Chapter: I

General Introduction
1.1 Introduction

Global human population growth rate increased rapidly after Second World War and in past two centuries the growth rate increased twice, with developing countries facing more population growth than developed countries (Postel, 1995). The human population growth rate has significant impact on human life style and the environment leading to increased food demand, in turn exerting pressure on stressed natural water resources. Water scarcity and decline in aquatic biodiversity are indicators of ineffective implementation of water protection policies (Rapport et al., 1995).

Quality of fresh water is essential for hygiene and healthy life, as water plays an important role in metabolic activities. Living organisms (Unicellular and Multi-cellular) depend on water for their various physiological activities and survival. Water is essential for photosynthesis, maximum agricultural production depend on water availability. Water is predominant inorganic constituent of living organic matter, forming nearly ¾ of the weight of living cell. Water covers about 71% of earth surface, whereas the land part is only 29% among 71% of water covering the earth’s surface, 97% is marine water and only 3% constitute fresh water which is present in the form of ice caps, glaciers, rivers, lakes, ponds and streams. Among 3% of fresh water only 0.6% is available for human consumption (Neill, 1993). India’s rapidly growing population is accompanied by increasing hazards of domestic and industrial pollution to the inland waters of the country, thus scientists visualized a rapid degradation of water quality and also an added contribution of agricultural pesticides and insecticides which further increases the problem of pollution in turn damaging public health as well as aquaculture (Singh and Singh, 1995). Pollution load in fresh water source increases the nutrient level of water thus encourage the
growth of aquatic weeds and algae, there by suppress the growth of essential species (Alam, 1998).

1.1.1 Fresh water ecosystem.

Available fresh water is in the form of surface and ground water; the need for preserving the surface water lead to the rise of dams in turn creating several reservoirs in many water deficit areas across the world. Fresh water is becoming scarce day by day as there is a progress in human civilization, man depend on these water bodies for satisfying his daily needs, also utilize them as disposal system for domestic and industrial wastes there by exploiting precious water resource, thus creating stress on the availability of drinking water.

Sustainable and optimal use of natural resources is imperative in any country due to its concomitant economic implications such as industrial and population growth infrastructure and development demands. Human beings utilize water resources for agriculture, skin products from aquatic organisms, medicinal products, ornamental products (aquarium fish). According to the Food and Agriculture Organization (FAO) inland fisheries contribute approximately 12% of all fish used for human consumption. The agricultural industry accounts for 70% of freshwater inhibited from the ecosystem for its practice such as irrigation and about 35% of agricultural water are lost through evaporation and leakages (Lanza, 1997). It is important to notice that irrigated agricultural products contribute about 40% of the world’s food crops (WHO, 1993). Urbanization and industrial development also increase the water demand through household supplies, food processing, mining, industrial cooling systems and power generation with hydropower contributing about 20% of the world’s energy supply (Gleick, 2006). Approximately 12% of living animals are freshwater inhabitants, with the majority depending on freshwater
ecosystems for their livelihood. Despite the importance of freshwater, increasing anthropogenic activities are continually degrading and changing freshwater ecosystems across the globe. The World Resources Institute (WRI) reported that 2.3 billion people live in areas where water demand is met by abstraction from river basins that are under serious water stress, as the annual per capita water availability is below 1700 liter. Serious water stress is caused by a combination of a growing human population, industrial and agricultural developments (Johnson et al., 2001). A vital function provided by freshwater ecosystems is habitat provision for a large diversity of aquatic species. Freshwater biodiversity is essential for maintaining ecosystem functions and their services such as primary productivity, nutrient recycling, freshwater and waste water purification (Revenga et al., 2000 and Palmer et al., 2005). Since freshwater ecosystems are pivotal in the preservation of aquatic biodiversity lead to over exploitation of aquatic ecosystems, which results in significant decrease in flow, habitat destruction and decrease in biodiversity thus it causes ecological imbalance in the affected areas (WHO, 1993; Revenga et al., 2000). Hunsaker and Levine (1995) reported that transformations of the landscape due to erosion and agricultural activities and hydrological pattern changes to streams and rivers. Construction of dams, weirs, bridges and mining with watercourses are major contributors of freshwater ecosystem destruction, these activities alter the species biodiversity, leading to ecological variations such as tolerant species domination and environmental water quality destruction (Daniel et al., 2002). Freshwater ecosystem experiences intense physical alteration, habitat loss and degradation, overexploitation and the elimination of sensitive species and introduction of non-native species, which collectively play a vital role in the decline of the freshwater ecosystems (Camargo et
Freshwater ecosystems can be divided into lentic ecosystems (still water) and lotic ecosystems (flowing water).

1.1.2 River ecosystems:

River ecosystem forms the lifeline of human society which is large natural stream of water emptying into an ocean (Ashwani and Anish, 2009). Although they contribute 0.0001\% of the total amount of water in the world at any given time, rivers are vital carriers of water and nutrients in the given flow path (Wetzel, 2001). The ecosystem of a river is viewed as a system operating in its natural environment and includes biotic (living) interactions amongst plants, animals and micro-organisms, as well as abiotic (nonliving) interactions. Rivers are of strategic importance across the world, providing main water resources for domestic, industrial, agricultural and recreational purposes, rivers also play a major role in assimilating or carrying industrial and municipal wastewater and runoff from agricultural fields. In recent years, rivers are the most vulnerable water bodies to pollution as a consequence of unprecedented development. Thus, the quality of river water resources is a subject of ongoing concern and has resulted in an increasing demand for monitoring river water quality. Water quality is described by its physical, chemical and microbiological characteristics. However, the declining quality of the water in these systems threatens their sustainability and is therefore is of prime concern. A regular monitoring of water bodies with water quality parameters not only prevents the outbreak of diseases and the occurrence of hazards, but also checks the water from further deterioration. The indicators of contamination by fecal matters is of great concern, therefore, routine monitoring is carried out to ascertain the quality and portability of water to ensure prevention of further dissemination of pathogens through the agency of water under investigation (Venkatesharaju et al., 2010). Quality of river water is prime
environmental issue that concern society; they are studied by a wide range of specialists, including hydrologists, engineers, ecologists, geologists and geomorphologies. River water quality is an important issue as it affects the well being of humans and other living organisms including plants. From the time of human civilization emergence, with the unplanned rapid urbanization and industrialization, river resources are being used as dumping grounds for sewage, industrial, and technological wastes, thereby polluting the aquatic bodies (Jindal and Sharma, 2011).

In most developing countries 90% of waste water is discharged into rivers and streams without treatment (Ashton, 2007). Dumping of industrial as well as urban pollutants in river form polluted ecosystem which are regarded as unfit even for industrial activities (WHO, 1993). Implementation of the appropriate management policies for water quality is declining thereby consequently has a negative impact on ecological health of river ecosystems.

Changes in physical parameters such as turbidity, total suspended solids (TSS) and temperature, or changes in chemical parameters such as pH, salinity, elevated concentrations of inorganic and organic nutrients, decreased dissolved oxygen, inorganic salts, such as magnesium sulphates, and toxic substances, such as cyanide and lead, causes serious threats to ecosystems (Dallas and Day, 2004). Elevated nutrient concentrations are associated with physical and chemical parameters; these changes can stimulate eutrophication, i.e. uncontrolled growth of algae and aquatic plants, which result in increased dissolved oxygen consumption leading to subsequent depletion of dissolved oxygen in surface water (Foxon, 2005). Physico-chemical changes of the river are influenced by the regions in which it flows, due to different climatic condition, geomorphology, geology and biotic composition (Dallas and Day,
As fresh water and its quality are of prime concern and availability of fresh water is decreasing day by day, developing countries have increased their interest in water quality monitoring programs (Patrick et al. 2005). In order to assess the suitability of water for diverse use, there is a need to develop an index similar to the air quality index that will categorize the quality of water.

### 1.1.3 Plankton

Plankton has been traditionally distinguished from nekton, which moves along water currents irrespective of direction. The word Plankton is derived from the Greek word meaning “drifters” which are micro plants and animals that drift along water currents. Plankton acts as the main source of food for most fauna, both in lotic and lentic ecosystem. Studies on the structure and functioning of planktonic communities in lotic ecosystems provide opportunities to investigate patterns of responses to cyclic variations and episodic disturbances (Suresh et al., 2009). The circulation of aquatic organisms and particularly spatial heterogeneity is a general feature in all ecosystems and is the consequence of many cooperating physical and biological processes.

Planktons are broadly divided into three types:

- **Bacterioplankton**: Bacterioplankton are bacteria that live in the open water, they are microscopic often abundant.

- **Phytoplankton**: Phytoplankton include both free floating and drifting plants such as diatoms, dino- flagellates, blue green algae, photosynthetic flagellates and photosynthetic bacteria.

### 1.1.4 Zooplankton:

Zooplankton (in Greek zoion means animals and plankton means wanders) are the animal members of the marine and fresh water planktonic community, that drift
along the water currents. They range in size from microscopic protozoan to larger jelly fish at over 10 mm long. Most of the Zooplankton occupies the second or third tropic level at the aquatic food web. Metazoan Zooplankton can be distinguished into two major groups; the **holoplankton**, that spend their entire life cycle as plankton (Eg. Copepoda) and the **meroplankton**, that spends only part of their life cycle as plankton (usually larval forms of benthic or nektonic adult). **Macroplankton** are more abundant in coastal area because of the vicinity of the benthic realm. In terms of biomass and productivity, the dominant groups of Zooplankton in most fresh waters are Crustacea and Rotifera. Zooplankton plays important role in aquatic food webs because they are important food for fish and Invertebrate predators and they graze heavily on algae, bacteria, protozoa and other Invertebrate. Zooplankton communities are typically diverse and occur in almost all lakes and ponds, Zooplankton communities are highly sensitive to environmental variation. As a result, change in their abundance, and species diversity or community composition, can provide important indications of environmental change or disturbance. Zooplankton populations of **Cladocerans, Copepods, Rotifers and Ostracods** face the same challenges like all other animals viz; the need for food and oxygen, excretion of metabolic wastes, and reproduction. Although they are tiny, the relative abundance and diversity of these organisms dramatically influences energy flow, nutrient cycling, and community dynamics within aquatic ecosystems. Zooplankton identification provides the necessary information to make informed decisions about management and restoration of aquatic ecosystems. This is on the basis that there were fairly distinct patterns in the species composition and abundance as the water quality changed spatially. This may be attributed to the fact that the Zooplankton community itself responds directly or indirectly to changes in the physicochemical
variables and the availability of phytoplankton food and is therefore less affected by
manipulation via farm management processes. There are numerous studies and
investigations about the general Zooplankton response to various sources of stress,
and subsequently their use as biological indicators. Zooplankton is recognized as
integral members of the ecosystem, reflecting top-down and vice-versa processes.

Zooplankton may form an important component of the biological communities
in large rivers due to their high abundances and their ability to cycle nutrients through
the aquatic environment (Kobayashi et al., 1998). The aquatic ecosystem covers a
vast area and the organisms occurring in this area are under the influence of its
physico-chemical parameters. The occurrence and abundance of Zooplankton depends
on its productivity, which in turn is influenced by abiotic factors and the level of
nutrients in the water. Abundance of Zooplankton is most pronounced in the slower
moving portions of a river system, where deeper water tend to reduce velocity of
current and silt deposition which make them indistinguishable from typical lentic
habitats. The Zooplankton of permanent swift-water stream is characteristically
reduced both in number and biomass. The study of freshwater fauna, mainly
Zooplankton, even of a particular area is widespread and convoluted due to
environmental, physical, geographical and chemical differences involving ecological,
extrinsic and essential aspects. The species composition, distribution, diversity and
relative abundance of Zooplankton in an aquatic ecosystem could have an important
impact on fisheries and public health of the river and its users. Zooplankton are
important for fry nourishment, the abundance of Zooplankton is an indicator for
eutrophication and pollution levels since the abundance and composition of
Zooplankton are closely associated with water quality and shows increasing and
decreasing pattern based on tropic levels of water. Zooplankton is the most valuable
as indicator of tropic status than generally been realized, since they are larger and easier to identify when compared to phytoplankton (Kovalev, et al., 1999). They contribute significantly to biological productivity of freshwater ecosystem, as they serve as good indicator of water quality, as Zooplankton are strongly affected by the environmental conditions and it is quickly responds to changes in environmental quality (Gannon and Stemberger, 1978).

Data collection of Zooplankton is important in order to identify chronic as well as acute changes in the system, provided long term data collection is done. The commitment to long term data collection must be assured; it is only long term data records that ensure sufficient information for detecting ecosystem change, whether through restoration efforts, fisheries management, or natural controls (e.g., climate change, variable river discharges, and hurricanes). Detailed description of four Zooplankton groups (Rotifer, Cladocera, Copepod and Ostracods) is given below.

1.1.4.1 Rotifers:

These are microscopic aquatic animals commonly called “wheel animalcules” commonly found in fresh water environments which are small pseudocoelomate animals with a length 0.4 to 2.5mm. Their name comes from the apparently rotating wheels of cilia known as corona which is used for locomotion and sweeping food particles towards mouth. The anterior end of rotifer is ciliated, body shape tends to be elongated and regions of head, trunk and foot are distinguishable. Rotifer are non predatory and have a transparent cylindrical shaped body lined by a thin cuticle. The trunk forms major part of the body and encloses the organs concerned with digestion, excretion and reproduction. Rotifers have the short life span which is nearly twelve days and reach their peak reproductive level in about 3.5 days (Altaff 2004). The rotifer fauna plays a significant role in the food chain and biological productions of
waters such as aqua pollution indicators, and water quality monitor (Fafioye, 2006). Rotifers are highly nutritive to planktivorus fish as its protein supports fast growth of fish larvae. Rotifers can reach high population densities in fresh and brackish water, as well as in marine coastal zones, forming an important element in aquatic food web, especially as starting food for fish larvae. Rotifer is important component of the littoral and limnotic invertebrate communities and an integral link of aquatic food-webs (Sharma and Sharma, 2012). These organisms are characterized as opportunistic, consuming and assimilating a wide variety of food resources and high tolerance to environmental conditions, resulting in a much more diverse community in the aquatic ecosystems (Bonecker et al., 2009). Rotifers are the key element as they contribute to the process of biological self purification of water bodies. Rotifers play an important role in anthropogenic sediments by acting as bio-filters in waste water plants.

1.1.4.2 Cladocerans:

The term Cladocerans describes crustaceans of similar appearance which are commonly known as “water fleas” because of their general appearance and jerky swimming motion. Cladocerans have a single compound eye and posses a carapace that is used as a brood chamber; they are present in all natural aquatic ecosystems including manmade wells and reservoirs. Cladocerans are tiny aquatic crustaceans, about 600 species of Cladocera have been recorded from all over the world so far (Gulam et al., 2008). The body is un-segmented but it is covered by a secreted shell, which has a bivalve appearance, head of Cladocerans is a very small compact structure with a recognized large compound eye there are five to six pairs of lobed legs and each leg is covered with setae or hairs. Generally males are smaller than females have a large antenna (Figuerola and green 2002). In addition to providing an
important food source for planktivorous fish and invertebrates, they are important grazers on algae and detritus (Balayla and Moss, 2004). Cladocerans play an important role in the food webs of the plankton community, the dominance of small Cladocerans in eutrophic environments is thought to be directly related to their ability to effectively avoid typically abundant cyanobacteria and feed on smaller algal particles (Neumann et al., 2005). Cladocerans generally contribute largely to Zooplankton biomass and act as a key element in the freshwater food webs. They control the algal growth by efficient grazing, therefore, are considered as indicators of water quality (Javaid and Ashok, 2013). Because of their intermediate trophic position, they often help in the transfer of energy through aquatic food webs, as well as in regulating the transfer of contaminants and pollutants to higher trophic levels. Cladocerans reproduce by cyclical parthenogenesis, when environmental condition become unfavourable they get in the sexual phase, producing males, and subsequently sexual eggs. These eggs are dormant and can withstand a wide range of disturbances, which is important for overlapping unfavourable conditions. Most of the Cladocerans are filter feeders which feed mainly on algae, protozoa, bacteria and detritus particles depending on species.

1.1.4.3 Copepods:

Copepods are the largest and most diversified group of crustaceans, which include over 14,000 species, 2280 genera and 210 families. They are considered as plentiful multicellular group on the planet earth, Copepods are the dominant forms of the marine planktons; the free living copepods shows variation in their morphology, however they are sexually reproducing organisms which shows similar patterns of life cycle. Copepod eggs hatch into small free swimming larvae termed nauplii and then develop by moulting through a number of subsequent larval stages the initial nauplius.
has three pairs of reduced appendages called first and second antenna and mandibles. The successive naupliar stages grow moult and acquire further appendages. After sixth naupliar moult the next moult result in an enlarged and more elongated form called the first copepodite instars. There are five copepodite stages; during which additional appendages and body segments develop, the sixth copepodite stage is adult information on the ecology of copepods is still scanty, and yet this taxonomic group usually comprises the major component of Zooplankton in terms of abundance and diversity (Osore 2003). Copepods first antennae are important organs, as they act as mechanoreceptors but are also used for jumping behaviour (e.g. escape responses in the presence of predators). They are obligatory sexual, and some species can go in dormancy during a particular stage in their development (e.g. dormant egg or copepodid stage) to survive harsh conditions. Copepods play major roles in aquatic ecosystems, serving as food for small fish, fish parasites, intermediate hosts of fish parasites, and hosts and vectors of human diseases. Copepods are also intermediate hosts for important fish parasites, including tapeworms and nematodes, damage from these parasites may lead to fish mortalities or reduce the market value of the fish products. Copepods are the key player of aquatic food-webs, as they consume microorganisms and are preyed upon by higher tropic levels, including fish and whales. In Particular, they serve as primary prey for early life history stages of many fish species of economic importance. During their long evolutionary history, starting from lower crustaceans, Copepods are spread over all the continents as well as they successfully colonized about all the available water habitats of earth, becoming well adapted or specialized to very different salinity regimes, from marine and hyper saline waters to continental freshwater bodies, and to a wide range of temperature from the
polar to the hot springs waters. Copepods are sub divide into three groups viz, Calanoid, Cyclopoid and Harpacticoid.

1.1.4.3.1 Calanoid-Copepods:

Calanoid-copepods are good indicators of water pollution as it is present only in good quality water. The body is divided into head region bearing five pairs of appendages representing antenna and mouth parts and the thorax with six pairs of swimming legs. The posterior urosome consists of abdominal segment, in females it is modified as genital segment. Calanoid-copepods range from 1mm to 5mm in length having elongated cephalothorax, very long antennules and furcal setae of equal length. Calanoid-copepods and their developmental stages constitute important food items for fish and fish larvae (Neumann, 2006).

1.1.4.3.2 Cyclopoid-Copepods:

They are dominion in fresh water bodies having length 6mm to 3mm. The last thoracic somatic is different from the preceding ones and is in fact a part of posterior body, antennules of females consist of nine to seventeen segments, antenna is uniramous, maxilliped is simple with prehensile claw, two genital pores, situated sub dorsally on each side of seminal receptacle are present antennules are shorter than calanoids and furcal setae are unequal in length.

1.1.4.3.3 Harpacticoid-Copepods:

Harpacticoid-copepods are most exclusive littoral, habituating macro vegetation, they are usually less than 1mm in length, anterior part of body is slightly broader than posterior, first antenna is very short extent from proximal 5th to end of head segment. The Harpacticoid-copepods contain over 3000 species most of which are free-living benthic organisms. They are found in almost all type of aquatic ecosystems and in all temperatures from polar to tropical zones, they are flexible and
well suited for shifts in their food preferences during different developmental stages, which makes it easier for them to be mass cultured and used with different experimental designs for pollution monitoring and aquaculture. Moreover, Harpacticoids are more sensitive to pollutants which make them good indicators of pollution (Ansari et al., 2013). Harpacticoid -copepods feed on microalgae and organic detritus particles, several Harpacticoid- copepods use purple phototrophic bacteria as a food. Among the copepod group, Harpacticiod-copepods are known to be mostly benthic, as they lead a benthic living mode, they depend on the diets available on bottom habitat including phytobenthos, microbes and detritus.

1.1.4.4 Ostracods:

Ostracods are commonly known as “Seed shrimps” and are small crustaceans, found in a wide variety of aquatic habitats like lake, pond and streams especially shallow places where weeds or algae are abundant (Zubeda, 2004). Ostracods secrete shells or valves made of calcite, which are often preserved in Quaternary sediments, in addition to providing a complementary line of evidence in multi-proxy investigations, Ostracods has a number of specific advantages as biological proxy. They are sensitive to a range of ecological variables, such as habitat type and water composition, their shells can be used in geochemical and isotope analyses because shell secretion is a rapid process, the results provide a “snapshot” of water conditions. Ecologically the planktonic copepods are important links in the aquatic food chain linking microscopic algal cells to juvenile fish to whales. Copepods also have the potential to act as control mechanisms for malaria by consuming mosquito larvae and inversely are intermediate hosts of many human and animal parasites (Holmes and Chivas, 2002). Ostracods are diverse and a widespread group in the world but one in which most species is sensitive to the changes in environmental conditions.
Therefore, they can be used as bio-indicators to determine water quality, spatial and temporal changes in environment.

1.2 REVIEW OF LITERATURE

Many researchers and scientists across the globe as well as in India carried out studies on lotic ecosystems to understand the water quality status and sources through which contaminants emerges and reach aquatic ecosystems, as well as numerous investigative studies have examined and reported about Zooplankton and physico-chemical parameters in different regions of the world.

1.2.1 International status:

Many research works have been done by researchers across the globe few of the literature have been mentioned at this juncture. Letswart, et al., (1999) studied the plankton dynamics in the river Rhine in Netherlands and they have reported that the value of Chlorophyll-a was low both in spring and summer seasons and Zooplankton density was very low. Gilbert (2004) studied on the population density of Zooplankton and he observed that Rotifers are good indicators for environmental changes. Fafioye (2006) recorded 29 Rotifer species in African river waters out of which family Brachionidae was dominant. Magalhaes, et al., (2009) studied the spatial and temporal density and biomass distribution of the Copepods in Caete river in Brazil and determined Copepod biomass using regression parameters based on the relation of dry weight and body length. Ashok, et al., (2006) in their research work to monitor water quality of Mackenzie river basin, Canada found that the river was impacted with high Turbidity and high metals due to the high suspended sediment loads. Adama, et al., (2007) studied the diversity, abundance and the seasonal dynamics of zooplankton community and he observed seven species of Cladocera and two species of Copepod in south Shara river. Shayestehfar, et al., (2008) carried out
a detailed study about the Rotifer species along with the seasonal fluctuations of physico-chemical parameters in Kor river, Iran, 13 species of rotifers belonging to 2 classes and 3 orders, 6 families and 10 genera were recognized and also observed that there is an inverse relationship between the population density of rotifer and the water current. Dirican, et al., (2009) made some observations about physico-chemical parameters of river water in Turkey and reported that temperature play an important role on BOD. Ozbay and Altındag (2009) studied the Zooplankton abundance in the river Kars, Northeast Turkey. The study revealed that the Zooplankton community was represented by thirty different Zooplankton species consisting of one Copepod, four Cladocera and twenty five Rotifers and the highest Zooplankton densities were recorded in July and the lowest in October. Also the study revealed that the water temperature and nutrients were the main environmental factors which affected Zooplankton abundance in the river. A survey on some physico-chemical parameters and Zooplankton structure in Karaman river, Antalya, Turkey was studied by Ahmet, et al., (2009) and reported 37 species of Zooplankton consisting Rotifer, Cladocera, Copepod. They identified 34 species of Rotifer, 2 species of Cladocera and 1 species of Copepod. Ayoade, (2009) studied about the changes in physico-chemical features and plankton of two regulated high altitude rivers Garhwal Himalaya, and observed that the water temperature, velocity, transparency and carbon dioxide content of the parent rivers were influenced by the dam. The planktonic communities of both rivers were impacted by these changes in abiotic features. Intiaj, et al., (2009) carried out a comparative study on the water quality parameters in the Panguchi rural river and Buriganga urban river besides Dhaka. This study reported that Buriganga river is severely polluted when compared with Panguchi river. Study also shows that the degree of river pollution is alarming for urban population. Zooplankton-based
assessment of the trophic state of a tropical forest river studied by Imoobetunde and Adeyinka (2010) showed that the river was oligotrophic. The study also reported that Zooplankton composition was typical of a tropical freshwater river, with a total of 40 species made up of 16 rotifers, 12 Cladocerans and 12 copepods and their developing stages in the following order of dominance; Rotifer > Cladocera > Cylopoid > Calanoid. Seasonal variations in physico-chemical properties and Zooplankton biomass in Greater Zab river – Iraq studied by Luay (2010) and the study carried out statistical analysis using correlation test and the result showed that there was a positive correlation between total count of Zooplankton and total count of phytoplankton during study period and also the water quality of the river was evaluated by using of WQI index.

1.2.2. National status:

In India, many studies on physico-chemical parameters and Zooplankton have been done few literature have been mentioned here. Pandey et al., (2004) studied the seasonal fluctuation of Zooplankton community in relation to physico-chemical parameters in river Ramjan of Kishanganj, Bihar and revealed that, the Zooplankton abundance was dominated by Rotifer, followed by Cladocera and Copepoda. The physicochemical and Zooplankton analysis of the Shendurni river, Kerala was studied by Sahib (2004) and the dissolved oxygen levels were observed to be highly saturated and a direct correlation between dissolved oxygen level and Zooplankton populations was observed. Sheeba and Ramanujan (2005) made observations about the qualitative and quantitative study of Zooplankton in Ithikkara river at Kerala. They have reported 13 species of Rotifers and 14 species of Copepods in that river and they also observed that copepods are the dominant group. Raja, et al., (2008) made an evaluation of physico-chemical parameters of river Cauvery in Tiruchirapally and observed that the
river water is moderately polluted. Mathivanan, et al., (2007) studied the assessment of plankton population of Cauvery river with reference to pollution at Salem district, Tamilnadu, state of India. They have reported that Cauvery river water shows high Zooplankton population and Rotifers were dominant group. Narendra Singh, (2008) studied the physico-chemical parameters of water samples of Kosi river and he observed that BOD and Turbidity were high in this river. Patil (2009) studied on the Physico-chemical parameters of river Patalganga in Uttarkhand, state of India and they recorded that Nitrate concentration was high in that river because of the run off due to heavy rain. Jayabhaya, (2009) studied on Zooplankton diversity of river Kayadhu, near Hingoli city, Hingoli district, Maharashtra; total 25 species of Zooplankton were recorded consisting of 11 species of rotifer, 6 species of Copepoda, 5 species of Cladocera and 3 species of Ostracod and the Species richness was high in the month of April (summer) and October (winter) and it was minimum during June (Monsoon). Smita, et al., (2009) Studied on water quality and Zooplankton community of the Panchganga river in Kolhapur city, the study revealed that high value of CO\textsubscript{2}, BOD, COD, phosphate, nitrate, Zn, Fe, Cu and low value of DO was due to untreated sewage and industrial effluents and the study also reported that the Zooplankton species such as, Brachionus, Brachionus keratella, Filinia, Anuraeopsis etc are pollution tolerant species. Study on Water Quality Index of Falgu river in Gaya town by Deepak et al., (2009) suggests that the water quality index increases from upstream to downstream along the town area. The study also reported that the river water is safe for human consumption. Ashwani and anish (2009) assessed the water quality of river Ravi at Madhopur, M.P, state of India and found out that the WQI values of river varies from 55.0 to 98.0 and DO was found to be the most important parameter among the 8 water quality parameters used. A comparative
study of three freshwater rivers (Cauvery, Bhavani and Noyyal) in Tamilnadu, state of India was done by Varunprasath and Nicholas on (2010) and they reported that the temperature, turbidity, electrical conductivity, total solids, PH, bicarbonate, COD values were higher in Noyyal river followed by Cauvery river. Present study also point out that the river Noyyal facing severe anthropogenic followed by Cauvery river. Shailendra, et al., (2010) studied the population dynamics and seasonal abundance of Zooplankton community in Narmada river (India) and reported that the total Zooplankton density exhibited a single peak during March. However, a sudden increase was noticed in the month of October which continued till March and also reported that the total Zooplankton comprises of 4 groups: Protozoa, Rotifera, Cladocera, and Copepod, out of this, Rotifer is the dominant group. Shinde (2011) studied about the physicochemical parameters of water and Zooplankton diversity in Kham river, Aurangabad district Madhya Pradesh state of India. In their study they found out that at four sampling station along the stretch, the river water was highly contaminated with untreated sewage and industrial effluents, while flowing through Aurangabad city, the high value of CO₂, BOD, COD, phosphate, nitrate, Zn, Fe, Cu and low value of DO at discharge zone indicates increase in organic pollution and they have reported 36 species of Rotifers, 16 species of Crustaceans, 5 species of Cladocera, 3 species of Ostracod, 8 species of Copepoda and 2 species of Brachiopod. Sharma and Bhardwaj, (2011) studied on the assessment of seasonal variation in phytoplankton community of Mahi river (India). In this study they observed that BOD, COD, Hardness, Chloride and Alkalinity were less and Nitrate and Phosphate were found to be high. Deksne (2011) studied on the influence of wastewater on Zooplankton community of the Daugava river after daugavpils wastewater treatment plant modernization. The result revealed that the wastewater discharged into the
Daugava river is adversely affecting the abundance and diversity of Zooplankton community. Srivastava and Srivastava (2011) studied the assessment of physico-chemical properties and sewage pollution indicator bacteria in surface water of river Gomti in Uttar Pradesh state of India. This study was aimed to estimate current status of Physico-chemical characteristics and level of sewage pollution indicator bacteria and their variation at whole stretch of river. Rehna and Mujumdhar (2011) studied on Tunga-Bhadra river water quality response under six hypothetical climate change scenarios and suggests that hypothetical climate change scenarios would cause impairment in water quality and they also found out that there is a significant decrease in DO level due to impact of climate change on temperature and flows, even when the discharge were at safe permissible limits. Kalavathi, et al., (2011) studied the water quality of Cauvery river in Tiruchirapalli and the Water Quality Index value revealed that the Cauvery river is moderately polluted in the upstream of the city and unfit for human use towards the downstream.

1.2.3 Regional status

Studies on physico-chemical parameters and Zooplankton in river Cauvery and river Kapila have been done by researchers; few available literatures have been mentioned at this point of time. Shahul (1997) made observations about Cauvery river water at Madikeri district, Karnataka, state of India, on Zooplankton and reported that the Radium concentration was high in Cauvery river water and this adversely affects the plankton population. Abida (2008) studied the quality of Cauvery river water in Mandya district, Karnataka, state of India and she reported that, Rotifer was more sensitive to water pollution as Turbidity was high in this river. Suresh, et al., (2009) studied on the Zooplankton of the Tungabhadra river, near Harihara, Karnataka and he reported nearly sixty four different Zooplankton species,
composed of four species of protozoan, sixteen species of rotifers, fourteen species of crustaceans and three groups meroplankton organisms mainly nymph/larval forms. It is found that among Zooplankton community rotifers (43.24%) were dominated group followed by crustaceans (37.84%) protozoan (10.81%) and meroplankton (8.11%).

Assessment of Water Quality of Bennithora river (Krishna Basin) near Gulbarga city of Karnataka through Multivariate Analysis was carried out by Sukarma and Priyanka, (2010) and significant variations among the parameters and interesting correlations were observed throughout the period of study. Multivariate technique, Principal component analysis (PCA) was applied to evaluate the annual correlation of water quality parameters. This study suggests that PCA technique is useful tool for identification of non-principal water quality physico-chemical parameters. Physico-chemical and bacteriological investigation on the river Cauvery of Kollegal stretch in Karnataka was studied by Venkatesharaju, et al., (2010) suggests that Conductance, Alkalinity and Hardness levels indicate the quality of water. The DO, BOD and COD level shows the absence or presence of major organic pollution sources. Mullar, et al., (2010) studied about the Seasonal variation in physico-chemical parameters of Hirahalla reservoir, Koppal District Karnataka and this study reported that there were more seasonal variations in physico-chemical parameters of the river. Sudevi and Lokesh (2012) evaluated the Cauvery river water quality at Srirangapatna in Karnataka using principal component analysis. This study illustrates the significance of multivariate statistics in simplifying complex data sets of monitoring stations in river Cauvery and also helps in understanding the monitoring strategy for effective water quality management. Krishna, et al., (2012) studied about the physico-chemical and bacteriological parameters of Cauvery river at Talakaveri region and reported that the carbon dioxide, nitrate and phosphorous were negatively correlated with other
parameters such as temperature, pH, conductivity, salinity, TDS, TSS and hardness. Krishna, and Jayashankar (2012) studied the physico-chemical and bacteriological study of Kaveri river at Kudige, Kodagu District, Karnataka and reported that the physico-chemical parameters were high at monsoon season. Hashemzadeh and Venkataramana (2012) studied the impact of physico-chemical parameters of water on Zooplankton diversity of Kapila river at Nanjangud industrial area, India and revealed that Zooplankton was made up of, Rotifera (62.00%), Copepoda (12.00%), Cladocera (19.50%), Diptera (4.00%) and Nematoda (4.50%). The status of the river water could said to be eutrophic as indicated by the diversity of Zooplankton. Mahadev et al., (2011) carried out studies on selected physico-chemical parameters and a taxonomic survey of fresh water algae of river cauvery in and around Mysore district. Reported that the environmental variables seems to play an important role in determining the species richness and diversity in the Cauvery river. Annalakshmi and Amsath (2012) studied on the hydrobiology of river Cauvery and its tributaries Arasalar from Kumbakonam region (Tamilnadu, India) with reference to Zooplankton. The study found out that during the winter and summer season maximum Zooplankton diversity was recorded which was mainly dominated by Rotifer population. Smitha and Shivakumar (2013) carried out studies on Physico Chemical Analysis of the Freshwater at River Kapila, Nanjangudu Industrial Area, Mysore, India and observed that Kapila river was contaminated with municipal waste and other organic pollutants resulting in moderately high concentration of TDS, hardness, nitrate and sulphate.

1.2.4 Local status.

Few notable studies have been carried out on Zooplankton in our laboratory, unpublished results on Zooplankton studies on river Cauvery and its tributaries like Shimsa, Arkavathy, Suvarnavathy and Kapila rivers by Harsha, (2006). Also
Mahadevaswamy (2007) studied on few Zooplankton groups of Lekshmanatheertha, Harangi, Hemavathy, Lokpavany, and Cauvery river ecosystems from our laboratory only (unpublished results). Koorosh, et al., (2009) made investigative studies about the abundance of Copepods on three contrasting lentic ecosystems in Mysore and reported that the Copepod abundance was less than that of Rotifers. He also studied about the biodiversity of four groups of Zooplankton. Beenamma and Yamakanamardi (2011) studied on the abundance of Zooplankton in Kukkarahalli lake for one year and reported that abundance was very low in rainy season due to high concentration of phosphate and nitrate and also Calanoids and Harpacticoids were completely absent throughout the study period. Savitha and Yamakanamardi, (2011) studied the abundance of Zooplankton in three lakes of Mysore and reported that Zooplankton are the indicators of water pollution and also found out that the total abundance of Zooplankton was high in polluted lake (Dalvoy) when compared to the other two lakes (Kalale and Alanahalli).
1.3. Objectives:

- To study fortnightly variations in the 21 physico-chemical parameters and WQI (Water Quality Index) in the surface waters of Cauvery and Kapila rivers and at the confluence site of Cauvery and Kapila rivers in Mysore for two consecutive years.

- To study fortnightly variations in the Abundance, Bio-mass, bio-volume and biodiversity of Rotifer, Cladocera, Copepod and Ostracod Zooplankton groups.

- To investigate the relationships if any, between abundance bio-mass bio-volume and biodiversity of Rotifer, Cladocera, copepod and Ostracod Zooplankton groups with 21 physico-chemical parameters and WQI in these three lotic ecosystems.

- To know, whether are there any drastic changes in physico-chemical parameters, WQI and also in the abundance, bio-mass, bio-volume and bio diversity of Zooplankton groups at the joining spot due to the confluence of Cauvery and Kapila rivers.