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Drivers of Ecosystem Change: A Case Study of River Ganga

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Abstract

Rivers have always played a vital role in shaping and sustaining various human civilizations and have been the lifeline of human settlements and cities that have flourished along the river banks. Freshwater supply for domestic utilization, industrial use, energy generation, sanitation, transportation, irrigation, livelihood genesis, merchandising in the form of fisheries and livestock, sheltering the biodiversity and promoting ecotourism are the benefits derived from rivers. Besides having cultural importance, riverine ecosystems act as regulators, supporters and provision givers in numerous ways by playing a key role in maintaining ecological sustainability, supporting biodiversity, transporting the nutrients through nutrient cycling, carrying the sediments, wastes and diffused pollutants, mitigating the droughts and floods. Many of these services are inherently related to components that denote the ecosystem status in the form of water quality characteristics, the river flows and its ecological state. The rivers are facing extreme pollution pressures in developing and developed countries such as over-abstraction of the water receding the river flows, inefficiently planned infrastructure developments across the river reaches (dams and barrages), which disturb the flow characteristics, pollution, industrialization, booming population and climate change. Severe degradation of the rivers has led to their decreased ability to contribute to critical ecosystem services. It is one of the biggest risks that the world is facing presently so that the rivers continue to provide these indirect benefits crucial to the present as well as future generations. River Ganga is one of the most important rivers of India from religious, socio-cultural and utility point of view that has sustained the country in innumerable ways over ages. However, due to over-exploitation and pollution arising out of various anthropogenic activities all along its course, the river has come under serious threat leading to its degradation and declining ecosystem services. The present study discusses the potential drivers leading to ecosystem changes in river Ganga.

Introduction

Water resources are most fundamental in sustaining ecological and environmental integrity and preserving life forms on this earth. Rivers are amongst the most crucial water resources that maintain environmental cohesiveness. Riverine ecosystems like any other ecosystem are also a dynamic complex of plants, animals, microbes and various abiotic components, which interact as a system. Rivers are reckoned to be the lifeline of the human beings and play a critical role in generating the livelihoods of the people and supporting their traditions by providing them with widespread benefits. These benefits are the services provided to the people both directly and indirectly by the ecosystem and the biodiversity. Our health and well-being is highly dependent upon these services provided by the ecosystems (Millennium Ecosystem Assessment, 2005a).The ecosystem services have found a comprehensive classification in the form of supporting, provisioning, regulating and cultural services (Millennium Ecosystem Assessment, 2005b).Water provisioning for drinking purposes, for non-drinking purposes(irrigation, industry, navigation, environment flows and others), fisheries (food provisioning),water purification, flood protection, preventing erosion, conserving nursery population, sequestering carbon dioxide, recreation(swimming, boating, kayaking, nature viewing, recreational fishing) are some of the ecosystem services provided by the rivers.

River Ganga holds great importance in India's rich cultural heritage. The river is considered to be very pious and pure that is religiously believed to cleanse the body, mind and soul of the bathers. It provides water for fulfillment of a wide variety of purposes such as drinking and non-drinking use, for production of electricity, for water sport activities, for livelihood generation, for promoting ecotourism and provides habitat for many indigenous and migratory birds. Unfortunately, now the river has been identified amongst the top 10 rivers in the world facing daunting pollution pressures and risks due to the booming population, mass scale emigrations from rural to urban areas, unplanned urban and industrial sectors, construction of dams and barrages across the river reaches, discharge of untreated municipal and industrial wastes, floral and religious offerings, cremation of the dead bodies on the river banks and others (Khwaja *et al*., 2001, WRG, 2009)

Pollution of rivers not only adversely affects the water quality but also gradually degrades the biotic communities thus disrupting the food web. Increasing water demands due to economic development and increasing population often disturb the demand-supply balance. The Water Resources Group (WRG, 2009) has predicted that if the current trend of competing water demand continues, only half of the water demands will be met by 2030.The type of land use in adjoining regions of the catchment area and the type of industries on the river banks have been reported to greatly influence the water quality of river Yamuna and Ghaggar (Kaushik *et al*., 2009; 2010). Anthropogenic activities such as deforestation and overgrazing also impact the water quality and affect the biodiversity of rivers (Joshi *et al*., 2009). As the water quality changes, the ecological characteristics and hence, the provisioning quality and ecological best designated use also changes as reported for river Yamuna (Khaiwal *et al*., 2003).

Ganga is a river, the water of which has been known to remain ever fresh and pure. However, now a decline in dissolved oxygen content and rise in coliform bacteria is reported associated with excessive pollution with sewage, indicating deterioration in its capacity to dilute its pollutants (Agarwal, 2015). The sediment quality is hugely affected due to urbanization in the Ganga stream (Singh *et al*, 2002). The urban clusters along the riverbanks are causing radical changes in the ground water renewal characteristics and also changing the existing systems and processes of the rivers (Misra, 2011).

The present study reviews the ecosystem properties of river Ganga and discusses the major ecological changes that have been reported for the river associated with various factors and their overall impact on ecological services. The study also compares water quality in the upper stretch of river Ganga including Devprayag and Rishikesh- Haridwar region, and the middle stretch of Kanpur and Varanasi region that are exposed to different magnitudes and types of driving forces, which seem to be causing the ecological changes in the river at present.

Materials and Methods

Secondary data on the riverine ecosystem: In order to get information about various important ecological characteristics of river Ganga, secondary data was collected from various reports and documented studies. Data of past years was also collected.

Sampling sites and sample collection for primary data: In order to have primary data on some major water quality parameters of the river in the present times, the upper Ganga stretch including Devprayag and Rishikesh- Haridwar region in Uttarakhand was taken , while in middle Ganga, Kanpur and Varanasi region in UttarPradesh, water was studied. Samples were collected in clean plastic bottles, which were pre rinsed with the sample three times, from all the four regions during pre monsoon season (May-June, 2017). Grab sampling was done for collecting samples from each region in triplicates.

The parameters such as electrical conductivity (EC) and dissolved oxygen (DO) were estimated on the spot immediately to prevent uncertain changes whereas analysis related to other parameters such as biochemical oxygen demand (BOD) and total coliform (TC) was carried out in the laboratory. Water samples for DO determination were collected in BOD bottles of 300 ml capacity. Insulated ice boxes were used to bring the samples to the laboratory for analysis

Analytical methods: The water samples from different regions were analyzed for DO, BOD, EC and TC. For BOD and TC, the 5-Day BOD test and multiple tube fermentation technique were used respectively following standard methods (APHA, 2012). Techniques used for the analysis of various parameters were: DO (mg/L) by Winkler's method, BOD (mg/L) using 5-Day BOD test, Total coliform (MPN/100 ml) by Multiple tube fermentation technique and electrical conductivity (µmhos/cm) by using Conductivity meter.

Results and Discussion

The Ganga riverine ecosystem: River Ganga has its geographical origin at Gangotri Glacier (Gaumukh) in Uttarakhand. Its basin catchment area constitutes 26% of the country's landmass, covering various states. The River traverses a distance of 2525 Km and it is one of the most densely populated river basins in the world housing approximately 40% population of the country and contributing to more than one-third of India's surface water resources, out of which 90% is used for irrigation (NGRBA, 2011; www.moef.nic.in).

The river flow is variable all along its course that greatly depends upon the type of the terrain and slope through which it flows as may be seen in Table 1.

Table 1. Some stream flow characteristics along different sections of river Ganga

Stretch	Section	Avg. Slope of land	Mean annual rate of flow (cum/second)
Source to Rishikesh	Mountainous	1 in 67	850
Rishikesh to Allahabad	Upper Plain	1 in 4,100	850-1,700
Allahabad to Farakka	Middle Plain	1 in 13,800	4,000-10,200
Farakka to Nabadwip	Deltaic non-tidal plain	1 in 23,000	1,000-1,300
Nabadwip to outfall	Deltaic tidal plain	1 in 24,000	Variable due to the tides

Source: Ganga gallery, NASI

The middle plain shows maximum annual flow rate (4,000-10,200cum/second), while flow rates of the river in upper plain (850-1700cum/second) and deltaic non-tidal plain (1000-1300cum/second) are medium, whereas the flow rate is lower in mountainous section up to Rishikesh. Close relationship between slope and flow rate can be seen in the Table.

Some of the important uses and services of the river are shown in Table 2. The table shows that UP is the state that is having longest river stretch (1000 km) and maximum water consumption (693 MLD). It is also supporting maximum number of industries in the catchment area (687), which is much higher than that in other states (13-42). Consequently, pollution caused by wastewater discharged is also the highest in the river basin of Ganga in UP. It is however, interesting to see that population density in UP river basin is much less (828 /km^2) as compared to that in Bihar and Bengal (1102-1129/km^2), which would also be important factors impacting the river ecosystem.

Table 2. Some important characteristics and services of riverine ecosystem of Ganga (Compiled from CPCB Report, 2013)

Characteristic/ service	Uttarakhand	Uttar Pradesh	Bihar	Jharkhand	West Bengal
River Length (Km)	450	1000	515(Sharing between UP & Bihar	40	520
Population Density in Catchment Area (Persons/km^2)	190	828	1102	720	1029
No. of industries in Catchment Area	42	687	13	0	22
Water consumption(MLD)	224	693	91	0.0	116
Wastewater discharged in the river basin(MLD)	127	269	17	0.0	87

Thus, overall impact on the river ecosystem is likely to vary according to the population pressure and anthropogenic activities in the basin. Industrial pollution contributes just 20%, volume wise, but it has a much greater impact because of the nature of the pollutants that are non-biodegradable and virulent. There has been an increment in the disposition of industrial effluents, domestic sewage and along with that various pollutants like toxic metals and organics to the natural water bodies due to rapid industrialization (Paul, 2017). All these anthropogenic stressors can be regarded as the direct drivers of change. Some of the indirect drivers of change can be demographic, economic, socio-political, cultural and religious.

Ganga riverine ecosystem is known to support a rich diversity of flora and fauna. The riparian zone possesses diverse plant species that hold both economic and ecological value. Most plants play an important role in the processes of nutrient cycling, water conservation and soil regulation. Also, many of the species have medicinal properties too. The fauna includes the endangered Ganges river dolphin (*Platanista gangetica gangetica*) and at least nine other species of aquatic mammals with high biodiversity value. Three species of crocodiles have been identified under reptiles along with single species of monitor lizard (*Varanus bengalensis*) and eleven species of fresh water turtles, and 378 species of fresh water fish fauna (Behera, 2002; Rao, 1995). However, the Ganges dolphin and the riverine turtles are considered to be the true reliable indicators that depict the ecosystem health of river Ganga (WWF Report, 2011), and therefore, monitoring these species is very important to know the ecosystem integrity.

River water quality in upper and middle Ganga stretch: The water quality of four regions of upper and middle Ganga (Devprayag, Rishikesh-Haridwar, Kanpur and Varanasi) based on the sampling of pre-monsoon, 2017 are shown in Table 3 below and compared with that of earlier CPCB report, 2013.

Table 3. Water quality of upper and middle Ganga stretch in pre-monsoon period (2017)

Variables	Sites	No. of Sampling Stations	Present Study (2017)	Mean± S.D	Yearly Mean (CPCB,2013)
Dissolved oxygen(mg/L)	Devprayag	3	9.2-9.3	9.23± 0.05	8.7
	Rishikesh-Haridwar	3	4.5-8.0	5.9± 1.5	7.9
	Kanpur	8	3.6-8.1	5.7± 1.6	8.1
	Varanasi	8	5.7-7.4	6.5± 0.49	6.0
Biochemical Oxygen demand (mg/L)	Devprayag	3	0.7-0.9	0.8± 0.12	0.7
	Rishikesh-Haridwar	3	1.8-5.2	5.8± 3.0	4.0
	Kanpur	8	3.3-8.2	5.0± 1.7	5.6
	Varanasi	8	3.0-7.8	5.9± 1.9	6.0
Total coliform (MPN/100 ml)	Devprayag	3	1700-9400	4800± 3318	26617
	Rishikesh-Haridwar	3	40-34000	11387± 15990	18494
	Kanpur	8	800-54000	16825± 17984	63692
	Varanasi	8	11000-54000	22375± 13729	35500
Electrical conductivity (µmhos/cm)	Devprayag	3	89.5-94.9	92.8±2.4	132.0
	Rishikesh-Haridwar	3	96.6-102.5	100.5±2.8	207.3
	Kanpur	8	147.0-187.1	157.1±12	402.3
	Varanasi	8	372.0-509.0	488.0±44	261.0

Maximum Permissible limits (CPCB):A. ***for Drinking*** *(without conventional treatment but after disinfection) DO* = 6 mg/l or less; BOD= 2mg/L or less; Total coliform (MPN) = 50 or less**; B. F*or Bathing*****DO=5mg/L*** or less; BOD= 3mg/L or less; Total coliform (MPN) = 500 or less

Mean DO level in the river was very good in Devprayag stretch (9.23mg/L) , which declined while moving downstream through Rishikesh-Hardwar and Kanpur (5.7-6.5mg/L), but improved in Varanasi(6.5mg/L). The values when compared to CPCB report (2013); show decline over the last few years in Hardwar and Kanpur, but some improvement in the other stretches (Table 3). Dissolved oxygen is a very important parameter indicating overall ecological status of a river ecosystem (Khaiwal et al., 2003). Open defecation and small drains discharging waste water directly into the river were found out as the possible reasons in the Upper Ganga leading to higher number of coliform bacteria and organic pollution load. The total coliform values were obtained in the range from 5-580000.In the middle stretch from Garhmukteshwar to Kanpur D/s in Uttar Pradesh DO was found in the range from 4.0-14.3 mg/L. BOD levels increased consistently as we moved from Devprayag (0.8mg/L) to Varanasi (5.9mg/L) attributable to the increasingly more organic discharge into the river due to different activities. Thus, except for Devprayag, BOD at all locations was surpassing the water quality criteria notified for category A –drinking and B –bathing. There was a distinct rise in BOD level as compared to 2011 levels in Rishikesh-Hardwar stretch. BOD concentrations indicate high organic matter pollution in the river diminishing its ecological uses.

Total coliform count was found to show wide fluctuations between stretches as well as within a stretch, ranging between 40-54,000. Mean MPN values of coliforms did not meet the Though at Devprayag DO and BOD were within limits, but coliform count was quite high, which is mainly because of the open defecation by the people in the river basin in this area, which, however, has shown a decline in the present study, may be a positive impact of the nationwide campaign on open defecation free India. Electrical conductivity also tended to increase moving from Devprayag (100µmhos/cm) to Varanasi (372 µmhos/cm), which may be because of the high salinity tract of the river basin in the Indo-Gangetic plains along with run-off and waste discharges high in salts. The water quality parameter values of the present study when compared with the results of water quality characteristics of River Ganga (Pollution Assessment Report, 2013), the variables were showing slight improvement in terms of some parameters as discussed, but still the water quality of River Ganga is not found suitable for potable as well as bathing purposes.

The present study and some previous reports on Ganga show that here has been a degradation of water quality as well as ecology of the river. The primary causes of pollution of river Ganga at Haridwar have been identified as contamination due to sewage, solid and liquid wastes that are organic in nature (Bhutiani et al., 2016). The increment in the sewerage and the contaminants that are organic in nature is increasing the number of pathogenic organisms leading to bacterial contamination in sources and supply of natural waters at Uttarakhand (Tyagi et al., 2015). However, at the same time the water quality of river Ganga at Rishikesh has been reported to be comparatively better in terms of coliform bacteria count that needs to be measured regularly and controlled (Haritash et al., 2016). The present study also shows similar trend. At Kanpur and nearby stretches also, the water quality is not suitable for drinking (Trivedi et al., 2010; Khare et al., 2011). The water quality of Ganga river basin is high both in terms of organic matter and faecal content (Singh et al., 2012). The important city of Kanpur has more than 300 leather tanneries, which contribute to high BOD, COD and toxic metals in the river (Beg and Ali, 2008). Studies have been carried out to assess the water quality of the Ganga for the pre and post Ganga Action Plan scenarios (Hasan, 2015) and it has been found that lot of efforts have to be put in before the riverine ecosystem comes to a stage of restoration. River Ganga not only provides us with the ecosystem services but it has become an icon in the cultural heritage of India (Das and Tamminga, 2012; Ministry of Home Affairs, 2012).

The possible reasons and drivers behind the degradation of river Ganga are changes in land use including industrial, commercial, agricultural, built-up land and socio-cultural use of river basin and ghats, activities such as discharge of large amounts of industrial, domestic, religious and agricultural waste, population growth, rapid industrialization, discharge of unburnt human and animal carcasses, dhobi Ghats discharges, pesticides dumping, increased sewage treatment discharges, over abstraction of water during lean period and others, which have together resulted in impacts on both the aquatic environment and the human beings. The water quality deterioration also creates risk for the ecosystem services that the river provides. The outcomes of present study indicates failure or obstruction in the provisioning of some of the important ecosystem services that river could provide, such as, water provisioning for drinking and non-drinking purposes, water purification, flood control, soil protection, carbon sequestration, recreational services, nutrient cycling, aesthetic experiences and others.

It may be stated that any contaminated water may be utilized for some beneficial use but it may lose its suitability for other purposes as the water demands and needs differ from person to person in terms of use. Governmental interventions seem to have played some role in improving the condition of the river in certain sites. The National Mission for Clean Ganga (NMCG) has achieved a list of milestones such as inspection of grossly polluting industries, deployment of trash skimmers, declaring the areas around the river as open defecation free, undertaking biodiversity conservation and Ganga rejuvenation projects, organizing many public outreach programmes, treks, cleaning of the Ghats, preparation of the Ganga River Basin Management Plan and others in order to rejuvenate the river and maintain its ecological health. For the rejuvenation and restoration of the river large-scale efforts are required at various levels.

Conclusion

Unprecedented population growth in the river basin, increasing food demands and industrialization has changed the land use, acting as drivers of change in the river ecosystem. The direct drivers of change include dam constructions, diversions of river, draining of the wetlands, land –use changes, overharvesting of the resource, introduction of exotic species, external inputs in the form of wastes, fertilizers, disposal of effluents and others that hugely impact the ecosystem integrity whereas the indirect drivers such as demographic, economic, socio-political, scientific and religious factors alter the direct drivers and deteriorate the ecosystem health. These drivers can put to risk various ecosystem services being provided by river Ganga such as provision of habitat for native species, recreation service, production of commercial fisheries, water supply provisioning both in terms of quantity and quality, sport activities, natural water purification, flood regulation, maintenance of flood plain characteristics, maintenance of deltas and their economies, habitat, hydropower generation and transportation. If the population and pollution issues and the carrying and assimilating capacity of the river are not given immediate attention, it will be difficult for us to reverse the natural state of river Ganga. Although environmental governance and legal policy framework are now taken up as prime issues, but proper implementation of environmental norms need to be practiced to manage the pollution stress and maintain the ecosystem health of the river so that its services are sustained.

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