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The Ganga River with Special Reference to Ecology

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ABSTRACT :

The Ganga is the lifeline of more than half a billion Indians. Anthropogenic activities driven by humans have had disastrous impacts on this river, from severe pollution to changing its course. Catastrophic landslides and floods in the Ganga basin have become more frequent in recent years.

KEYWORDS:-Ecosystem. Environment, Process, Treatment, Marine

INTRODUCTION :

Water being the most manageable natural resource casing almost 70 % of the land, is central to all the ecosystems for maintaining the biodiversity and integrity of biota. It is capable of diversion, transport, storage and recycling and serves as a linkage to relocate nutrients from one realm to another, either by precipitation (rain, snow, sleet etc.), as groundwater, as lentic systems or as flowing water in lotic system e.g. rivers. This makes water the most credible agent influencing ecosystem structure and functioning by regulating nutrient cycling. Freshwater, which is the most important component to sustain terrestrial life and freshwater ecosystem habitats, constitutes only a small share of the biosphere. Among the freshwater resources, river play significant role in transport, human supply and terrestrial-oceanic linkages. Rivers are longitudinal hydrologic connectivity (continuum) between terrestrial and oceanic system. Continuum is a vital process in land-oceanic system and refers to transfer of energy, matter and organisms mediated by water either within or among elements of riverine corridors (Ward et al., 1998). Alteration of this continuum due to anthropogenic influences fluctuates with the nature and scale of disturbance and is still a major global issue (Van Dijk et al., 1994) to ponder. Rivers are rapidly being transformed by human activities such as urbanization, industrialization, damming and trans-basin linkage. Water quality is rapidly degrading by human releases. For instance, about 90% of wastewater in developing countries is received directly by the rivers without treatment (Xie et al., 2003). In China, >3/4th (~80%) of the 50000 km of major rivers is unfit to sustain fisheries and have been completely eliminated from 5% (FAO, 1998). Similar to other aquatic ecosystems, rivers are subject to multiple stressors that affect their structure and functioning, both of which respond in a completely contrasting and complementary ways to environmental stressors. River ecosystem structure refers to characteristics such as channel form, water quality or the composition of biological communities, whereas functioning is reflected in processes such as metabolism, organic matter decomposition or secondary production. Nutrients are the pivotal point to the survival of biota in an ecosystem in the prevailing environment. Some factors of the environment serve as resources (carbon), while others act as regulatory factors (N and P). The environmental factors vary spatio-temporally due to variation in climate, soil type and topography and give shape to various climatic patterns at global, regional and local scales. The biotic factors through exchange of matter and energy influence the hydrosphere, atmosphere and the lithosphere. The biota copes with the external environment temporally ranging from few minutes to days; seasons or over a geological time scale. For instance, phytoplankton populations may vary with the change in light conditions within a few days in aquatic systems, while changes in the lithosphere occur over a geological time scale. Rivers are under strong control of their watershed. A watershed is a type of ecosystem. “It is an area of land draining water, sediment and dissolved substances to a common receiving body”. Watersheds vary from the largest river basins to just a few acres in size. The total structure of a watershed -- its headwaters area, side slopes, valley floor, and water body, as well as its soils, minerals, native plants and animals are, in one sense, resources/ raw material for all the human activities that may potentially occur there. Its natural processes like land surface runoff, sediment transport, groundwater recharge, and plant succession etc, serve mankind when functioning properly, but may cause disasters when disrupted or misunderstood. Understanding structure and processes of watersheds is therefore, crucial to grasping how anthropogenic activities can degrade or improve the condition of a watershed. According to the natural systems concept a watershed is more than just a variety of resources present in a place naturally. It performs works like transporting sediment, water, and energy by interaction of its components and forms floodplains, channels, biological communities and new energy outputs. The cross-system synergism makes the whole watershed greater than the sum of the parts and therefore watershed is an integrated unit.

Rivers as self-purification :

Rivers are longitudinally flowing freshwater systems of tremendous heterogeneity, subjected to stochastic and catastrophic controls dominated by catchment processes and supported by subsidiary processes in the water body itself and in the sediments. Inputs in a river are often diffuse in nature and influence the system downstream. Rivers generally have a significant flow rate for self-purification. The term "self-purification" has been adopted to describe rapid degradation of organic compounds in a river ecosystem, where turbulent mixing effectively replenishes consumed oxygen and thus DO is maintained. Also, this term considers the processes of removing (diluting) undesirable substances from water diluting contaminants, including processes such as adsorption to sediments. Substances bound to sediments may accumulate in the bottom, be released back into the water, and may be transported downstream. This process is particularly important for phosphorus. Sediments, thus, act as sinks for important nutrients such as phosphorus, but if conditions change, the sediments may also serve as source, liberating the nutrient back into the water column where it can stimulate the growth of cyanobacteria and other algae due to self-fertilizing effect. The overall affect is a change in ecosystem functioning and composition/structure of the biotic community. The significant role of algae in biological estimation of lotic waters is largely appreciated because of their role as primary producer and transformers of inorganic nutrients into organic forms available to other organisms of the food-web and their sensitivity to environmental stressors (Lamberti, 1996). Anthropogenic alterations in the catchment land cover/use and riparian instability directly influence the microbial response (Leland and Porter, 2000), both spatially and temporally. Physical barriers such as dams/reservoirs transform the lotic systems, lead to loss of biodiversity and are more disruptive to fishes than to algae in general and diatoms in particular. Heavy metal contamination may eliminate sensitive diatoms, cause toxicity to fishes that can lead to bioaccumulation and effect on human health. The quicker response of diatoms to riverine conditions make them admirable tool for evaluation of river health and crosssystem comparison. It provides clues for resolving variance between water chemistry and biology due to their high sensitivity to environmental stressors (Fore, 2002)

The Ganga River :

The Ganga River in India, together with Brahmaputra-Meghana River System is the second largest system after Amazon River System with respect to water discharge and total drainage area of about 1.75 million km2 . It is lifeline to over 26% of Indian population. However, after completion of Tehri dam in 2006, the Ganga River ecology has experienced a massive change. The river was comparatively free from anthropogenic activities until 1940s. During 1972-74 and 1979-80 the water quality was recorded as bad but not at alarming rate in West Bengal (Mukherjee et al., 1993). Along the river there are many tanneries, distilleries and chemical plants; textile mills and slaughter houses which discharge effluents/ dump wastes directly or indirectly into the Ganga River. Along the Ganga River, there are 36 Class I cities and 14 Cass II cities (Samanta et al., 2005) generating about 2601.3 and 122 MLD wastewater respectively. Out of these, only 1192.4 and 16.4 MLD (44% of the total) enters into treatment facilities. Additionally, the river, along its entire length, receives massive input of heavy metals, pesticides and religious wastes. The land use pattern in the watershed is a major way that controls regional runoff, discharge regime, erosion and sediment transport in the rivers (Gilvear et al., 2002; Sen et al., 2014). Nutrient retention and loss in a watershed is closely linked to land-use, dominant vegetation and soil characteristics (Aber and Driscoll, 1997) along with other meteorological factors. This has strong causal relationship with downstream eutrophication. The major portion (over 74%) of the Ganges basin land use constitutes agricultural land (Rai et al., 2012). For this reason, the river receives a large input of nutrients from agricultural residues. On an average, annually about 115,000 tons of fertilizer, which has 88,600 tons of N, 17,000 tons of P and 9200 tons of K is washed away with agricultural runoff to the Ganga River (Jain, 2002). Further, dam construction has been recognized as the most substantial human impact that transform the river ecosystems leading to water quality degradation and biodiversity loss (WII, 2012; Grumbine and Pandit, 2013). To meet rising energy demand, the Government of India has embarked on a rapid dam-building plan aiming to erect 292 dams throughout the Indian Himalaya (which feed most of the tributaries of the Ganga River) in the future (Grumbine and Pandit, 2013).The river was once characterized by steadiest runoff evident from the fact that before construction of Tehri Dam in Garhwal in 2006 the mean annual discharge of Ganga River was 41,000 to 45,000 m3 s -1 (Pekarova et al., 2003), which after damming declined by over 70% in dry season leading to dilution effect and overall quality of the Ganga River. The Ganga basin is predominantly an agricultural watershed . Intensive agriculture in the basin (73.44 % area of total 783950.19 sq km) renders the soil more prone to erosional losses of dissolve organic carbon (DOC) and nutrients (N and P) all along 2525 km length of the river. Continental erosion and fluvial transport accelerate mobilization of organic carbon (OC) from soils and transferring this pool to the ocean through downstream rivers and streams. The GangesBrahmaputra river system is one of the largest carriers of sediment and terrestrial carbon to ocean (Galy et al., 2007; Galy and Eglinton, 2011). Earlier studies have exemplified the critical role of catchment geology and land use change regulating biogeochemistry of river waters (Thornton and Dise, 1999; Sen et al., 2014). The medley of natural areas, afforested areas, urban-rural settlements and large agricultural lands overlying a miscellaneous geology across the Ganges basin transforms the river water with varying chemical characteristics. River water in areas characterized by urban-industrial settlement receives high concentration of heavy metals (Pandey et al., 2009), whereas transect of the rivers draining agricultural land receive relatively high levels of nitrogen (Thornton and Dise 1999; Beman et al., 2005) and carbon (Pandey et al., 2014 a). Activities like crop harvesting (agriculture), irrigation, grazing etc. are N sinks, whereas point and non-point input along with naturally fixed nitrogen are N sources in the nitrogen budget of the watershed . These sources and sinks have a detrimental role in the nitrogen export to the ocean via hydrologic regime. The river in the third segment has undergone considerable changes in the sediment transport and deposition and experiences intense flooding with frequent changes in the path and most importantly is subject of international dispute on flows and interventions made. The ecosystem services of a river are not confined to provisioning water and food supply but probably most importantly lie in the assimilation of wastes from their catchment including those from anthropocentric origin which result in degraded water quality and enhanced productivity. 10 In case of rivers, their flows are the master variable that determines all characteristics of the ecosystem either directly or indirectly and also affects other attributes including the biota. Ever increasing storage, diversion and abstraction of flowing water to meet the large and diverse human needs through a variety of constructional interventions (barrages, dams, canals etc.) have drastically altered the flows to the scope that many long stretches of even large rivers stay dry in summer season. By damming, the sediments, nutrients, organic matter and organism propagules are vetoed from being transported downstream, thus fragmenting them into alternating pools and dry stretches. The loss of Hilsa fisheries upstream of Farakka Barrage is a conspicuous example of the harsh impacts of habitat destruction in Ganga River (Bhaumik and Sharma, 2012). Habitat loss and destruction is also caused by the embankments of floodplains to channelize the rivers for flood control. It is advanced further with the release of large flushes of liquid wastes and disposal of solid wastes and using river margins/floodplains as landfill sites and for reclaiming land for various uses. Ganga River receives massive amount of pollutants through leachates added from solid waste disposal sites (Pandey et al., 2014c).The impacts of reduced river flow are further provoked by the discharge of both domestic and industrial waste waters. Waste generation rates are directly proportional with the growing population rates (Jha et al., 2007) and is expected to increase significantly as the country strives to attain an industrialized nation's status by end of this decade (Sharma and Shah, 2005). The failure of tangential connectivity and purging of river channel floodplain exchanges will have a direct and rigorous impact on biodiversity of the river. It not only reduces ecosystem resilience (Lambin and Geist, 2006) but also have a serious concern for human health.

River Eutrophication :

The problem of eutrophication is not so severe in lotic ecosystems. This happens due to dilution effects driven by water flow. Stream flows continuously disperse and dilute carbon, nutrients and other matter in water and constrains the aggregation of blooms. However, during recent years habitat fragmentation, for instance, damming and massive input of sewage lead to eutrophy in rivers and streams as well. Fluxes of nutrients and organic matter in rivers are derived predominantly from the processes occurring in the watersheds which are often modified by factors associated with human activities. The quantity and timing of such highly variable fluxes are regulated by watershed/basin geology, time and intensity of precipitation, and the nature and scale of anthropogenic pressure, influencing autotrophic-heterotrophic linkage with variable river response in space and time. Dodds and Welch (2000) raised concern about stream eutrophication, which led United States and other European countries to adopt nutrient control in stream management. The seasonal succession of phytoplanktons is found to be regulated by the shift in the interaction between nutrients and physical factors in flowing waters and often influenced by global warming and factors of eutrophication (Sommer et al., 2007). Changes in key ecosystem processes like gross primary productivity (GPP), community respiration (CR) according to Dodds and Cole (2007) are responses to catchment disturbance and are a signature of stream health. The supply rates of inorganic nutrients have been found to potentially limit many autotrophic and heterotrophic processes in carbon cycling (Ferreira et al., 2015). This has relevance, because many sources of detritus although rich in carbon are poor in N and P content that influence heterotrophic colonization. Cultural eutrophication of fresh water ecosystems refers to the development of algal blooms caused by enhanced concentration of nutrients of anthropogenic origin. The role of allochthonous input in food webs of lakes, rivers and oceans, is now considered substantial and occasionally found greater than autochthonous fixation (Dodds and Cole, 2007). Rivers despite being a flowing system are equally influenced by nutrient-driven changes in trophic status. The debate that was earlier focused over the importance of carbon (C) relative to P in eutrophication (Edmondson, 1991), now with denser human populations globally has shifted to nutrient management in streams, rivers and coastal-marine areas (Smith, 2003). This invites attention because more fertilizer use has become inevitable to produce food grains to feed burgeoning 19 human population, and likely intensification of watershed disturbances and nutrient pollution (Carpenter and Kitchell, 1993). Because autochthonous carbon input rates are linked to nitrogen and phosphorus subsidy, describing trophic state in running waters require a stoichiometric (nutrient ratio) approach. Also, nutrient stimulation of algal productivity (with algal biomass serving as a proxy for production) has been the historic focus of eutrophication in lakes, rivers, estuaries and coastal areas. The variables such as chlorophyll-a, total phosphorus etc. independently estimate algal biomass and are interrelated. When phosphorus increases, that means there is more food available for algae, so algal biomass accrual increase. Trophic State Index although not necessarily interchangeable with water quality, offers an accurate prediction of eutrophication of surface waters. Water bodies can be classified using the total phosphorus index, which is essentially a predictor of potential algal biomass accrual. Hutchinson (1969) suggested that lakes and their drainage basins should be considered as trophic systems, where an eutrophic system is one in which the concentration of available nutrients is high. The index allows the classification of that potential concentration for a watershed or region, at least on the basis of phosphorus. As expanding human populations continue to survive on finite resources, the quality is sure to get compromised (Wear et al., 1998). This has emerged as an important issue in natural resources management to gratify human desires while sustaining natural ecosystems. Horton (1965) in United States developed water quality index (WQI) by using 10 most common water quality variables like dissolved oxygen (DO), pH, coliforms, specific conductance, alkalinity and chloride etc. It has gained wide acceptance in European, African and Asian countries. Water quality of any specific area or specific source can be determined using physical, chemical and biological parameters either to focus eutrophication or pollution status or both. Anthropogenic activities in the watershed interfere with natural processes, for instance, increased erosion and leaching from the catchment soil associated with land use change and inputs of mineral salts and inorganic fertilizers. Synthetic organic compounds, such as solvents, pesticides, aromatic hydrocarbons, etc. become part of aquatic ecosystems through the same pathways, and behave similar to fertilizers and pesticides. Alteration of watersheds due to anthropogenic activities has enhanced natural land degradation and associated changes in receiving waters (Alan, 2004). 20 Urban-industrial growth in a watershed alters land use, cause soil degradation and change in water quality (Wear et al., 1998). Thus, shifts in water quality also reflect health of watershed ecosystems. Most urban pollutants enter receiving waters as point sources, usually as treated or untreated sewage effluents. However, urbanization increases water pollution by non-point sources also by increasing impervious surface, preventing water infiltration naturally leading to increased runoff from roads, sidewalks, rooftops and landfills. Due to these reasons, the availability of good quality freshwater for domestic and agricultural purpose in future may become critical (Postel, 1997). The anthropogenic activities in watershed influence also the river hydrology through the volume, quality, and timing of water and sediment discharge. A threefold increase in population is accompanied by six-fold increase in water use to fulfill their needs by the limited resources, such as land and water (Lubchenco, 1998). Anthropogenic activity has considerably transformed the landscape mosaic found on the Earth's surface (Vitousek et al., 1997) in general and Ganga Basin (Pandey et al., 2016) in particular. Intensive use of natural resources such as land for agriculture increases potential impacts to water and other natural resources in the watershed. For instance, the Ganges Basin accounting for ~1/4th of the total geographical area of India, harbors 30% of its water resources and supports over 40% of its population. The basin witnesses intensive agricultural activity over 73.44% of the total 783950.19 sq km area. This signifies the relevance of the basin and the water bodies as well in context of the countries well being. The Ganges basin is one of the thickly populated and most productive/fertile river basins in the world. The Ganga River flows through 29 megacities, 23 small cities, and 48 townships (Pandey et al., 2016). All the sewage from these urban centers, over 1.3 BLD, passes directly into the river, along with animal carcasses. Some 260 million liters of largely untreated industrial wastewater is also discharged by factories, while major pollutant inputs also arise from runoff from some 6 million tons of inorganic fertilizers and 9,000 tons of pesticides used annually in the basin (Jain, 2002) for agricultural purposes. Jha et al. (2007) reported that waste production rates are proportional to the population expansion rate and are expected to increase significantly till the end of this decade. Pandey et al.

(2014c) reported that the river also receives massive amount of pollutants as leachates from solid waste disposal sites. Such inputs, according to researchers, reduce ecosystem's resilience and adversely affect the human health. The mosaic of natural areas, afforested areas, urban-rural settlements and large agricultural lands over a mixed geology 21 across the Ganges basin gives the river water varying chemical characteristics. Extensive agricultural land receiving massive amount of inorganic fertilizers has left the soil in the catchment more prone to erosional losses of carbon and nutrients along its entire course. Nutrients enrichment and auto-and allochthonus carbon contributes to eutrophication of the Ganga River. Land use refers to utilization of the land at any one point or place, whereas land cover is the physical material such as grass, asphalt, trees, bare ground, water, etc. at the surface of the earth. Global development during last 300 years has transformed >1million km2 of forested area and ~6 million km2 of grassland and pasture to other human uses (Ramankutty and Foley, 1999), thus expanding cropland area by ~10 million km2 . Currently, 10 to 15% of global land resource is used for agriculture or urban-industrial purpose, whereas only 6 to 8% is used as pasture land (Agarwal et al., 2000). A land use decision in a watershed has important impacts on water and other natural resources and has wide implications ranging from water quality degradation to climate change (Riebsame et al., 1994; Loveland et al., 2001).). Loss of forest cover and the proportion of exposed bedrock to deep soils and sediments, coupled with intermittent human modifications, all have profound effects on rivers discharge characteristics. This urges the need to study the temporal and spatial dynamics of anthropogenic impacts on water resources at a watershed scale. Water dynamics and ecological exchange of watersheds are principally the result of interactions between components of the watershed such as agricultural runoff, sediment and nutrient transport etc. Land-cover modifications at regional to global scales according to Binford et al.(2000) controls land surface runoff, sedimentation, land-atmosphere exchanges, biodiversity and the cycling of water, carbon and nutrients. According to Lowrance et al. (1984) new land use practices at local and regional scales harmfully affects water quality, enhancing sedimentation and nutrient load to aquatic ecosystems. These new practices alter the structure of terrestrial ecosystem communities through fragmentation, invasive species, and modification of nutrient and water pathways (Ojima et al., 1994; Loveland et al., 2001) and consequently, the downstream receiving waters. Discharge characteristics of rivers are significantly tailored by the nature of anthropogenic activities like agricultural intensification, industrialization and urbanization in the watershed. 22 Due to urbanization the increase in impervious surface alter the water infiltration rate leading to degradation of the groundwater recharge system and thus alters the run-off characteristics of the watershed. Groundwater discharge regulates river base flow or base discharge, which refers to the minimum quantity of water flowing within the individual river system. This has relevance, because groundwater river-base flow continuum help maintain minimum water need and regulating salt and ions concentrations. Flow regulation by damming and impoundments is the most invasive modification of flowing water. It leads to habitat fragmentation and ultimately affects the biotic community of the riverine ecosystem by decreasing the accessibility to water and sediment in terms of quantity, quality and timing (Poff et al., 1997). The river flow pattern and sediment discharge due to impervious surfaces in urban settlements leads to lofty peak flows (Chadwick et al., 1999) and enhance erosional loss. It also reduces the storage and base-flow characteristics of rivers (Pekarova et al., 2003) Studies have demonstrated profound effects of forest cover shrinkage on river water discharge and the exposed proportions of bedrock to deep soils and sediments. Deforestation thus affects the river channel structure and reduces community habitat volume. According to Miller (2003), runoff chemistry varies subject to its origin, for instance, croplands, industrial areas and human settlements, and likewise the nearby aquatic system receiving it differs in water quality. Areas having low levels of nitrogen in runoff generally have high phosphorus content. River transect draining urban-industrial settlements are characterized by high concentration of heavy metals (Pandey et al., 2009), whereas transect of the river draining agricultural land receive relatively high levels of nitrogen (Thornton and Dise, 1998; Beman et al., 2005) and carbon (Pandey et al., 2014 a). Agricultural intensification in the basin leads to increased soil erosion by rivers and streams. Fluvial transport hastens organic carbon (OC) mobilization from soils and emptying this pool into the ocean through downstream effect. Reduced river flow as a result of high demand for irrigation and domestic uses, can result in stranding of fishes with increased rates of mortality (Harvey, 1987) due to increasing nutrient input above the threshold levels. For instance, although indirect yet harmful effects of increasing nutrient concentration on fish communities are detected when TN exceeds 610 µg L-1 and TP exceeds 60 µg L-1 (Borges et al., 2010)

Atmospheric Deposition :

Among non-point sources, atmospheric deposition (AD) has become an important vector transporting nutrients and other particulates/ aerosols to longer distance and subsequently to earth surfaces including water bodies (Pandey et al., 2014; 2016). Atmospheric deposition adds nutrients directly on water surfaces and indirectly through land deposit followed by runoff (Pandey et al., 2014). Increased human demand for food and fuel is accountable for growing AD inputs (Liu et al., 2013). Atmospheric deposition refers to settling of airborne particles/ aerosols and gases released in to the atmosphere from motor vehicle emissions, slash burning and industrial sources, which contain nitrogen, sulphur etc., to the ground either near or far-away from the source. It may occur as dry deposition either by adsorption or absorption or wet deposition where rain, snow or fog precipitate particles and gases from air to the surfaces of aquatic and terrestrial landscapes on the earth surface. With a global increase in anthropogenic activities, the atmosphere has become an important pathway for nutrient addition to ecosystems (Azimi et al., 2003). Meteorological conditions and local emissions both sturdily affect dry deposition and wet deposition (Chen et al., 2008). The available data on atmospheric deposition of air-borne elements indicate a rising trend globally, especially in developing countries due to rapid urbanindustrial growth. It has a potential to alter the functioning of ecologically sensitive ecosystems and significantly contributes to eutrophication of freshwater ecosystems (Pandey et al., 2014a; 2014b) and coastal areas (Dodds, 2007). Currently, there exist an exhaustive literature characterizing atmospheric deposition and nutrient budgeting of ecosystems (Xie et al., 2008; Bergstrom et al., 2005; Azimi et al., 2003; Galloway and Cowling, 2002). Also, transport of substantial fraction of nutrient, both natural and anthropogenic, in many global biogeochemical cycles today occurs through the atmosphere (Prospero, 2007), still atmospheric deposition pathway has remained the least understood mechanism. Anthropogenic activities like biomass burning, planting and tillage generates airborne nutrient particles of nitrogen (N) and phosphorus (P). Nitrate/nitrite and ammonia from excessive fertilizer use in the croplands enter the atmosphere as gases. These particulates and gases either by fallout or wash out get deposited to the terrestrial or aquatic ecosystems. Input of N and P through atmosphere is an important nutrient source where extreme land disturbances in form of agricultural activity are practiced. Nitrogen and phosphorus are key limiting nutrients in terrestrial 24 and freshwater ecosystems. P emissions arise from soils and vegetation, from biomass burning, and industrial and mining activities (Mahowald et al., 2008).

According to researchers the land use practices and climate change are contributing to soil dust emissions at regional scale. Biomass burning occurs due to natural fires along with tropical deforestation also leads to P emission (Steffen et al., 2007). Major dust and ash sources are found closer to the equator and in the Southern Hemisphere. Study by Brahney et al. (2014) confirmed atmospheric transport of P to be an important pathway of nutrient delivery to aquatic ecosystems. Atmospheric deposition in Ganga River basin has been extensively studied by Pandey and his coworkers. Beginning from local to regional scale in the middle Gangetic segment at Varanasi to basin scale (Pandey et al., 2016), the team has generated vital data from decades of research to understand the role of atmospheric deposition in the ecosystem functioning of Ganga River and its catchment, which is under immense anthropogenic pressure due to population expansion and rapid urban-industrial growth. Their analysis has shown an increase in P deposition relative to those of N in Varanasi, resembling the trend reported in Ecuador, causing a reduction in N: P ratios. This has been attributed to relatively more P emission from biomass burning and other sources. A reduced AD-N:P ratios in Ganges bain has implication, as such shifts make the ecosystem more regulated by P subsidies, when N is in sufficient quantity (Pandey et al., 2014; 2016a; 2016b) Nutrient accessibility in ecosystems is important for development and preservation of ecological processes. Nutrients can be lost from ecosystems during fire and displacement of soil/ash, herbivory, leaching and volatilization (Chapin et al., 2002). In natural ecosystems the major pathways for nutrient input are nitrogen fixation, rock weathering and atmospheric deposition (Vitousek et al., 1997). In many ecosystems, in the absence of N2-fixing plant species and on nutrient depleted bedrock, atmospheric deposition becomes the most significant nutrient source (Chadwick et al., 1999).Whereas, short temporal scale nutrient availability in terrestrial ecosystems is maintained by recycling from soil and biotic community pools (Odum, 1969), long temporal scale availability for ecosystem development depends on equilibrium between inputs and outputs rate of nutrients (Vitousek et al., 1997). For the maintenance of nutrient stocks at equilibrium, nutrients lost from ecosystems must be replenished by additions from external sources like rock weathering, N2-fixation and atmospheric deposition. During 4 million years of ecosystem development history in Hawaii, atmospheric P transport in form of mineral dust from 25 Asia accounted for major fraction of soil P, with annual deposition rates >2.5 kg ha –1 (Cundiff, 2001). Nitrogenous compounds deposited from the atmosphere affect the amount of carbon dioxide that is absorbed into terrestrial and aquatic ecosystems by photosynthesis. Studies suggest that for every kilogram of nitrogen deposited, 35-65 kilograms of carbon gets sequestered in terrestrial ecosystem. Whereas, Martinez et al. (2009) observed atmospheric nitrogen deposition to have no measurable effect on the yield of crops but noticed a reduction in species number, equal to the effect through eutrophication and acidification. Extensive studies characterizing lithogenic and anthropogenic emissions by Palmer and his associates (Palmer et al., 2010) confirm long range transport of nutrients and their addition to forest and river catchments. These studies suggest the need to incorporate changes to earth system modeling in terms of atmospheric nutrient input and their possible effect on carbon sequestration in terrestrial and aquatic ecosystems

REFERENCES :

1. Gilvear DJ, Heal KV and Stephen A (2002) Hydrology and the ecological quality of Scottish river ecosystems. Science of the Total Environment, 294:131-159.
2. Goulding K, Stockdale E, Fortune S and Watson C (2000) Nutrient Cycling on Organic Farms, Journal of Royal Agricultural Society, England, 11:5-75.
3. Government of India (GOI) (2010) Union budget and economic survey.
4. Government of India (GOI) The state of forest- India: 2015 report.
5. Griffith MB, Norton SB, Alexander LC, Pollard AI and LeDuc SD (2012) The effects of mountaintop mines and valley fills on the physicochemical quality of stream ecosystems in the central Appalachians: a review. Science of the Total Environment, 41:1–12.
6. Griscom SB, Fisher NS and Luoma SN (2000) Geochemical influences on assimilation of sediment-bound metals in clams and mussels. Environment Science and Technology, 34:91–99.
7. Grumbine RE and Pandit MK (2013) Threats from India's Himalaya dams. Science, 339:36-37.
8. Gudasz C, Bastviken D, Steger K, Premke K, Sobek S and Tranvik LJ (2010) Temperature controlled organic carbon mineralization in lake sediments. Nature, 466:478–481.
9. Kumar PS, Muraleedharan PM, Prasad TG, Gauns M, Ramaiah N, De Souza SN and Madhupratap M (2002) Why is the Bay of Bengal less productive during summer monsoon compared to the Arabian Sea? Geophysical Research Letters, 29: 88-91.
10. Kumar S, Mishra PK, Singh NL, Singh KK and Srivastava P (2012) Water Quality of River Varuna in Varanasi City, Uttar Pradesh India. Asian Journal of Biochemical and Pharmaceutical Research, 2:231-240.
11. Kumari M, Tripathi S, Pathak V and Tripathi BD (2013) Chemometric characterization of river water quality. Environment Monitoring and Assessment, 185: 3081-92.
12. Lamberti GA (1996) The role of periphyton in benthic food web. In: Algal Ecology: Freshwater Benthic Ecosystems, Academic Press, San Diego, CA, 533-573.
13. Lambin EF and Giest HJ (2006) Land Use and Land Cover Change: Local Processes, Global Impacts. Springer, 322:314-318.
14. Landell-Mills N and Porras IT (2002) Silver bullet or fools' gold? a global review of markets for forest environmental services and their impact on the poor. International Institute for Environment and Development, London.
15. Lane EW (1947) Report of the subcommittee on sediment terminology. Trans AGU, 28:125.
16. Langley JM and Megonigal JP (2010) Ecosystem response to elevated CO2 levels limited by nitrogen-induced plant species shift. Nature, 466:96–99