed (Ca, Mg, K, Na) showed higher values at all points in the lake Calcium showed values of 86.9±32 9 mg/L, 89 5±33.5 mg/L and 86 1±40 7 mg/L at inlet, centre and outlet respectively, which is due to detergent pollution (Figure 13.11- 13 12). High values of sodium ranging from 66-160 mg/L, shows pollution due to domestic sewage

The results obtained from the twelve-month sampling of the seven tanks in and around Bangalore city revealed that most of them were polluted due to the inflow of domestic sewage and industrial effluents Bannergatta tank was relatively clean due to its location (inside the national park) and similarly Sankey was unpolluted as the water was mainly used for boating and watering the forest nursery In contrast Madivala, Ulsoor, Yediyur, Kamakshipalaya and Hebbal were polluted as to render the water unusable for any purpose Kamakshipalaya was eutrophic as elucidated by the DO (0 5 to 3 9 mg/L), BOD (27 to 192 mg/L) and COD (170 to 621 mg/L) values Madivala, the second largest lake of Bangalore city was polluted due to the inflow of domestic wastes and detergent from the nearby residential areas and was covered by water hyacinth for most of the study period The organic and inorganic chemical pollution in water samples are reflected by high values of COD (84 – 374 mg/L) and total hardness (181 – 206 mg/L) Yediyur tank covering about a hectare receiving both domestic and industrial effluents showed high COD (84 – 378 mg/L) values and was infested with microcystis (an indicator of pollution). Hebbal tank one of the largest tanks although supporting agriculture was highly polluted due to the inflow of untreated domestic sewage and vehicular pollutants from the adjacent national highway High values of TSS (568 – 968 mg/L) and COD (41 –

368 mg/L) revealed an urgent need to restore the lake as it supports a large number of migratory birds. Hebbal and Madivala tanks are being restored under Indo-Norwegian Environment programme (Co-ordinated by the Karnataka State Council for Science and Technology). Ulsoor tank situated in the heart of the city receives domestic effluents and industrial wastes. Almost all the parameters were in excess of the standards prescribed for surface waters (CPCB, NEERI and WHO). The poor state of waterbodies evident from water monitoring results stress the need for implementation of restoration and conservation strategies. This requires thorough appraisal of wetlands values

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