1. Introduction
INTRODUCTION

India consists of ten numbers of major river basins that flow into Bay of Bengal. In this context of study, the river Tunga from southern India joins one of the major river basin called the Krishna river basin in the compound form as Tunga Bhadra and thereby continues its flow towards Bay of Bengal.

The river is born in the Western Ghats on a hill known as varaha parvata at a place called gangamoola, situated in Chikmagalur district. Three important rivers such as Tunga, Bhadra and Nethravathi take their origin here. Annual rainfall at gangamoola is 550 to 750 cm. It lies at 13° 14' 54" N Longitude and 75° 9' 41" E Latitude. At this point, there is no direct intervention of man or man made activities with the river. From here, the river flows through two districts in Karnataka - Chikmagalur and Shimoga. The river travels around 147 km long distance and merges with Bhadra river at Koodli, a small town near Shimoga city, Karnataka. The river is given the compound name Tunga Bhadra from this point onwards. The Tunga Bhadra flows eastwards and merges with Krishna river in Andhra Pradesh.

Tunga river eco-system consists of wide variety of micro flora such as algae, desmids, diatoms, bacteria and both aquatic and extra aquatic fungi. Aquatic fungi play a very important role in the river eco-system. They are vital links in food webs, primarily as decomposers and pathogens of both plants and
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animals. Aquatic fungi, in the broadest sense include, fungi present transiently in water and function entirely with in water, terrestrial fungi that release spores, which are dispersed in water.

River Tunga originates in Chikmagalur district, and it traverses around 147 km in and around Shimoga and Chikmagalur districts covering various cities, taluks and villages viz., Sringeri, Thirthahalli, Mandagadde, Gajanur, Shimoga and Koodli. From the origin of the river up to Sringeri, the quality of river water was found to be good. Due to the interference of the pollution onwards, the river water was found to be moderately deteriorated. Rapid urbanization, industrialization and unscientific method of disposal of sewage and agricultural runoff have led a moderate decline in abundance of fungal diversity from Sringeri onwards.

In Koodli, the river water seems to be recovered from the pollution because of confluence with another stream called Bhadra, and considerably has a high fungal diversity and occurrence. The richness of plank tonic diversity of Tunga river has led to the wide and rich distribution in fish fauna. Intend, it will also attract some fish fungal pathogens of class chytrids and oomycetes. Due to the accumulation of urban sewage, agricultural and industrial wastes, the fungal population retards in the downstream of the river, because only some species of aquatic and extra aquatic fungi can survive as against increased degree of pollution.
Fungi are an integral part of any ecosystem biota. However, little attention has paid to study their role in aquatic ecosystem. The fungi in aquatic ecosystems play an important role in the energy transfer from allochthonous and autochthonous particles to other components of the food chain. Odum (1971), hypothesized that, “among saprotrophes, the bacteria and fungi inhabiting a water body are possibly of similarly great importance”. The first serious studies of aquatic zoosporic fungi were published in the middle of the 19th century, where many genera of these organisms were described. For a long time, the studies were focused on the morphology, taxonomy, and physiology of freshwater fungi, while, ecological data were scarce. By that time, the zoosporic fungi were attributed to chytridiomycetes and phycomycetes (oomycetes). First summary of the studies on freshwater fungal ecology was composed by American researcher, Sparrow, who collected the data on the distribution of biotrophic and saprotrophic fungi (chytridiomycetes and oomycetes) in water bodies and their dependence on various abiotic factors, the seasonality of their development, preferable substrates, etc.

Cooke (1961, 1963) divided the fungi encountered in fresh water into two principal groups, the hydro fungi, which require the presence of water to complete their life cycle and the geo fungi or typical soil fungi, which were not specifically adapted to aquatic existence, but nevertheless, might found in water because of an adequate supply of nutrients. These were regarded as “Facultative aquatic fungi”.

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Thus, there are at least four groups of fungi have been identified. Which are active in aquatic systems in different ways, they are true water molds, chytridiomycetes and oomycetes comprising of aquatic phycomycetes, whereas aquatic hypomycetes, aero or extra aquatic hypomycetes and terrestrial or typical soil fungi belongs to Deuteromycetes.

Chytridiomycetes and oomycetes are the group of aquatic fungi that are most widespread in water bodies with low water turnover rates. The effects of various ecological factors upon their distribution and biology were studied. It was shown that, light has no definite effect upon fungal growth (Sparrow, 1968). However, this factor stimulates the development of oogonia and oospores (Krause, 1960).

Temperature is also an important factor for the development and distribution of fungi in both terrestrial and aquatic eco-system. It strongly influences, the amount of oxygen dissolved in water, growth and reproduction and maintains the structure and distribution of fungi (Voronin, 2008).

Water-borne oxygen content (DO) is an important limiting factor, which regulates the occurrence of zoosporic fungal in water layers, differing in depths. The importance of the oxygen contents varies for different saprotrophic fungi: some develop if water is rich in oxygen; others are able to grow at very low oxygen concentrations, especially, within the near-bottom water layers (Lund,
1934). It was revealed that, zoospores of the aquatic fungi usually concentrate in the water layers saturated with oxygen. They undertake diurnal vertical migrations dependent on the water oxygen dynamics (Suzuki, 1961a,b,c). Further, the number of spores closely correlates with the water oxygen content along the river profile.

The studies on the zoosporic fungal distribution dependence on the water hydrogen concentrations have revealed that, these fungi may be found in the water bodies with variable pH values. However, there are groups of fungi that prefer acidic, neutral- or alkaline waters (Lund, 1934). Generally, chytrids and oomycetes prefer neutral and alkaline hydro-environment for mass formation of oogonia (Lund, 1957).

The relationship of aquatic phycomycetes with regard to the polluted water bodies was interpreted by early workers, from the United States of America. Eleven species of the class chytridomycetes and oomycetes have been isolated from the polluted zone of Lytle Creek, a short tributary of Todd's Fork of the Little Miami river, in Clinton County, Ohio. In that, only two species of *Aphanomyces* and *Allomyces* are found to be associated with the polluted water. Occasionally, isolates of *Saprolegnia*, *Achyla*, *Dictyuchus*, *Brevilegния* and *Pythium* have been obtained from samples, with a mild degree of pollution (Harvey, 1952). The diversity, periodicity and occurrence of aquatic phycomycetes, mainly depend upon the environmental conditions and physico-chemical characteristics of the riverine system. There are several environmental factors that decide the growth,
abundance and morphology of these phycomycetes. Around 12 species of aquatic phycomycetes were isolated from Neema lake of Allahabad India, in which, species of *Aphanomyces* followed by *Achlya flagellata*, *Pythium undulatum* and *Pythium carolinum* were found to be dominant. Maximum fungal incidence occurred during mid July to October. Minimum incidences were recorded during summer (Dayal and Tandon, 1963). Morphological and taxonomic investigation of the aquatic phycomycetous flora of the Varanasi district, was made during later summer of 1965-66. Among, the many aquatic fungal taxa which were identified and studied, only two species viz. *Achlya rodrigueziana* and *A. crenulata* were new records from India (Dayal and Thakurji, 1966).

The diversity of aquatic phycomycetes mainly depends upon the altitude and temperature of the prevailing region. As the altitude increases, the species richness also increases. Generally, lower temperature favors the luxuriant growth of aquatic phycomycetes.

Seventeen species of aquatic phycomycetes have been isolated in around subtropical lakes from Nainital for the first time and four of them are found to be new records to India (Khulbe, 1979).

Many workers from Saudi Arabia and Egypt, documented the fungal flora of several lakes in and around the regions of Abha, Riyadh, Al-asha and Assiut. They recorded their correlation and significance with the environmental factors
that are affecting their abundance (Farida et al., 1990; Arif, 1999; El-Nagdy and Nasser, 2000; Laila, 2005).

Another parameter that regulates the diversity of aquatic phycomycetes in lentic or lotic water bodies is mainly the depth of the aquatic ecosystem. The surface strata yields a high amount of fungal load, in which *Achlya* sp., *Aqualinderella* sp., *Pythium* sp. and *Saprolegnia* sp. are found to be common. On the inter depth samples, the incidence is found to low because of less in dissolved oxygen. Along the vertical strata in which these species are found to be common, they are *Allomyces*, *Aphanomyces*, *Dictyuchus Pythiopsis* etc.

*Noctonecta glauca* an insect, naturally found in the riverine and terrestrial ecosystem is used as bait in the isolation of aquatic phycomycetes with reference to the hydro chemical parameters from surface waters situated near Białystok in Podlasie Province of Poland. The highest contents of carbon dioxide, ammonium, nitrogen, phosphates, and chlorides were noted in Biała river of the province, where the species are found to be retarded, when compared to other water bodies in the province, where *Blastocladiopsis parva*, *Achlya debaryana*, *Saprolegnia parasitica* and *Pythium rostratum* are found to be moderately common in the eutrophic conditions of the river (Kiziewicz and Kurzątkowska, 2004). Many of the aquatic phycomycetes, form the class *Chytridomycota* are found to be parasitic on phytoplanktons, which are present in the benthos of lentic and lotic systems and
their role in the aquatic ecosystem, with respect to abiotic factors which have been reviewed with respect to modern state of knowledge (Voronin, 2008).

Diversity of aquatic phycomycetes is found to be more in lotic, when compared to the lentic ecosystem. Distribution of phycomycetes is mainly dependent on physicochemical characteristics of riverine systems, such as pH and total organic matter. Maximum of fungal incidences were found to be in spring and in rainy season, whereas minimum incidence was found to be in winter (Paliwal and Sati, 2009).

Terrestrial fungi are often passively introduced into riverine system in the form of high loads of fungal propagules via inflowing streams, rainwater, and wind (Smirnov, 1964). However, it is often unclear, whether such fungi, lacking typical morphological adaptations, are terrestrial or truly aquatic. For example, species of *Aspergillus* and *Penicillium* are among the most common fungal isolates from terrestrial, freshwater and marine environments, even from deep-sea sediments. Some are active and partially adapted to aquatic habitats. Conversely, true aquatic fungi have been found active in several terrestrial habitats. Some species from class, such as, Deuteromycetes, Ascomycetes and Pyrenomycetes are also found to be dominant in aquatic eco-system. They are regarded as facultative or extra aquatic fungi. These fungi are also found to be present in potable water. The fungal occurrence was found to be more in open wells compared to the bore well samples (Kumar and Saha, 1992).
River receives a various kinds of waste materials, many of them are organic in nature. So, these organic wastes are easily biodegradable by microbes like bacteria and fungi, which are naturally present in water. River sediment contains lot of litter, which is derived from various sources like, plant and animal debris, domestic wastes, Agricultural and industrial effluents.

An important direction in fungal ecological studies is the assessment of their functional role as bicenoses components (Gorlenko, 1981). The Zoosporic fungi are an important component in natural water bodies. They play a greater role in the biological processes in freshwaters such as, productivity, mineralization of organic matter, self purification, water quality formation, the regulation of insects abundance, etc. (Dudka et al., 1987; Mil’ko, 1983; Mil’ko, 1984). The main importance of these fungi as well as other aquatic fungi in the water purification and the transformation of plant residues into fodder used by invertebrates and other organisms (Dudka, 1974). Along with other heterotrophes, these constant dwellers of freshwaters, partially consume live organic matter, but mostly, they process dead organic matter produced and transformed at all trophic levels of aquatic ecosystem, thus, they participate in the formation of the structural and functional organization of aquatic biocenoses (Voronin, 2005; Dudka et al., 1988). Zoosporic fungi participate in the destruction of dead plant substrates, but, the published data on the species composition and distribution of the substrate transforming fungi are scarce (Voronin, 2005).
Hunter (1975) studied the water molds and their role in the degradation of organic matter in the river Great Ouse and its tributaries. The waste which is accumulated in the river creates several problems in the river eco-system. The deposited waste at the bottom carries many toxic substances. These toxic substances are responsible in killing aquatic microbes, which are useful for the biodegradation process.

The presence of multiple cellulolytic enzymes system in a thermophillic phycomycete, *Mucor pusillus* and its components have the specific roles in the degradation of cellulose. They contained hydrolytic enzymes that attacked native cellulose, acid-swollen cellulose, carboxymethylcellulose, and cellobiose. The glucose was the only product of hydrolysis when native cellulose was used as the substrate, Acid-swollen cellulose, when treated with cellulase free of f-glucosidase activity, gave rise to glucose, cellobiose, and at least two higher molecular weight components which were also hydrolyzed in turn to cellobiose and glucose (Somkuti and Babel, 1969).

One of the most important structural polysaccharides of the plant kingdom is cellulose. The degradation of cellulose is often discussed in connection with the action of fungal parasites. The ability of Oomycetes to produce cellulolytic enzymes has been infrequently investigated. In addition, most studies that are reported lack quantitative data. Preliminary investigations of growth on a semichemically defined medium, indicated that, *Pythium mamnmillatum* Meur, *P.*
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dissoticum Drechsler, Pythium sp., Achlya americana Humphrey, Saprolegnia parasitica Coker, and Thraustotheca clavata (de Bary) Humphrey could be utilized for a quantitative investigation of the cellulolytic activity of Oomycetes (Berner and Chapman, 1977).

Thompstone and Dix (1985) identified 25 isolates of Achlya and Saprolegnia sp. and studied their cellulolytic activity. Active cellulolytic enzymes were first observed in Aphanomyces euteiches, Achlya proliferia, A. flagellata, Saprolegnia turfosa and two unidentified isolates.

Chamier (1981) studied the colonization pattern of pectinase in leaf degradation in relation to water chemistry and available inoculum. Further, he reported about fourteen aquatic hypomycetes associated with colonized leaf packs, out of which seven species could elaborate both polygalacturonase and pectin trans eliminases. Tricladium splendon and Articulospora tetracladia elaborated 3PG isoenzymes, while, Tetrachaeum elegans and Mycocentrospora anguitata elaborated an exo PTE and endo PTE activity, respectively. They utilized PTE'S mainly with in 9 to 12 days, completely macerarting the strips of adler leaf. He also pointed out that, the degradation of Alllochthonous litter was most rapid in streams of high calcium concentration.

Singh (1982) studied the cellulose decomposition of the five species of aquatic hypomycetes like Angullospora longissma, Latrimulosa uninflata, Lunulospora curvula, Margarisispora aquatica and Triscelophorus monosporous.
He also provides evidence about these fungi, played an active role in the decomposition of leaf material in water surface area. Average aquatic hypomycetes grew better and faster, when easily digestible substances were available in water.

In woodland streams and rivers, aquatic fungi are commonly associated with decomposing plant detritus. Studies of aquatic hypomycetes grown on leaves in culture indicate, these fungi can colonize and degrade leaf litter (Chamier and Dixon, 1982; Suber Kropp and Klug, 1980, 1981; Suber Kropp et al., 1983). All species of aquatic hypomycetes examined to date, soften or macerate the leaf matrix and cause significant dry weight losses. They also release necessary enzyme complex to degrade structural polysaccharides (Pectin, lignin, xylan and cellulose) present in plant litter.

Sources of fungal colonization of plant materials can also improve the resulting detritus as food (Barlocher and Kendrick, 1973ab, 1981). Many workers have shown that, higher fungi are active bio degraders in marine environment. On the other hand, the results of several studies have shown that, aquatic hypomycetes actually decomposes leaves and in turn utilized as nutritional sources.

Kohlmeyer (1968) and Schatz (1983) observed that, the colonization of fungi on decaying leaves showed, changes in the total carbon and nitrogen content in the detached strip tissue and determined the pattern of microbial activity in decay process.
Straminipiles and other true fungi are the active group in riverine ecosystem. Their extra cellular enzymes degrade complex macromolecules. A characteristic community dominated by *Nowakowskiella elegans, Phytophthora* sp. and *Pythium* sp. were found and their changes in the fungal community structure over time (succession) was observed in terrestrial mitosporic fungi, which appeared during the early stages, zoosporic fungi, straminipiles, and aquatic hypomycetes appears in early-to-intermediate stages, while representatives of the phylum Zygomycota were found at early and later stages of the decomposition. These observations highlight the importance of zoosporic fungi and straminipiles in the degradation of organic substances in aquatic ecosystems (Marno *et al.*, 2009).

In this scenario, a detailed study has been undertaken in understanding the diversity, periodicity and seasonal variation of several aquatic fungi and extra aquatic fungi, with regard to some of the important physico-chemical parameters of the riverine ecosystem, that are governing their distribution and seasonal variation. Some of the important and abundant species of aquatic and extra aquatic fungi are isolated and studied for their biodegradative ability of cellulosic substances.