Impact of COVID-19 on Water Quality Index of river Yamuna in Himalayan and upper segment: analysis of monsoon and post-monsoon season

Shiwani Sharma1 · AnuShri Gupta1

Received: 8 April 2021 / Accepted: 8 March 2022 / Published online: 15 April 2022
© The Author(s) 2022

Abstract

Rivers are the lifeline of every living being, be it humans or animals. Clean water is essential for everyone. However, increased urbanization and rapid industrialization have led to rising pollution level in rivers. COVID-19 on the contrary has changed the entire ecosystem. Limited industrial activities, reduced people movement during COVID times has led to improvement in environment, be it atmosphere or hydrosphere. Present work aims to study the impact of COVID-19 on water quality index of river Yamuna as it traverses from Himalayan segment to Upper segment. Five sites are chosen between a stretch of 60+ km, and samples are collected during monsoon and post-monsoon seasons. Physico-chemical parameters (pH, Turbidity, Sulphate, Phosphate, Fluoride, Chloride, Total Hardness, Calcium, Magnesium, Dissolved Oxygen, BOD, COD, Alkalinity), water quality index and Pearson correlation coefficient were calculated for all chosen sites. Since the study was initiative during COVID, initial results show the impact of reduced industrial and urban activities in improving the overall water quality.

Keywords Physico-chemical parameters · Water quality index · River Yamuna · Water pollution · Himalayan and upper segment · COVID-19

Introduction

Water is the most vital resource for human existence and for developmental activities that take place around the world (Wan Mohtar 2019). Rivers have been the prime source of water since ancient times. Cities and industries have developed close to rivers. Along with industrial usage, rivers act as a major source for irrigation and daily needs (Meybeck 1976; Ridoutt and Pfister 2010; Somashekar et al. 2010). Even today, close to 50% of the world’s population is residing within 3 km of some surface freshwater source (Matti et al. 2011). While rivers have contributed to the overall development of the world, it has put a lot of pressure on the quality of water because of increased pollution levels. Over time, there has been deterioration in water quality due to natural and anthropogenic factors (Vadde et al. 2018; Nitasha and Sanjiv 2014). Deterioration of water quality has impacted the human as well as aquatic life (Aswal et al. 2016; Jindal and Sharma 2010; Kamboj et al. 2017; Sreebha and Padmalal 2011). Because of the importance that fresh water holds for humans and deterioration that has been happening since decades, it becomes important to assess the water quality on regular intervals and take appropriate measures to improve it.

Year 2020 holds and will continue to hold a lot of mind-space, as it has completely changed the way whole world operates. COVID-19, declared as an International Emergency of Public Health by World Health Organization (Kambalgere 2020; Sohrabi et al. 2020), has deeply impacted the economic development of twenty-first century. While the sudden lockdowns across countries have harmed the economic activities, overall environment has benefitted because of limited anthropogenic activities (Beine et al. 2020; Ray et al. 2020; Huang et al. 2020). Various studies done across nations showed significant ecological restoration (Ma et al. 2020; AnuShri Gupta1 · AnuShri Gupta1

anushrigupta894@gmail.com

Shiwani Sharma1 · AnuShri Gupta1

1 Department of Chemistry, School of Sciences, Abhilashi University, Chailchowk, Mandi, Himachal Pradesh 175028, India
Vasistha and Ganguly 2020a, b). It has been noticed that during various physical, chemical and biological parameters (Mukherjee et al. 2020).

Indian Standards (BIS 2012).

standards used are the ones recommended by Bureau of Indian Standards (IS 15654, 1998, Nives 1999; Pesce and Wunderlin 2000). There are various methods to calculate the water quality index: weighted arithmetic index method (Brown et al. 1970), National Sanitation Foundation Water Quality Index (NSFWQI) (Hoseinzadeh et al. 2014), etc. In our study, weighted arithmetic index method was used to calculate WQI. This is the most comprehensive way to measure water pollution where bulk of data is reduced to a single value to express information in simple way. The standards used are the ones recommended by Bureau of Indian Standards (BIS 2012).

Study area

The study is done between a distance of 65+ km. Sampling sites have not only been selected from origin and end points but in between the stretch too. Study aims to show variation in various physico-chemical parameters in Himalayan and Upper Segments, where variation in water quality could happen due to influx of various pollutants. Variation in water quality index is analysed to show the impact of pollutants within the mentioned range, which can be of help to improve the situation at specific sites. Description of 5 sample sites in three states—Uttarakhand, Himachal Pradesh and Haryana—is given in Table 1 and Fig. 1.

Methodology

Samples were collected from each site in September and December’20. September was the monsoon month with limited industrial activity and commercialization because of COVID. Another lot of samples were collected in December’20 (Post-Monsoon period). Most of the industrial and commercial activities had started (similar to the Pre-COVID times). Samples were collected from 50 cm depth at each site. Pre-cleaned and De-ionized bottles were used to collect the samples and were preserved in a proper way. Various physico-chemical parameters were considered to assess the pollution levels/water quality. Temperature and dissolved oxygen were calculated at sample collection points. Methods recommended by APHA (23rd edition) were used for analysis. pH was analysed by pH Meter (Systronics pH System 361). Electrical conductivity was measured using Conductivity Meter (Systronics Conductivity Meter 306). Total hardness was measured using EDTA Titrimetric method (IS 3025). TDS was calculated using 2540-C method, and TSS was calculated using 2540-D. Biological oxygen demand (BOD) was calculated by incubation of sample for 5 days (APHA 5210-B) and chemical oxygen demand (COD) by closed reflux method (522C and D). Spectrophotometer was used to detect fluoride (Spadns method) and nitrate. Titrimetric method was used to analyse Chloride (Arginometric method).

Calculation of water quality index (WQI) using weighted arithmetic method

Step 1: Collect data of various physico-chemical water quality parameters.
Step 2: Calculate Proportionality constant “K” value using formula;

\[ K = \left[ \frac{1}{\sum n_i s_i} \right] \]

where “s_i” is standard permissible for n^th parameter.
Step 3: Calculate quality rating for n^th parameter (q_n) where there are n parameters. This is calculated using formula

\[ q_n = 100 \left( \frac{v_n - v_{io}}{s_n - v_{io}} \right) \]

where v_n = Estimated value of the n^th parameter of the given sampling station. v_{io} = Ideal value of n^th parameter in pure water. And s_n = Standard permissible value of the n^th parameter.
Step 4: Calculate unit weight for the n^th parameters. \( W_n = (k/s_n) \).
Step 5: Calculate water quality index (WQI) using formula,

\[ WQI = \frac{\sum W_n q_n}{\sum W_n} \]
Water quality status is judged on the basis of numerical value received from WQI depicted in Table 2.

**Table 2** Various Index levels and their corresponding water quality

| Water quality index level | Water quality status | Possible usage                      |
|--------------------------|----------------------|------------------------------------|
| 0–25                     | Excellent            | Drinking, irrigation, industrial   |
| 26–50                    | Good                 | Drinking, irrigation, industrial   |
| 51–75                    | Poor                 | Irrigation and industrial          |
| 76–100                   | Very poor            | Irrigation                         |
| > 100                    | Unsuitable for drinking | Treatment required before use     |

Water quality status is judged on the basis of numerical value received from WQI depicted in Table 2.

**Results and discussions**

Results of all the analysed physico-chemical parameters during the monsoon and post-monsoon seasons are shown in Table 3 (BIS 2012; Pipraiya et al. 2017).

Conductivity shows higher values than the standards in Site 5 during post-monsoon season. Calcium hardness, magnesium hardness, DO and total alkalinity are more than the permissible limits set by BIS (Bureau of Indian Standards) in both monsoon and post-monsoon season.

The water quality index for various sites of the river Yamuna was calculated from thirteen parameters, namely pH, turbidity, conductivity TDS, TSS, nitrate, chloride, total hardness, calcium hardness, magnesium hardness, total alkalinity, DO and sulphate. Five sampling stations were chosen to assess the aptness of river water for general purposes.

The descriptive statistics of these physico-chemical water quality parameters for each site were considered (Singh et al. 2018; Vasistha and Ganguly 2020a, b) and calculated by adopting weighted arithmetic method and given in Tables 4 and 5.

The above values depict that water quality index of 5 sites under analysis show deterioration during the post-monsoon season. This is against the regular trend where monsoon season usually witnesses higher WQI than the post-monsoon season. The primary reason attributed to this variation is the impact of COVID on industrial, commercial and tourist activities. Since the industrial activities
were less because of precautionary/administrative measures, the pollution through discharge of effluents was also minimal. To add on, there was less movement of people to work and leisure.

Water quality index of all sites in post-monsoon season is higher than monsoon season. While most of the sites show poor Water Quality Index, there is a major variation at Site 5 (WQI changed from poor to very poor as shown in Table 6 and Fig. 2).

Table 3 Results of analysed physico-chemical parameters in monsoon and post-monsoon period

| Parameter     | Standards | Monsoon | Post-monsoon |
|---------------|-----------|---------|--------------|
|               | BIS-2012  | Site 1  | Site 2  | Site 3  | Site 4  | Site 5  | Site 1  | Site 2  | Site 3  | Site 4  | Site 5  |
| pH            | 8.5       | 7.2     | 7.3     | 7.3     | 7.5     | 7.9     | 7.5     | 7.6     | 7.7     | 7.8     | 7.9     |
| Turbidity     | 10        | 3       | 4.1     | 5.3     | 7       | 6.5     | 3.1     | 3.4     | 3.3     | 8.5     | 9       |
| Conductivity  | 300       | 206.4   | 212.4   | 219.6   | 264.1   | 279.1   | 277    | 284.8   | 300.75  | 232.9   | 349.6   |
| TDS           | 500       | 215     | 169     | 157     | 175     | 164     | 288    | 288     | 267     | 202     | 254     |
| TSS           | 500       | 6       | 10      | 8       | 28      | 32      | 2       | 37      | 6       | 39      | 42      |
| Nitrate       | 45        | 0.4     | 0.45    | 0.41    | 0.66    | 0.85    | 0.81    | 0.84    | 0.85    | 1.06    | 1.67    |
| Fluoride      | 1.5       | 0.39    | 0.36    | 0.36    | 0.39    | 0.49    | 0.37    | 0.34    | 0.41    | 0.7     | 0.98    |
| Sulphate      | 150       | 25.3    | 25.78   | 28.7    | 22.12   | 28.64   | 16.98   | 36.86   | 37.89   | 30.05   | 33.03   |
| Phosphate     | 5         | 0.13    | 0.14    | 0.14    | 0.16    | 0.16    | 0.09    | 0.12    | 0.14    | 0.12    | 0.12    |
| Chloride      | 250       | 6.2     | 9.94    | 7.1     | 14.2    | 24.14   | 11.36   | 12.78   | 12.21   | 11.36   | 22.72   |
| Total hardness| 200       | 123     | 138     | 126     | 134     | 134     | 138    | 200     | 182     | 124     | 168     |
| Calcium hardness | 75     | 96      | 80      | 106     | 100     | 84      | 90      | 130     | 112     | 78      | 104     |
| Magnesium hardness | 30    | 27      | 58      | 20      | 34.01   | 50      | 48      | 70      | 70      | 46      | 64      |
| DO            | 5         | 8.4     | 7.6     | 8       | 7.3     | 7.1     | 8.5     | 6.7     | 8.2     | 7.7     | 5.2     |
| BOD           | 5         | 0.7     | 0.8     | 0.7     | 0.9     | 1       | 0.2     | 0.9     | 0.5     | 1.1     | 2.8     |
| COD           | 5         | 2.4     | 2.4     | 1.6     | 4       | 4.8     | 1.6     | 2.4     | 1.6     | 4.8     | 5.6     |
| Total alkalinity | 120   | 360     | 245     | 300     | 245     | 230     | 135    | 170     | 150     | 105     | 165     |
| Bicarbonate   | 120       | 360     | 245     | 300     | 245     | 230     | 135    | 170     | 150     | 105     | 165     |

Table 4 Standard values and standard weights of various parameters

| Parameters     | Standard value ($S_n$) | Standard weight ($W_n$) |
|----------------|------------------------|------------------------|
| pH             | 8.5                    | 0.2272                 |
| Turbidity      | 10                     | 0.1931                 |
| Conductivity   | 300                    | 0.0064                 |
| TDS            | 500                    | 0.0039                 |
| TSS            | 500                    | 0.0039                 |
| Nitrate (as Nitrogen) | 45                    | 0.0429                 |
| Chloride       | 250                    | 0.0077                 |
| Total hardness | 200                    | 0.0097                 |
| Calcium hardness | 75                    | 0.0257                 |
| Magnesium hardness | 30                    | 0.0644                 |
| Total alkalinity | 120                   | 0.0161                 |
| DO             | 5                      | 0.3862                 |
| Sulphate       | 150                    | 0.0129                 |

Correlation between various parameters

Correlation between various variables is depicted through Pearson correlation coefficient. It is a statistical tool that measures the relationship between various variables (physico-chemical parameters in our study). It provides information on magnitude of correlation and the direction of its relationship. (Tables 7 and 8).

The above correlation matrix indicates that highly positive correlation values for conductivity with pH and turbidity; TSS with pH, turbidity and conductivity; nitrate with pH, turbidity, conductivity and TSS; Chloride with pH, turbidity, conductivity, TSS and nitrate; magnesium hardness with total hardness and total alkalinity with DO in monsoon season.

In post-monsoon season, highly positive correlation exists between turbidity with pH; nitrate with pH and turbidity; chloride with conductivity and nitrate; calcium hardness with total hardness; magnesium hardness with sulphate, total hardness and calcium hardness; total alkalinity with total hardness, and calcium hardness.

Conclusion

COVID-19 has had a significant impact on the overall environment. This research signifies its impact on the Water Quality Index of river Yamuna during the monsoon season and compares it with the post-monsoon season.
Pollution arising from various sources significantly impacts the water quality. In this study, the primary focus was on thirteen water quality parameters (pH, Turbidity, Sulphate, Phosphate, Fluoride, Chloride, Total Hardness, Calcium, Magnesium, Dissolved Oxygen, BOD, COD and Alkalinity) to illustrate impact of rising pollution levels of river water quality from five sampling stations. Conductivity shows higher values than the standards in Site 5 during post-monsoon season. Total hardness is on specified limit in Site 2 during post-monsoon season. Calcium hardness shows higher than standard values for all sites during monsoon and post-monsoon season. Magnesium hardness is more than limits at Site 2, 4 and 5 during monsoon season and across all sites in post-monsoon season. D.O and alkalinity show higher values than limits across all sites during both seasons. Emphasis was also given on comparison of WQI during monsoon and post-monsoon season. Water quality index (WQI) during monsoon season usually shows deterioration. However, because of minimal industrial activities and low tourism during COVID, there is a significant improvement in overall parameters at all sites. As normal activities start post opening up by the administration, the water quality index (WQI) shows deterioration during the post-monsoon season, when compared with monsoon season. Correlation coefficient depicts the relation of various parameters with each other.
### Table 7  Correlation among various parameters during monsoon season

| Parameters                      | pH   | Turbidity | Conductivity | TDS  | TSS  | Nitrate | Sulphate | Chloride | Total hardness | Calcium hardness | Magnesium hardness | Dissolved Oxygen | Total alkalinity |
|--------------------------------|------|-----------|--------------|------|------|---------|----------|----------|----------------|------------------|--------------------|------------------|-----------------|
| pH                             | 1    |           |              |      |      |         |          |          |                |                  |                    |                  |                 |
| Turbidity                      | 0.74 | 1         |              |      |      |         |          |          |                |                  |                    |                  |                 |
| Conductivity                   | 0.93 | 0.90      | 1            |      |      |         |          |          |                |                  |                    |                  |                 |
| TDS                            | −0.44| −0.64     | −0.41        | 1    |      |         |          |          |                |                  |                    |                  |                 |
| TSS                            | 0.91 | 0.87      | 0.99         | −0.36| 1    |         |          |          |                |                  |                    |                  |                 |
| Nitrate                        | 0.98 | 0.78      | 0.97         | −0.35| 0.97 | 1       |          |          |                |                  |                    |                  |                 |
| Sulphate                       | 0.26 | −0.08     | −0.04        | −0.42| −0.14| 0.05    | 1        |          |                |                  |                    |                  |                 |
| Chloride                       | 0.99 | 0.71      | 0.92         | −0.40| 0.92 | 0.98    | 0.18     | 1        |                |                  |                    |                  |                 |
| Total hardness                 | 0.46 | 0.45      | 0.45         | −0.54| 0.53 | 0.50    | −0.19    | 0.55     | 1               |                  |                    |                  |                 |
| Calcium hardness               | −0.36| 0.14      | −0.13        | 0.06 | −0.22| −0.34   | −0.13    | −0.47    | −0.68          | 1                |                    |                  |                 |
| Magnesium hardness             | 0.43 | 0.08      | 0.27         | −0.25| 0.36 | 0.43    | 0.01     | 0.54     | 0.86           | −0.96            | 1                  |                  |                 |
| Dissolved Oxygen               | −0.84| −0.83     | −0.87        | 0.62 | −0.90| −0.87   | 0.06     | −0.87    | −0.82          | 0.43             | −0.62              | 1                |                 |
| Total alkalinity               | −0.70| −0.74     | −0.70        | 0.74 | −0.74| −0.71   | 0.02     | −0.74    | −0.92          | 0.49             | −0.70              | 0.96             | 1                |

### Table 8  Correlation among various parameters during post-monsoon season

| Parameters                      | pH   | Turbidity | Conductivity | TDS  | TSS  | Nitrate | Sulphate | Chloride | Total hardness | Calcium hardness | Magnesium hardness | Dissolved Oxygen | Total alkalinity |
|--------------------------------|------|-----------|--------------|------|------|---------|----------|----------|----------------|------------------|--------------------|------------------|-----------------|
| pH                             | 1    |           |              |      |      |         |          |          |                |                  |                    |                  |                 |
| Turbidity                      | 0.89 | 1         |              |      |      |         |          |          |                |                  |                    |                  |                 |
| Conductivity                   | 0.35 | 0.11      | 1            |      |      |         |          |          |                |                  |                    |                  |                 |
| TDS                            | −0.69| −0.79     | 0.42         | 1    |      |         |          |          |                |                  |                    |                  |                 |
| TSS                            | 0.67 | 0.74      | 0.08         | −0.49| 1    |         |          |          |                |                  |                    |                  |                 |
| Nitrate                        | 0.85 | 0.84      | 0.63         | −0.36| 0.62 | 1       |          |          |                |                  |                    |                  |                 |
| Sulphate                       | 0.48 | 0.10      | 0.28         | −0.12| 0.43 | 0.16    | 1        |          |                |                  |                    |                  |                 |
| Chloride                       | 0.69 | 0.61      | 0.84         | −0.03| 0.50 | 0.94    | 0.23     | 1        |                |                  |                    |                  |                 |
| Total hardness                 | −0.08| −0.42     | 0.54         | 0.61 | 0.08 | −0.06   | 0.71     | 0.22     | 1               |                  |                    |                  |                 |
| Calcium hardness               | −0.19| −0.48     | 0.48         | 0.67 | 0.08 | −0.14   | 0.64     | 0.15     | 0.99           | 1                |                    |                  |                 |
| Magnesium hardness             | 0.11 | −0.30     | 0.63         | 0.48 | 0.09 | 0.07    | 0.80     | 0.32     | 0.97           | 0.92             | 1                  |                  |                 |
| Dissolved Oxygen               | −0.66| −0.61     | −0.67        | 0.07 | −0.79| −0.84   | −0.42    | −0.90    | −0.37          | −0.33            | −0.40              | 1                |                 |
| Total alkalinity               | −0.03| −0.28     | 0.80         | 0.71 | 0.11 | 0.21    | 0.45     | 0.52     | 0.89           | 0.89             | 0.86               | −0.57            | 1                |
Acknowledgements The facilities provided by Himachal Pradesh Pollution Control Board (HPPCB) for allowing carrying out the research work in their laboratory is gratefully acknowledged.

Author's contribution AG involved in conceptualization, methodology, software, formal analysis, and supervision. SS involved in investigation, resources, data curation, writing—original draft, and writing—review and editing.

Funding The author(s) received no specific funding for this work.

Availability of data and material All data and material related to this paper are readily available.

Code availability Not applicable.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical approval I hereby declare that the research paper: ‘Impact of COVID 19 on Physico-Chemical properties of River Yamuna in Himachal and Upper Segment’, is my original work and has not formed the basis of any degree/diploma or fellowship. It has not been submitted to any other Journal.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

Aswal RS, Singh P, Kamboj N, Singh R (2016) Chemometric techniques: a comparative study of drinking water sources of Dehradun and Haridwar, Uttarakhand (India). Adv Health Environ Saf Select Proc HSFEA. https://doi.org/10.1007/978-981-10-7122-5_33

Beine M, Bertoli S., Chen S, D’Ambrosio C, Docrigue F, Dupuy A, Fusco A, Girardi S, Haas T, Islam N, Koulovatanos C (2020) Economic effects of Covid-19 in Luxembourg

Bera B, Bhattacharjee S, Shit PK, Sengupta N, Saha S (2020) Significant impacts of COVID-19 lockdown on urban air pollution in Kolkata (India) and amelioration of environmental health. Environ Dev Sustain 23(5):6913–6940. https://doi.org/10.1007/s10668-020-00898-5

Bharti N, Katyal D (2011) Water quality indices used for surface water vulnerability assessment. Int J Environ Sci 2(1):154–173

BIS (2012) Bureau of Indian Standards, New Delhi. https://bis.gov.in/wp-content/uploads/2020/10/PM-IS-10500.pdf

Brown RM, McClelland NI, Deininder RA, Tozer RG (1970) A water quality index—do we dare? Water Sew Works 117(10):339–343

Chakraborty S, Mitra A, Pramanick P, Zaman S, Mitra A (2020) Scanning the water quality of lower Gangetic delta during COVID-19 lockdown phase using dissolved oxygen (DO) as proxy. NUJS J Regul Stud. https://www.researchgate.net/publication/341151469_Scanning_the_water_quality_of_lower_Gangetic_delta_during_COVID-19_lockdown_phase_using_Dissolved_Oxygen_DO_as_proxy

CPCB (2020) Impact of lockdown (25th March to 15th April) on air quality. Ministry of Environment, Forest and Climate Change) Govt. of India, pp 1–62

Dhar I, Biswas S, Mitra A, Pramanick P, Mitra A (2020) COVID-19 lockdown phase: a boon for the river Ganga water quality along the city of Kolkata

Gautam S, Hens L (2020) SARS-CoV-2 pandemic in India: what might we expect? Environ Dev Sustain 22:3867–3869

Hoseinzadeh E, Khorsandi H, Wei C, Alipour M (2014) Evaluation of aydughmesh river water quality using the national sanitation foundation water quality index (NSWQI), river pollution index (RPI), and forestry water quality index (FWQI). Desalin Water Treat 54:2994–3002

Huang X, Ding A, Gao J, Zheng B, Zhou D, Qi X, Tang R, Ren C, Nie W, Chi X, Wang J (2020) Enhanced secondary pollution offset reduction of primary emissions during COVID-19 lockdown in China. Natl Sci Rev. https://doi.org/10.1093/nsr/nwaal137

Jindal R, Sharma C (2010) Studies on water quality of Sutlej River around Ludhiana with reference to physicochemical parameters. Environ Monit Assess 174:417–425

Kambalagere Y (2020) A study on air quality index (AQI) of Bengaluru, Karnataka during lockdown period to combat coronavirus disease (Covid-19): air quality turns ‘better’ from ‘hazardous.’ Stud Indian Place Names 40(69):59–66

Kamboj V, Kamboj N, Sharma S (2017) Environmental impact of riverbed mining—a review. Int J Sci Res Rev 7(1):504–520

Khatri N, Tyagi S (2015) Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. Front Life Sci 8(1):23–39

Ma Y, Zhao Y, Liu J, He X, Wang B, Fu S, Yan J, Niu J, Zhou J, Luo B (2020) Effects of temperature variation and humidity on the death of COVID-19 in Wuhan, China. Sci Total Environ 724:138226

Mani KS (2020) The lockdown cleaned the Ganga more than ‘Namami Gange’ ever did. https://science.thewire.in/environment/ganga-river-lockdown-cleaner-namami-gange-sewage-treatment-ecological-flow/

Matt K, Moel HD, Ward PJ, Olli V (2011) How close do we live to water? A global analysis of population distance to freshwater bodies. PLoS ONE 6(6):e20578

Meybeck M (1976) Total mineral transport by world major rivers. Hydrol Sci Bull 21:265–284. https://doi.org/10.1080/02626667609491631

Mukherjee P, Pramanick P, Zaman S, Mitra A, (2020). Eco-restoration of river Gsanga water quality during COVID-19 lockdown period using total coliform (TC) as proxy. NUJS J Regul Stud Spec Issue

Nives SG (1999) Water quality evaluation by index in Dalmatia. Water Res 33(16):3423–3440

Pesce SF, Wunderlin DA (2000) Use of water quality indices to verify the impact of Córdoba City (Argentina) on Suquía River. Water Res 33(16):3423–3440

Pipraiya A, Vishwakarma RK, Tiwari S (2017) Effect of nearby cities on water quality of Chambal river. Int J Adv Eng Res Dev 4:438–443

Ray D, Salvatore M, Bhattacharjiya R, Wang L, Mohammed S, Purkayastha S, Halder A, Rix A, Barker D, Kleinsasser M, Zhou Y (2020) Predictions, role of interventions and effects of a historic
national lockdown in India’s response to the COVID-19 pandemic: data science call to arms. Harv Data Sci Rev. https://doi.org/10.1162/99608f92.60e08ed5

Ridoutt BG, Pfister S (2010) A revised approach to water foot printing to make transparent the impacts of consumption and production on global freshwater scarcity. Glob Environ Chang 20(1):113–120. https://doi.org/10.1016/j.gloenvcha.2009.08.003

Sargaonkar A, Deshpande V (2003) Development of an overall index of pollution for surface water based on a general classification scheme in Indian context. Environ Monit Assess 89:43–67

Sharma S, Zhang M, Gao J, Zhang H, Kota SH (2020b) Effect of restricted emissions during COVID-19 on air quality in India. Sci Total Environ 728:138878

Singh PK, Panigrahy BK, Verma P, Kumar B (2018) Evaluation of the surface water quality index of Jharia coal mining region and its management of surface water resources. In: Singh VP, Yadav S, Yadava RN (eds) Environmental pollution, water science and technology library, vol 77. Springer, Singapore

Sohrabi C, Alsafi Z, O’Neill N, Khan M, Kerwan A, Al-Jabir A, Llosa E, Vehik F, Yameen Z, Kazem Z, Zobova K, Ali Haider M, Hadi周りの学者が2020年1月17日にデジタル出版された論文で、世界保健機関が2019新型コロナウイルス（COVID-19）の世界的な緊急を宣言したことをレビューしています。Int J Surg 76:71–76

Sreebha S, Padmalal D (2011) Environmental impact assessment of sand mining from the small catchment rivers in the southwestern coast of India: a case study. Environ Monag 47(1):130–140. https://doi.org/10.1007/s00267-010-9571-6

Somashekar RK, Nagaraja BC, Sunil C (2010) Riparian vegetation assessment of Cauvery River Basin of South India. Environ Monit Assess. https://doi.org/10.1007/s10661-009-1256-3

Sunil C, Somashekar RK, Nagaraja BC (2010) Riparian vegetation assessment of Cauvery River basin of South India. Environ Monit Assess 170:545–553

Vadde KK, Wang J, Long C, Yuan T, McCarthy A, Sekar R (2018) Assessment of water quality and identification of pollution risk locations in Tiaoxi river (Taihu watershed), China. Water 10:183

Vasistha P, Ganguly R (2020a) Assessment of spatio-temporal variations in lake water body using indexing method. Environ Sci Pollut Res 27:41856–41875

Vasistha P, Ganguly R (2020b) Water quality assessment of natural lakes and its importance: an overview. Mater Today Proc 32:544–552

Wan Mohtar WHM, Abdul Maulud KN, Muhammad NS, Sharil S, Yaseen ZM (2019) Spatial and temporal risk quotient based river assessment for water resources management. Environ Pollut 248:133–144

Yongjian Z, Jingu X, Fengming H, Liqing C (2020) Association between short-term exposure to air pollution and COVID-19 infection: evidence from China. Sci Total Environ 727:138704

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.