CHAPTER 1
INTRODUCTION
Pollution studies of two distinct tropical lentic wetlands of central Gujarat with reference to spatial and temporal heterogeneity of biotic and abiotic components

1. INTRODUCTION

1.1 WETLANDS

Our planet is characterized by large volumes of water that covers about three-quarters of the Earth's surface. Although water characterizes this planet, vast majority of it is salty (95.1 per cent) and contained in the world's oceans (Speidel and Agnew, 1998). Of the small percentage that is fresh water (~4.9 per cent), most is inaccessible, either in groundwater or frozen in glaciers and polar ice. Only a tiny fraction (~0.01 per cent) of our water resources is contained in freshwater lakes and rivers. A second feature characterizing our planet is the incredible number and diversity of life forms. This truly is 'the Living Planet' (Attenborough, 1984). Water and life are intricately linked. More than half of the world's species of plants and animals live in water, and even our terrestrial-derived food is totally dependent on them.

Wetzel (2001) estimated that the Earth contains 100 million lakes that are greater than 1 ha in area, and ~1 million lakes that are greater than 1km². The study of these inland waters is called limnology. Limnology is a diverse science, which includes the study of lakes and rivers and other inland waters, e.g. ditches, ponds, wetlands, reservoirs, swamps, saline lakes, etc.

Wetlands are basically wet lands where the soil is saturated with water for sometime during the year. They are characterized besides their soils by specific plants and animals, which are particularly adapted to waterlogging or submergence of the soils during their growth period. Wetlands are environments subject to permanent or periodic inundation or prolonged soil saturation sufficient for the establishment of hydrophytes, habitat for waterbirds, plankton, flora and fauna and/or the development of hydric soils or substrates. Thus, the term 'wetlands' include a variety of habitats with temporary water such as the flood plains which are periodically flooded by the river overflowing its banks, shallow water bodies, ponds, shallow peripheral areas of large lakes and reservoirs and coastal areas. Wetlands have supported mankind since historical times. Agriculture had
Pollution studies of two distinct tropical lentic wetlands of central Gujarat with reference to spatial and temporal heterogeneity of biotic and abiotic components

its beginning in the flood plains as early man took advantage of the soil moisture and nutrients after the recession of floods to grow the first cereal crops.

Wetlands are valuable as sources, sink and transformers of a multitude of chemical, biological and genetic materials. They stabilize water supplies, clean polluted waters, protect shorelines, and recharge groundwater aquifers. They have increasingly become recognized for their unique ecological functions in the environment and are the focus of increased research by scientists and study programs by schools, communities, and nature centers. On the other hand, the idea of using constructed wetlands for wastewater treatment has been encouraging because of their environmental friendliness and enhancement on landscape quality.

1.2 CLASSIFICATION AND KINDS OF WETLANDS

1.2.1 Classification Based On Ramsar Convention

Globally, at present, wetland classification, inventories, and input into reserve selection are heavily based on the system adopted by the contracting parties to the Ramsar Convention, the convention for Wetlands of International Importance, especially as Waterfowl Habitat, hereafter referred to as the "Ramsar classification". Though it was originally devised to be of use in defining wetlands for the Ramsar convention objectives, this system has gained wider international usage as a general classification of wetlands to facilitate a common language and better communication between wetland scientists. The Ramsar classification, currently, the classification of wetlands adopted by the Ramsar bureau is based on a modified approach of Cowardin et al. (1979). The Ramsar classification recognizes 3 broad groups of wetlands:

1. Marine and Coastal
2. Inland
3. Man-made

Within these, on the bases of setting (e.g., palustrine or riverine), water permanence (e.g., permanent, seasonal or intermittent), soils, substrates and vegetation, the system resolves
Pollution studies of two distinct tropical lentic wetlands of central Gujarat with reference to spatial and temporal heterogeneity of biotic and abiotic components into 35 types of wetlands. Within the broad group of the inland wetlands, the Ramsar classification delineates 16 main groups, which further divided into 24 types.

1.2.2 Classification by Nutrient Status

The classification of lakes and wetlands according to their nutrient status focuses on the biotic community in a lake, particularly the plants. Aquatic and semi aquatic plants, particularly the algae, are highly responsive to nutrient levels. Nutrients are chemicals needed by plants and animals alike: the chemical building blocks of life. Plants require nitrogen, potassium, calcium, magnesium, phosphorus, and sulfur, in descending order of quantity required, to build carbohydrates and more complex molecules. They also require a host of other chemicals in small quantities; these are termed micronutrients. In wetlands and lakes (and bodies of water in general), plants usually have plenty of all the nutrients they need except for nitrogen and phosphorus. The key nutrients that limit population growth are termed limiting nutrients; nitrogen, phosphorus, or both are frequently limiting nutrients in aquatic systems.

Although there are no generally agreed-upon, precisely measurable differences between lakes with different nutrient levels, a lake is termed oligotrophic (from Greek meaning "low level nutritious") if its low level of key nutrients results in a generally low level of plant biomass, particularly of algae. A eutrophic (meaning "high level nutritious") lake, at the other end of the spectrum, typically is rich with plant and animal life. Often in extreme cases, for example, where human wastewater discharges to a lake have greatly increased nitrogen and phosphorus levels, lakes are termed "hypereutrophic". Mesotrophic ("medium level nutritious") lakes occupy the middle ground between oligotrophic and eutrophic lakes. A last category is sometimes included called a dystrophic ("malnutritions") lake. While oligo-, meso-, and eutrophic all refer to the level of plant production within the lake itself, dystrophic lakes have low levels of production but high levels of organic (carbon-based) material. The organic material is of terrestrial origin (leaves, pine needles) and may be in a dissolved form. Lakes classified as dystrophic are usually highly acidic bog lakes dominated by Sphagnum moss.
1.3 WETLAND CHARACTERISTICS

1.3.1 Abiotic Components

1.3.1.1 Water

The pattern of rises and falls in water level over time in a particular wetland is called its hydroperiod, the “signature” of water on that particular land area. The water level’s ups and downs could be caused by surface and near-surface runoff of precipitation (in basin-shaped wetlands), by surface or subsurface lateral flows caused by rising and falling water levels of nearby lakes or rivers (in fringe, riverine, and tidal wetlands), or by fluctuations in groundwater levels. With water, nutrients, sediment, organic material, dissolved solids and organisms may enter (or leave). For example, floodplain wetlands regularly receive large inputs of sediment, nutrients, and organic materials from flooding rivers. But if a wetland’s water leaves solely via evapotranspiration, nutrients, sediment, organic material, and dissolved solids will be left behind. This may result in a buildup of salts that eventually will turn a freshwater into a saline wetland. The buildup of organic material and sediment can change a wetland from one type into another over time.

The chemical nature and concentration of various substances dissolved in the water determine its pH, hardness, salinity, nutrient content, and other measures used to categorize water chemistry, and can have a significant impact on the flora and fauna of the wetland. Dissolved oxygen provides valuable information about the biological and biochemical reactions going on in water. Oxygen may be added to the water from the atmosphere or as a by-product of photosynthesis from aquatic plants and is utilized by many respiratory biochemical reactions as well as by inorganic chemical, reactions. The concentration of dissolved oxygen in water depends also on temperature, pressure and concentrations of various ions.

An increase in trophic status of a wetland is associated with an increase in its nutrient status. Phosphorus and nitrogen are the major nutrients for all phytoplankton growth and the limited availability of these nutrients in water usually limits phytoplankton growth in natural aquatic systems. On the contrary, excess availability of both triggers eutrophication. Accumulation of N and P in natural waters is more closely...
Pollution studies of two distinct tropical lentic wetlands of central Gujarat with reference to spatial and temporal heterogeneity of biotic and abiotic components

related to external factors such as cultural influences, fertilization, and the rate of flow. Use of detergent may increase the phosphate concentration to a great extent. Higher amounts of nitrate and phosphate represent the high pollution load and are causes of eutrophication of the aquatic body. Nitrate and phosphate are the most important nutrients for the growth of algal flora (Bostan et al., 2000). Sulphate is generally considered to be non-toxic. Decaying plant and animal matter may release sulphate into water. Numerous chemical products, including ammonium sulphate fertilizers contain sulphate in a variety of forms, which release sulphate in water bodies through runoff. Nitrate is a valuable plant nutrient which indicates the productive nature of aquatic systems. It is widely present in substantial quantities in soil, in most waters and in plants, including vegetables. Fertilizer use, decayed vegetable and animal matter, domestic effluents, sewage sludge disposal to land, industrial discharges, leachates from refuse dumps and atmospheric washout all contribute to phosphate, sulphate and nitrate ions in water sources.

1.3.1.2 Soils (Sediment)

Wetlands are characterized by soils known as hydric soils. Hydric soils are formed under conditions of saturation and flooding long enough during the growing season to develop anaerobic conditions in the upper part. These “anaerobic conditions” refer to a lack of oxygen caused by saturation with water. In anaerobic soils, decomposition of organic material occurs slowly; under some conditions (low temperatures, for example), decomposition may be so slow that the annual addition of organic material is greater than the annual removal of organic material by decomposition. Wetland soils are classified as either organic or mineral. Organic soils have a high proportion (greater than a third) of organic material. Compared with mineral soils, their ability to hold water is high. They are also quite permeable, meaning that water passes through them readily. Therefore, wetlands with organic soils can form only when there is a layer of relatively impermeable material beneath the hydric soils to keep water from percolating down into the groundwater system. Organic soils tend to be acidic and
nutrient poor. Mineral soils have less than one-third organic content. They hold less water than organic soils and also have relatively low permeability.

The sediments are both carriers and potential sources of natural geochemical constituents derived principally from rock weathering. The nutrient economy of an aquatic system is mostly governed by the sediments and knowledge on the role of sediment-nutrient is especially useful in determining the sediments water interaction, which eventually affects the productivity. The sediments act as a sink and play a vital role in changing the quality of the overlying water column. The main source of organic matter in the wetland is the plant and animal matter. Sediments receive a mixture of labile and organic and inorganic phosphorus compounds from the overlying waters and surrounding land masses. Sediment is a suitable substratum for biological and chemical reactions; it plays an important role in biochemical and geochemical processes, and also serves as a surface for adsorption processes and bacterial activity.

1.3.2 Biotic Components (Communities)

The biotic communities in the wetlands differ within the different zones in the wetland. In the littoral zone, which is typically defined as the shallow part of a lake, rooted aquatic macrophytes usually grow. Although the littoral zones of some lakes are not very large, a significant, sometimes dominant, portion of the overall production occurs there. Many organisms, such as some fish, feed and find refuge and reproduce in these areas. Since littoral zones are the closest to land (and to human influences), they are often critical areas in pollution studies. Organisms, such as algae, living in the littoral zone are often attached to a substrate and are collectively called the periphyton. For example, the epiphyton are organisms living attached to plants, epilithon attached to rocks and stones, epipsammon attached to sand grains, and the epipelon living on the sediments.

The deeper, open-water region is often referred to as the pelagic region. Plankton live unattached to any substrate in the open-water system, and are largely at the mercy of water movements, although some have limited motility (e.g. with flagella). Plankton that are photosynthetic, such as algae, are called phytoplankton, whereas those that are more
animal-like, such as water fleas (Cladocera), are called zooplankton. Animals with strong locomotory capabilities, such as fish and large invertebrates, are called the nekton. A smaller, poorly studied community lives closely associated with the surface tension of the water's surface; this is collectively called the neuston. Organisms living in such a manner above the water line are called epineuston; those below the water line are called the hyponeuston. The profundal region typically refers to the deep waters in the middle of the system. Organisms living on and in the sediments are called the benthos.

1.3.2.1 Phytoplankton

Phytoplankton are significant fractions of the water ecosystem (Wilk-Woz'niak and Zurek, 2006). They are integral components of freshwater wetlands, which significantly contribute towards succession and dynamics of zooplankton and fish (Payne, 1997). Community structure, dominance and seasonality of phytoplankton in tropical wetlands are highly variable and depend on nutrient status, water level, morphometry of the underlying substrate and other regional factors (Gopal and Zutshi, 1998; Zohary et al., 1998; Agostinho et al., 2001). The species composition and biomass of phytoplankton in fresh water are affected by various factors both natural and artificial. In many lakes and reservoirs, the progress of eutrophication has resulted in changes in the species composition and biomass of phytoplankton. In particular, cyanobacterial blooms are associated with taste and odor problems, and in some cases, they produce toxins (Pearl, 1988).

Planktonic organisms are also known for their potential as bioindicators. Phytoplankton form the main producers of an aquatic ecosystem which control the biological productivity. They not only provide an estimation of standing crop but also represent the more comprehensive biological index of the environmental conditions (Misra et al., 2001). Many herbivores, mostly zooplankton, graze upon the phytoplankton thus, passing the stored energy to its subsequent trophic levels. Phytoplankton, which include blue-green algae, green algae, diatoms, desmids and euglenoids are important among aquatic micro-flora. They form the basic link in the food chain of all aquatic animals (Misra et al., 2001). Many herbivores, mostly zooplankton, graze upon the phytoplankton thus, passing the stored energy to its subsequent trophic levels. The
Pollution studies of two distinct tropical lentic wetlands of central Gujarat with reference to spatial and temporal heterogeneity of biotic and abiotic components

Phytoplanktons float passively and spread uniformly and extend down to various depths, where hydrochemical properties influence the plankton population and its occurrence.

1.3.2.2 Vegetation

Plants that are found in wetlands are either obligate (plants that only grow in a wetland environment) or facultative (plants that can grow in wetlands but can also thrive in other environments). Obligate wetland plants occur in wetlands 99 percent of the time and only 1 percent are found outside wetlands, whereas facultative wetland plants are found in wetlands 67 to 99 percent of the time. Obligate wetland plants are used as wetland indicators—plants whose presence indicates the existence of wetland conditions with a high degree of confidence. Wetland plants have a number of adaptations that enable them to live in wetlands. Aquatic plants (macrophytes) play an important role in nutrient cycling due to large quantities of biomass they produce, and their capacity to accumulate large concentrations of nutrients (Clarke and Wharton, 2001; Abdo and Da Silva, 2002).

1.3.2.3 Avifauna

Birds are important components of wetland ecosystems and are often used as bioindicators (Furness and Greenwood, 1993; Kushlan, 1993). Avian population density and diversity depend on available food, shelter resources and environmental conditions. Lake size and abundance of invertebrates are the main factors contributing to the distribution of bird populations (Hurlbert, 1991). Water depth is also another important factor, because it regulates the bird's feeding capacity over the benthic fauna (except diving birds) (Erwin et al., 1994). An analysis of the census data collected during 30 years in Israel demonstrated a relation between different types of wetlands (e.g., fish ponds, water reservoirs, oxidation pools, rainpools), the presence of bird species, and their population sizes, and correlation between numbers of coots and ducks and mean winter temperatures (Shy, 1998).
1.4 SIGNIFICANCE OF WETLANDS

Wetlands serve important, biological, environmental quality and socio-functions such as flood storage, ground-water recharge, sediment trapping, retention and removal of nutrients and pollutants, and wildlife and recreational habitat (Metzler and Tiner, 1992; Tiner, 1998). The benefits derived from wetlands can be divided into three groups; wetland products, wetland services and wetland attributes. Wetland products are visible, well known and understood by most communities, especially those living adjacent to wetlands or who harvest these products. These are the valuable products or goods that individuals or communities can derive from wetlands. One of the most important wetland resources for the local communities is wetland fisheries. On the other hand, the environmental services that wetlands provide are usually not well understood by the local community or simply taken for granted. These ecosystem services are poorly appreciated until they become degraded, for example, the provisions of drinking water and protection against flooding are both important social and economic ecosystem services (Table 1.1). Wetland attributes include conservation of biodiversity and genetic resources, cultural importance and aesthetic values. These are not necessarily directly "used" by people but are seen to have an inherent value, making wetlands well worth conserving (Kansiime et al., 2007).

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<tr>
<th>FUNCTION</th>
<th>EFFECT</th>
<th>SOCIETAL VALUE</th>
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<td><strong>Hydrologic</strong></td>
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<td>Short-term surface water</td>
<td>Reduced downstream flood peaks</td>
<td>Reduced property and crop damage from floodwaters</td>
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<td>storage</td>
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<tr>
<td>Long-term surface water</td>
<td>Maintenance of stream flows, seasonal stream flow moderation</td>
<td>Maintenance of fish habitat during dry periods</td>
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<td>Maintenance of high water</td>
<td>Maintenance of hydrophytic plants, groundwater for tree and crop growth</td>
<td>Maintenance of biodiversity, increased timber and crop production</td>
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Pollution studies of two distinct tropical lentic wetlands of central Gujarat with reference to spatial and temporal heterogeneity of biotic and abiotic components

Biogeochemical

| Transformation and cycling of elements | Maintenance of nutrient stocks within wetland, production of dissolved and partially decayed organic matter | Timber production, food for fish and shellfish downstream, support of recreational and commercial fishing |
| Retention, removal of dissolved substances | Reduced transport of nutrients and pesticides downstream | Maintenance of water quality; safer drinking water |
| Accumulation of peat | Retention of nutrients, carbon, metals, other substances | Maintenance of water quality, reduction of global warming |
| Accumulation/retention of inorganic sediment | Retention of sediment and attached pesticides, phosphate and other nutrients | Maintenance of water quality, clear water, high-quality fish populations in streams |

Habitat and Food Web Support

| Maintenance of characteristic plant communities | Food, refuge, and nesting cover for wildlife; spawning, refuge and nursery habitat for fish and shellfish; food for humans | Support for waterfowl and other wild game, furbearers, uncommon and rare and endangered species, fish, and shellfish; recreational and commercial hunting, fishing and bird watching |
| Maintenance of characteristic energy flow | Support for populations of vertebrates and invertebrates | Maintenance of biodiversity, bird watching, aesthetics |

1.5 POLLUTION IN WETLANDS

1.5.1 Eutrophication

Eutrophication continues to be ranked as the most common water quality problem in the world. Wetland degradation, linked to anthropogenic pressures and climate change is a major global problem. Eutrophication refers to the problem of nutrient enrichment of water bodies (Figure 1.1) and continues to be ranked as the most common water quality problem in the world. The reasons for this are related to the myriad of symptoms that
Pollution studies of two distinct tropical lentic wetlands of central Gujarat with reference to spatial and temporal heterogeneity of biotic and abiotic components

eutrophic lakes, reservoirs, and rivers often exhibit, such as unsightly algal blooms, large growths of aquatic macrophytes, excessive accumulations of decaying organic matter, taste and odour problems, decreased deepwater oxygen levels, and marked shifts in the structure of the food web, including possible extirpations of some fish species and other organisms, as well as many other problems. The intensification and widespread algal blooms result in further ecological consequences. For example, cyanobacteria (blue-green algae) are often associated with eutrophic waters and are well known for their negative impacts on water quality, including the production of taste and odour problems, and interfering with certain water treatment processes. When certain cyanobacterial populations (e.g. *Microcystis*) reach very high proportions, they can also produce toxins that can render water unsafe for consumption.

Fig. 1.1 Generalized diagram depicting the process of eutrophication in a wetland.

1.5.2 Human Impacts on Wetlands

The human impact on wetlands has been extensive and pervasive. With the advent of science and technology which aided rapid utilization of natural resources and favored land-based development, wetlands came to be treated with contempt. Emphasizing the negative side, and ignoring their virtues, these habitats were considered as obstacles in
the path of progress and reservoirs of diseases. Common human impacts on wetlands include hydrologic alteration, pollution, disturbance and fragmentation. Wetlands were drained, filled and reclaimed for more economic gains. The rivers were dammed, regulated and channelized leading to the modification and elimination of floodplains. The wetlands have been converted to agricultural or urban land, they have been fragmented by roads and canals, and degraded through logging, water pollution, hydrologic alteration, and introduction of exotic invasive species. These processes of wetlands' destruction are well established in industrial countries and, as the less developed countries adopt the ways of the developed countries, they are spreading. The underlying trends that historically have led to wetlands destruction will intensify.

Increasing anthropogenic interventions influence in and around aquatic systems and their catchment areas have contributed to a larger extent towards deterioration of water quality leading to accelerated eutrophication. After large areas of wetlands have been destroyed, their importance has once again dawned on mankind, and efforts are being made to protect the few remaining wetlands, although already highly modified and impacted by human activities, from further deterioration and loss. This led to the Convention on wetlands known as the RAMSAR Convention in 1971. The Ramsar Convention, which is administered by the United Nations, maintains a list of wetlands of international importance, known as "Ramsar sites." As of November 2006, there were 1,634 Ramsar sites on the list, covering a total area of 562,312 mi² (1.45 million km²). The Ramsar Convention also conducts research and disseminates information. While the original focus of the Ramsar Convention was on the conservation of wetlands for their habitat value for waterfowl, the scope of the Convention has broadened to include all aspects of wetlands conservation and use. The sustainable use of wetlands promoted by the convention, means beneficial human use that is compatible with maintenance of the natural functions and values of the wetland. However, attitude toward wetlands have changed considerably, and wetlands conservation and restoration are being widely applied. The value of intact, healthy wetlands is now widely recognized among scientists and resource managers.
Gujarat being one of the industrial states in India, the industrial wastewaters directly and indirectly discharge into either open lands or into the surface waters including the wetlands like ponds and lakes. These wetlands get polluted day-by-day not only by the industrial discharges but also by the different anthropogenic interventions. The pollution of wetland hydrology is essential to understanding, quantifying, and evaluating wetland functions and processes. Therefore, it is very much essential to undertake “Pollution studies of two distinct tropical lentic wetlands of central Gujarat with reference to spatial and temporal heterogeneity of biotic and abiotic components”.

In regard to the above study following objectives were hence carried out in two selected wetlands Pariej and Malwar from September, 2007 to August, 2009 at two sites of each wetland:

1. To study the degree of pollution, hydrochemical properties like temperature, pH, transparency, dissolved oxygen (DO), total solids, dissolved and suspended solids, free CO$_2$, total and phenolphthalein alkalinity, carbonates, bicarbonates, chloride, total hardness, calcium and magnesium hardness, phosphate, sulphate, nitrate, sodium and potassium were analyzed.

2. To explore the geochemical composition for chloride, phosphate, sulphate, nitrate, total organic matter, sodium, potassium.

3. To enumerate the enormity of phytoplankton as indicator and markers of pollution, periodic changes of phytoplankton—diversity and density for one year.

4. To assess macrophytes as indicators of quality of wetlands—composition and diversity.

5. To screen out the waterfowl census including diversity, density, population, fluctuations in different months for abundant, common and rare.

6. To propose the site specific problems and their suggestions for the better management and conservation of wetlands.