Chapter I

Introduction & Review of Literature
INTRODUCTION AND REVIEW OF LITERATURE

Water is the mother of life and it is the most precious gift of the nature. About 71 percent of earth’s surface is covered with water 97.3 percent of global water exists in ocean and remaining 2.7 percent in glaciers, lakes, rivers and wetlands. The total surface area of lakes accounts to roughly 1.8 percent of the land area, or about 2.5 million km$^2$, the volume of water contained in them is $2.80 \times 10^3$ (Schwoerbel, 1987).

Due to unique hydrological properties, the aquatic ecosystem has supported the development of a very complex biotic community on the earth. Virtually every form, composition, altitude and latitude are populated with organisms both plant and animal, although the composition differs greatly with differences in the various waters. With few exceptions, all the major groups of plants and animals are represented, often by a great array of species. Aquatic ecosystem is thus important sustainers of biodiversity which encompasses freshwater ecosystems, including lakes, ponds and reservoirs, rivers and streams, groundwater and wetlands. Aquatic biodiversity has enormous economic and aesthetic value and is largely responsible for maintaining and supporting overall environmental health. Human has long depended on aquatic resources for food, medicines and materials as well as for recreational and commercial purposes. Other organisms also rely upon the great diversity of aquatic habitats and resources for food materials and breeding grounds.

The organisms of lake are conveniently grouped ecologically into those associated with the free water, those associated with solid-water interface and those at the surface in film and can undertake swimming movements in any direction in spite of turbulence. Gams (1918) have given systematic classification suitable for all organisms living in aquatic environment. These three assemblages are known as ephaptomenon, rhizomenon and planomenon respectively. As far as aquatic form are concerned, the ephaptomenon, consist of attached plants which were called as Nereid’s by Warming (1895) and Haptobenthos by Hutchinson (1967).

However, the organisms associated with solid liquid interface are ordinarily
termed as benthos (Haeckel, 1891) and may be divided into phytobenthos and zoobenthos. The term Benthos is derived from two Greek words “Ben” meaning ‘the collection of organisms living in or on the sea or lakes’ and “Thos” ‘the bottom of sea or lakes’. Hutchinson (1967) defined benthos as an association of species of plants and animals that live in or on the bottom of a body of water.

Their size may vary from 1 micrometer to > 1 millimeter and they are named accordingly:

Microbenthos: Organisms 1-100 micrometer in size e.g. bacteria.

Meiobenthos: Organisms which are 100-1000 micrometer in size

Macrobenthos: Organisms which are more than 1000 micrometer in size

In the distribution of benthic flora, light plays a very important role when the water is sufficiently shallow. Light reaches the bottom sediments in plenty and as a result of it, benthic algae and macrophytes grow in greater abundance. Hustedt (1922), Warming (1923) and Hurter (1928), reported that the nature of the substratum is of the great importance in determining the composition of algal association living upon it. A shallow water body has greater part of water mass in the direct contact with the bottom than the deeper ones. This allows nutrients, like nitrogen and phosphorus, to dissolve more efficiently from the basin.

The distribution of the diverse fauna within waterbody is extremely heterogenous. Benthic organisms either possesses adaptive mechanisms to cope with these changes, either relatively dormant stages until more physiologically amenable conditions return, move, or die. The adaptive capabilities of the benthic animals to the dynamics of environmental parameters are basic to their distribution, growth and reproductive potential (Wetzel, 1983).

These animals are widespread in their distribution and can live on all bottom types, even on man-made objects. They can be found in hot springs, small ponds and large lakes. Some are even found in the soil beneath puddles. Many
species of benthos are able to move around and expand their distribution by drifting with currents to a new location during the aquatic phase of their life or by flying to a new stream during their terrestrial phase. Most benthic species can be found throughout the year, but the largest numbers occur in the spring just before the reproductive period. In colder months, many species burrow deep within the mud or remain inactive on rock surfaces. Many aquatic insects undergo a complete metamorphosis - the transition from egg to larva to pupa and finally to adult. They remain in the water for most of their lives (typically one month to four years). After becoming adults, the majority of insects live for only a brief time, usually a few hours to a few days, while they locate mates and reproduce.

Many organisms adapted to deep-water pressure cannot survive in the upper parts of the water column. Dead and decaying matter from higher up in the water column drifts down to the depths sustains the benthic food chain. Most organisms in the benthic zone are scavengers or detritivores. The depth of water, temperature and salinity, and type of local substrate all affect what benthos is present. In coastal waters and other places where light reaches the bottom, benthic photosynthesizing diatoms can proliferate. Filter feeders, such as sponges and bivalves, dominate hard, sandy bottoms. Deposit feeders, such as polychaetes, populate softer bottoms. Fish, sea stars, snails, cephalopods, and crustaceans are important predators and scavengers.

The littoral benthos is extremely varied when compared with that of deeper region. Protozoan, sponges, coelenterates, rotifers, nematodes, bryozoans, crustaceans, molluscs, insects, annelids, echinoderms and many lower vertebrates are abundant in the shallow waters. Biglow (1928) divided the littoral benthic micro-organisms of Nipigon lake, Canada into ecological groups. The ooze films group comprises those micro-organisms living in and on the film ooze which form the upper surface of the lake bottom. The assemblage was found to contain following microscopic organisms e.g. bacteria, green algae, diatoms, protozoans, rotifers, several entomostracan (mostly cladocera), tardigrada and certain water mites.
Nonetheless, it is also clear that significant seasonal, interannual, and decadal changes of food supply to the benthos do occur, and that major climate shifts are associated with marked changes in the abundance and species composition of the epibenthic megafauna (Billett et al., 2001; Ruhl and Smith, 2004; Smith et al., 2006).

Microbenthic algae are known to regulate the cycle of nutrients from the sediment to the water column (Hargrave, 1972; Shaffer and Onuff, 1983; Rizzo, 1990; Wiltshire, 1992). The biomass of benthic microalgae is high and they retain a part of the newly mineralized nutrients at the sediment surface (Cartlon and Wetzel, 1988). The benthic algal productivity accounts for large percentage of total primary production in shallow estuarine water bodies (Josson, 1991).

Many species of benthos are sensitive to pollutants such as metals and organic waste. Mayflies, stone flies and caddis flies are generally intolerant of pollution. Stream macro-invertebrates have been used extensively to biomonitor numerous environmental stresses (Rosenberg and Resh, 1993). Benthos are sensitive to watershed condition and exhibit sufficient stability in assemblage structure over time to make them useful as long term monitor of stream health (Richards and Minshell, 1992) and indicator of water quality (Gauffin and Tarwell, 1952; Wilhm and Dorris, 1968 and Resh, 1995). Hynes (1961) reported that the density of benthos in a water body is useful index of water quality although density may fluctuate widely with changes in the seasons and space. Some benthic forms are often considered to be best indicator of organic pollution because of their constant present, relatively long life span, sedentary habits and different tolerance to stress habitat (Webber et al., 1989). According to Brinkhurst (1974), the community of benthic invertebrate in lake has been used as indicator of lake fertility and even been used as a basis for lake classification (Johnson et al., 1993). Knowledge of littoral benthos also becomes more important because of the increasing human influence on the aquatic ecosystem. Moreover, the effect of pollution or even more the effect of the regulation of water level can not be understood or even can not be predicted without knowledge of the natural state of the littoral zone.
Despite the great importance of benthic communities in general, relatively fewer studies have been carried out as compared to plankton and nekton.

Studies which have revealed a clear cut seasonal and spatial variation in relation to sediment characteristics along west coast have been carried out by Harkantra *et al.* (1980), Devasy *et al.* (1987) and Gopalkrishna and Nair (1998). The need for comprehensive studies on benthic fauna is important for better understanding of benthic community and also in evaluating their role as fish food. The earliest and very brief records on great lakes benthos came from the works of Jackson (1844), Agassi (1850), Hoy (1872) and Stimson (1971). A brief classification of benthos was given by Warming (1895) and Gams (1918) and sessile and slowly moving epifauna have been differentiated by Petersen (1926). More information has been gathered on benthic community by Birge and Juday (1911), Allee (1912), Juday (1922), Petersen (1926) and Rawson (1930). Bigelow (1928) described ooze film layer of the bottom. Ecology and economy of benthic community was studied by Eggleton (1936), Pennak (1939), Ward (1940), Hoff (1943) and Kenk (1949). Needham (1959) published papers on culture methods for benthic invertebrate animals. Berg (1938), Meuche (1939), Roll (1939) and Mare (1942) also provided information on benthos. The biology of bottom invertebrates was studied in detail by Cooper (1969), Anderson and Day (1986), Bass and Bruce (1986), Kendall and Lewis (1986) and Lewis (1986). The correlation between benthic primary production and temperature and irradiance was studied by Colijn and Jonge (1984). Nutrients and benthic primary productivity in shallow estuarine system of Australia have been studied by Lukatelich and Comp (1986). Kutti *et al.* (2007) found that at deepwater sites, organic waste affected the benthic community on a much larger spatial scale than at shallow water sites. In temperate regions, the impacts of finfish cage farming on the surrounding environments have been studied, using with a number of different approaches, including water chemistry, plankton and macro-benthos (Chong *et al.*, 2004; Hall-Spencer *et al.*, 2006 ; Lee *et al.*, 2006) sediment chemistry and nutrient fluxes (Christensen *et al.*, 2000; Porrello *et al.*, 2005).
Benthic diversity indices were developed and used for assessing different ecological impacts. In this respect the Shannon-Wiener index $H$, the BQI (Benthic Quality Index) and the AMBI (Anti Marine Biotic Index) are among those indices generally used. The AMBI had been proposed for the assessment of the ecological status of estuarine and coastal waters. Whereas the BQI were mainly designed for application in marine areas. Diversity includes diversity within species and among species, and comparative diversity among ecosystems. The main purpose of all of them is to separate impacted sites from undisturbed (Borja, 2003; Muxika et al., 2005). Their application, however does not necessarily allow distinguishing between natural or man-induced disturbances and their natural variability both on temporal and spatial scales has to be assessed (Vincent et al., 2002).

A lot of work has been done on the benthic fauna. Some important contributions from India and abroad are those of Jackson, 1844; Aggasive, 1850; Hoy, 1872; Warming, 1895; Gams, 1918; Birge and Juday, 1911; Juday, 1922; Petersen, 1926; Daken, 1927; Rawson, 1930; Eggleton, 1936; Pennak, 1939; Ward, 1940; Kenk, 1949; Needham, 1959; Rokop, 1974; Dayton and Oliver, 1977; Pillai, 1977; Capitoli et al., 1978; Bemvenuti et al., 1978; Word, 1978; Feder et al., 1979; Haflinger, 1981; Chandran et al., 1982; Tyler et al., 1982; Ordner and Lawrence, 1987; Atkinson and Wacasey, 1987; Bemvenuti, 1987; Grebmeier et al., 1988; Grebmeier and McRoy, 1989; Highsmith and Coyle, 1990; Carey, 1991; Grebmeier and Barry, 1991; Uitto and Sarvala, 1991; Allan and Maguire, 1992; Tyler et al., 1992; Ambrose, 1993; Blake, 1993; Prabadevi, 1994; Allan et al., 1995; Ambrose and Renaud, 1995; Bacher et al., 1995; Hobson et al., 1995; Rosenberg, 1995; Eckman, 1996; Nunes et al., 1997; Piepenburg et al., 1997; Ambrose and Renaud, 1997; Ritzrau and Thomsen, 1997; Focken et al., 1998; Rysgaard et al., 1998; Shishehchian and Yusoff, 1999; Bauerfeind et al., 2000; Wollenburg and Kuhnt, 2000; Iken et al., 2001; Shishehchian et al., 2001; Bolam et al., 2002; Cromey et al., 2002a; Grant et al., 2002; Hargrave et al., 2002; Hobson et al., 2002; Borja et al., 2003; Carroll and Carroll, 2003; Chong et al., 2004; Dunstan and Johnson, 2003; Klages et al., 2004; Lohrer et al., 2004; Perus et al., 2004; Ruhl and Smith, 2004; Solan et al., 2004; Wenzhöfer and Glud, 2004; Dowd, 2005; Grant
et al., 2005; Porrello et al., 2005; Cranford et al., 2006; Hall-Spencer et al., 2006; Lee et al., 2006 and Smith et al., 2006; Coyle et al., 2007; Kutti et al., 2007; Blanchet et al., 2008; Borja et al., 2008; Callier et al., 2006, 2007, 2008; Dauer et al., 2008; Lewis and Gripenberg, 2008; Puente et al., 2008; Teixeira et al., 2008; Weisberg et al., 2008; Borja et al., 2009.

In India several attempts have been made to study the benthic fauna by Pillai (1977), Chandran et al. (1982) and Prabadevi (1994). The study of benthic communities as best indicator of pollution was carried out by Venugopal (1982), Satyanarayana (1994) and Gopalkrishnan and Nair (1998).

**Aims and objective of the study**

Aquatic ecosystem is one of the important sustainers of biodiversity. Aquatic diversity encompasses large marine and freshwater ecosystems including estuaries, lakes, ponds, reservoirs, rivers, streams, ground water and wetlands. Being a support- system of many species (benthos, plankton, aquatic plants, insects, fish, birds and mammals) waterbodies maintain a complex ecological balance in nature. However the aquatic habitats in recent time have undergone major changes worldwide due to eutrophication and pollution resulting from agricultural activities, urbanization and climatic changes.

Benthic fauna are especially of great significance for the fisheries that they themselves act as a food of bottom feeding fishes (Walker et al., 1991; Vijaykumar et al., 1991) forming an important part of the food chain, thus plays a critical role in the natural flow of energy and nutrients. When benthic invertebrates die, they decay leaving behind nutrients that are reused by aquatic plants and other animals.

The usefulness of benthic organisms, especially the benthos in pollution monitoring programme to ascertain the health of estuarine and marine environments has been re-emphasized. Studies made on benthos led to the development of the indicator organism concept, which is the presence of a particular species or a group of species in a given locality reflecting the status of the environment. Among benthos, polychaetes are ideal indicator organisms,
since they constitute well over half of the total number of organisms in and on the bottom and thus give a good indication of health conditions of the aquatic environment.

The salient features of Benthos are

- They are ubiquitous and they are affected by perturbations in different habitats.

- Their longevity allows temporal changes in abundance and age structure and provides long-term exposure to toxic substances as they live in close contact with sediments, which enhances their intimacy with many pollutants.

- The infaunal organisms reflect the situations not only at the time of sampling but also during year after year.

- They are species rich, so the large number of species produces a range of responses.

- They are mostly sedentary, so they stay in place, which allows determination of the spatial extent of a perturbation.

- They provide evidence of comparing the response of the diversity of each single group to environmental variables with the response of the total diversity of macrobenthos conditions over long periods of time.

The present study proposes to identify indicator species of pollution among benthos from the derelict waterbodies of Aligarh, India and explains their effectiveness as graphical tools for diversity indices in pollution-monitoring studies.

The present work includes:
1. Study of monthly variations in important physico-chemical factors
2. Study of monthly abundance of benthos, species composition and community structure in selected waterbodies.
3. Study degree of relationship between benthos density and different physicochemical factors.
4. Statistical analyses including various measures of diversity and Canonical Correspondence Analysis (CCA).

All these would be helpful in knowing the status of benthic diversity in such water bodies and their conservation from biodiversity point of view.