Original Article

Journal of Microbiology and Related Research
Volume 7 Number 1, January - June 2021
DOI: http://dx.doi.org/10.21088/jmrr.2395.6623.7121.1

Effect of COVID-19 Pandemic on Quality of Ganga River water in Uttrakhand: A Longitudinal Study

Prashant Kumar[1], Ashish Kothari[2], Madhur Uniyal[3], Anissa Atif Mirza[4], Balram Ji Omar[5]

How to cite this article:
Prashant Kumar, Ashish Kothari, Madhur Uniyal, *et. al.*/Effect of COVID-19 Pandemic on Quality of Ganga River water in Uttrakhand: A Longitudinal Study/J Microbiol Relat Res. 2021;7(1): 9–17.

Abstract

This study aims to show the Indirect effect of SARS Covid-19 on the River water of Ganga flowing in Uttrakhand. The Ganga River has shown a positive sign of quality improvement on many parameters due to the 68 days' nationwide lockdown tobreak the spreading chain of the Covid-19 pandemic in India. During that time, various types of industrially contaminated water and sewage water flowing by the hotel industry were closed as shown in the Abstract figure. The impact could be seen in reduced Biological oxygen demand (BOD) and chemical oxygen demand (COD) and total coliform count and faecal coliform count also found in decreased in number compared to previous studies results from the outcome of these collection points (fig. 1). This paper concludes that River can be rejuvenated if the rule made are strictly followed.

Keywords: SARS-CoV2; Lockdown; Pandemic; Water Quality Index (WQI).

Introduction

Rivers are an important part of the ecosystem. It is the main source of drinking water in our country. Therefore, cleanness of river water is very important for a Nation at present time water pollution is the biggest problem in developing Country. Ganga River was declared a national river in India. At present time, Ganga is also the most polluted river in India. Indian government has taken many initiatives for the cleanness of Rivers. A Big Project known as Namami Gangeyojna is going on. Ganga water pollution is a very challenging task for Govt. of India. The first case of COVID-19 was registered in India on 30th January, subsequently, a nationwide 14-hrs voluntary curfew was observed. On 22nd march 2020 due to an extreme jump in the positive cases. This curfew was extended for another 21 more days from 25th March to 14th April initially. This lockdown resulted in shutting down schools, industries, businesses, markets, religious and social gatherings, and kept people at home. It suspended all forms of travel except in case of emergencies and closed national and international travellers. The lockdown period was extended in many phases till June 8, 2020, and a lockdown of a total of 68 days completed with very strict guidelines, and the nation came to a standstill during this period at the same time there is lots of news coming out about pollution decrease in high levels.[1] This has led to a decline in emissions and restricted the production of industrial waste and other pollutants in the urban and rural centres of India during the duration of lockdown. Ever Since the lockdown applied due to COVID-19 in numerous countries has nearly seized the manufacturing, industrial events, and vehicle movement, a decrease in air pollution across the globe has been reported. According to the Ministry of Ecology and Environment, China, the air quality went up 11% in the category 'good' in as many as 337 cities[2] Scripps Institute of Oceanography reported that the use of fossil fuel would decline by about 10% around the world

Author Affiliation: [1]PhD Scholar, [4]Professor, Department of Biochemistry, [2]PhD Scholar, [5]Professor, Department of Microbiology, [3]Assistant Professor, Department of Trauma & Surgery, All India Institute of Medical Sciences, Rishikesh 249203, Uttarakhand, India.

Corresponding Author: Balram Ji Omar, Professor, Department of Microbiology, All India Institute of Medical Sciences, Rishikesh 249203, Uttarakhand, India.

E-mail: drbalramaiims@gmail.com

Received on: 12.10.2021 **Accepted on:** 25.11.2021

owing to the COVID-19 spread.[3] These upgrades in environmental pollution during lockdown are considered temporary; the current level of river Ganga pollution is reduced from various polluted regions of Ganga.

The water quality of five major rivers in the country, including the Ganga, deteriorated during the coronavirus-induced lockdown due to factors like the release of sewage and no upstream freshwater inflows, the Central Pollution Control Board said on Wednesday. According to the report, titled 'Assessment of Impact of Lockdown on Water Quality of Major Rivers', the quality of water in seven of the 19 rivers monitored by State Pollution Control Boards (SPCBs) improved during the lockdown period.[4]

While aerosol levels over the Indo Gangetic Plains reported a 20 year low during the lockdown as per the satellite data on optical depth measurements published by NASA due to restrictions imposed on industries, surface, and air transport.[5] The impact on water quality in the Ganga River was arguable. Various news reports, as well as social media posts, indicated that 'life seemed to be returning to the river'.[6] It was reported that the lockdown had improved the health of River Ganga, which many projects of the government could not do during the past two decades. The water quality of the Ganga River had witnessed visual improvement since enforcement of the nationwide lockdown started on March 24, 2020, which has led to a reduction in the discharge of industrial effluents into it. The lockdown was extended for more than seven weeks, with its 1.3 billion people instructed to stay home because of the coronavirus outbreak. With people, staying indoors and industries shut during the lockdown period, it is crucial to assess if the water quality in the Ganga River has indeed seen a significant improvement.[7] Researchers observed Signs of rejuvenation and a significant improvement on many parameters in the Ganga River, following nationwide lockdown due to coronavirus pandemic Lockdown period coincides excess rainfall (60 percent above normal), reduced irrigation and power demands in the basin resulting in increased storages and more flow in the river improving the quality Increasing trends of dissolved oxygen (DO) and decreasing trends of biological oxygen demand (BOD) and nitrate (NO3-) concentration River become fit for drinking (Class A) in the upper stretches and for outdoor bathing (Class B) in the middle and lower stretches Ganga river water classified in different classes. Table No.7[8]

Sources of Pollution

The Ganga River pollution made by various sources of pollution and the main source of pollution is municipal sewage, directly dumped in River without any treatment. The source of pollution can be divided into five types, Sewage pollution, Industrial effluent, Agriculture runoff, Religious Activities, and unplanned development.

Sewage Pollution

Discharge of sewage without treatment is 75% of total pollution with millions of liters generated per day in towns along the Ganga.[9] According to the total wastewater generation from 222 towns in the Ganga basin is 8250 MLD, while the treatment facilities are available only for 3500 MLD.[10]

Industrial Effluent

Thousands of Industrial units are situated in the Ganga Basin area and 956 only in Uttar Pradesh and approx. 10-30 industry situated very close to Ganga River in Uttrakhand. Various textiles, sugar mills, synthetic rubber industry, Paper pulp factories, and pesticides production unit. According to an estimate, about 2500 MLD of industrial wastewater is generated in the entire Ganga basin.[11]

Agriculture Runoff

Indo Gangetic plain is one of the most important plains in the world. It is 13% of the total geographical area of the country it includes Uttrakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal. About 50% of the total food grain is produced in this region to feed 40% of the population of the country.[12]

Religious Activities

Gangaconsidered as a mokshadyini River means a dip in the Ganga liberates from the cycle of death and rebirth. The Ganga basin has many historical towns like Rishikesh, Haridwar, Garhmukhteshwar, Kannoj, Pyagraj, Mirzapur, Vanaras, and Ganga Sagar. These are important pilgrim centers where several religious activities like fairs take place throughout the year at the Bank of Ganga.[13]

Religious Bathing

Every day millions of peoples take baths throughout the Ganga, however, some of the auspicious days are particularly important when a large number of

people take a dip in the river. Kumbh is the main event for mass ritualistic bathing, which takes place at four places; Haridwar (Har Ki Pauri), Allahabad (Prayag), Nashik (Godavari Ghat), and Ujjain (Shipra Ghat) During Kumbh billions of people take bath at a specific stretch of river. Several devotees and ascetics reside on the bank of river Ganga during the whole Kumbh period. The effect of mass ritualistic bathing on the Ganga water quality during ArdhKumbh, Kumbh, and MahaKumbh, at different places, has been evaluated by various workers.

Temple Waste and Religious Material

More than 1000 tons of flowers and garlands are thrown in the river as an offering during the worship of Ganga as well as those used in the temples nearby. At various places such as Haridwar, Varanasi, etc. splendid evening prayer of Ganga is being held during that the devotees offer flowers and hundreds of floating lighted earthen lamps.[14]

Pollution due to Idol Immersion

Idol immersion is a religious activity that is also responsible for adding several pollutants in the rivers including Ganga. In India, a lot of religious activities take place around the year. Durga Puja is one of the most important festivals celebrated in West Bengal, Bihar, and Uttar Pradesh. In the last 15 years, Lakshmi Puja and Ganesh Chaturthi are also celebrated at an equal pace in Uttar Pradesh and Bihar, which wereoriginally belonging to other parts of India. In these festivals, huge numbers of Durga, Lakshmi, and Ganesha's idols of different sizes (up to 40 ft.) are formed every year and immersed in Ganga at the end of the event. The idols are constructed by plaster of Paris, clay, cloths, small iron rods, bamboo and decorated with different paints such as varnish, watercolors, etc., plastic, and polystyrene that can lead to a significant alteration in the water quality after immersion. Paints that are used to color these idols contain various heavy metals/metalloids, such as As, Cd, Cr, Hg, and Pb which are known carcinogens.[15]

Dead body cremationin India it is believed that death and cremation along the banks of the Ganga, particularly in Varanasi, releases the soul from the cycle of rebirth and the soul shall directly go to heaven. Due to this religious belief, thousands of dead bodies are being cremated every day on the bank of Ganga.[16]

Material and Methods

Graphical Abstract

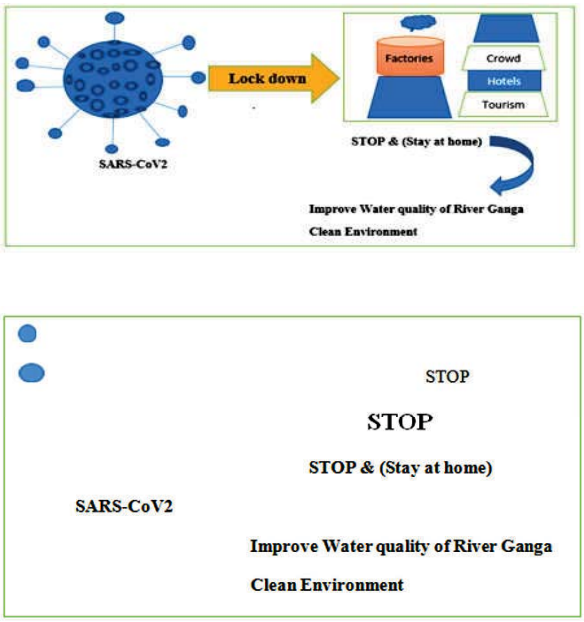

Fig.1: A Graphical Abstract of Covid -19 effects.

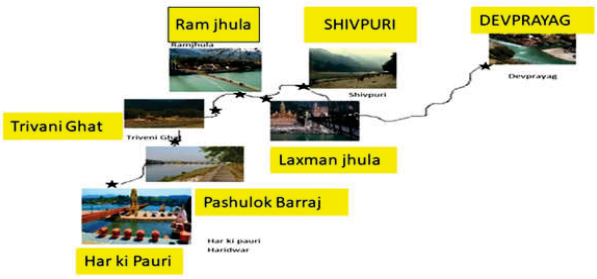

Fig. 2: Showing the View of All Collected Ganga water Samples Sites.

Study Area

In this study, the water quality of the Ganga River has been assessed between DevPrayag to Haridwar located at Uttrakhand during the lockdown period April to May 2020 for water quality testing we have used some physicochemical and Microbiological parameters and compared them with pre lockdown water quality data of February 2019.

River Water Sample Collection Procedure

- According to the requirement of test protocol sample nature, are different and water Samples were collected in a triplicate form.
- A two different new sterile plastic containers.
- Note-sample was collected in triplicate from

each site and then pours & mix in a particular site labelled container with a waterproof marker. The date, time, site & nature of the specimen should be mentioned on this slip.

Table 1: Water samples collection procedure in different containers.

1st Container (1 litre) For Physio-chemical Analysis	2rd Container (1 Litre) Microbiological Analysis
Water sample collected from 0.5m depth from the surface of river using a clean plastic bucket, transfer in to labelled container and transported to the laboratory on ice and stored in a deep freezer (-200c) till analysis.	Water sample collected from 0.5m depth from the surface of River using a sterile sample bottle. • Aseptically remove the cap and cover of the sterile sample bottle. • Face the mouth of the bottle upstream. • Plug the neck downwards about 30 cm below the water surface • Tilt the neck slightly upwards to let it fill completely before carefully replacing the cap and cover

Water samples were collected during the lockdown in all phases between April to May 2020 from five study designed sampling sites. Showing in fig. no. 2 Water sampling sites of the Ganga River flowing in Uttrakhand were nominated on the source of catchment characteristics and sources of anthropogenic involvement along its course of a run. Among water sampling sites of Ganges, two sites were of hilly regions Devpyag (GD), Shivpuri (GS), and others five sites were Laxman Jhula Rishikesh (GL), Ram Jhula (GR), Triveni Ghat (GT), Barrage (GB) and Haridwar (GH) of Uttrakhand. From every sampling site, water was collected in triplicates at the depth of 10 cm below the superficial water level; water samples were mixed and poured in two separate sterile polyethylene containers. Each container filled with water sample was tightly sealed and labelled with a site of water sampling and mode of specific analysis viz physicochemical & microbiological analysis described in tab. No.1 Water sample containers were transported and stored in an icebox shield until analysed in laboratories.

Physiochemical Analysis

All Ganga river water samples collected in polyethylene sterile containers from eleven different sites were checked for physicochemical analyses using a specific methodology. pH, temperature, conductivity, and dissolved oxygen were measured by HACH HQ40D portable multipara meter two channels advanced digital meter. Dissolved Oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), and total solid solutes were measured by Wrinkle's methods, volumetric analyser, and titration methods.[17]

Microbiological Analysis of Water samples

The precise identification of pathogenic bacteria is tremendously challenging; the coliform group of organisms is used as an indicator of the presence in the wastewater of pathogenic organisms. Coliform bacteria are found in the intestinal tract of human beings. The coliform group of bacteria includes genera Escherichia. (According to Environmental protection Agency) the contaminant level of Coliform count should be zero per 100 ml of water for drinking purposes and for the bathing purpose the faecal coliform should be less than 500 /100 ml of water. Most probable number test (MPN Test) – Included presumptive test, confirmation test, and complete test. In the MPN method by the use of sterile pipette 10 ml, 1ml, and 0.1ml of water samples from sterile containers were inoculated in a 50 ml test tube having 10 ml double strength Lauryl Tryptase (LT) broth medium and 5 ml single strength and 5 ml LT broth respectively. All tubes were incubated for 24 hours at 37°C. After the growth of mixed culture, they were inoculated in the Broth culture tube for confirmation test viz. Brilliant Green Bile Broth (BGBB), EC Broth, and Tryptone water, Azide Dextrose for a complete test. Selenite F Broth, Alkaline peptone water was used to a culture of some specific bacteria like Vibrio cholera and salmonellae typhi species, growth present was then subcultured on Xylose Lysine Deoxy Cholate (XLD), Thiosulfate Citrate-Bile Salt Sucrose (TCBS) Agar culture plate respectively. Various morphological characteristics of improved isolates, colony morphology shape, color, arrangement, biochemical tests, and Gram staining were carried out for the identification of isolates. The water samples were also checked for Fungi using two methods, direct plate and dilution plate with the use of two types of growth media Sabouraud's dextrose agar (SDA) and potato dextrose agar (PDA) incubate for 7 days on 25^0c.

For Salmonella and Shigella Culture Procedure:

Firstly takes the 20-25 ml of Ganga water sample and centrifuged at 1520x g for 15 min and after that pour off all supernatant except 1-2 ml bottom part and re-suspend the pellet and add 8 ml selenite F or GN Broth and incubate for 24hrs at 35^0C examine to the plate and streak on the TSI slant incubate at

37^0C for overnight confirm by oxidase and catalase test.

For Faecal Streptococci Count

Inoculate loop full of a sample was taken from a positive presumptive tube in an Azide dextrose Broth (selective media for faecal streptococci) and incubate on 45^0C for 24 hrs. If the turbidity is, found then streak loop full material on bile Esculin Agar at 44-45^0C for 24hrs. Presence of brownish black colonies with brown halos sign of confirmation presence of streptococci.

For Vibrio Species

In this procedure, we have used alkaline peptone water with added colistin and incubate 6-8 hrs. at 35^0C if the turbidity occurred then streak the loop full material on TCBS Agar (Thio sulphate Citrate bile salt sucrose Agar) look for yellow colonies on TCBS Agar and typical haemolytic colonies on sheep Blood Agar if these color colonies found then identification process required by agglutination with Antisera.

WQI

The water quality index is the way to represent the water quality only. While computing WQI there are three steps, which we have to be taken. Firstly, we assigned the weight (wi) for each selected parameter as per their relative importance in describing the water quality for drinking purposes. The assigned weight remains within a range of 1 to 5.

Secondly, we calculate the relative weight (Wi) for all chooses parameters with help of the following equation.

$Wi = wi / \sum wi$ (i =1 to n)

Where Wi is the relative weight, wi is the assigned weight to the chosen parameters.

Final and last step, we go to calculate the quality scale (qi) for each parameter by following the equation give below.

$qi = (Ci / Si) \times 100$

Where,

Qi is the quality rating,

Ci is the trace concentration of each chemical parameters

Si is the standard.[18]

For computing the WQI, firstly we have to determine the sub-index (SI) for each selected parameters with the help of the following equation

$SIi = Wi \times qi$

$WQI = \sum SIi\text{-}n$

The Calculated WQI values are categorized into five categories: excellent water (W<50); Good Water (WQI=50-100); Poor Water Quality (WQI=200-300) and water unsuitable for drinking (WQI>300)(19). The results of the water quality index calculation shown in table no 2, 3 and 4.

Statistical Analysis

The statistical analysis work done by using paired t test in Graph pad prism software version 5.0.

Results and Discussion

All Physicochemical and microbiological analyses were carried out at Namami Gange Research Unit, AIIMS Rishikesh. Pre lockdown data analysis was done in Feb-march 2019 and during the lockdown period, Ganga water samples were collected every lockdown phase I to IV and analysed.The parameters such as pH, TDS, Conductivity, BOD, and DO were found within acceptable limits in water samples collected before and during a lockdown. The Chemical oxygen demand of Ganga water samples collected from Rishikesh Triveni ghat and Barrage siteswas found in high amount in Pre lockdown period data andCOD had decreased during a lockdown. In our study, the physicochemical parameters result (table. 2) during the lockdown period showed better improvement in Ganga water quality.

Table 2: Variations of Microbiological parameters (MPN, TCC, FCC, E.coli count and FSC) in collected Ganga water samples of Pre-lockdown and During Lockdown periods.

Study Location		Microbiological Indicators					
Site	**Timing**	**MPN count**	**Total Coliform count**	**Faecal coliform count**	**E.coli Count**	**Faecal streptococci count**	**Salmonella, Shigella, V. cholaerae, Fungal (SDA,PDA**
GD	Pre Lockdown	–	–	–	–	–	No growth
	During Lock down	–	–	–	–	–	No growth

GS	Pre Lockdown	–	–	–	–	–	No growth
	During Lockdown	–	–	–	–	–	No growth
GL	Pre Lockdown	111 ± 12.7	87 ± 8.4	26.3 ± 2.3	35.3 ± 5.1	–	No growth
	During Lockdown	–	–	–	–	–	No growth
GR	Pre Lockdown	140 ± 14.1	111 ± 12.7	41.6 ± 1.8	71.3 ± 5.1	04	No growth
	During Lockdown	71.3 ± 5.1	41.6 ± 1.8	20.6 ± 0.4	21.3 ± 1.2	–	No growth
GT	Pre Lockdown	1100 ± 00	460 ± 00	230 ± 14.1	240 ± 00	–	No growth
	During Lockdown	453 ± 12.4	245 ± 3.2	208 ± 2.8	216 ± 6.2	–	No growth
GB	Pre Lockdown	2400 ± 00	1100 ± 00	376.6 ± 117	376 ± 117	–	No growth
	During Lockdown	1100 ± 00	460 ± 00	376± 117	210 ± 00	–	No growth
GH	Pre Lockdown	140 ± 14.1	111 ± 12.7	111 ± 12.7	140 ± 14.1	–	No growth
	During Lockdown	41.6 ± 1.8	26.3 ± 2.3	20.3 ± 0.4	24.6 ± 2.3	–	No growth

Table 3: Computing WQI for Pre Lock down.

Parameters	Weight (wi)	Relative Weight Wi=wi ∑wi	Ci Pre Lockdown	Si	qi=(Ci/Si)×100	Sub Index SI=Wi×qi
pH	4	0.5	7.17	7	102.43	51.21
TDS	4	0.5	120.3	500	24.06	12.03
	∑wi=8	∑Wi=1				∑SI=63.24

WQI=∑SI=63.24

Table 4: Computing WQI for during Lock down.

Parameters	Weight (wi)	Relative Weight Wi=wi ∑wi	Ci Post Lockdown	Si	qi=(Ci/Si)×100	Sub Index SI=Wi×qi
pH	4	0.5	7.25	7	103.57	51.8
TDS	4	0.5	154.3	500	30.86	15.43
	∑wi=8	∑Wi=1				∑SI=67.23

WQI=∑SI=67.23

Table 5: Showing the water quality category of both sampling periods.

WQI Value	Water Quality	Sample Description	Pre Lock down	During Lock down
<50	Excellent	NA	×	×
50-100	Good Water	During Both Study period WQI	✓	✓
100-200	Poor water		×	×
200-300	Very Poor Water		×	×
>300	Water Unsuitable for Drinking		×	×

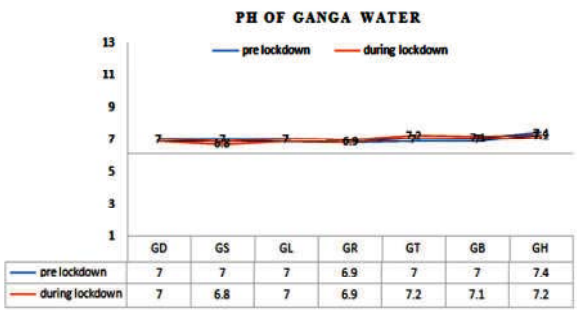

Fig. 3: Variation in pH during and pre lockdown stage of Ganga Water samples from seven different sites.

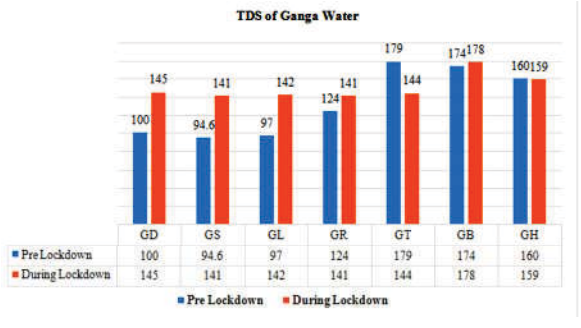

Fig. 4: Variation in TDS during and pre lockdown stage of Ganga Water samples from seven different sites.

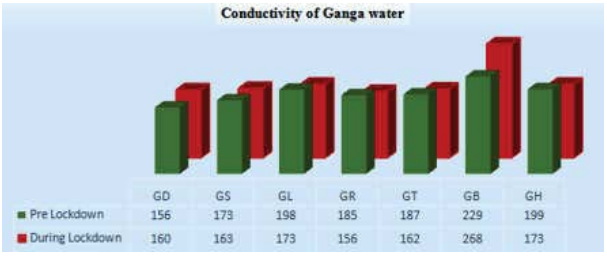

Fig. 5: Variation in conductivity during and pre lockdown stage of Ganga Water samples from seven different sites.

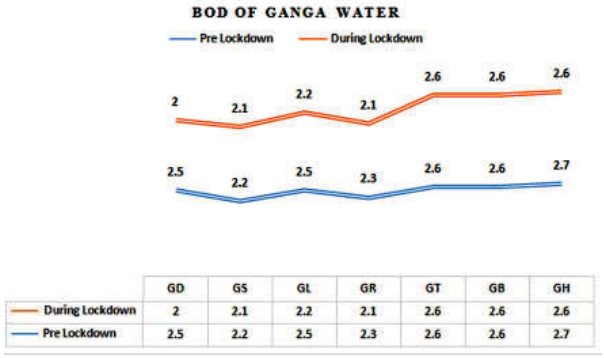

Fig. 6: Variation in BOD during and pre lockdown stage of Ganga Water samples from seven different sites.

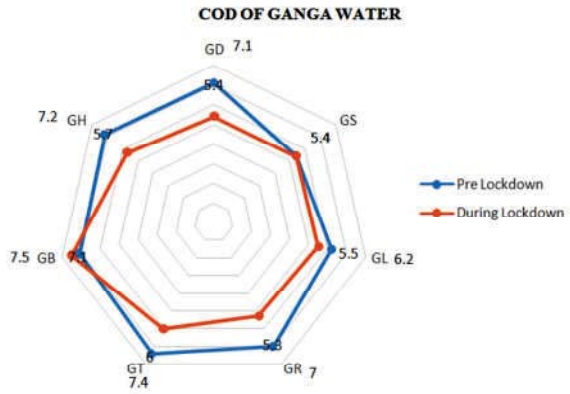

Fig. 7: Variation in COD during and pre lockdown stage of Ganga Water samples from seven different sites.

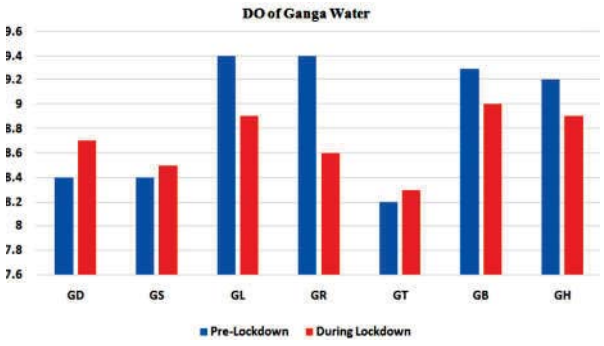

Fig. 8: Variation in DO during and pre lockdown stage of Ganga Water samples from seven different sites.

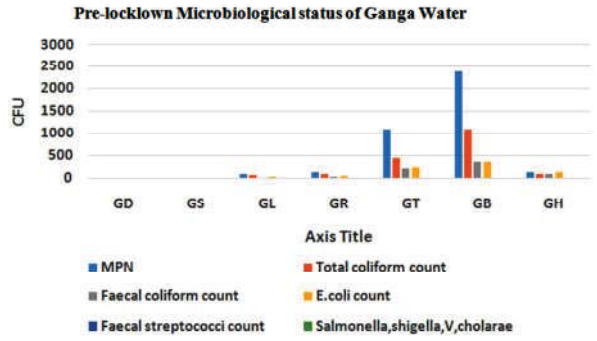

Fig. 9 (a): Variations in Bacterial count of different Ganga water collected samples in pre-lockdown.

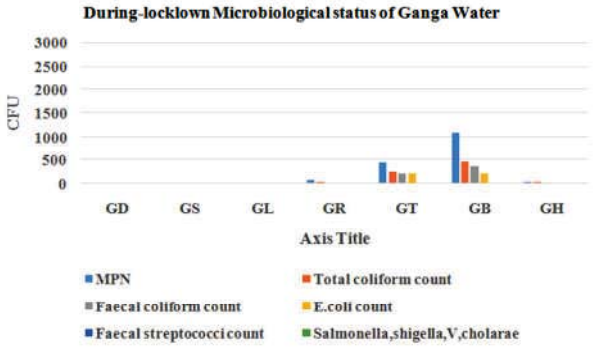

Fig. 9 (b): Variations in Bacterial count of different Ganga water collected samples During-lockdown period.

In our study, the microbiological analysis showed no microbial contamination before and during the lockdown in the first two collection sites i.e., Devpryag and Shivpuri.In our third collection site Laxman Jhula having some microbial contamination before lockdown water samples. and there was no microbial contamination during the lockdown phases. There was a 50% decrease in microbial contamination from other sample collection sites such as Ramjhula, Trivenighat, Barrage, and HarkiPauri Haridwar. In Prelockdown period feb 2019 we found some pathogenic Bacteria like Acenatobactor, Klabsiallae, Pseudomonas and Enterococci found that time but we found E. coli during Lockdown periods collected water samples. It's a positive sign on behalf of microbial contamination in river water of Ganga. Water quality Index the pre lockdown and during lockdown are approximately equal calculated values ∑SI=67.23 for pre lockdown and during lockdown value was ∑SI=67.23 and water quality found in good condition with the Normal range (50-100) table No. 6. Our study aims to bring out the effect of lockdown on the water of the Ganga River in Uttrakhand. Thisstudy mainly focused on the effect of lockdown on the water quality of River Ganga. Results of the study intelligibly announce

that there was significant devaluation in water pollution indicators during this lockdown these results of the study are similar to other studies.A lot of reports showing improvement of water quality of Indian River like Hindon, Yamuna, Cauvery, and Ganga has Improved during the Current lockdown due to Covid-19 crisis.[20] There was also a reduction in bacteriological count in the Ganga River during a lockdown.while aerosol levels over the Indo Gangetic plains reported a 20 year low during the lockdown due to restrictions imposed on Industries, surface, and air transport.[21] A questionnaire based survey found that the population of the plain area had a high incidence (75%) of water-borne disease as compared to the hilly area (20%) (Table 4). The estimated result of hazard quotient (HQ) and hazard index (HI) for non carcinogenic concern related to adult and child by ingestion of Ganga River water.[22]

Conclusion

Our studyindicates that all parameters of water quality assessment have significantly improved that it has shown that Ganga auto purification increased very fast. Its shows a positive angle of Lockdown Covid-19 on nature. The Government of India has spent thousands of crores of rupees on many cleaning programs for rejuvenation of the Ganges for the last several years and is doing so further. However, the Ganges has not yet been completely clean. There has been a pleasant experience also during this so called trial based pandemic era. Human activities were restricted in making an addition to waterpollution by doing so called holy celebration or ritual activities. In the lockdown period, the public was restricted mostly in some boundaries, home, and town, so they could not make a frequent visit for pilgrimage and tourism. Due tothis, Ganga water quality from devprayag to Laxman Jhulahas changed from Class B to Class A. Now it has become potable for drinking water sources without conventional treatment.

Conflict of interest: No conflict of interest

Acknowledgment: We are grateful to the Head of Institute Director (AIIMS Rishikesh) Who provided financial support for work on Ganga water Analysis and provided an institute vehicle for the collection of a water sample.

References

1. Carbon emissions are falling sharply due to coronavirus. But not for long. [Internet]. Science. 2020 [cited 2021 Mar 1]. Available from: https://www.nationalgeographic.com/science/article/coronavirus-causing-carbon-emissions-to-fall-but-not-for-long
2. Henriques M. Will Covid-19 have a lasting impact on the environment? [Internet]. [cited 2021 Mar 1]. Available from: https://www.bbc.com/future/article/20200326-covid-19-the-impact-of-coronavirus-on-the-environment
3. Scripps Research finds "possible Achilles heel" in the coronavirus - The San Diego Union-Tribune [Internet]. [cited 2021 Mar 1]. Available from: https://www.sandiegouniontribune.com/news/science/story/2020-04-03/scripps-research-find-evidence-of-an-anchilles-heel
4. Dutta V, Dubey D, Kumar S. Cleaning the River Ganga: Impact of lockdown on water quality and future implications on river rejuvenation strategies. Sci Total Environ. 2020 Nov 15;743:140756.
5. Thanks to lockdown, aerosol levels hit 20-year low in India, finds NASA | Business Standard News [Internet]. [cited 2021 Mar 1]. Available from: https://www.business-standard.com/article/news-ani/as-people-stay-home-aerosol-levels-hit-20-year-low-in-india-nasa-120042300139_1.html
6. Lockdown impact: Ganga water in Haridwar becomes "fit to drink" after decades - India News [Internet]. [cited 2021 Mar 1]. Available from: https://www.indiatoday.in/india/story/lockdown-impact-ganga-water-in-haridwar-becomes-fit-to-drink-after-decades-1669576-2020-04-22
7. India, Day 1: World's Largest Coronavirus Lockdown Begins - The New York Times [Internet]. [cited 2021 Mar 1]. Available from: https://www.nytimes.com/2020/03/25/world/asia/india-lockdown-coronavirus.html
8. Katariya M. River Ganga Water In Haridwar Has Been Classified As "Fit For Drinking" For The 1st Time In Years [Internet]. 2020 [cited 2021 Mar 1]. Available from: https://www.scoopwhoop.com/news/river-ganga-water-in-haridwar-classified-fit-for-drinking-first-time-in-years/
9. Das S. Cleaning of the Ganga. J Geol Soc India. 2011 Sep 9;78(2):124.
10. National status of waste water generation & treatment: SulabhENVIS Centre [Internet]. [cited 2021 Mar 1]. Available from: http://www.sulabhenvis.nic.in/database/stst_wastewater_2090.aspx
11. Pollution Assessment : River Ganga. :206.
12. Koshal AK. Changing Current Scenario of Rice-Wheat System in Indo-Gangetic Plain Region of India. 2014;4(3):13.
13. Tyagi S, Sharma B, Singh P, Dobhal R. © Science and Education Publishing DOI:10.12691/ajwr-1-3-3 Water Quality Assessment in Terms of Water Quality Index. 2013.
14. Dwivedi S, Mishra S, Tripathi RD. Ganga water

pollution: A potential health threat to inhabitants of Ganga basin. Environ Int. 2018;117:327–38.

15. Bhattacharya S, Bera A, Dutta A, Ghosh UC. Effects of Idol Immersion on the Water Quality Parameters of Indian Water Bodies: Environmental Health Perspectives. 39:30.
16. Cremation Ghats of Varanasi [Internet]. Atlas Obscura. [cited 2021 Mar 1]. Available from: http://www.atlasobscura.com/places/cremation-ghats-of-varanasi
17. Standard Methods for the Examination of Water and Wastewater, 23rd Edition [Internet]. AWWA-American Water Works Association. [cited 2020 Jun 15]. Available from: https://www.awwa.org/Store/{ProductName}/ProductDetail/{ProductId}?productId=65266295
18. IS 10500 (2012): Drinking water. :18.
19. Batabyal AK, Chakraborty S. Hydrogeochemistry and Water Quality Index in the Assessment of Groundwater Quality for Drinking Uses. Water Environment Research. 2015;87(7):607–17.
20. DRP NB 6 April 2020: Ganga-Yamuna-Cauvery flow cleaner in lockdown: What can we learn? – SANDRP [Internet]. [cited 2021 Mar 1]. Available from: https://sandrp.in/2020/04/06/drp-nb-6-april-2020-ganga-yamuna-cauvery-flow-cleaner-in-lockdown-what-can-we-learn/
21. Aerosol levels at 20-year-low in north India: NASA satellite data [Internet]. [cited 2021 Mar 1]. Available from: https://www.downtoearth.org.in/news/air/aerosol-levels-at-20-year-low-in-north-india-nasa-satellite-data-70612
22. Kumar P, Kothari A, Kumar A, Rathi H, Goyal B, Gupta P, Singh B, Mirza AA, Dhingra GK. Evaluation of physicochemical, heavy metal pollution and microbiological indicators in water samples of Ganges at Uttarakhand India: an impact on public health