Madridge
Journal of Molecular Biology

Research Article

Open Access

Comparative Review on Water Quality Assessment of Ganga and Yamuna during the COVID-19 Lockdown

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Received: November 23, 2021
Accepted: December 20, 2021
Published: December 27, 2021

Citation: Mishra AK, Pandey RP. Comparative Review on Water Quality Assessment of Ganga and Yamuna during the COVID-19 Lockdown. *Madridge J Mol Biol.* 2021; 2(1): 30-36.
doi: 10.18689/mjmb-1000106

Abstract

According to WHO, the Ganga and Yamuna rivers are among the most polluted in the world (World Health Organization). The Ganga and Yamuna rivers are India's most important rivers, but their water quality has been steadily deteriorating. Thus, the goal of this study is to convey the current state of pollution levels in a concise manner by decoding the research investigations completed to date, and to draw a comparison between how lockdown during the COVID-19 epidemic resulted in a substantial change. Varied pollution sources responsible for pollution and different parameters necessary for water quality evaluation are extremely important and have been discussed. A huge amount of waste water is generated every day in India but only a fraction of it can be treated before discharge into rivers. Therefore, it becomes really necessary to put focus on cost and operational effective technologies. In-spite of government initiatives and advancement in the treatment technologies there is no substantial change in the water quality of Ganga and Yamuna this might be due to lack of resources, infrastructure and high cost of the treatment technologies but during the lockdown all major source of pollutants were mitigated and bring a appreciable change in the water quality. Thus, it is understood quality restoration of such mythologically important rivers is a sophisticated task, but could be through mitigation of pollution sources and this could only be achieved through a sense of conscience and ethics in the youth.

Keywords: Pollution; Ganga River; Yamuna River; Biological parameter; Physicochemical parameters; Microbial load.

Introduction

India is a divine as it's also referred as "Land of Rivers" and the people worship them [1]. Around 14 water basins are there, that are being used for human and development activities. In spite of having a sense of respect, though inefficient to maintain their purity, cleanliness and the physical well-being. In the present scenario there is majority of the rivers are affected from pollution. River pollution causes severe diseases and health problems in humans, animals, fish, and birds in the environment. The Ganga and Yamuna rivers are among the world's most contaminated rivers, according to the World Health Organization, the United Nations Environment Programme (UNEP), and the Water Supply and Sanitation Collaborative Council. Because the Ganga and the Yamuna are among India's most polluted rivers, they are included in the topic of debate for the title.

Ganga River

The Ganga is a uttermost important river of India, and it is a crucial resource of water for a huge population. Approximately 40% of the population resides near River Ganga basin [2]. For domestic, industrial and agricultural purposes it's a vital source of water. The quantities of waste water and solid waste debris have been hiked due to rapid development and simultaneously problems of water pollution are also started emerging. In particular, the type of pollution that causes water-borne diseases through bacterial load increasing due to raise in organic disposition is a major social problem for the Indian people who have frequent contact with the river [3]. It is important because: The densely populated Ganga basin is inhabited by 37 per cent of India's population [3]. Ganga basin has drains eight states of India**.** About 47 % of the total irrigated area in India is located in the Ganga basin alone. It has been a major source of navigation and communication since ancient times [3].

The Ganga rises on the southern slopes of the Himalayan ranges (Figure.1) from the Gangotri glacier at 4,000 m above mean sea level. It flows swiftly for 250 km in the mountains, descending steeply to an elevation of 288 m above mean sea level. In the Himalayan region the Bhagirathi is joined by the tributaries Alaknanda and Mandakini to form the Ganga. After entering the plains at Hardiwar, it winds its way to the Bay of Bengal, covering 2,500 km through the provinces of Uttar Pradesh, Bihar and West Bengal (Figure 1). In the plains it is joined by Ramganga, Yamuna, Sai, Gomti, Ghaghara, Sone, Gandak, Kosi and Damodar along with many other smaller rivers.

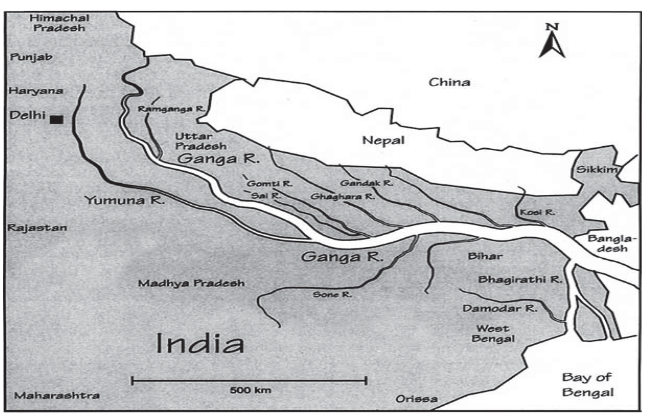

Figure 1. Map of Ganga

The velocity of the flowing stream and and pollution dissolving capacity of a river are the important aspects for its purity. At the entrance of Haridwar huge fraction of water is used for the irrigation [2]. The Ganga River carries the highest silt load of any river in the world and the deposition of this material in the delta region results in the largest river delta in the world (400 km from north to south and 320 km from east to west) [2]. The rich mangrove forests of the Gangetic delta contain very rare and valuable species of plants and animals and are unparalleled among many forest ecosystems [4].

1.1. a. The Ganga Action Plan (GAP)

To bring the water quality status to class B (i.e., bathing quality) Ganga Action Plan has been introduced [5]. To practice ritualistic mass bathing this is taken as an appropriate step by the government [6]. This will also ease the comfort of aquatic life through increase in OD level and Downfall in bacterial Load [5]. Through downfall in household waste and industrial waste it would bring a huge change in mitigation of water pollution. The long-term objectives were to improve the environmental conditions along the river by mitigating the entire polluting source [5]. Ignition of the phase 2 of the program indicates the success of the action plan. The existing plan has been further modified and now includes some lakes which were not included before and it's referred as "National Rivers Conservation Plan".

1.2 Yamuna river

It is India's longest tributary and has also considered as the second largest Ganga tributary river. Its origination begins from Yamunotri Glacier of Banderpooch peaks in Uttarakhand as shown in Figure 2; it is stretch of about 1,376 kilometers [1]. It converges Triveni Sangam, Prayagraj though emerging with the Ganga River [3]. It passes through all major states in north India, and gets converge with other tributaries followed by Sindh, the Betwa, and Ken [7]. The river flows from Uttarakhand into the state of Himachal Pradesh [8]. It assists around 70% of Delhi's water supply [9]. It also has a mythological status like Ganga and has a spiritual standard in Hinduism [1].

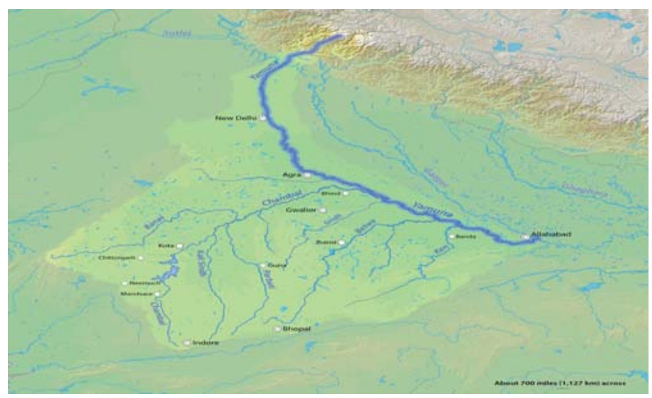

Figure 2. Map of Yamuna River

2. Pollution sources

As per Centre for Science and Environment, river's pollution caused due to domestic waste, industrial waste and lettering thrown into rivers contributes around 70 to 80%. Thus, various programs have been initiated and millions of dollars are spending [1]. Because of the rapid growth in pollution, the river is becoming inappropriate for even class B in terms of quality. Due to industrialization and urbanization, water quality is at an all-time low near cities, towns, and developed areas [8].

2.1 Pollution caused by industries

Near the metro cities Yamuna and Ganga River water nowadays has become dark in colour, and its smell stinks due to allocation of industries near them. As per Central Pollution Control Board (CPCB) majority of the industries discharge untreated waste + into rivers [8]. A CPCB report shows there were many industries in Delhi which directly discharge untreated waste water in Yamuna [2].

2.2 Pollution due to waste water

Domestic waste contributes significantly to waste. The Yamuna is the most polluted river in Delhi, thus using it as an example to illustrate pollution caused by waste water is a good idea [10]. As per CPCB survey, cities like Delhi generate 23% waste water. It is found that more than 47% of the waste water is generated through densely populated cities [11].

2.3 Pollution from agriculture

In northern India Ganga and Yamuna has a vital role in the agricultural sector. Waste water from agriculture runoff gets mixed with main streams [12]. Predominantly agricultural states like Punjab, Haryana, and Uttar Pradesh for their greed of high yield of crops started using pesticides and other chemical products. The chemical and the pesticides get merge into the streams through soil erosion water runoff or through Ariel transmission [12]. Further these chemicals get consumed by the marine life and gradually involved in the food chain and started affecting human health also [12]. In the report on Ghaghara River, "presented the aldrin and dieldrin were below detection limits but both hexachlorocyclohexane (HCH) and dichlorodiphenyltrichloroethane (DDT) were present in significant amount. HCH and DDT in all samples collected were above the permissible limits prescribed by European commission directive from drinking purpose" [12].

2.4 Pollution due to solid wastes

The solid wastes are the unwanted solid material, it is composed of human fecal, cow dung, generated from various authorized and unauthorized dairy colonies are being discharged untreated into rivers and are considered as one of the major non-point sources of pollution and it is necessary that their management is done properly [13]. Disposal of solid waste in Ganga and Yamuna is one of them or because of their pollution. The discharge of untreated water and solid waste into the river has increased which has become the main reason behind the increase of content of suspended solids in Rivers [14].

2.5 Other sources

Other reasons of pollution of river water, such as on holy and religious activities which increases the suspended materials in the water [15]. Lack of awareness and moral conscience has encouraged such activities. Lack of proper sanitation is another major factor in India which promotes water pollution. Practice of throwing dead bodies bodies of human beings and animals into the river is a factor contributing in water pollution [1].

3. Water Quality Assessment

To assess the Quality of the water particularly two types of parameters are considered i.e., physicochemical parameters and biological parameters. Since we are presenting the report on most polluted rivers of India (majorly Ganga and Yamuna) thus all the parameters discussed are in general and major aspects related to a particular river that are relevant for the justification has been taken into account.

3.1 Microbial load

In account of biological parameters, Bacterial load and coliform count are required to be studied, bacterial load is used as an indicator of portable water, and where coliform count is used as indicator for fecal contamination [7]. Bacterial load can be determined by total hetero-trophic bacteria count, salmonella and shigella count, Total vibrio count [14]. The acceptable level of bacterial load can be determined through WHO (world health organization) standards. In the downstream of the river where the organic pollutants are discharge into the river, there the no. of hetero-trophic bacteria count, salmonella and shigella count, and total vibrio count are high as compared to less polluted upstream [14]. since yet any researcher or analyst has not considered these bacterial load parameter for the detailed assessment of water quality, therefore no official data has been provided by the government authorities like central pollution control board (CPCB). CPCB is more focused on fecal contamination of water resources [16]. Presence of microbial load can cause typhoid, cholera, and diarrhea, vomiting cramps, headache, fever, fatigue and even death [17]. The presence of microbial load is the indicator of organic pollutants and that further results in the decrease of dissolved oxygen [8].

3.2 Physico-chemical parameters

3.2. a. Biological oxygen demand (BOD)

BOD (mg/l) measures the amount of oxygen utilized by biological organisms, in water body, to decompose the organic matter present in domestic/industrial waste. If BOD rises, it indicates that the level of dissolved oxygen is falling. Up to Palla in Delhi from Yamunotri, Yamuna River is full of marine life which is the natural indicator that level of BOD is within permissible range of 1 to 3mg/L as illustrated by the CPCB.

3.2. b. Chemical oxygen demand

It is an indicative measure of the amount of oxygen which can be consumed during reactions [14]. It is commonly expressed milligrams per litre (mg/L). If it is higher than the permissible limit, it indicates the presence of organic and inorganic contaminants [13].

3.2. c. Dissolved oxygen (DO)

It is inverse of BOD (mg/l) and DO (mg/l) is essential for marine life as aquatic organisms required dissolved oxygen to breathe under water [13]. DO level in Yamuna and Ganga River is found nil (as per reports of CPCB) in their downstream, which indicates the breading of microbial load due to organic pollutants deposition [10]. To increase the amount of DO in water different technologies has been further discussed in the paper.

3.2. d Temperature

High temperature of water promotes breeding of the microbial load that's why it is suggested to cool down the industrial waste water before discharging it into rivers [13].

3.2. e. Velocity

Velocity is a crucial factor when it comes to self-purifying capacity of a river, if the velocity of the river is high then it will be less polluted [3]. This can be observed physically that stagnant water is more likely to get polluted easily.

3.2. f. Hardness

It is the amount of dissolved minerals, mostly calcium and magnesium [2]. Hard water is not suitable for both drinking and irrigation purpose [2]. Hardness of river water is mainly found high near industrial area, due to direct inclusion of untreated industrial effluents in the rivers [2].

3.2. g. PH

PH level indicates the presence of organic pollutants and organic pollutants encourage breeding of microbial load so high PH level is atrocious [2]. The PH of the Ganga at Haridwar is noted slightly alkaline. It ranges from 7.06 to 8.35, whereas PH of Yamuna in Delhi segment ranges from 7.5 to 11.8 [2]. High alkalinity in the human body can cause digestive problems and irritation of the skin [2].

3.2. h. Total dissolved salts (TDS)

Depending on the type of water requirement for drinking or irrigation purpose the quality of water depends on type and the quantity of the dissolved salts. Salts originate from dissolving or weathering of rocks and soil, including dissolution of gypsum, lime and other soil minerals. Water with higher TDS is unsuitable for irrigation purpose thus results in the reduction in the yield of crops as the salts get accumulate in the root zone to such as an extent that roots are not able to abstract sufficient water from the salty soil.

3.2. i. Electrical conductivity (EC)

For the productivity of the crop the most influential water quality aspect is the water salinity hazard and is measured by Electrical Conductivity. The dominant effect of high EC of water on crop productivity is the inability of the plant to compete with ions in the soil solution for water. Less water is available to plants if the EC is high. In the down streams of the rivers, EC is found to be increased due to release of industrial effluents without pretreatment [2].

3.2. j. Heavy metals

Heavy metals tend to build up inside the human body and are stored faster than they are broken down [18]. Living organisms require different number of heavy metals for example: iron, copper, manganese, magnesium, molybdenum, zinc, for proper functioning of their body and for metabolic reactions [19]. However, high levels of these metals cause damage to the organs. Research conducted by TERI, showed moderate levels of toxic metals at several locations in the Yamuna River [19].

4. Technologies for waste water treatment

In India 16,662.5 million of litre per day (MLD) of waste water is produced every day but only 4037.2 MLD can be treated before discharge into rivers [20]. Therefore, it becomes really necessary to put focus on cost and operational effective technologies. At present, water technologies can be classified as primary, secondary and tertiary treatment technologies [20].

4.1 Primary water treatment technologies

These methods are usually employed when water is highly polluted.

4.1. a Screening, filtration and centrifugal separation

The general aim of screening is to remove solid waste from wastewater and remove wastes of cloth, paper, wood, cork, hair, fiber, fecal solids, etc. In the filtration process, water passes through a medium containing fine pores. It removes the particulate matter, fats, oils, microbes etc. Different filters may be used, for example membranes and cartridges. Centrifugal separation has been used to eliminate the suspended non-colloidal solids (size up to 1 mm). The wastewater is applied to centrifugal devices and rotated at different speeds, segregating and offloading the solids [21].

4.1.b Sedimentation and gravity separation

By allowing water to be undisturbed / semi-disturbed for different time intervals, the suspended solids, grits and silts are removed.

4.1.c Coagulation

Under the sedimentation and gravity method, the suspended solids do not settle down and thus non-settable solids are allowed to settle by adding certain chemicals, this process is called coagulation [20].

4.2 Secondary water treatment technologies

Secondary water treatment includes biological pathways to remove microbes from soluble and insoluble pollutants. Water circulates in a reactor that keeps the microbes high. Microbes, usually strains of bacteria and fungi, convert organic matter to water. Wastewater then should be free of organic and inorganic toxic substances. Biological treatment includes wastewater digestion in aerobic and anaerobic form.

4.2. a. Aerobic processes

Activated sludge processes or oxidation ponds conduct the aerobic process.

4.2.b. Anaerobic process

This method is applied in the absence of air to reduce the biological wastewater load.

4.3 Tertiary water treatment technologies

The methods used here are solvent extraction, evaporation, distillation, coagulation, oxidation crystallization, electrolysis, precipitation, ion exchange, reverse osmosis and adsorption [21]. The techniques are discussed below.

4.3.a Distillation

In this process, water is heated upto 100°C and then vapours are collected. This technique is about 99% free from impurities.

4.3.b Crystallization

Crystallization is a method of eliminating contaminants by increasing their concentrations to a point where they start crystallizing out [9]. It is useful for the treatment of wastewater with high concentrations of TDS, including soluble organic matter and inorganic matter.

4.3.c Evaporation

Evaporation is a natural form of distillation.

4.3.d Oxidation

Organic materials are oxidized into carbon dioxide and water or other quickly biodegradable items such as carboxylic acids, alcohols, ketones and aldehydes which are easily biodegradable [9].

4.3.e Advanced oxidation process

It involves the usage of more than one oxidation step concurrently and the accelerated production of the extremely reactive radical hydroxyl-free [21]. UV photolysis, Fenton reagent oxidation, and sonolysis are some of the methods used in this process [21].

4.3.f Precipitation

Contaminants dissolved in water are converted into stable precipitates by reducing their solubility and eliminating precipitate [9].

4.3.g Ion exchange

Toxic ions are exchanged in wastewater using non-toxic ions, using solid material called an ion exchanger.

4.3.h Reverse osmosis

It is a water purification method based on the development technology of the membranes. Its opposite to the process of osmosis.

4.3.i Adsorption

This method is a surface phenomenon. Fly ash is commonly used as adsorbent for treatment of waste water for removal toxic compounds and color [20].

4.3.j. Electrolysis

The process in which electrochemical redox reaction take place is called electrolysis. In this, soluble materials are either deposited or decomposed on the electrode surface. In this method, most metal ions are accumulated on the surface of the electrode, whereas organics are decomposed into low or non-toxic carbon dioxide and water.

4.4 Other Technologies

4.4. a. Vermiculture

Earthworms are used in vermiculture biotechnology to convert organic solid waste into a valuable by-product, rich manure used in farming or in horticulture [1].

4.4. b. Aeration technology

Dissolved oxygen level can be increased through Aeration process. Aeration is the method for introduction of air into a material.

1. Aerator devices are the mechanical devices that are used to add oxygen into water.

- Mechanical aerator circulates and splashes the surface water into the air such that the falling droplets would get saturated with oxygen demand.
- Diffused aerators are placed in the bottom of the water flow and air or oxygen pumping which has spread from a compressed state to a free state.

2. Creating cascades in the water stream i.e., the water that flows the side of a significant height so that the water will get sufficiently aerated.

5. Policies and strategies to restore water quality

In India the water quality of rivers has been continuously degraded all along their vast stretches that's why it becomes essential to adopt some phenomenal measures to control the water pollution in the rivers and to again restore their autochthonic status. So, the following measures are as directed below:

5.1 Enhancement of quality standards in agriculture

Agricultural states like Punjab and Haryana in northern region are more accountable for water pollution in the rivers and they are also most dependent on rivers for the irrigation purpose, so it becomes really important to conserve the irrigation water and to implement advanced technologies that cause less waste of water and focus on its conservation [10]. Greed for greater yield of crops and better-quality farmers use much larger amount of pesticide and insecticide chemicals than required prescribed dose and those results in health issues as these harmful chemicals get involved in our food chain [3].

5.2 Enhancement of treating wastewater & technology

The Government should support work on developing efficient and easily and economically feasible wastewater treatment techniques [11]. It includes encouraging more people to use low cost and low maintenance wastewater treatment techniques at common collection points to reduce wastewater generation in social gathering.

5.3 Wastewater recycling and utilization

Wastewater could be recycled using innovative resources and re-used for varying objectives such as agriculture and landscape Irrigation, Industrial methods, etc.

5.4 Promote Strategies for wastewater management

Many government organizations, NGO's, private companies and environmental agencies are working in the field of wastewater management [1]. These organizations should be actually focusing on waste disposal strategies that could be funded by different schemes and projects.

5.5 Enhancing the collection of sewage and reducing the gap between generation of sewage and treatment

Areas where poor sanitization condition and Network for the collection of wastewaters are either absent or exist in poor conditions should be implemented with raw sewage through uncovered open drains that are either mixed with treated waste-water or directly discharged into the rivers [11]. The gap between generation of sewage and its treatment should also be minimized so as to prevent untreated waste-water get its way to the rivers without treatment [11].

5.6 Enhancing wastewater treatment plant

The old, obsolete sewage networks are one of the primary causes of water contamination in rivers. It has now become crucial to enhance all existing waste-water treatment plants and increase their capacity. Areas lacking a sewage network require urgent intervention, as most wastewater is directly discharged into the river.

5.7 Solid waste management

Increase in population and urbanization has led to increase in the environmental problems, such as solid waste management. Many cities don't really have an effective waste management system [3]. Some effective methods can be used such as door to door collection and segregation of solid wastes in three bags or bins where one is for mixed waste second is for biodegradable waste and third is for recyclable waste [3].

5.8 Formation of public toilets

In most of the rural areas and even in slum areas of urban cities, there is lack of proper sanitization facilities [1]. People in such regions usually do open defecation and discharge of sewage in the catchment region of the Yamuna River, due to which the quality of water in the rivers is continuously decreasing [1]. So, to control the decreasing water quality, formation of public sanitation services in particular in slum areas close to river banks is the best solution.

5.9 Establishment of electric crematorium

Cremation on the river banks has also been one of the reasons of river water pollution. Approximately 100 to 150 cremations are performed every day, and there are some who cannot afford cremation and whose bodies are simply thrown into the holy rivers like Ganga and Yamuna [1]. The shortage of sufficient cremation facilities leads to significant amounts of partly unburnt corpses floating down the Yamuna. The only solution to shut off such pollution sources is the establishment of electric cremation.

5.10 Plantation of dye absorbing trees

There are trees whose leaves can act as low-cost absorbent and can be grown along open flow channels. These trees are well efficient in absorbing toxic components like methylene blue, malachite green and safranine from the industry's dye [3].

6. Recovery of Water Quality During COVID-19 Lockdown

In the previous sections different sources of pollution, water treatment technologies, and different strategies and policies have been discussed and are currently implementing in the pollution control management though they cannot bring any significant change in the system due to the lack of availability of resources, infrastructure and expensive water treatment processes, but the lockdown during the COVID-19 pandemic has brought a significant change which is further discussed in this section. As per the reports of the CPCB during lockdown on the water quality it is shown that quality of water has improved, it could be said that which couldn't be achieved from past 34 years through Ganga Action Plan started in 1986 and other government initiatives like nation river programme, has been achieved during the lockdown. It has been noted that cities where there are large companies are allocated like Delhi, Kanpur, Gurgaon there is a drastic positive change in the water quality in terms of DO, BOD and industrial effluents. Close down of industries results in the downfall of industrial effluents and heavy rainfall during the lockdown results in raise of DO and accordingly drop in the BOD. Since spiritual spots like temples and mosque were also closed so the temples and mosques allocated near the rivers has also bring down the solid organic waste, this has resulted in the drop of microbial load and also the BOD. It is well understood that if the flow of the water in the river is enough then the rivers are self-capable to purify them. Dr. Tripathi from Banaras Hindu University has tested some water samples on the Ganga river before and after the lockdown and from the sample test result it illustrates a significant change in the water quality as shown in an article "how lockdown has been a gift for ganga" and can be accessed through this link https://timesofindia.indiatimes.com/india/how-lockdown-has-been-a-gift-for-river-ganga/articleshow/75569852.cms. For sampling he has taken samples from 5 locations, i.e as follows Samne ghat, Assi Ghat, Shooltankeshwar, Raj Ghat, Dashashwamedh Ghat. In the Table.1 an arithmetic mean of the sample values has been provided.

Table 1. Recovery of Water Quality

	Before Lockdown	After lockdown
FCC(Fecal Coliform Count)	2,200	1,400
BOD	3.8	2.8
DO	8.3	10

Conclusion

This report is a review of variety of research papers for the upcoming global researchers to know about all the relevant research work done yet in subject of matter discussed. Review has been done to present the current status of water quality and comparative outcomes before and after the lockdown has been presented to show the how significant change has been brought in the water quality during the lockdown. It is having been substantiated through references that Ganga and Yamuna River are unfit for drinking and irrigation purpose near polluted areas in their respective stretches while taking the common biological and physicochemical parameters into account. And this is leading to limitation in fresh water resources in future decades. In-spite of government initiatives and advancement in the treatment technologies there is no substantial change in the water quality of Ganga and Yamuna this might be due to lack of resources, infrastructure and high cost of the treatment technologies but during the lockdown all major source of pollutants were mitigated and bring a appreciable change in the water quality. Therefore, it is understood Remediation of the polluted rivers is possible, if described measures to control the pollution are implemented and followed strictly and if proper cease on disposal of pollution sources sprightly into rivers is executed just like during the lockdown, then a phenomenal change can occur in restoring the quality of water to its autochthonic status again same as we get to see during the lockdown. Our youth has to play a vital role in taking the initiative since this could only be achieved through a sense of conscience and ethics in the youth.

Authors Contributions: AKM and RPP contributed to the conception and design of the study. All authors contributed to manuscript revision, read, and approved the submitted version.

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