Pollution studies on Gomati River and its gloomy state in Jaunpur, Uttar Pradesh, India
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The rainfed Gomati River is a tributary of the river Ganga... flows southeastward for almost 940 km through nine districts of Uttar Pradesh before joining river Ganga. Large amounts of human, agricultural and industrial pollutants are discharged in this river as it flows through the highly populated regions. River is polluted and the source of pollution is from city drainage systems, unplanned municipal waste, industrial waste, religious idol immersions, garbage, faecal flow and plastic bags. It is necessary to constantly assess the river water quality and take proper mitigation measures to reduce the pollution level in Gomati River.

I visited Jaunpur, a city in the eastern Uttar Pradesh state of India, in the early part of December 2018 and spent five days there meeting relatives and friends. During those days I used to join my relatives for morning walks to the Shahi Fort. The distance between their home and the Shahi Fort is no more than a kilometer and one must cross the Sadbhavana Bridge over the Gomati River to reach the fort (Figure 1).

Jaunpur District

Jaunpur District covers an area of 4,038 square kilometers between 24.240 N-26.120 N latitude and between 82.70 E-83.50 E longitude. The whole region comprises of flat plains of sandy, loamy and clayey soil with shallow river-valleys that lie at an altitude ranging from 261-290 feet above the Mean Sea Level. Average annual temperatures of Jaunpur range between 4.3\(^0\) C and 44.6\(^0\) C and average annual rainfall is around 987 mm. This district is frequently affected by severe floods. Additional information can be found in the official website of the Jaunpur District (website 1). A brief history of Jaunpur can be seen in a YouTube video (website 2).

Gomati River pollution in Jaunpur City

During my morning walks I noticed the highly polluted nature of the river water and was able to locate a few sources of such pollution. Gomati River pollution is a serious threat to the health of the city’s population since it flows almost in the middle of the city. People bathe in these
toxic waters (Figure 2 C) and consume fish inhabiting the river (Figure 2 A, B, D). The problem is man-made and apparently nothing visible is being done to rectify it. In this article I present an account of my observations, provide an overview of the scientific work done on this subject, discuss various attempts that have been made in the past to rectify the problem and suggest ways to improve the overall situation. A You Tube video shows this ugly picture of the river Gomati in Jaunpur City (website 3).

A highly critical report by Binay Singh in the Times of India dated March 11, 2015 about pollution in Gomti at Jaunpur states as follows (website 4):

“that Sankat Mochan Foundation (SMF), Varanasi reveals very low oxygen at certain points, high levels biochemical oxygen demand (BOD) and very high levels of fecal coliform bacteria. There are 10 municipal sewage discharges in the river and effluent mixed with acid from the ornament refineries also goes directly into the river. There is no sewage treatment plant in Jaunpur. Gomti Action Plan was formulated in 1993 with massive funding but nothing seems to have been done as seen from the present state on the river in Jaunpur.”

Present condition of the river water between Shahi Bridge and Sadbhavana Bridge

The description of the Gomati water described here only covers the area between the Shahi and the Sadbhavana bridges (Figure 1). I find it extremely painful to explain the present condition of the water in early December and worry for the people who use the river for their daily chores and earn a living by fishing in its highly polluted waters. The fishing community uses blue coloured nets in the shallow banks of the river to store the fish they catch (Figure 2D) and fish caught in the lakes and ponds in the nearby region as well (Figure 2A). They sell their fish to local retail traders (Figure 2B) and clean and bathe along the banks of the river (Figure 2C). The river water here is very polluted; it is of black colour (primarily due to decomposition of organic wastes discharged by sewage) and the nearby river-bank too is polluted with scattered garbage including human and animal feces and all kinds of organic and inorganic waste including plastics. I would strongly suggest that the fish caught and stored in this environment is not fit for human consumption. It
seems that the fishermen and the local people who consume the fish are not aware of the danger to their health by consuming the fish they buy here.

In this short span of the river (less than one kilometer) quite a few drains empty their highly toxic and polluted water into it. Such drains are both open drains (Figure 3A) and piped drains forming islands of filth in the river water (Figure 3C). A large dump of rusted bodies of autorickshaws can be observed on the left bank of the river very close to the Hanuman Ghat (Figure 3C). One can only imagine how much rust flows in the river water during the rainy season. There is a small pond along the right bank of the river near the Shahi Bridge that has been turned into a garbage dump and an area of open defecation (Figure 3D). Amid such filth and pollution, it is ironic to see a warning signboard asking people to keep Jaunpur clean and beautiful and warns people against open defecation (Figure 3A). This signboard is a good example of political and administrative apathy and total disregard for the health concerns and welfare of the local population. The concerned authorities consider their job well done just by putting such a warning signboard hoping that people will understand the environmental concern and obey the instructions. Obviously, it has absolutely no impact on the local environment and most people happily ignore it.

Farcical administrative duties of the local authorities are manifested by yet another signboard at the Gopi Ghat that informs people of “Clean Gomati Drive” and welcomes them to Mother Gomati’s aarti or prayer (Figure 4A). The Gomati River waters in this region are polluted from the bottom to the top. Floating garbage of organic and inorganic origin and plastic artefacts can be seen floating on the water surface along with a film of floating oil (Figure 4B). The islands of filth above the water level appear small (Figure 4D) but they are more widespread and larger under the water (Figure 4C). Peoples’ faith primarily drives them to bathing on these ghats (Figures 5A, B, D) where one or more Hindu temples are located. After ritual bathing most people worship in these temples mostly oblivious to the dangers they face to their health. Fishermen spend a lot of their time in the river primarily due to economic reasons and fish in deeper waters (Figures 2D; 5D) and store them for selling near the river bank (Figures 2A, B).
Figure 1. Google Earth image of Jaunpur City (image saved on December 30, 2018) showing Gomati River and other locations. A. Shahi Fort. B. Shahi Bridge (or Akbari Bridge). C. Hanuman Ghat (on the left bank). D. Gopi Ghat (on the right bank). E. Sadbhavana Bridge. The blue arrow indicates the flow direction of the Gomati River. The red star is location of my relative’s home that offers a good view of the river and the fort.

Figure 2. Fishing in Gomati River. A. Blue nets along the river’s shore holding fish caught in the ponds and lakes around the city and from the river. The river water is black, highly polluted and the dirty riverbank is clearly visible. B. Selling fish to retail fish sellers. C. Washing and bathing in the river. D. Fishermen in the middle of the river.
An overview of pollution studies on Gomati River

The rainfed Gomati River is a tributary of the river Ganga that originates from Gomath Tal (formerly Fulhaar Jheel) south of the Himalayan foot hills near Madhogani Tanda village in Pilibhit district in northern Uttar Pradesh. It flows southeastward for almost 940 km through nine districts of Uttar Pradesh; they are Shahjahanpur, Lakhimpurkheri, Hardoi, Sitapur, Lucknow, Barabanki, Sultanpur and Jaunpur before joining river Ganga near Saidpur in Varanasi district. Large amounts of human, agricultural and industrial pollutants are discharged in this river as it flows through the highly populated regions of Uttar Pradesh. Lakhimpurkheri, Lucknow, Sultanpur and Jaunpur are major cities located along this river; they are a major source of municipal and domestic waste and sewage water causing pollution in this river. The Sai River is a major tributary of the Gomati that joins it between Jaunpur and Kerakat in Jaunpur district (Figure 6). Gomati River drains a basin of about 18,750 square kilometers. Bhaskaran et al. (1963) presented one of the earliest studies on the pollution of Gomati River near Lucknow.

Various geological aspects of the Gomati River have been published by Kumar and Singh, (1978), Singh, (1996) and Thakur et al. (2009). These papers were summarized in an article by the author (Kumar, 2015). A brief overview of environmental studies on the Gomati River water is presented below. This is divided into the chemical studies that includes studies on the physico-chemical analyses of water, sediment and various biological entities and biological studies that include microorganisms, phytoplankton, macrofauna and fishes. The overview presented here includes brief descriptions of the relevant points taken mostly from the abstracts and conclusions of the papers.

A. Chemical Studies

The River Gomati all along its 940 km length traverses through the alluvial plains covering agricultural lands and several small and large urban centers. These regions provide huge quantities of untreated sewage, agricultural runoff that brings pesticides and various chemical fertilizers, along with oil, asphalt, sediment and heavy metals. Primary sources of heavy metals are from industries like tannery, sugar, beverages, paints, chemicals, fertilizers, batteries, automobiles, factories, food processing units, cement, thermal power plants, petroleum refineries and sewage
disposal water (Singh et al. 2016a). Heavy metals are toxic and carcinogenic; they are a global problem, adversely impact crop yields, soil biomass and fertility, and contribute to the bioaccumulation and biomagnification in the food chain in an aquatic and terrestrial ecosystem. High concentrations of heavy metals like chromium, copper, nickel, lead and zinc were found in the Gomati water in Lucknow (Mishra and Mishra, 2008). Drains are the primary source of pollution within the city limits that carry industrial effluents, municipal and domestic waste, sewage and medicinal waste (Srivastava et al., 2011), etc. This is true for the Gomati water in Jaunpur city limits as well.

Kumar (1989) was one of the earliest studies on heavy metal pollution in Gomati River sediments around Lucknow; the study concluded that municipal waste discharged into the river through drains is responsible for the higher values of heavy metals and PO4 but in general Gomti River sediments can be termed as unpolluted with heavy metals.

Gupta and Subramanian (1994) analyzed water and sediment samples from the Gomati River during the post monsoon season to estimate major elemental chemistry. Downstream samples from Lucknow show the influence of anthropogenic loadings for a considerable distance in the river water. Chemistry of the bottom sediments shows domination of Silica (36 %), reflecting a high percentage of detrital quartz, which makes up about 74 % of the mineralogy of the bed sediments in the river Gomti.

Gupta and Subramanian (1998) studied geochemical factors controlling the chemical nature of water and sediments in the Gomati River in Lucknow. They collected water and bed sediment samples at the riverbank from 15 locations throughout the river basin during the second half of October 1991, a period immediately after the monsoon season. They performed R-mode factor analysis of the recently acquired data on water and sediment chemistry and found that water chemistry seems to be controlled by three factors: bicarbonate, rainfall and silicate and phosphate factors; and sediment chemistry is largely controlled by four factors: clay, adsorption/desorption, iron-manganese hydroxide and mercury.

Singh et al. (1997) studied concentration of various heavy metals (Chromium, Copper, Cobalt, Iron, Manganese, Nickel, Lead, Zinc, and Cadmium) in recently deposited surface
sediments of the Gomati River in the Lucknow urban area with the objective to see the levels of river pollution. Distinctly elevated concentrations were observed progressively downstream due to 4 major drainage networks discharging their urban effluents into the river indicating that the urbanization process is associated with higher concentrations of heavy metals. Authors advised that to keep the river clean urban effluents should be treated before their discharge into it.

Singh et al. (2002) studied freshly deposited stream sediments from six urban centers of the Ganga Plain including the Gomati deposits in Lucknow. They analyzed heavy metals to understand the sediment quality. They conclude that urban centers act as sources of Chromium, Nickel, Copper, Zinc, Lead and Cadmium and cause metallic sediment pollution in rivers of the Ganga Plain.

![Figure 3. Pollution and filth in Gomati River. A. Open drains (od) flowing from the city into the river. B. A sign to keep Jaunpur clean and beautiful that warns against open defecation. Enormous amounts of garbage surround this sign board and open defecation is common all along the river banks. C. Piped drains (pd) flowing from the city into the river forming islands of filth in the river. D. A pond along the right bank of the river near the Shahi Bridge has been turned into a garbage dump and an area of open defecation.](image)
Figure 4. Pollution and filth in Gomati River. A. A signboard at Gopi Ghat says “Clean Gomati Drive” and welcomes people to Mother Gomati’s aarti (prayer). B. Floating filth, especially plastic pieces dirt and film of oil. C. Islands of filth under water (if). D. Islands of filth above water level (if).

Singh et al. (2004) collected twenty-four physical and chemical parameters of water quality data of the Gomati River from eight different sites belonging to relatively low, moderate and high pollution areas for a period of 5 years between 1994 and 1998. They used multivariate statistical techniques to evaluate temporal/spatial variations of a large and complex water-quality data set. The purpose of the study was to get better information about the water quality and to design monitoring network for effective management of water resources.

Gaur et al. (2005) studied impacts of domestic/industrial wastes on the water and sediment chemistry of river Gomti. They analyzed concentrations of six heavy metals (Cadmium, Chromium, Copper, Nickel, Lead and Zinc) during summer, winter and the rainy season for seven
sampling sites spread along the river Gomati in Lucknow. They found higher concentrations of all the metals in water and sediment during the rainy season compared to summer and winter. This is because during the rainy season runoff from open contaminated sites, agricultural fields and industries directly discharges into the river without any treatment.

Malik et al. (2004) generated data on distribution of polycyclic aromatic hydrocarbons (PAHs) in water and bed sediments of Gomati River at different locations. PAHs are a group of organic compounds found in fresh water environments, marine sediments, atmosphere and ice. They are usually transported by atmosphere and have cancer causing potential to mammals including human beings.

Singh et al. (2005d) carried out a hydrochemical study along 630 km stretch of the river Gomti and examined the distribution of heavy metals in sediments and partitioning of their chemical species between five geochemical phases viz. exchangeable fraction, carbonate fraction, Fe/Mn oxide fraction and organic fraction. They found that in most cases the average metal concentrations were lower than the standard shale values. Various physicochemical parameters such as pH, total solids, total dissolved solids, total suspended solids, COD, BOD, DO, conductivity, chloride, sulphate, phosphate, fluoride, total alkalinity, total hardness, etc. were also recorded.

Singh et al. (2005a) studied the Ganga alluvial plain (GAP) of Northern India; the GAP feeds its weathering products to the Ganga–Brahmaputra River system. It is a geochemical study of the GAP weathering products transported by Gomati River; a tributary of Ganga River to understand weathering processes of an alluvial plain in a humid sub-tropical climate. They collected 28 samples and analyzed them for 25 major trace elements. Authors found that mineral sorting during fluvial transportation acts as the single important factor that controls the geochemistry of these weathering products and strongly influences major and trace element distribution in the individual sediment samples.

Singh et al. (2005b) studied possible sources of heavy metal contamination in the bed sediments of the Gomti River for five years (Jan. 1994 - Dec. 1998) through continuous monitoring of the river water and bed sediments at eight selected sites and water/waste water of its
tributaries/drains. They evaluated the influence of anthropogenic activities on metal contamination of the bed sediments by computing the geoaccumulation index for various metals at the studied sites. They found seasonal (monsoon-related) differences in metal profiles for the river water and suspended solids and absence of seasonal differences for bed sediment and waste-water and suggested that the river bed sediments are contaminated with heavy metals, that may contribute to sediment toxicity to the freshwater ecosystem of the Gomati River.

Singh et al. (2005c) studied the concentrations of cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc in water and bed sediments of river Gomati along 500 km from Neemsar to Jaunpur. They studied samples of water (October 2002-March 2003) and bed sediments (December 2002 and March 2003) from 10 different locations. They also collected data on physico-chemical parameters like pH, total solids, total dissolved solids, total suspended solids, dissolved oxygen, biological oxygen demand, chemical oxygen demand and hardness because these have direct or indirect influence on the incidence, transport and speciation of the heavy metals. Based on the geoaccumulation indices, the Gomti river sediments from Neemsar to Jaunpur were considered unpolluted with respect to Cr, Cu, Fe, Mn, and Zn and unpolluted to moderately polluted with Pb. In case of Cd it varies from moderately polluted to highly polluted. As far as Ni is concerned the sediment is very highly polluted at Barabanki and Jaunpur.

Singh et al. (2005d) examined distribution and fractionation of heavy metals in Gomati river sediments on its 630 km long stretch. Authors concluded that, “According to the Risk Assessment Code (RAC), the sediments having 11–30% carbonate and exchangeable fractions are at medium risk. The concentrations of cadmium and lead at mid Lucknow, Pipraghat, Sultanpur U/S and Sulthanpur D/S are between 31 and 50%. They thus pose a high risk to the environment. Since the concentrations of cadmium and lead at Neemsar (Cd 56.79%; Pb 51%) are higher than 50%, the RAC as very high. In most cases, the average metal concentrations were lower than the standard shale values. Various physicochemical parameters such as pH, total solids, total dissolved solids, total suspended solids, COD, BOD, DO, conductivity, chloride, sulphate, phosphate, fluoride, total alkalinity, total hardness, etc. were also reported.”
Figure 5. Life on the ghats of Gomati River. A. A view of the Gopi Ghat showing people bathing. B. A view of the Hanuman Ghat showing people bathing. C. Vijay Stambh: an ancient sculpture of an elephant and lion near the Shahi Bridge indicating long history of Jaunpur. D. A common view of the Gopi Ghat (Figure 1-D) and the Hanuman Ghat (Figure 1-C) across the river showing the Shahi Bridge, people bathing and fishing in the river.

Figure 6. Google Map showing locations of Jaunpur and Kerakat along with the course of the rivers Gomati and Sai (a tributary of Gomati). The white star indicates the location of the confluence of the two rivers.
Agarwal et al. (2007) investigated concentration of toxic metals mercury and lead in edible fish species in the Gomati River in Lucknow with the objective that these might cause adverse health effects for the consumer. They showed that the accumulation pattern of total mercury in the fish species was quite variable. The most commonly eaten fish *Labeo rohita* (Rohu) accumulates a very low mercury concentration that might be possible because this fish variety does not allow mercury to accumulate in tissues compared with other species available in the same aquatic environment. All the fish species examined had a mercury content below the permissible level of 0.50 μg/g (wet weight of fish) for human consumption recommended by World Health Organization (WHO 1990). Their study indicated that the Gomati river water is not contaminated with mercury or lead to cause any current health risks.

Malik et al. (2007) studied the levels and distribution patterns of some organochlorine pesticides (OCPs) in fish samples of the Gomti river collected from three sites during 2004–2005, in the pre- and post-monsoon seasons. The results revealed that the fish of the Gomti river are contaminated with various OCPs.
Figure 7. Gomati River in Kerakat. A. Gomati River flowing downstream showing thick vegetation and mango orchards on both sides of the river. B. Gomati River in Kerakat has more water than in Jaunpur because its tributary Sai River joins it between Jaunpur and Kerakat (Figure 6); see also the flood deposit (FD) deposited by an ancient flooding event of the river. C. Upstream view of the Gomati River from the ghat in Kerakat. D. A view of the clean ghat in Kerakat (Sunit Srivastava (left) and Sher Singh).

Singh and Tandon (2010) assessed the water quality of Gomati river using parameters like pH, conductivity, turbidity, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), hardness, chlorides, alkalinity, and total dissolved solids (TDS). The water samples were collected at specific time intervals during January, May and August in 2007 and 2008 from five sites between Gaughat to Piperaghat in Lucknow. January data showed a marked decrease in pH values and an increasing trend in conductivity. January, May and August months showed an increasing trend in turbidity, BOD and COD whereas August showed a decrease in values of dissolved oxygen (DO). January and May also showed the increasing values of TDS.

In Lucknow several drains discharge waste water in Gomati sometimes without any treatment. River water between Gaughat and Mohan Meakin is slightly polluted and is fit enough for beneficial uses except for drinking without treatment. But afterwards the river becomes highly polluted and is not suitable for most beneficial uses except irrigation, fish culture and industrial cooling.

Srivastava et al. (2011) studied water from 26 drains located between Gaughat and Piperaghat in Lucknow that discharge waste into the Gomati River between November 2007 and November 2008 with the objective to document the extent of pollution caused by drains to the river water. Thirteen physical and chemical parameters were statistically evaluated and concluded that most of the indicator parameters are above the permissible limits of BIS and WHO standards. This is indeed alarming for the people who depend on this water for consumption. Although these drains are treated, the waters are highly contaminated with various pollutants from industrial effluent, domestic waste, sewage and medicinal waste from hospitals and houses (Mishra and Mishra. 2008).
Tiwari et al. (2013b) assessed concentrations of various heavy metals and their distribution in the organs of *Cyprinus carpio;* a commonly found fish in the Gomati river at Sultanpur during a period between 2011-2012. The heavy metals copper, chromium, lead and zinc were determined in its liver, gill and muscles. Highest levels of heavy metals were observed in the liver compared to gill and muscles. The increase in concentration of metals in fish could be mainly due to the metals contaminated diet that comes from the discharge of effluents into rivers from different industries and other sources in the form of particulate and solution. Tiwari et al. (2014) reported on the distribution of four heavy metals Copper, Chromium, Lead and Zinc in muscles, gills and livers of fish species *Oreochromis niloticus* from the Gomati river in Sultanpur during 2011-2012. The results indicate that the edible parts (muscle) of the *Oreochromis niloticus* are safe for human consumption, but constant screening of heavy metals is required.

Jigyasu et al. (2015) studied mobility of the element Aluminum in the Gomati River Basin, a part of the Ganga Alluvial Plain, India. They found that 19% of Lucknow groundwater samples and all the Gomati River water samples have Aluminum values above the permissible limit (200 ppb) recommended by the World Health Organization. Authors suggest a systematic multi-disciplinary study to understand the geological association of high Aluminum mobility with human health in the densely populated regions of the Ganga Alluvial Plain.

Parveen and Singh (2016a) developed an enhanced dissolved oxygen (DO) model for Gomati River at Lucknow as a proxy for the quality of the river water. They state, “In order to test the applicability of model, flow data sets of various sampling sites of river Gomti are collected during the period of January 2015 to December 2015. Gomti river is highly polluted and receives effluents from large number of drains that enter directly into the river carrying untreated industrial and domestic waste. Analysis indicates that the dissolved oxygen has been deteriorated from Gaughat to Pipraghat due to discharge of effluents from about 26 major drains in its entire course at Lucknow Stretch. Water of the river Gomti at upstream of Lucknow i.e. Gaughat showed minimum (biological oxygen demand) BOD and maximum dissolved oxygen.”

The authors concluded their study as follows: Analysis revealed that water quality of Gomti river was found to be more polluted at the downstream of the stretch as compared to the other
sampling sites. Physico-chemical and microbiological quality of Gomti river was poor, unsafe and not acceptable for any purpose. The level of all the indicators are above the standards which are the serious concern for the ecology of the river. The deterioration of water was due 26 drains along its stretch. It leads to increase in the content of heavy metals that results in pollution of river water. Various industrial waste, agricultural waste and domestic wastes are the main cause increasing urbanisation and population resulted in the increase in the generation of waste that is beindischarged into the river. Due to huge amount of organic and inorganic matter, river lost its self-purification nature, resulting higher bacterial growth. At the downstream of Lucknow the Self-purification capacity of Gomti river has become almost nil due to the discharge of treated and untreated waste from various point and non-point sources. The content of BOD is maximum at Upstream barrage and Pipraghat and dissolved oxygen has become negligible at these sampling sites due to which aquatic animals cannot survive. The water at the downstream point showed higher turbidity due to the pollution from various drains and untreated discharge that leads to the river highly contaminated. The sullage content in the river at the Nishatganj site location is very high due to the disposal of domestic waste and from here there is excessive increase in BOD and dissolved oxygen drastically decreases till Pipraghat. That is why it is very necessary to treat the waste coming from industries and other sources before merging into the river so that the aquatic as well as human life may not get affected. The generalized modeling equations which has been used for finding out the dissolved oxygen for the river Gomti gave the more accurate as compared to Streeter and Phelps (1925) equation. This model is user-friendly, once it is developed it can be used for any river requiring the data suitable for that river and includes the change in the values of the constant.”

Parveen and Singh (2016b) studied physico-chemical and microbiological characteristics of the Gomati water in Lucknow. They measured level of organic matter, various heavy metals and sewage pollution and their variation from upstream (Gaughat site) to downstream (Piperaghat site) in Lucknow. They analyzed total solids, total dissolved solids, total suspended solids, conductivity, pH, chemical oxygen demand (COD), biological oxygen demand (BOD) and dissolved oxygen (DO) and concluded that many drains are responsible for pollution in the river. Water quality steadily deteriorated from Gaughat to Pipraghat due to discharge of untreated waste
water from about 26 major drains in its entire course. Upstream water in Lucknow i.e. Gaughat showed minimum BOD and maximum dissolved oxygen but due to the presence of 26 drains dissolved oxygen level decreases along its stretch and showed minimum DO at Pipraghat. Authors suggest that the physico-chemical and microbiological quality of Gomti river was poor, unsafe and not acceptable for any purpose.

According to Nag et al. (2018) “Triclosan (TCS) is an antibacterial agent commonly used in personal care products is highly toxic to aquatic lives particularly algae, zooplankton and fish. It is bio-accumulative and has endocrine disruptive properties. In this present study, we monitored the occurrence of TCS in water, sediment and fish samples collected from stretch of about 450 km of River Gomti, a major tributary of River Ganga, in India.” Authors concluded that, “It was also found in fishes of different species in concentrations ranging from 13 to 1040 μg/kg on wet weight basis. However, estimated daily intake of TCS through contaminated fish was much below the acceptable daily intake (50 μg/kg body wt/day) and thus safe from human health hazard point of view.”

B. Biological Studies

Microorganisms as proxies for variations in environmental factors affecting Gomati River was earlier studied by Pathak (1991). Phytoplankton are minute organisms that float in the water column and can be studied only under a microscope. They are effective tools in the environmental bio-monitoring of an aquatic ecosystem. Being primary producers they play a very significant role in the river ecosystem, aquatic food chain and water characteristic. Variations in phytoplankton density in a water column primarily results from an intricate interplay of physical, chemical and biological processes. Water quality, availability of nutrients and seasonal changes control their species diversity and concentrations in the water.

Varshney (2006) and Varshney et al. (2006) conducted a major study on the fisheries potential of the Gomati River in Lucknow and statistically analyzed the benthic diversity of the river to the environmental conditions at four sites. They found that generally dissolved oxygen was low at three sites, but chemical oxygen demand values were high at all sites. Authors found that benthic fauna was dominated by oligochaetes and chironomus larvae, and leeches, nematodes,
sponges, crustaceans, pelycypodes, gastropodes and fish fry were reported as well. Seasonally, population density was maximum during pre-monsoon and minimum during monsoon. River water was found to be filthy, foul smelling throughout the length of the river; this indicates that the river is under severe pollution stress due to anthropogenic discharges.

Mayank et al. (2009) studied the assessment of sex ratio and sex structure of a fish species *Labeo calbasu* (Hamilton) from the Gomati river at Sultanpur, Uttar Pradesh. The sex structure is very important to the reproduction of a population, and consequently there are mechanisms for adjusting this structure to any changes, and especially changes in food supply. Knowledge of sex ratio is considered essential in the management of fisheries as it enables to follow the movement of the sexes in relation to the season.

Ahmad et al. (2010) conducted a comparative study on seasonal variations of zooplankton and phytoplankton density in the Gomati River and ponds of Lucknow.

Sarkar et al. (2010) conducted surveys to explore the diversity of fish, distribution patterns, abundance, threat, and habitat status in the upper, middle, and lower stretch of river Gomati. A total of 56 fish species belonging to 20 families and 42 genera were collected among them; five belonged to the ‘endangered’ category and 11 belonged to the vulnerable category. They identified six major categories of habitat, fish assemblages and dominant genera in each habitat and observed significant differences in the fish species richness and relative abundance of various species in the different sampling sites. Authors concluded that “*Indiscriminate catch, poisoning, using of fine mesh sized nets, dumping of sewage, siltation, water abstraction, changing land use pattern, decreased water discharge, and exotic species threaten the fish diversity. Urgent need exists for taking up research on the priority fish species and their habitat. Restoration measures have been proposed based on ecosystem scale approach for fish biodiversity conservation.*”

Sarkar et al. (2013) studied the length weight relationship of selected freshwater fish species found in rivers Ganga, Gomati and Rapti.

Singh et al. (2010a) assessed the effect of sewage and effluents on the primary productivity of phytoplankton from four sampling sites in Gomati River in Jaunpur. They found maximum values of gross primary productivity and net primary productivity during summer and lower during
rainy season and the rate of primary productivity is adversely affected by untreated sewage and effluents.

Gupta (2011) studied fish diversity and aquatic habitat of river Gomti for biodiversity conservation and management.

Singh (2013) studied biological productivity as an ecological indicator to identify the quality of river Gomti in Lucknow. She observed 17 species of phytoplankton and 10 species of zooplanktons during different seasons and demonstrated that phytoplankton density was maximum (140-900 In/l) during monsoon season and minimum (40-140 In/l) during winter season. Simultaneously zooplanktons were highest (168-220 In/l) during winter and lowest (114-155 In/l) during summer season.

Kumar et al. (2014) studied length–weight relationship of seven fish species of the Gomti River with the objective to evaluate length–weight relations of freshwater fish to help in the conservation and management of riverine fish populations.

Gupta et al. (2014) evaluated pollution in Gomati River by analyzing seven heavy metals (Cadmium, Chromium, Copper, Manganese, Nickel, Lead and Zinc) in water, sediment and mollusk (*Vivipera bengalensis*) samples from six different sites. Results indicated heavy contamination with heavy metals, and heavy metal distribution was higher in the mid-stream of Gomti. *V. bengalensis* shows high levels of metal bioaccumulation, since the river suffers from serious anthropogenic pollution; immediate measures should be taken to control anthropogenic pollution of Gomti. Authors used cluster analysis to indicated that Lead, Zinc, Cadmium and Nickel in sediments may have anthropogenic sources.

Singh (2015) observed phytoplankton diversity, density and distribution in three different seasons, summer, monsoon and winter, during 2012-13 at five different sites. She recorded the following algal taxa belonging to family Chlorophyceae: *Chlamydomonas, Spirogyra, Oedogonium, Ulothrix, Hydrodictyon, Vaucheria, Scenedesmus, Desmidium, Zygnema, Mongeotia spp., Microspora spp., Gonium sociale, Pediastrum, Ranunculus aquatilis*, family Bacillariophyceae: *Stauroneis pusilla, Cosmarium formosuhum, Micrasterias desmids, Synedra ulna, Navicula sphaerophor, Nitzschia stagnorum, Synura* and family Myxophyceae: *Volvox*
aureus, Oscillatoria, Stigonema. Role of planktons as bioindicators of aquatic health and their role in survival of aquatic animals in river Gomti has been discussed.

**Environmental studies on Gomati River in Jaunpur**

Scientists primarily working in the colleges of Jaunpur district and Varanasi have carried out several environmental studies in the Gomati River within the city limits and successfully demonstrated how municipal and domestic waste and sewage water from the city drains pollute the river. They have studied various microbiological, physical and chemical proxies to show various levels of pollution in the Gomati water.

In a pioneering work for Gomati River in Jaunpur, Misra (2000) carried out a detailed study of the ecological investigation of river Gomati under the influence of municipal wastes of Jaunpur city. Later Misra and Ram (2007) carried out a comprehensive study of phytoplanktonic community in the polluted ponds of Jaunpur city.

Ali et al. (2009) studied algal phytoplankton from four sites along the Gomati River in Jaunpur City and identified 44 species belonging to Cyanophyceae, Chlorophyceae, Euglenophyceae and Bacillariophyceae. They demonstrated that algal phytoplankton species populations showed a direct correlation with physical and chemical properties of the water and found a positive correlation with pH, dissolved oxygen (DO), alkalinity, phosphate and nitrate and a negative correlation with temperature and chloride. They also recognized algal phytoplankton Aulosira, Microcystis, Oscillatoria, Chlamydomonas, Chlorella, Pediasrtum, Euglena, Cyclotella, Nevicula, and Nitzschia as pollution indicators and concluded that this river has become polluted because of various human activities at Jaunpur such as discharges from municipal and industrial sources, human excreta, agricultural run-off and burning of corpses.

Ali et al. (2009a) demonstrated the role of metallic pollution in the riverine ecosystem on phytoplankton health. They studied the concentration of metals in river water and in algal population from four sites in the Gomati River in Jaunpur and found that metal concentrations in the water and algal cells were higher during summer followed by winter and the rainy months. The study found high metallic levels in river water at the effluent mixing zones, that correlated well
with metal concentration in algal cells that significantly reduce the biotic community and trophic level in riverine ecosystem.

Singh et al. (2010) studied heavy metal concentrations (zinc, copper, iron, cadmium and nickel) in algal cells, bottom sediments and river water at four sites within a span of four kilometers from Kalichabad to Ramghat in Jaunpur City to understand their relationship with pollution in river Gomati. Between these two points five major drainage channels and several open drains discharged effluents and domestic wastes into the river. They found higher levels of heavy metal concentrations in algal cells and bottom sediments than the river water.

In nature, various chemicals including heavy and non-heavy metals, get into the bodies of water and are required for growth of plants and animals that inhabit these water bodies. Their higher concentrations adversely impact aquatic life and through the food chain they create serious health problems for human beings. Various forms of human activities are responsible for contamination of river water by heavy metals. Their biomagnification and accumulation in the food chain adversely impacts aquatic life and causes serious health problems for people. Heavy metals present in such waste waters of the industrial and municipal sewage end up in the river, and their toxic concentration causes serious health problems.

Alauddin et al. (2012) carried out a spectrophotometric study of iron, nitrate and phosphate contents of the river Gomati in Jaunpur City to understand its water quality. River water contains significant concentration of iron, nitrate and phosphate and there is marked variation in the levels of these parameters during 2009, 2010 and 2011, and occasionally it is more than the WHO maximum contamination level. The phosphate concentration is increasing due to the uncontrolled use of phosphate fertilizers and dumping of household garbage containing huge amounts of phosphate and industrial wastes. The concentrations of iron, nitrate and phosphate is increasing with every passing year. Prevention of dumping of untreated sewage, agricultural wastes and industrial wastes in the river is required to save it from pollution.

Tiwari et al. (2013a) studied bioaccumulation of four heavy metals, Copper, Cromium, Lead and Zinc, in Cyprinus carpio (common carp) from the river Gomti at Jaunpur during 2011-2012. The accumulations were found to be lesser in monsoon than in the winter and summer
seasons. The results showed different affinities of metals to different tissues. Highest levels of heavy metals were observed in the liver compared to gill and muscles. Most laboratory research on the bioaccumulation of heavy metals suggests that no single mechanism is responsible for metal uptake in aquatic systems. The accumulation of a particular metal depends to a large degree on the presence of the metal in the water column.

Singh and Singh (2014) conducted bacteriological analysis of Gomati water in Jaunpur with the objective of understanding pollution levels at various places within the city limits. The study was carried out during June 2009 and May 2010 at five sampling sites: Kalichabad Ghat (upstream control site outside the city limit), Gular Ghat, Hanuman Ghat, Baluwa Ghat and Miyanpur Ghat towards downstream respectively. Bacterial pollution in Gomati water within the city limits has been increasing steadily due to increasing discharge of organic wastes, human excreta, sewage waste, municipal garbage and toxic discharge from factories. It is widely known that fecal-indicator bacteria found in polluted water are the primary cause for cholera, dysentery, typhoid fever, hepatitis and other water-borne diseases. It may also cause eye, ear, nose and throat infections.

The analysis included total coliform count, fecal coliform count and fecal streptococcal count. All these counts were significantly higher in the four downstream sites in comparison with the upstream control site indicating discharge of fecal organic content in the river through several drains carrying municipal untreated sewage from both sides of the river. Authors concluded that Gomati water in the city limits is unsafe and dangerous for human consumption and suggest that sewage must be treated before discharging it in the river.

Tiwari (2014) collected water samples from Gomati River at Jaunpur during winter, summer and monsoon seasons between January 2011 and December 2012. The sampling was done between 9.30 and 11.00 am. He studied the water quality of the river by analyzing physico-chemical properties and heavy metals and concluded that the water quality of the river was poor. He reports that the Gomti river hosts some fish species like Cyprinus carpio and Oreochromis niloticus and few catfishes which are considered tolerant of poor water quality.
Dwivedi et al. (2015) analyzed heavy metals Copper, Chromium, Lead and Zinc in *Oreochromis niloticus* collected from the Gomati River in Lucknow and Jaunpur between 2011 and 2012. They found slightly higher levels of bioaccumulation and bioconcentration factor of heavy metals in different fish organs in the fish from Lucknow than in Jaunpur.

Singh et al. (2016a) studied physical and chemical parameters like pH, temperature, total dissolved solid, total suspended solid, hardness, dissolved oxygen, nitrate, nitrite, chloride, total coliform bacteria counts and heavy metals (Copper, Iron, Zinc, Lead, Arsenic, Cadmium and Nickel) from the Gomati River water samples collected at four locations between upstream Gokul Ghat to downstream Ram Ghat. They found that most physical and chemical parameters indicated that the Gomati River water in the city limits was highly polluted and not suitable for human consumption without conventional treatment. The water pollution is due to the discharge of domestic, municipal and industrial waste through several drains into the river.

Singh et al. (2016b) studied phytoplankton density in the Gomati River as proxies for quality of water. Four sampling sites were selected in about an 8 km stretch of the river. The water samples were collected from Gokul Ghat, Jogiyapur (Shiv) Ghat, Miyapur Ghat and Ram Ghat; from upstream towards downstream respectively during the monsoon (July - October), winter (November - February) and summer (March - June) seasons. The river comprises the maximum density of phytoplankton during summer season, when turbidity, velocity and volume of water in the river were lower and minimum density of phytoplankton during monsoon season, when turbidity, velocity and volume of water in the river were higher. The lower values of phytoplankton density are also controlled by pollution caused by bathing, washing, chemical discharge by goldsmiths, slaughter houses and sewage and thus goes down within the city limits. They identified thirty-five species and concluded that the phytoplankton density was maximum during summer season and minimum during the monsoon season.

Kumar et al. (2017) estimated the pollution status of river Gomati in Jaunpur. Four sites from Gokul Ghat (upstream), Gular Ghat, Shastri Bridge and Gomti Barrage (downstream) were sampled during March 2016 to February 2017. Six parameters, temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), Nitrate and Phosphate, were analyzed for the summer,
monsoon and winter months. River is polluted and the source of pollution is from city drainage systems, unplanned municipal waste, industrial waste, religious idol immersions, garbage, faecal flow and plastic bags. It is necessary to constantly assess the river water quality and take proper mitigation measures to reduce the pollution level in Gomati River.

**Promise of beautification and de-silting of Gomati in Jaunpur in 2016**

According to a television report on April 21, 2016, the district administration of Jaunpur launched a beautification plan along the Gomati River front that included desilting and widening of the river, tree plantation on the river banks and treatment of sewage and polluted water before it entered the Gomati River. The news showed desilting work in progress as well. This report can be seen in the video (Website 5). Unfortunately, I could not see any promised beautification or treatment of dirty drains in December 2018. The administrative promise remained as a hollow promise only and as a matter of fact Gomati became far dirtier as described and illustrated above.

**Restoration plan and riverfront development in Lucknow**

Dutta et al. (2011) proposed a restoration plan for Gomati River. They collected water quality data from river expedition, monitoring and quality assessment of water. Using satellite maps they found that there has been severe reduction in forest cover and wetlands in the entire Gomati basin due to rapid land use change and increasing urbanization. These changes adversely impacted the flow of water in Gomati river due to reduction in water availability. They also found that quality of the water in the river has deteriorated due to the discharge of untreated wastewater from about 50 major drains in its entire course of 960 kms.

Dutta et al. (2015a; 2015b) assessed the potential impact of human-induced interventions on hydrological regimes of Gomati River. They compared satellite data between 1978 and 2008 and found increased built-up areas, decreased forest and plantation cover and decreased inland water bodies. Their data shows significant changes in the basin over the recent past that are still continuing. Several tributaries of Gomati are drying-up due to the indiscriminate exploitation of groundwater. They suggest that Gomati and its floodplain offer multiple ecosystems and they need an integrated approach for conservation and restoration.
Dutta et al. (2018) studied the ecological impact of Gomati riverfront development during April 2015 and March 2017 in Lucknow. The project work included straightening and shortening of the river channel by controlling its width, shape and riverbed by constructing a heavily reinforced diaphragm wall on both banks on an 8.1 km stretch. Their study assessed the loss of river processes and ecosystems under changed hydraulic regimes post a riverfront development project. They argued that due to heavy channel engineering there would be decline in freshwater species and water quality and lowering of groundwater tables in the city. The reduction in water flow will further impact the minimum flows required to maintain the healthy ecosystem in the river broadening the area of ecological disturbances.

**Concluding Remarks**

While researching the environmental studies of the Gomati River I came across a good number of published research papers on this subject. Heavy metals analyses of the Gomati water, sediments and biological entities that inhabit the river are the prime concern of the researchers. In addition, few papers described how phytoplankton populations have been impacted by the river pollution and their role in contaminating the food chain that produces various fish populations which are toxic and not fit for human consumption. These papers describe the source of pollution and suggest remedial measures. But it seems that the scientists’ responsibility ends once the papers are published. I can hazard a guess about the money spent on environmental research on Gomati River by looking at the number of papers published, and the quantum of scientific data generated by so many scientists and non-scientists involved in these projects during the past four decades. Hundreds of crores of rupees must have been spent on these projects. After so much effort by so many scientists and heavy expenditure of money, sadly, Gomati River remains a highly polluted river. I feel utterly gloomy and strongly believe that somewhere we have lost our way in addressing this extremely serious problem. Just highlighting the problems and its source or even addressing solutions is not enough. All such efforts must lead to tangible results in cleaning the river and that would require a strong political and administrative will. Most likely we appear to lack that. My observations in Jaunpur clearly show that most people are ignorant of the severity of the problem they face every day due to river pollution. It is adversely impacting their health and quality of life.
The serious problem of Gomati River pollution is not restricted only to Jaunpur; the situation in Lucknow and other urban centers along this river is equally bad or even worse. Personally, this issue has hurt me very much because I was born in Jaunpur and grew up in Lucknow. I consider both these cities as my home-towns. Again, the billion-rupee question is what more can be done in addition to publishing research papers that highlights the seriousness of the problem to make the river water cleaner; suitable for human activities and produce fish populations that is safe to consume. Environmental activism of the scientists and concerned people might be an answer. Concerned people should take up responsibility in making the common man aware of the problem so that they are not involved in polluting the river and forcing the responsible people and administrative authorities to act.

I have been fortunate to have visited some of the great cities of the world that are located along the rivers, for example, river Thames in London, river Seine in Paris, river Moskva in Moscow, river Potomac in Washington D.C. and river Parramatta in Sydney. All these cities have beautiful river banks and riverside developments that are major tourist attractions. In India, we have an excellent example of beautiful riverside developments along the Sabarmati River in Ahmedabad (Websites 6 and 7). I lived in Ahmedabad for three years between 1970 and 1972 and I remember that Sabarmati River was no more than a dry, dusty and dirty river bed with a little stream of water visible only during the rainy season. Political will and administrative efficiency in Gujarat have changed this river and its banks into a major tourist attraction. A similar project is being developed along the Gomati River in Lucknow as well, but I did not notice tangible developments of this project in November 2018. Even if there are parks and new open spaces developed on the river banks in Lucknow, the river water remains polluted; that defeats the whole purpose of the riverside development project. I sincerely hope one day the Gomati River front in Lucknow will be as beautiful the Sabarmati River front in Ahmedabad.

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