CHAPTER 1

INTRODUCTION
1.1 Background

The ecosystem comprises both biotic and abiotic components and the interactions between them. A well functioning ecosystem is integral to the existence of the living organisms. The ‘five basic elements’ central to the ecology is well stated in the Prasna Upanishad as “kshiti, jal, pawak, gagan, sameera; panch tatwa yah adham sharira”. This means soil, water, fire (energy), sky (space) and air, respectively, are integral part of our existence and the living world surrounding us (Singh, 2008; Lal, 2010). One of the ‘basic elements’ essential for our survival is the water. Water, the most wonderful of all natural resources, is rightly called the elixir of life, as life cannot exist without it. The hymn IX of Book 10 of the Rig Veda recognizes the ability of water to give life both in physical and spiritual senses. It is responsible for nourishment, health and wellbeing of the living organisms. The prayer emphasizes that bountiful supply of water, the most delicious sap, should always be available in pure form (The Rig Veda: An Anthology by O’Flaherty, 2000). Proper knowledge of conservation and management of water resources is necessary to maintain their purity. The Isha Upanishad says: “the nature gives resources to the mankind for their living and it is absolutely necessary to have the knowledge of using these resources” (Jha, 2002; The Asian Tribune, 2007; Lessem et al., 2013)

1.2 Water as a natural resource and its present state of affairs

The natural surface water, which includes sea water, rivers, lakes, polar ice and glaciers, contains numerous life forms such as phytoplankton, zooplankton, fish and many other organisms. The presence of dissolved gases like oxygen and carbon dioxide is essential for the aquatic biota. The pure water, on the other hand, means water free from living organisms, especially microbial life, all types of toxic materials, and having salts within tolerable limits. The occurrence of pure water is absolutely indispensable for drinking and
cooking; and is also required for industrial, agricultural and various other purposes. Although about three-fourths part of the earth is made up of water sphere, very little quantity of it is in usable form. Moreover, in search of better life quality, human beings have introduced loads of toxic materials and other contaminants into the water, from urbanization, industrialization, change in land use pattern, making water unsafe for many purposes, including drinking. Presently, water has become a precious commodity because of human-induced developmental activities, and its quality is threatened due to pollution (Dasmohapatra, 2011).

Water quality deterioration and problems incurred due to it were acknowledged by the United Nations Conference on Environment and Development, Rio de Janeiro, Brazil, 1992. The chapter 18 of the “Agenda 21” document on ‘protection of the quality and supply of freshwater resources’ lays down principles and guidelines for effective management of water resources (UNCED, 1992). Freshwater is in essence a finite and vulnerable natural resource, essential to sustain life, development and the environment (Singh et al., 2012). The modern society and lifestyles have extensively contributed to the rise of manufacture of chemicals and use; and with this has come concerns regarding the presence of environmental chemicals in water resources. Although the terms ‘contamination’ and ‘pollution’ are used in similar sense in everyday speech and journalism, the scientific community has different meanings for them. The term ‘contamination’ is used for a chemical when it is present in a given sample without any evidence of harm, and ‘pollution’ is used in situations when the presence of the chemical is causing harm. Thus, pollutants are the chemicals which can cause environmental harms (Ranveer et al., 2012). Polluted surface waters critically alter the balanced ecosystem which is essential for the beneficial interactions of the living things and the environment.
(İscen et al., 2008). In other words, pollution leads to disturbance of harmony in the nature.

It is not that only developing countries are suffering from the acute problems of water pollution, developed countries still continue to struggle with the menace of aquatic pollution. For example, in a recent national report released in the United States on water quality, 45% of the total assessed stream miles, 32% of the total assessed estuarine and bay square miles, and 47% of the total assessed lake acres were classified as polluted (Singh et al., 2012). The water pollution affects productivity due to heavy costs associated with providing safe water. This in turn puts constraints on economic activity (Ranveer et al., 2012). Statistically, India holds around 17.5% of the global population and approximately only 4% of the globally available freshwater resources. In terms of available water, per capita water availability which was 1820 m$^3$/person/year in 2001 AD is estimated to fall down to quantities 1341 and 1140 m$^3$/person/year by 2025 AD and 2050 AD respectively (Hegde, 2012; Manoj and Padhy, 2013). These projections show that by the year 2020 AD India would develop into a water stressed country; with per capita water availability plummeting below the benchmark quantity 1667 m$^3$/person/year. Some factors responsible for this water stressed state are rising population and escalating demand pressure from various sectors ranging from industry to agriculture (Kole, 2005; Manoj and Padhy, 2013).

Pollution renders freshwater undrinkable and unsuitable for consumptions in industrial and agricultural activities. Most of the substances that are regarded as pollutants are actually naturally occurring constituents of the environment, although at levels which are generally non-injurious and harmless. The problem arises when the concentration of these natural constituents increase, usually by human-influenced activities, to levels at which they may produce harmful effects (Radojević and Bashkin, 2006). Water is characteristically referred to as polluted when anthropogenic contaminants impair its properties, which either makes
it unsuitable for human use, such as, drinking, and/or causes a marked deviation in its capability to support its biotic components, such as, communities of fishes. Water is called a unique substance due to its inherent renewing and cleansing properties, by causing breakdown of pollutants and allowing them to settle out, or by diluting the harmful concentrations of the pollutants to tolerable levels. However, the natural purification process is time consuming, and becomes difficult when human interference adds excessive amounts of harmful contaminants in water bodies (Singh et al., 2012).

Water is a vital resource, indispensable for all aspects of human civilization and ecosystem survival and health. However, in recent years, alarming situations of increasing water contamination (and consequently pollution) and scarcities have cropped up (Sharma, 2009); which demands a vast understanding of water science and associated processes. To understand water science it is essential to gain knowledge about its multi-dimensional aspects which involve the sources, composition, reactions and transport of water. The knowledge of aquatic environmental processes forms the basis of understanding water pollution and its control.

1.3 Water body-bed sediment interaction

Both surface water and its bed sediments are used by the aquatic organisms as their habitats. Alterations in the properties of water and sediments can affect the wellbeing of the habitants. This can result in sequential actions affecting all life forms including human beings. The harmful substances released into water bodies become bound to the suspended particulate matters. These particulate matters, in due course, settle down and become part of the bed sediments. The substances, such as toxic elements, adsorbed to the bed sediments can remobilize under changed environmental circumstances, such as, change in
aquatic pH and content of organic matter. Thus, bed sediments which are the regular sinks of the toxic substances can become immediate source of the same substances in the water bodies. Degradation of river bed sediment quality portrays river degradation as a whole because it is the outcome of river water pollution. Environmental evaluation of the river bed sediment, therefore, becomes essential to study the impact of human-induced developmental projects on its quality.

1.4 Aquatic system and environmental health

It should be noted that, conservation of aquatic resources is equally important in terms of both quantity as well as quality (De, 2010). The water pollution is responsible for billions of illnesses and more than two million deaths per year. The patho-physiological conditions imposed by the polluted water are immense (Ranveer et al., 2012; Singh et al., 2012). Water scarcity makes these health problems worse. When pollutants enter the aquatic ecosystems they not only affect the aquatic organisms, but terrestrial life including human beings as well. Rise in quantities of nutrients like nitrogen and phosphorous based chemicals in aquatic ecosystems may lead to increased algal growth, which in turn may give rise to the phenomenon eutrophication that is harmful to the aquatic biota (TOI, 2014a). Pollution of aquatic resources is also spreading antibiotic resistance genes in bacteria that cause many life-threatening diseases. To check proliferation of these detrimental agents, it is urgent to check pollution of aquatic resources. Poor water and sediment quality can also cause decline in biodiversity and mass of aquatic life. Chemical pollution of surface water can cause health hazards, because such water resources are often used directly for domestic consumption or linked with shallow wells utilized for drinking water, especially in developing countries like India. In addition to domestic use such as drinking, cooking, washing and cleaning, the waterways are widely used for fishing and
fish culture, and also for recreational purpose. The water pollution affects the soil health and disturbs the vegetation including crop production (Ranveer et al., 2012).

1.5 Water resources scenario, with special emphasis to river basins, in India

Out of many freshwater sources, rivers are the lifelines of our culture and economy, and severe water pollution is increasingly making them dead. The interlinked concepts of water pollution abatement and resource management are increasingly becoming the top priority of water conservation programmes. However, as mentioned earlier, the availability of water does not mean only quantity; in fact, it includes the quality component as well. The river freshwater resources are increasingly under threat due to rise in pollution level, which is severely affecting the river ecology (Khadse et al., 2008; Bhardwaj et al., 2010; Rita et al., 2011; Shraddha et al., 2011; Srivastava and Srivastava, 2011). Compounding this is the fact that most of the Indian rivers are rain-fed and, therefore, seasonal; and only a few rivers are perennial. Before going to the research problem it is crucial to acquaint about the scenarios of water resources and knowledge of river basins in India. The following paragraphs give a brief description of the water resources and river basins in India.

As per estimates, in India, the total water availability, including surface and ground water, is around 1869 Billion Cubic Metres (BCM). Out of this total content, about 60% (which also includes 690 BCM from surface water) is in usable form. Various geological and topographical considerations make the remaining 40% available water, in current scenario, not accessible for consumption. Precipitation, as rain and snow, provide about 4000 BCM of available fresh waters. However, most of this water is lost to the seas through rivers (Mall et al., 2006; WaterAid, 2008; Manoj and Padhy, 2013). Agricultural sector consumes
about 89% of the surface water, while industrial and domestic sectors consume 2% and 9% respectively (WaterAid, 2008; Manoj and Padhy, 2013).

Based on the catchment area, the river basins have been categorized into three groups, designated as, major, medium and minor. The major river basins, thirteen in number, hold 82.4% of the total drainage basin areas, and account for 85% of the total surface flow. Moreover, these basins house 80% of the India’s population. Furthermore, the country also has some desert rivers (Bhardwaj, 2005; Manoj and Padhy, 2013). The classification system of river basins is given in Table 1.1. A short description of the major river basins is provided in Table 1.2.

<table>
<thead>
<tr>
<th>River Basins</th>
<th>Catchment Area in Km² and %</th>
<th>No. of Basins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
<td>&gt; 20,000 (82.4)</td>
<td>13</td>
</tr>
<tr>
<td>Medium</td>
<td>2000 – 20,000 (8)</td>
<td>48</td>
</tr>
<tr>
<td>Minor</td>
<td>&lt; 2000 (9.6)</td>
<td>52</td>
</tr>
</tbody>
</table>

Table 1.1: Classification system of river basins in India

Source: Bhardwaj (2005)

Although the country is rich in networks of river basins and is productively blessed by the South-West Monsoon (which accounts for 75% of the annual rainfall), the availability of water is increasingly emerging as a huge challenge for its socio-economic and sustainable development (Bhardwaj, 2005; Manoj and Padhy, 2013).

Environmental research of rivers in India is essential because rivers are the lifeline of the country. They sustain population by providing freshwater not only to produce food but also for drinking purposes. In India, regular examination of rivers is also required for the impending river linkage projects. Recently, in the 2014 budget, the Finance Minister
strongly pitched for the inter-linking of rivers, which comprises 30 river-linking projects (TOI, 2014b). The linking of rivers will also make flow of pollutants from one river to another. Thus, for conservation and management of these precious resources, research on rivers becomes all important.

Table 1.2: Description of major river basins in India

<table>
<thead>
<tr>
<th>Direction of Rivers</th>
<th>River Basin</th>
<th>Catchment Area (Km²)</th>
<th>Mean Annual Runoff (BCM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West flowing rivers</td>
<td>Indus (to Pakistan border)</td>
<td>321,000</td>
<td>73.30</td>
</tr>
<tr>
<td></td>
<td>Mahi</td>
<td>35,000</td>
<td>11.00</td>
</tr>
<tr>
<td></td>
<td>Narmada</td>
<td>99,000</td>
<td>45.60</td>
</tr>
<tr>
<td></td>
<td>Sabarmati</td>
<td>22,000</td>
<td>3.80</td>
</tr>
<tr>
<td></td>
<td>Tapi (Tapti)</td>
<td>65,000</td>
<td>14.90</td>
</tr>
<tr>
<td>East flowing rivers</td>
<td>Brahmani and Baitarani</td>
<td>52,000</td>
<td>28.50</td>
</tr>
<tr>
<td></td>
<td>Cauvery</td>
<td>81,000</td>
<td>21.40</td>
</tr>
<tr>
<td></td>
<td>Ganga</td>
<td>861,000</td>
<td>525.00</td>
</tr>
<tr>
<td></td>
<td>Godavari</td>
<td>313,000</td>
<td>110.00</td>
</tr>
<tr>
<td></td>
<td>Krishna</td>
<td>259,000</td>
<td>78.10</td>
</tr>
<tr>
<td></td>
<td>Mahanadi</td>
<td>142,000</td>
<td>66.90</td>
</tr>
<tr>
<td></td>
<td>Pennar</td>
<td>55,000</td>
<td>6.30</td>
</tr>
<tr>
<td>Eastern India</td>
<td>Brahmaputra</td>
<td>194,000</td>
<td>585.00</td>
</tr>
</tbody>
</table>

*Source: Smakhtin and Anputhas (2006)*

1.6 Research problem

In the last decade research work on river basins has increasingly gained momentum in India (Singh et al., 2005a,b; Begum and Harikrishna, 2008; Sundaray et al., 2009;
However, comprehensive environmental quality assessment of the river basins has largely remained ignored. Except for a few studies, such as on the Gomti River (Singh et al., 2005a,b) and the Hindon River (Suthar et al., 2009a,b), only partial studies are available for most of the rivers. One of the river systems whose comprehensive assessment has largely remained unapprised is the Subarnarekha River. Some of the most important industrial, mining and urban belts of India are located along the Subarnarekha basin. The basin area lies mostly in the Indian state of Jharkhand. The river for the most part flows through the tribal regions and is widely exploited for industrial, agricultural and domestic purposes. The Subarnarekha River stays more or less as a stagnant pool in its upper and middle reaches. As the groundwater resource of the region is still underutilized, the Subarnarekha and its tributaries become the main sources of water supply for the urban consumption. About 60% of the water supplies, in due course, return back to the Subarnarekha River system as waste (CPCB, 2011). It is the major surface freshwater body which receives wastes and discharges of industrial and populated regions like Ranchi, Adityapur, Jamshedpur and Ghatsila located along the basin. Discharged effluents of heavy and small scale industries, runoffs of mined areas and the generated domestic and municipal wastes of the rural and urban areas enter the river. Because of limited and inadequate conventional water treatment plants additional stress on the freshwater ecology of the river occur. Presence of rich amount of mineral resources along the river basin has led to a significant occurrence of mining and mineral processing units. Based on the information discussed above; and the relatively new occurrence of two activities i.e., excessive river bed quarrying for construction materials and encroachment, a comprehensive appraisal of the water and sediment environment of the Subarnarekha River system becomes essential for its conservation and management with respect to
ecological reasons and applicability for activities such as domestic and agricultural consumptions. The following section provides a brief description of the Subarnarekha basin.

1.7 The Subarnarekha River basin

The word “Subarnarekha” literally means “streak of gold”. The Subarnarekha River derives its name from the precious metals because its sand contained very fine particles of gold (Dora and Roy, 1987). The Subarnarekha River drains three Indian states, namely, Jharkhand, West Bengal and Odisha (formerly Orissa), and covers 395 km, before meeting the Bay of Bengal (Figure 1.1). The river rises on the eastern slopes of the tropical Chottanagpur plateau in the Ranchi district of the landlocked state Jharkhand, which also has the greatest presence of the river. The river travels 269 km in the Jharkhand state (Forest Resources Survey, 2006). The Subarnarekha River, situated in the northeast corner of the Peninsular India (CWC, 2006), is one of the most important interstate rivers. The basin has catchment area of about 19,236 km$^2$ and can almost be classified as a major basin. Its annual runoff and specific yield is estimated to be 10.8 km$^3$/year and 370 mm/year respectively (Subramanian, 2004). The Chottanagpur plateau marks the north-west portion of the basin, while the south-west, south and south-east is delineated by the Brahmani River basin, the Burhabalang River basin and the Bay of Bengal respectively (IRBMS, 2012). The Subarnarekha basin along with the Rasulpur and Piehabani streams (total 19,296 km$^2$), two small streams between the Subarnarekha and the Burhabalang Rivers (2,418 km$^2$), the Burhabalang River basin (4,837 km$^2$) and two small streams between the Burhabalang and the Baitarani Rivers (2,645 km$^2$) comprise total catchment area of 29,196 km$^2$ (NIH, 2010).
The Subarnarekha basin is asymmetrical and elongated in shape, and is one of the most important inter-state river basins in India. The basin occupies 0.6% of the country’s total geographical area (Roy et al., 2013). As per the assessment of the International Water Management Institute (IWMI, Colombo, Sri Lanka), the population density of the basin is 347 persons per km², which is much ahead of the national average of 282 persons per km²; and out of the total estimated population about 76% is rural (Amarasinghe et al., 2004 for IWMI).

**Figure 1.1: The Subarnarekha River basin**

Based on the points raised in the previous two sections, a systematic assessment, characterization and classification of the Subarnarekha River environment in the Jharkhand state, where it is most industrialized and urbanized, was undertaken with the objectives mentioned below.

1.8 Specific objectives of the research

1. Physicochemical characterization of the Subarnarekha River water and sediment to understand the most recent environment quality of the basin.

2. Development of statistical approaches to describe the river basin.

3. To assess the impacts of different Subarnarekha water quality on the physiology of the organism, through mice model, with respect to oxidative stress mechanisms.

4. To propose and suggest suitable conservation and management scenarios for the Subarnarekha River basin on the basis of outcomes of the investigation.

1.9 Structure of the thesis

The Thesis is organized into 7 chapters. Chapter 1 introduces the present aspects of the surface water resources, especially with respect to the river watercourse, and their bed sediments; issues of water and bed sediments pollution and their potential impacts; the river basins in India; the research problem and the objectives of the research. Chapter 2 deals with the literature review on various aspects of the research problem including statistical approaches and oxidative stress mechanisms.

Chapters 3, 4 and 5 are written in the form of a paper manuscript, albeit in more detail, and include the methodologies, results and discussions of each individual aspects i.e., river water quality, bed sediment quality and physiological complications. The river water quality has been presented as the physicochemical characterization (Chapter 3) and trace elements analyses (Chapter 4) of the Subarnarekha. Chapter 4 also includes geochemistry
of the Subarnarekha River. Chapter 5 deals with the assessment of oxidative stress in model organism from deteriorated water quality.

Chapter 6 provides some suggestions which can be employed for the conservation and management of the Subarnarekha River basin. Chapter 7 gives an overall summary and conclusion on major findings of the different aspects of the investigations undertaken; and proposes a few key measures regarding further research in the area of river basin management in India.

Finally, the bibliography section provides all the cited works that were used to write this thesis.