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Taking the pulse of Mother Ganga - Revealing the visible and invisible water pollution crisis along the Ganges River

Stefan Krause[1,2,3] and the Team SAPTANADI[*]
[1]University of Birmingham, School of Geography, Earth and Environmental Sciences, School of Geography, Earth and Environmental Sciences, Birmingham, UK (s.krause@bham.ac.uk)
[2]Institute of Global Innovation, Birmingham, UK
[3]LEHNA-Laboratoire d'ecologie des hydrosystemes naturels et anthropises, Université Claude Bernard Lyon1, Lyon, France
[*]A full list of authors appears at the end of the abstract

It is probably hard to overestimate the significance of the River Ganges for its spiritual, cultural and religious importance. As the worlds' most populated river basin and a major water resource for the 400 million people inhabiting its catchment, the Ganges represents one of the most complex and stressed river systems globally. This makes the understanding and management of its water quality an act of humanitarian and geopolitical relevance. Water quality along the Ganges is critically impacted by multiple stressors, including agricultural, industrial and domestic pollution inputs, a lack and failure of water and sanitation infrastructure, increasing water demands in areas of intense population growth and migration, as well as the severe implications of land use and climate change. Some aspects of water pollution are readily visualised as the river network evolves, whilst others contribute to an invisible water crisis (Worldbank, 2019) that affects the life and health of hundreds of millions of people.

We report the findings of a large collaborative study to monitor the evolution of water pollution along the 2500 km length of the Ganges river and its major tributaries that was carried out over a six-week period in Nov/Dec 2019 by three teams of more than 30 international researchers from 10 institutions. Surface water and sediment were sampled from more than 80 locations along the river and analysed for organic contaminants, nutrients, metals, pathogen indicators, microbial activity and diversity as well as microplastics, integrating in-situ fluorescence and UV absorbance optical sensor technologies with laboratory sample preparation and analyses. Water and sediment samples were analysed to identify the co-existence of pollution hotspots, quantify their spatial footprint and identify potential source areas, dilution, connectivity and thus, derive understanding of the interactions between proximal and distal of sources solute and particulate pollutants.

Our results reveal the co-existence of distinct pollution hotspots for several contaminants that can be linked to population density and land use in the proximity of sampling sites as well as the contributing catchment area. While some pollution hotspots were characterised by increased concentrations of most contaminant groups, several hotspots of specific pollutants (e.g., microplastics) were identified that could be linked to specific cultural and religious activities. Interestingly, the downstream footprint of specific pollution hotspots from contamination sources

along the main stem of the Ganges or through major tributaries varied between contaminants, with generally no significant downstream accumulation emerging in water pollution levels, bearing significant implications for the spatial reach and legacy of pollution hotspots. Furthermore, the comparison of the downstream evolution of multi-pollution profiles between surface water and sediment samples support interpretations of the role of in-stream fate and transport processes in comparison to patterns of pollution source zone activations across the channel. In reporting the development of this multi-dimensional pollution dataset, we intend to stimulate a discussion on the usefulness of large river network surveys to better understand the relative contributions, footprints and impacts of variable pollution sources and how this information can be used for integrated approaches in water resources and pollution management.

Team SAPTANADI: University of the West of England (UK): Darren M Reynolds, Robin MS Thorn, Gillian E Clayton, Eva Perrin, Bethany G Fox; Bose Institute, Kolkata (India): Tapan K Dutta; UKCEH (UK): Michael J Bowes, Daniel S Read, David J.E. Nicholls, Linda K Armstrong; IIT Roorkee (India): Moushumi Hazra, Himanshu Joshi; University of Manchester (UK): Laura A Richards, David A Polya; Mahavir Cancer Sansthan (India): Ashok Ghosh, Arun Kumar, Rupa Kumari, Aman Gaurav, Siddhu Kumar; National Institute of Hydrology (India): Sumant Kumar, Biswajit Chakravorty; British Geological Survey (UK): Daren Gooddy; University of Birmingham (UK): Stefan Krause, Kieran Khamis, Holly Nel, Uwe Schneidewind, Ben Howard, Danielle Mewes, David Hannah; University of Lincoln (UK): Daniel Magnone