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Surface water quality and pollution load in river Kali-east: A tributary of river Ganga, India

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ABSTRACT

River Kali-East, a tributary of river Ganga, is a non-perennial river of India which is highly driven by the discharge of industrial effluent. The surface water quality of the river indicated that color varied as 20-200 Hazen, dissolved oxygen (DO) as 0-8.16 mg/L, biochemical oxygen demand (BOD)as 6.6-410 mg/L, chemical oxygen demand (COD) as 22-1409 mg/L, total suspended solids as 38-4386 mg/L, total dissolved solids as 180-2536 mg/L and fecal coliform as 4.9×10^{2}-34×10^{7} MPN/100 mL. The river was highly polluted in the stretch from Muzaffarnagar to Bulandshahar district (DO was NIL and BOD reached up to 410 mg/L). No location in the stretch from Muzaffarnagar to Aligarh was found suitable for bathing with respect to DO and BOD. High BOD and COD in the river revealed untreated/partially treated industrial discharge into the river and the self-purification capacity of the river Kali-East has been inhibited for a long distance by heavy and undiminished influx of domestic sewage into the river. Twenty-six drains discharge a total organic load of 148 tonnes per day into the river. Maximum pollution load was contributed by Odean Nala (42%) in Meerut district. This study recommends strict regulatory norms for discharge of industrial effluents by the industries in the catchment area of the river, reduction in sewage treatment gap by utilizing alternative treatment technologies (such as constructed wetlands) and proper dilution of polluted river water to improve the overall quality of the river.

Key words : *Environmental pollution, Industrialization, River water quality*

Introduction

River Kali-East (a tributary of river Ganga) is a non-perennial river driven by sewage and industrial effluent discharge in non-rainy seasons. The catchment area of the Kali-East river consists of sugar, textile, pulp and paper, dairy and food, distillery, slaughter houses and chemical industries. The industrial effluents are characterized with high BOD, high COD, high amounts of organic and inorganic contaminants. Some of the difficult-to-treat pollutants such as chlorinated organics, suspended solids and organic wastes (released by pulp and paper mill effluents), phenols and mineral oils (released by petrochemical industry), etc. are also among the released industrial pollutants. These toxic industrial pollutants, if released untreated into the river stream, may degrade the quality of the river severely. These organic and inorganic pollutants are carcinogenic and cause serious physiological and neurological disorders (Pal *et al.,* 2012).

Considering the pollution load in the river Ganga, there is a strong need to assess and regulate pollution sources in the river Ganga and its tributaries. The present study was carried out with following objectives: (i) to carry out a comprehensive evaluation of surface water quality of river Kali-East from its origin to the confluence with river Ganga;

and (ii) to evaluate the status of pollution load and treatment in the catchment area of river Kali-East.

Materials and Methods

Description of the Study Area

Kali-East river is a non-perennial tributary of the holy river Ganga in India. It originates in Khatauli town (29°16'45.09"N, 77°47'18.96"E) in Muzaffarnagar district of Uttar Pradesh state of India. Thereafter, it traverses a distance of approximately 550 km through the districts of Meerut, Hapur, Ghaziabad, Bulandshahar, Aligarh and Kasganj in Uttar Pradesh. The river Kali-East meets river Ganga in Kannauj district of Uttar Pradesh at 27°0'45.34"N, 79°59'6.76"E. Climate is humid subtropical with predominantly three seasons namely summer season (March-May) which is extremely hot, winter season (November-February) which is cold and rainy season between June and October. The temperature in the area varies from 0 to 50 °C. For the present study, 27 monitoring locations on river Kali-East were selected from its origin to confluence with river Ganga in Kannauj. During its course, 26 drains with different sources (domestic/industrial/mixed) meet with the river. At two locations, freshwater Ganga canals (upper and lower Ganga canals) meet with the river which decreases the pollution load in the river.

Collection and Analysis of River and Drain Samples

Surface river water samples were collected from 27 selected locations during the pre-monsoon season (March-May) of 2019. Grab-samples were collected for physico-chemical (color, pH, DO, BOD, COD, TSS, TDS, Cl^-, NH_3-N, NO_3-N and PO_4^{2-}) and biological (total and fecal coliform) properties of river water. Wastewater samples were collected from 26 drains discharging into the river Kali-East. Grab samples were collected for physico-chemical (color, pH, BOD, COD, TSS, TDS, NH_3-N and NO_3-N) and biological (total and fecal coliform) properties of wastewater in drains. For metal analysis, grab samples of water/wastewater from the river and drains in polypropylene bottles were also collected. After reaching the laboratory, samples were analyzed following standard methods (APHA, 2017). The flow in drains was calculated through ball-float method (CPHEEO, 2013).

Results and Discussion

Physico-chemical Properties of Surface Water of River

In river water, the pH varied as 4.9-8.6, color as 20-200 Hazen, DO as 0-8.16 mg/L, BOD as 6.6-410 mg/L, COD as 22-1409 mg/L, TSS as 38-4368 mg/L, TDS as 180-2536 mg/L, Cl^- as 27-845 mg/L, NH_3-N as 1.5-77.4 mg/L, NO_3-N as 0.1-5.8 mg/L and PO_4-P as 0.2-5.2 mg/L. The color of water influences the photosynthesis process due to differential penetration of light, energy budget, stratification due to thermal gradients, and the aesthetic appearance of the aquatic ecosystems (Branco and Torgersen, 2009). The temperature drives certain chemical and biological reactions taking place in water and aquatic organisms. The pH rigorously affects the water quality by changing the alkalinity, the solubility of metals and hardness of the water (Sener *et al.*, 2017). The dissolved oxygen governs the metabolism of the biological community in an aquatic ecosystem and indicates the trophic status of a water body (Saksena *et al.*, 2008). The DO reduces in the water due to respiration of biota, decomposition of organic matter, rise in temperature, oxygen demanding wastes and inorganic reductants such as hydrogen sulfide, ammonia, nitrates, ferrous iron, etc. BOD accounts for the extent of organic pollution in aquatic ecosystems (Khan *et al.*, 2016). The oxygen requirement during the decomposition of organic matter and oxidation of inorganic chemicals is predicted through COD tests. Theoretically, if COD concentration is higher, then the water is considered polluted.

Nitrates are the most thermodynamically stable and non-toxic form of inorganic nitrogen as it is the end product of the aerobic decomposition of the organic nitrogenous compound (Jaji *et al.*, 2007). The nitrate concentration in the surface water is normally low (0-18 mg/L) however it may reach to elevated levels due to agricultural runoff, oxidation of nitrogenous waste products in human and animal excreta and refuse dump runoff (Mitra *et al.*, 2018). The excess nitrogen transported as nitrate-nitrogen to rivers leads to eutrophication and episodic and persistent hypoxia (DO< 2 mg/L) (Mitsch *et al.*, 2005). The existence of chloride in river water is due to the organic waste in water, primarily of animal origin. Also, major sources of phosphate in river water are domestic sewage, agricultural effluents and industrial wastewaters (Saksena *et al.,* 2008).

In the present study, the river was highly polluted in the stretch from Muzaffarnagar to Bulandshahar district, (DO was NIL and BOD reached up to 410 mg/L). However, after the mixing of the upper and lower Ganga canal in the polluted water of the river Kali-East, the water quality improved (DO increased and BOD decreased). The DO level increased to 7.7 mg/L and BOD decreased to 15.6 mg/L before meeting the river Ganga. In Muzaffarnagar district, high BOD (410 mg/L), COD (1070 mg/L) and TDS (1094 mg/L) in the river water downstream sugar mill drain were observed. Also, low pH (4.9) in river water indicates industrial discharge from near-by industries. In Meerut district, pronounced foul smell around the river was observed D/s Chhoiya drain and Hapur drain. The color of the river water at these locations varied as 154-178 Hazen. The foul smell in the river water may be attributed to anaerobic decomposition of organic matter present in the river. Also, it was observed that river water U/s Chhoiya drain, D/s Chhoiya drain, and D/s Hapur drain is being utilized for irrigation of adjoining agricultural fields. Irrigation of agricultural fields with the polluted river water may lead to bio-amplification of pollutants to the human food chain. In Bulandshahar district, the river water quality (BOD-186 mg/L, COD-1409 mg/L) deteriorated after the discharge of 11 drains into the river. Till Bulandshahar, there was no DO in the river. However, after traversing a distance of approximately 143 km, the river meets upper Ganga canal and lower Ganga canal and the river water quality after meeting the canals improved (DO-5.9 mg/L and fecal coliform-490 MPN/100 mL) at U/s Kasganj drain. In Kannauj district, the DO in the river Kali-East increased to 7.7 mg/L before the confluence with river Ganga.

Biological Properties of Surface Water of River

In river water, the total coliform varied from 790 to 2×10^9 MPN/100 mL and fecal coliform varied from 490 to 34×10^7 MPN/100 mL. Fecal pollution in river water could be caused by untreated sewage, fecal bacteria remaining in the treated wastewater, and feces of wild and farmed animals. Moreover, open defecation along the banks of the river could also be the reason for elevated fecal coliform concentrations in river water (Haque *et al.,* 2019). The stretch of river from Muzaffarnagar to Bulandshahar contained high total and fecal coliform levels due to the discharge of untreated domestic sewage from the drains. However, after meeting the upper Ganga canal and lower Ganga canal in Aligarh, the total coliform and fecal coliform levels in river water at U/s Kasganj drain reached 790 and 490 MPN/100 mL, respectively. For fecal coliform, only two locations, namely, (i) U/s Kasganj drain in Kasganj and (ii) at Khudaganj bridge in Kannauj were meeting bathing water quality standards. The total and fecal coliform concentration in surface water of the river Kali-East before the confluence with river Ganga were 2.8×10^8 and 9.4×10^6 MPN/100 mL. The discharge of high levels of coliforms by the river Kali-East into the river Ganga increases the fecal pollution load in river Ganga which could have adverse effects on the population dependent on the water of the river Ganga for drinking and cooking purposes.

Metals Concentration in Surface Water of River

Metals concentrations (mg/L) ranged as Cd bdl (below detection limit)-0.15, Cr bdl-0.19, Cu bdl-0.77, Fe bdl-15.7, Pb bdl-0.32, Mn bdl-0.89, Ni bdl-0.17, Hg bdl-0.11, Zn bdl-1.96, Sb bdl-0.01, Co bdl-0.03 and V bdl-0.17. The sources of metals such as Cd, Cr, and Cu are reported to be domestic as well as commercial (Masood and Malik, 2011). Apart from domestic wastewater, the catchment area of the river Kali-East comprises of several industries pertaining to sugar, textile, pulp & paper, dairy & food, distillery, and chemical sectors. These industries may also contribute to metal pollution in the river Kali-East. For e.g., textile wastewater consists of Cu, Fe, Mn, Pb, Zn, Cd, and Cr (Oyebamiji *et al.,* 2019), and distillery wastewater contains Cu, Cr, Zn, Fe, Ni, Mn, and Pb (Chowdhary *et al.,* 2018). The composition of wastewater generated by food and dairy and chemical industries depends upon the product-specific raw materials.

Pollution Load due to Drains

Twenty-six drains (domestic and industrial) discharge wastewater into the river Kali-East accounting for total flow and an organic load of 803 MLD and 148 tonnes per day, respectively. Odean Nala is the major contributor in terms of pollution load (42%). Two drains namely the Odean Nala (25%) and Abu Nala-2 (25%) accounted for 50% of the total wastewater being discharged into the river. The maximum pollution load was contributed by Meerut i.e. 67.7 % of the total pollution load on the river Kali-East. In drains, the colour varied as 37-317 Hazen, pH as 5.1-8.2, BOD as 21.8-1067 mg/L, COD as 104-1752 mg/L, TSS as 48-946 mg/L, TDS as 552-2572 mg/L, NH_3-N as 5-82 mg/L and NO_3-N as 0.7-4.6 mg/L. High BOD (1067 mg/L), high COD (1752 mg/L), and acidic pH (5.1) were observed in the Sugar mill drain in Muzaffarnagar which indicated the untreated/partially treated industrial discharge into the river. Saini Village drain in Meerut consisted of high BOD (385 mg/L) and high COD (893 mg/L) which may be attributed to the discharge of wastewater from paper industries in the catchment area. Also, Odean Nala comprised BOD-311 mg/L and COD-721 mg/L which may be due to industrial discharge from textile industries and illegal slaughtering activities in the vicinity.

Conclusion

This study revealed that the river was highly polluted in the stretch from Muzaffarnagar to Bulandshahar district, (DO was NIL and BOD reached up to 410 mg/L). However, after the mixing of the upper and lower Ganga canal in the polluted water of the river Kali-East, the water quality improved (DO increased and BOD decreased). The DO level increased to 7.7 mg/L and BOD decreased to 15.6 mg/L before meeting the river Ganga. With respect to DO, no location in the stretch from Muzaffarnagar to Aligarh was found suitable for bathing. Also, no location in the whole stretch of the river meets bathing water quality w.r.t. BOD. High BOD and COD in the river revealed untreated/partially treated industrial discharge into the river and the self-purification capacity of the river Kali-East has been inhibited for a long distance by the heavy and undiminished influx of domestic sewage into the river. A total of 26 drains discharge an organic load of 148 tonnes per day into the river. The maximum pollution load was contributed by Odean Nala (42%) in the Meerut district. This study recommends strict regulatory norms for industries in the catchment area of the river, reduction in sewage treatment gap and proper dilution of polluted river water to improve the overall quality of the river.

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