Integrated Effects of Climate Change and Pollution on the Ganges River Biodiversity

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Introduction

In its fifth assessment report, IPCC has drawn the attention of the world by projecting the increase in average global temperature by 1.5-4.5°C (IPCC, 2014). According to this assessment, the globally averaged combined land and ocean temperature shows a warming of 0.89 (0.69 to 1.08) °C over the period 1901–2012; with the rate of warming at 0.05 (−0.05 to +0.15) °C per decade over the past 15 years (1998–2012). This report postulates that with increase in warming; the freshwater-related risks of climate change is likely to increase significantly where each degree of warming is projected to decrease renewable water resources by at least 20%. These trends may exacerbate the problems of raw water quality due to of increase in temperature, sediment, nutrient and pollutant loadings due to heavy rainfall; reduced dilution of pollutants during droughts, and unmanageable treatment facilities during floods (Sun *et al*, 2012).

Under diverse processes of climate change; the rivers are in unsafe state as due to their unique properties of turbulence and mixing, rivers respond to changes in atmospheric conditions quite easily and thus becoming warmer (Durance and Ormerod, 2009). It is now well established that increase of temperature influences physical, chemical and biological properties of aquatic ecosystems imparting undesirable impacts on the water quality causing changes in planktons and in turn affecting the animal-plant structures at the higher trophic levels (Arain, 2011). Temperature increase may alter pollution degradation, ambient partitioning of pollutants and solvent depletion in river waters (Meyer and Wania, 2008). Together with increased salinity this is able to enhance the toxicity of pollutants in aquatic biota by changing biotransformation mechanisms of contaminants impairing homeostasis and affecting physiological responses, reproduction, and development of aquatic organisms (Noyes *et al.*, 2009). These complex interactions between climate change and contaminants are dangerous for vulnerable species having low physiological tolerance range (Noyes *et al*, 2009).

The Ganges basin is the part of the combined Ganga-Brahmputra-Meghna basin spread across China, Nepal, India and Bangladesh (Figure 1). Out of the total drainage basin area roughly 80%, is located in India covering around one-fourth of the country's total geographical area and thus is biggest river basin of India. It has much complicated hydrology with peak discharge between 70000 m^3/s to 180 m^3/s; highly seasonal stream flow with average dry season to monsoon discharge ratio of 1:6, causing both drought and flood in this river basin. Together associated with population explosion and indiscriminate urban-industrial growth along this river basin, massive fluxes of nutrients and other contaminants are being added day by day. Consequently it is witnessing huge concerns for its increasing pollution levels and associated ecological crisis. Increased temperature and irregular rainfall patterns over this basin in recent decades has stimulated climate change stressors causing threat of ecological as well socio-economical crisis to it (Tripathi and Singh; 2013). So it is imperative to view the status of pollution and other ecological problems associated with this river in the context of regional climatic change and weather variations to understand the complex relations among pollution problems and climatic stressors acting in this river basin.

Interrelation of climate change and pollution in Ganges basin

From India, sporadic reports are available about the climatic impacts on water systems, and

Figure 1: Ganges basin map (source: Google)

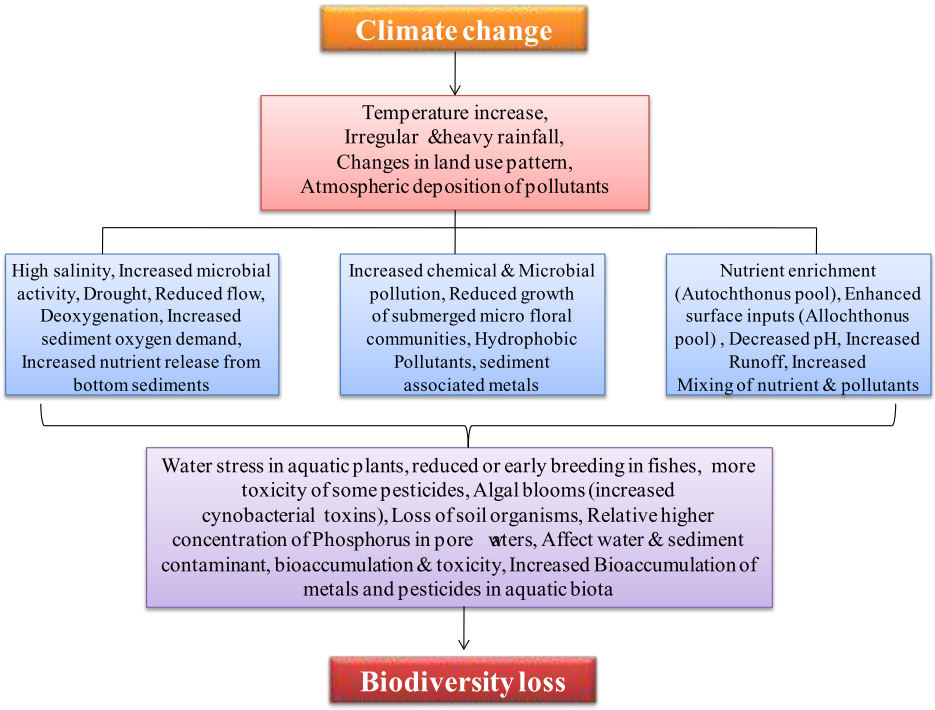

Figure 2: An overview of the climate change interaction with pollution problems and their combined impacts.

most of them are limited to assessing temperature and rainfall analysis over a time period and effects on the species distribution in river (Nautiyal *et al*, 2013; Tripathi and Singh, 2013). There are evidences about a marked change and shift in weather patterns over Indo Gangetic region which can be noticed by increasing mean annual maximum and minimum temperature and decline in total monsoonal rainfall (Tripathi and Singh, 2013). Few studies have taken into account the impact of climate change on river hydrology and hydro-geochemical dynamics of Ganges basin (Gosain *et*

A: *Glossogobius giuris* (courtesy: Randall J.E.)

B: *Xenentodon cancila* (courtesy: Enrico Richter)

C: *Cyprinus carpio* (courtesy: Google)

D: *Aristichthys nobilis* (courtesy: Google)

Figure 3: Some examples of the Ganges fishes affected due to change in climate in this region (A-B) and alien fish species which are being found in the Ganges river basin (C-D).

al, 2006). Various simulation studies on extreme temperature over Gangetic basin show considerable seasonal and spatial variations due to warming with increasing numbers of warm nights/days as compared to cold ones (Cluis and Laberge, 2001).

Variety of pollutants arising out and getting transformed due to climate change and are causing danger to Gangetic ecosystem (Raha *et al,* 2012). Erosional features, salinity increase and more sedimentation in this river system are now prominent (Manna *et al*, 2013). Future changes in temperature and precipitation scheme in the Ganges river basin, may also increase the extreme events in the basin leading to more pollution load (Whitehead *et al*, 2015; Figure 2). Atmospheric nutrient loading in Ganges river basin is also big problems which also pollute the water along with anthropogenic pollution sources but model projections and scenario developments to estimate future effects are clearly lacking (Pandey *et al*, 2015). Distribution and transport of carbon, nitrogen, phosphorus and silicon in Ganges basin is linked to climatic aberrations and their interactions are complex (Singh *et al*., 2007). Arsenic and fluoride concentration and salinity increase in Ganges river basin in recent decades are also some important problems which have some linkages with changing temperature regimes of this basin (Raha *et al*., 2012). Since arsenic and fluoride is mainly derived from weathering which is directly affected by changes in pH, temperature and solubility product of chemical, the variation in climate would have interrelations with leaching of theses in water (Wetzel and Likens, 2000). It is predicted that the increase in temperature and decrease in precipitation can reduce groundwater recharge by 50%, raising salinity of soils and waters in catchments (Cañedo-Argüelles *et al*, 2013). Increased monsoon flow and flux also affect the concentration and dispersion pattern of metal pollutants in sediments of Ganges Rivers (Mittal *et al*, 2014; Figure 2). Most monsoonal discharge has also been notified to add the elevated levels of some radioactive elements such as Ba, Ra and Sr in Ganges river basin basically due to increased chemical weathering in Himalayas region and subsequent changes during transportation and deposition process which would be somewhere indirectly

linked with changing climate in this region (Singh *et al*, 2010).

Integrated effects of climate change and pollution on biodiversity of Ganges system

Under the influence of climate change, the organic matter and nutrients load in the river interact with many environmental factors changing the physiological properties of the water and thus affects its biota (Mittal *et al*, 2014). The Ganges river basin is witnessing the alteration in fish population dynamics, diversity and community structures for which climate change induced sedimentation and species invasion are thought to be the major cause (Sarkar *et al*, 2012). Invasion of alien fish species in the Ganga River is a threat which is related to changes in food chain and biotic communities which are the results of climate and pollution induces changes in the river (Singh *et al*, 2013; Figure 3). Downstream sediment transport by the river under increased flood conditions has caused much danger to fish biodiversity in this basin (Sarkar *et al.*, 2012). The increased temperature and related change in pollutant behaviour affect biodiversity spatial patterns in structure and distribution of benthic diatoms, macro invertebrates and ichthyofauna in Ganges (Nautiyal *et al*, 2013). An investigation reports 0.99°C increase in minimum water temperature in the upper stretch of river Ganges and 0-1.4°C increase in aquaculture waters of some Gangetic plains impacting breeding in native fishes and increasing the assemblages of non native fishes in polluted upstream (Das *et al,* 2013). The changes in thermal stratification in water columns may also impact the prey-predator relationship of this river causing manifold damages (Vass *et al*, 2009, Manna *et al*, 2013). An impact of climate change on breeding is evident in the advancement and extension of the breeding period of Indian major corps (Vass *et al*, 2009). Under the influence of climate change, a geographic shift of warm water fish species Glossogobius giuris and Xenentodon cancila (Figure 3) to the colder stretch of the river Ganga is a characteristic example. The predator prey ratio in the middle stretch in the river Ganga has also declined in the last three decades. The shift in minimum air temperature coupled with increase in post monsoonal rainfall is clearly evident in this basin which has impacted the warm water fish migration and spawning in great deal (Sinha and Khan, 2001).

Ganges River biodiversity facing threats due to rise in water. Temperatures and temperature is an important influencing factor controlling the occurrence of different phytoplankton (Singh, 1993). Variability in pre and post monsoonal flow has been an important factor to assess the pollution variance in these river systems. Several water quality parameters such as turbidity, transparency, DO, pH, free CO2, specific conductivity, salinity, hardness, silicate silica remarkably affect the distribution of biotic communities and are related with the change in the climate of the region (Mall *et al*, 2006). Furthermore, the impact of increasing water temperature and their role in augmenting the pollutant behaviour and their effects on flagship animals of Ganges such as ghariyal, dolphin and turtles are still not established which warrants serious scientific studies. Apart from these studies on the impact of temperature induced changes on the ecology and behaviour of bacteriophages in this river system is also needed. This requires elaborative studies to identify different groups of phages and their role in microbial pollution abatement and the changes under climatic variables and pollutants.

Future approach

Pollution problems in river Ganges are now being viewed with broader aspects and with various dimensions of the climate change. However, there is a huge need to establish various interactive experimental evidences by intriguing climate variables and pollutant interactions to understand pollutant dispersion and transformation and their effects in water, sediments and biota. In view of these facts the river basin management authority should acquire adequate baseline information on water flows and related water quality disturbances interacting with climate change to develop comprehensive scenarios of the likely impacts of climate change in this river basin. Strong management actions should be employed to restore the ecosystem functioning of Ganges River in conjugation with scientific research outputs establishing climate interactions with pollutions. To reduce the

effects of climate change and related pollution problems, making augment water availability in the basin by rainwater collection, water conservation and water abstraction affected optimum flow determination in various segments of the Ganges river is urgently needed.

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