

INTRODUCTION

1.1. Background

Life without water can't be thought of, therefore, the rivers being the major source of water are the backbones of civilization. Since ages, rivers have been taken as a source of water. For people in India, River Ganga is "MOTHER GANGA". Seeing its importance, the Government of India declared River Ganga as the National River in the year 2008 (MoWR, 2014). However, the river is getting polluted from many sources, including domestic sewage flow, industrial wastewaters and surface runoff from fields. Different types of pollutants enter the river system which affect the water quality in turn affecting the aquatic organisms present in riverine environment (Etchanchu and Probst, 2006; Guillaud and Bouriel, 2007; Yang et al. 2010; Bouguerne et al. 2017). To protect the rivers from degradation river health assessment and monitoring is needed. For most of the times, water resource managers understand water quality by measuring a few physico-chemical and bacteriological parameters and suggest its suitability for various beneficial uses. Ganga River Basin Management Plan (GRBMP) 2015 of Government of India has considered River Ganga as 'Ecological Entity'. From this perspective, researchers and experts in the field have been feeling the need to define River Health, and parameters for its assessment. The river is important because they provide water for various uses such as drinking, industry, agriculture, electricity generation, recreation, transportation and during floods rivers also act as buffers. In addition, a healthy river also provides fish and other products for human use and

benefits. As rivers become unhealthy, they lose their capacity to provide these valuable goods and services. It has been realized that in addition to physico-chemical and bacteriological water quality parameters, it is necessary to include aquatic organisms, such as algae, macroinvertebrates and fishes present in the riverine environment as indicators to define river health. These aquatic organisms convey the integrated and continuous characteristics of water quality. Therefore, many experts (Hawkes, 1979; Sladeczek, 1979; Tittizer and Koth, 1979; Hellowell, 1986; Rosenberg and Resh, 1993; Allan, 1995, Bonada et al., 2006; Carter et al. 2006; Carter and Resh, 2013) are of the view that algae, macroinvertebrates and fish should be considered as suitable indicators for assessing the health of the river.

1.2. Need of the Study

Till date, for achieving sustainable river management targets numerous river health assessment methodologies have been proposed using water quality parameters, aquatic biota, condition of the riparian zone, sediments and combined indices (Brown et al., 1970; Simpson et al., 2000; ISC, 2006). However due to large geographical area, different characteristics of catchment and species present in different habitats in river systems throughout the world, it has not been possible to develop comprehensive methodologies of assessment of river health for world river systems (Pinto and Maheshwari, 2014). Very few studies are available on the river health assessment in India. Baruah et al. (2011) assessed the health of the river Subansiri (Assam, India) and identified a meaningful way for assessing the status of river health. The study noted that riparian flora, fauna, crops, fishes depend almost exclusively upon their streams' flooding cycles for their way of life. Joshi (2013) developed an Ecological Quality

Index (EQI) for evaluating the health of ecology in Mutha river in Maharashtra, India. Yadav et al. (2014) calculated river health using Ecological Quality Index (EQI), River Pollution Index (RPI) and Overall Index of Pollution (OIP). Yadav et al. (2015) calculated the Ecological Health Index (EHI) of Chambal River by using EQI equation developed by Joshi (2013). The terms 'EQI' as used by Joshi (2013) and 'EHI' as used by Yadav et al. (2015) appears to be the same.

These developments indicate a strong possibility to define and develop a River Health Index (RHI) which is reflective of true ecological state of the stream. An overview of available literature on the subject of River Health indicates that by now it has evolved from conceptual levels to measurable models. However in India relatively very few studies have been done and reported in terms of River Health Assessment. In order to precisely define and express the health of a river, it appears that apart from the water quality parameters as currently being monitored by Central Pollution Control Board (CPCB) of India on regular basis, there is a definite need to include estimation of algae, macroinvertebrates and fish species, to formulate a River Health Index (RHI). Based on RHI, the stretches of river can be marked as healthy or unhealthy. Overall a proper definition of river health including abiotic and biotic parameters and indexing system for river health assessment appears to be the need of the hour.

1.3. Objectives of the Study

Broad objective of the present study is to formulate a Framework for River Health Assessment based on Water Quality and Biotic Indicator groups.

Specific Objectives may be enlisted as follows:

1. Identification of Water Quality and Biotic Indicator groups and parameters/indices to be included in each Indicator Group.
2. Setting 'Target' value (Healthy condition) and 'Critical' value (Unhealthy condition) limits of each parameter/index.
3. Development of Indicator Group Score and formulation of **River Health Index (RHI)** using these Indicator Group Scores.
4. To categorize **River Health Condition (RHC)** based on River Health Index (RHI) score.
5. Representing River Health Condition (RHC) in colored pictorial form.
6. Identification of critical parameters if any for 'Poor' River Health Condition.
7. Suggestive phased intervention plan for river health improvement/restoration.

1.4. Organization of the Thesis

This thesis is organized into five Chapters:

Chapter 1: Gives a brief description of the importance of water quality and biotic parameters in the River Health Assessment. The need and objectives of the study are outlined.

Chapter 2: Reviews the whole range of available literature covering different aspects of River Health Assessment. Approaches based on physico-

chemical and biological indicators have been described. A critical review of some of the studies on different rivers conducted around the globe has been presented. Finally, the research gaps have been identified and summarized.

Chapter 3: Presents a proposed framework for River Health Assessment and discuss the overall research methodology adopted in this study.

Chapter 4: Presents the results and discussion on the validation of the proposed River Health Assessment Framework using observed data on river Ganga near Varanasi. Subsequently the application of this framework has been extended on river Ganga along six Indian cities stretching from Rishikesh to Patna. A two-phased Intervention plan for River Health Improvement has also been presented and discussed.

Chapter 5: Summarizes the major finding and list the conclusions drawn from the study. It also includes the recommendations and scope for the further studies.