CHAPTER 1: INTRODUCTION

1.1. Significance of freshwater resources

Water and freshwater ecosystems are critical to sustaining all forms of life including humans (McAllister *et. al.,* 1997; Small and Cohen, 1999; Greenhalgh, 2001). It is used not only for drinking but also is fundamental for the sustenance of environmentally dependent livelihoods (Daily *et. al.,* 1997; Gleick, 1998; Daily *et. al.,* 2000) such as agriculture, industrial activities, transportation, energy production, waste disposal and food extraction (Small and Cohen, 1999). Therefore, without adequate quantity and quality of fresh water sustainable development will not be possible (Kumar, 1997; Mahananda *et. al.,* 2005). The provision of good quality household drinking water is often regarded as an important means of improving health and key to increase human productivity and long life (Urbansky *et. al.,* 2002; Moyo *et. al.,* 2004; Mandal *et. al.,* 2009). Therefore, every effort should be made to achieve drinking water quality as safe as possible (WHO, 2008a).

1. 2. Threats to freshwater resources

Despite the significance of freshwater, the availability of freshwater on the earth is very small and it represents only about 2.75 % of the total water available on the earth. About one third of the drinking water requirement of the world is obtained from surface water sources like rivers, canals and lakes which represent a mere 0.3 % (Pidwirny, 2006). Globally, 3240 km^3 of fresh water is drawn and used annually; 69% of this is used for agriculture, 23% for industry and 8% for domestic purposes (WRI, 1992). However, freshwater resources throughout the world are deteriorating (Gupta *et. al.,* 2005). A variety of anthropogenic activities such as increase in population, industrial development, overuse of fertilizers, pollution and deforestation are some of the major causes of diminution and degradation of the available water resources (Gupta *et. al.,* 2005). These factors in turn have added stress on the available water resources (UN, 2009).

The lack of access to water limits sanitation and hygiene practices in many households, especially rural, where water is prioritized for drinking and cooking purposes (Addisie, 2012). Thus, poor water quality continues to pose a major threat to human health with diarrhoeal disease alone causing an estimated 4.1 % of the total

Daily Adjusted Life Years (DALY) global burden of disease (WHO, 2004a). Nearly one billion people are living without the access to clean drinking water (Holmstrom, 2012) with an almost 3 billion people in the world facing water scarcity (UNDESA, 2014). Accordingly, in recent times most cases of cholera and abdominal infections reported in hospitals can be traced to the consumption of polluted and contaminated water (Agha, 2006; Kumbhar *et. al.,* 2014). Owing to population explosion pressure and increasing pollution of water resources, at least 30,000 human deaths are caused daily by contaminated water and poor sanitation and more than 1.7 billion people have no direct access to freshwater; this number is likely to double within the next 25 years (WHO, 1992). About one-fifth of the world's population lacks access to safe drinking water and with present consumption patterns two out of every three persons on the earth will live in water-stressed conditions by 2025 (Fletcher, 2002). Pollution, scarcity of water resources and climate change will be the major emerging issues in the next century (UN, 2009).

1.3. Lake water pollution

Lakes are important sources of drinking water, however a number of anthropogenic activities are responsible for lake water pollution which may have either point or nonpoint sources (Carvalho *et. al.,* 2002; Adak *et. al.,* 2002; Sedamkar and Angadi, 2003; Kerker, 2003; Halvorsen, 2004). Grazing, birds' defecation, malfunctioning septic trenches (Johnson *et. al.,* 2004), agricultural runoff, municipal wastes, combined sewer overflows and wastewater and industrial effluents (McLellan, 2004; Karikari and Ansa-Asare, 2006; Ahmed *et. al.,* 2005, 2009); garbage and oil spills (Admassu *et. al.,* 2004) are potential point and non-point sources and threats to lake water pollution. Non-point sources of contamination are of significant concern with respect to the dissemination of pathogens and their indicators in the water systems (Girones *et. al.,* 2010). Faecal contamination is known to be a major source of pollution and of grave concern in a number of lakes worldwide (Niewolak, 1998; Kistemann *et. al.,* 2002; VanPoucke and Nellis, 2000; Derlet *et. al.,* 2005; Chaidez *et. al.,* 2008) because in general, human faecal wastes have the highest risk of waterborne diseases, environmental degradation, and economic losses (Field and Samadpour, 2007; Balleste *et. al.,* 2010). In India also, a large number of lakes have been subject to lake water deterioration associated with human activities and some of the examples are mentioned below (Table 1.1).

Table 1.1. Lake water deterioration associated with human activities

Source/causes	Impacts	Reference(s)
Urbanization	Lake drying and disappearance	Indira and Shivaji, 2006; Mathur *et. al.,* 2008; Sinha and Biswas, 2011; Kumari *et. al.,* 2011.
Cleaning, washing and bathing activities	Decline in lake water quality, eutrophication	Jha and Barat, 2003; Pradhan, 2004; Koshy and Nayar, 1999; Sinha and Biswas, 2011; Sati *et. al.,* 2011; Thakur *et. al.,* 2014, Geetha *et. al.,* 2014.
Sewage, industrial effluents, domestic and industrial waste disposal	Water quality degradation, eutrophication, loss of self-purification capacity	Paratkar *et. al.,* 2004; Prakash *et. al.,* 2005.
Agricultural waste runoff	Leaching of chemicals, eutrophication	Rathod *et. al.,* 2014
Religious and cultural activities	Leaching of chemicals, eutrophication	Walavalkar and Tekale, 2004; Mathur *et. al.,* 2008; Puri *et. al.,* 2011.
Tourism associated activities and infrastructural development	Increase in turbidity, loss of aesthetic value, eutrophication	Mathur *et. al.,* 2008

1.4. Rationale of the study

Lakes in the Himalayan region are not only known for their picturesque beauty and attract tourists from worldwide; in temperate and alpine locations, they are also one of the most important sources of water supply along with springs. However, the availability of potable water has always been one of the major problems in many areas of the Himalayan region including Darjeeling Hills. The population growth in the region has further led to water scarcity and other sanitary problems (Chhetri and Tamang, 2013). Mirik Lake and Jorepokhari Lake are two such lakes in Darjeeling Hills which form the primary sources of drinking water for the communities of Mirik and Sukhia Pokhari town. These artificial lakes are also famous for tourism attracting a large number of tourists every year. However, growing urbanization around the lake, construction of infrastructure for attracting tourism, deforestation in the catchment areas of the lake and encroachment in the lake area along with several anthropogenic activities like bathing, washing, cattle rearing around the lake shores, offerings during religious ceremonies and rituals, recreational activities like boating and horse riding, dumping of garbage particularly in the Mirik Lake have degraded the water quality which could be a serious threat to public health in future (Sinha and Biswas, 2011). Diarrhoeal disease associated with consumption of contaminated water adds to the global burden of disease (WHO, 2004b). Therefore study on the water quality of these lake waters, pollution load and identifying sources of pollution and ways to resolve the water impacts is imperative.

A number of studies have proved that plants possess a range of anti-diarrhoeal properties (Goh *et. al.,* 1995; Vieira *et. al.,* 2001). However, scientific exploration of such plants in the Darjeeling Hills are scanty (Rai and Sharma, 1994; Saha *et. al.,* 2011) and many of the studies have focused on documentation and taxonomic studies in the region (Yonzone *et. al.,* 1984; Rai and Bhujel, 1999; Das, 1995, 2004, Das and Mondal, 2003; Gurung and Palit, 2007; Das *et. al.,* 2010; Tamang and Palit, 2010; Mukherjee and Chanda, 2010). Only a few recent studies have revealed that some amount of work has been conducted on antimicrobial properties and phytochemical analysis of some of the local medicinal plants (Saha *et. al.,* 2011; Rajbhandary *et. al.,* 2011). The confirmation of the antimicrobial properties of traditional anti-diarrhoeal medicinal plants of Darjeeling Hills would be useful to treat the patients in case of outbreak of intestinal diseases and unavailability of antibiotics and also help the population of the area in escaping the side effects of antibiotics (Sharma, 2005).

Therefore, this research attempts to study the microbiological contamination of the Mirik Lake and Jorepokhari Lake along with Nakhapani Lake and anti-diarrhoeal properties of some traditional medicinal plants of the Darjeeling Hills on the pollution indicator microbes of the lake water.

1.5. Objective of the study

The main objective of this research is to study the microbiological quality of water of three important lakes of tourist importance in Darjeeling Hills. The specific objectives of the research are:

- To assess bimonthly variation of few physico-chemical properties of the lake-waters.
- To assess bimonthly variation of the density of total bacterial population, total and faecal coliforms and faecal streptococci in the lake-waters.
- To determine the biochemical properties of the selected coliform isolates.
- To determine the antibiotic sensitivity pattern of the selected coliform isolates.
- To assess antimicrobial properties of few locally used antidiarrhoeal medicinal plant extracts on the coliform isolates
- To construct a native PAGE profile of the selected coliform isolates.