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Original Article

Monitoring Changes in Water Quality of River Yamuna, India from 2012-2021

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Abstract *- The Yamuna River sustains nearly 57 million people in northern India, but rapid urbanization, industrial growth, and untreated waste discharge have severely degraded its water quality. This study analyzes CPCB data from 2012 to 2021, examining key physicochemical parameters such as temperature, conductivity, dissolved oxygen, pH, nitrates, BOD, and coliform levels. Findings indicate a significant decline in water quality, with high BOD and coliform contamination rendering it unfit for human use. The results highlight the urgent need for sustainable water management and pollution control measures.*

Keywords *- Yamuna, Urbanization, Physicochemical parameters, Total coliform, Pollution control.*

1. Introduction

Water is a fundamental resource for sustaining life, yet its availability and quality are under increasing threat due to pollution and overuse. While water can be diverted, transported, stored, and reclaimed, it remains difficult to depollute and costly to transport in bulk [1]. Despite covering a significant portion of the Earth's surface, only 0.5% of freshwater ecosystems are accessible, as over 68% of freshwater is locked in ice caps and glaciers [2]. Water pollution, defined as any alteration in water's physical, chemical, or biological properties due to contaminants, poses serious risks to human health and biodiversity [3]. In India, rivers are crucial for agriculture, hydroelectric power, transportation, and urban water supply. Many major cities, including New Delhi, Agra, Kolkata, and Haridwar, are situated along riverbanks, highlighting their socio-economic significance. The Ganga River basin alone supports nearly 400 million people, while the Yamuna sustains approximately 57 million.

The Yamuna River holds immense spiritual and religious significance. Human activities, particularly untreated industrial discharge, sewage, and solid waste dumping, have polluted the river throughout time. Its water flow is further controlled by several barrages, such as the Tajewala barrage [4], which have an indirect impact on water quality and the biological ecology. The most polluted river flow is said to pass through Nizamuddin (Delhi) and the district of Agra (Uttar Pradesh) [5]. The River Yamuna is classified as Water Quality Category E and is only suitable for recreational and industrial cooling. It is considered unsuitable for aquatic life survival and household use [4]. Experiments by Joshi et al. (2022) reveal that the Yamuna River at Palla station (2009–2019) demonstrates high levels of severe pollution, high BOD, COD, and total coliforms that fail to meet WHO standards. The poor water quality is attributed to untreated industrial effluents and sewage despite considerable investments made towards treatment plants [6].

Likewise, Shukla et al. (2020) examined the River Yamuna water in Prayagraj and found abnormal hardness and free carbon dioxide levels, which were above the WHO standards. It was reported by the study that water from the studied locations is unfit for household use in the absence of treatment [7]. This study addresses a key knowledge gap by analyzing the long-term spatial variations in River Yamuna's water quality across its entire course. The current study aims to analyze the water quality of the Yamuna River from 2012 to 2021 using CPCB data to assess spatial pollution patterns and environmental changes. It aims to determine the river's suitability for domestic use and highlight the need for effective water management measures.

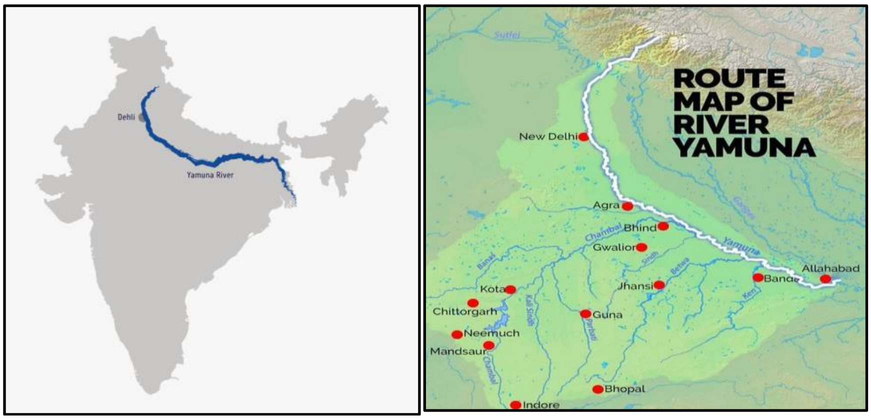
2. Methodology

This study used open-source secondary data on the water quality of River Yamuna from 2012 to 2021 provided by the Central Pollution Control Board (CPCB) of India's Ministry of Environment, Forest, and Climate Change [8]. Temperature, dissolved oxygen (D.O.), pH, conductivity, biochemical oxygen demand (B.O.D), nitrate + nitrite, faecal coliform, and total coliform were among the characteristics tested. The data presented in Table 1 was first extracted and then compiled. Mean values were then calculated, which were graphically represented using Microsoft Excel to help visually identify trend patterns and compare them to the standards for best-use classifications C and D, essential for assessing the lake's ecosystem health.

The reasoning for selecting these specific parameters is as follows:

3. Site Selection

This study examines the water quality of River Yamuna throughout its length. Yamuna originates from the Yamunotri Glacier (31.0140° N, 78.4600° E), situated at an altitude of 3,293 meters (10,804 ft). It travels 1,376 km to merge with River Ganga, the longest river in India, at Allahabad (25.4358° N, 81.8463° E) [9]. Finally, the river flows into the Bay of Bengal near Gangasagar (21.6490° N, 88.0754° E) in West Bengal. River Yamuna is the longest river that does not directly flow into the sea. Given its vast length and diverse geographical settings, the river's water quality is influenced by multiple natural and anthropogenic factors. To ensure a comprehensive analysis, this study incorporates 10 years of data obtained from the Central Pollution Control Board (CPCB), covering monitoring stations along the entire course of the river. The Yamuna holds immense cultural, religious, and economic significance. Revered as a goddess and closely linked to Lord Krishna's childhood, it is integral to India's spiritual landscape. Beyond its religious importance, the river sustains nearly 4% of India's population, serving as a crucial water source for drinking, irrigation, and industry. Understanding its water quality dynamics across different regions is essential for effective conservation and sustainable management.



(a) **(b)**

Fig. 1 (a) Location of River Yamuna on the Map of India (b) Route Map of India [10]

4. Results & Discussion

Table 1. Annual mean data for various water quality criteria throughout the length of River Yamuna collected from the CPCB for a period of 10 years, from 2012 to 2021 [8]

Year	Temperature (ºC)	Dissolved oxygen (mg/L)	pH	Conductivity (μmho/ cm)	Nitrate + Nitrite (mg/L)	Faecal coliform (MPN/100ml)	Total coliform (MPN/100ml)	BOD (mg/L)
2012	19.5	6.48	7.72	263.14	0.59	268773967.2	250076599.1	9.39
2013	19.576	6.18	7.77	177.3	2.82	13727.88	1432408.23	7.52
2014	23.06	5.25	7.73	344.66	1.2	40827	2921154.05	8.92
2015	24.93	6.1	7.88	742.11	–	15872.41	778756.75	9.46
2016	22.58	7.13	7.67	1130.52	0.3	2526353.16	4345599.82	10.8
2017	16.7	6.34	7.65	953.3	1.38	3110590.96	4017029.07	11.51
2018	21.79	7.36	7.69	862.93	1.2	2075326.26	4856293.36	11.52
2019	22.75	6.85	7.56	973.8	1.23	1259407.24	1661876.41	9.09
2020	21.51	7.13	7.68	827.91	1.23	539556.35	1910207.1	11.04
2021	23.84	6.36	7.61	871.15	1.11	2181794.36	2513621.66	13.15

Table 2. Permissible range for drinking water by WHO (World Health Organization) [11] and CPCB water quality standards [8].

Parameter	Permissible range for drinking water
Temperature (ºC)	10 - 22
Dissolved O2 (mg/l)	> 6.5 - 8
pH	6.5 - 8.5
Nitrate + Nitrite (mg/l)	< 1
Conductivity (μmhos/cm)	< 800
BOD (mg/l)	< 2
Fecal Coliform (MPN/100ml)	< 1
Total Coliform (MPN/100ml)	< 50

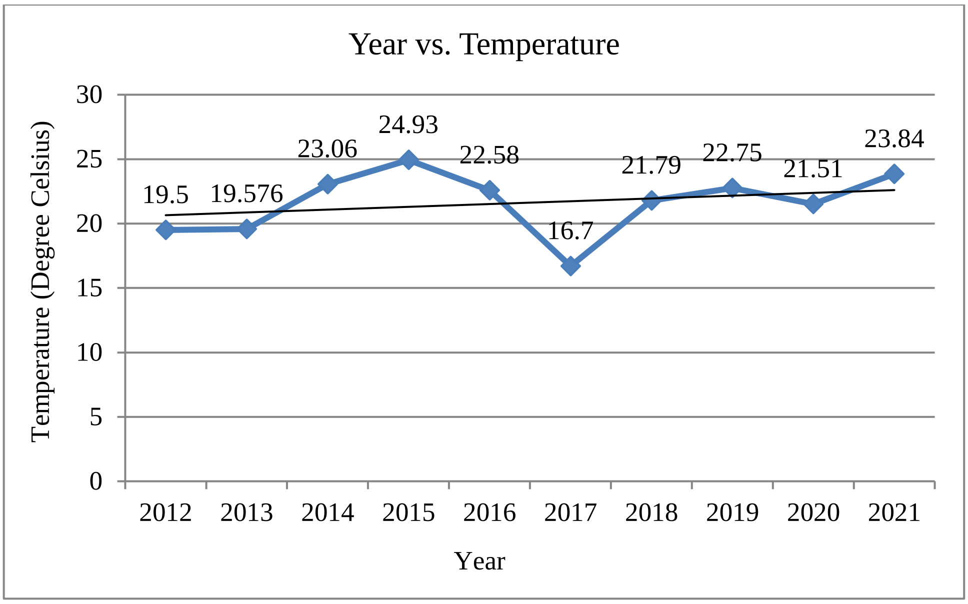


Fig. 1 Changes in the Surface Temperature of River Yamuna from 2012-2021

The surface temperature of the Yamuna River directly reflects atmospheric conditions, often influenced by climate variability. The general warming trend observed in recent years aligns with global warming impacts, as rising greenhouse gases contribute to higher atmospheric and, subsequently, water temperatures. In 2017, however, an unusual dip to 16.7°C was recorded in the Yamuna River, likely a consequence of the severe cold wave that struck North India that year. This deviation highlights how both ongoing climate change and sudden extreme weather events shape the thermal characteristics of river systems like the Yamuna, affecting the local ecosystem and potentially altering biodiversity within the river.

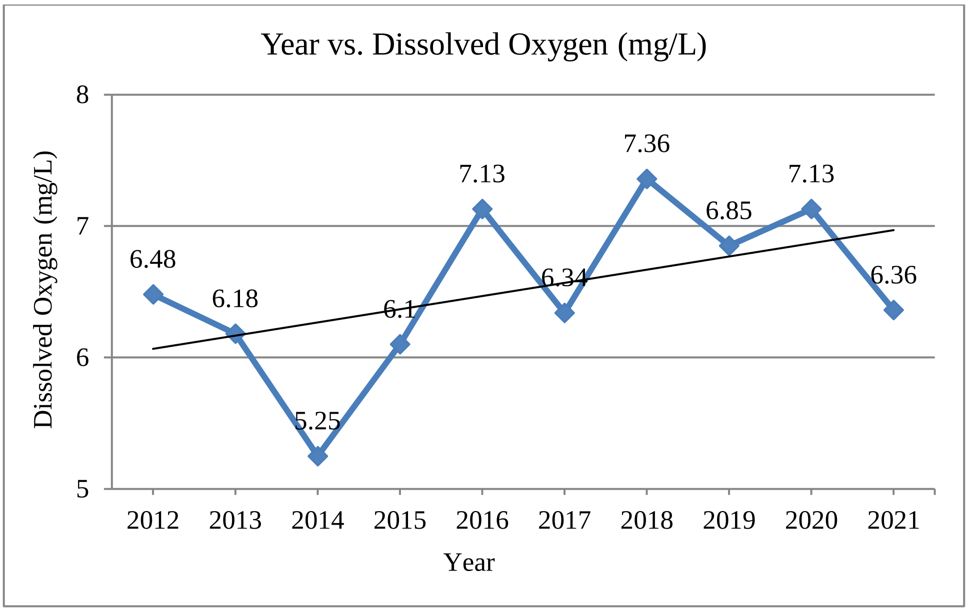


Fig. 2 Changes in the Dissolved Oxygen of River Yamuna from 2012 to 2021

In the Yamuna River, dissolved oxygen (D.O.) levels have been recorded between 5.25 and 7.36 mg/L, surpassing the 4-6 mg/L range recommended for drinking water quality. These high levels of D.O. are helpful since they facilitate aquatic life and render the Yamuna more favorable to biodiversity. But in 2014, there was a significant drop in the levels of D.O., which can be attributed to the rise in organic pollutants in the river, which depletes dissolved oxygen as they rot.

This decrease in D.O. levels also coincides with an increase in surface temperatures in 2013–2014 since warming lowers the oxygen-holding capacity of water.

The concurrent rise in temperature and drop in D.O. levels highlight how climate oscillations and pollution inputs can seriously affect water quality in the Yamuna, influencing both ecosystem well-being and usability of water.

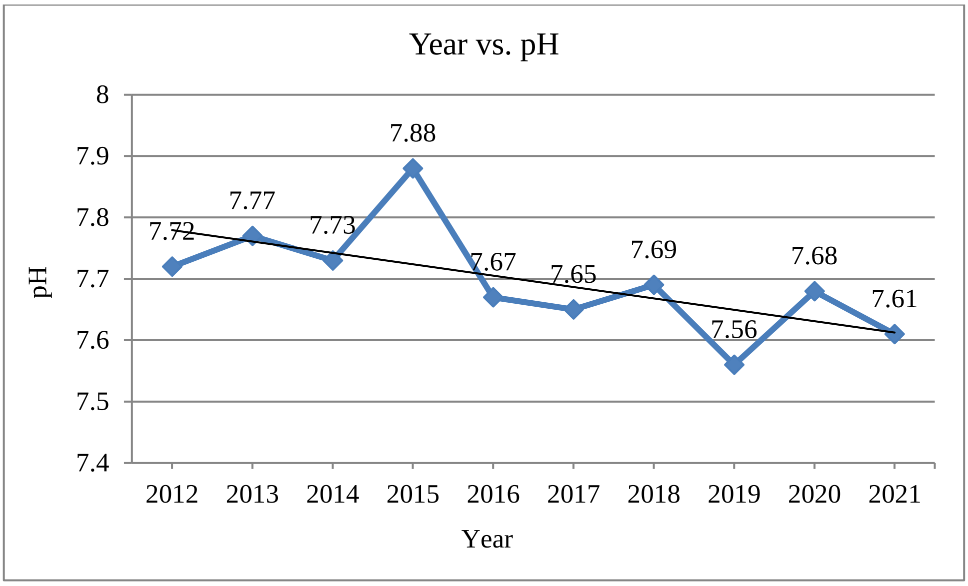


Fig. 3 Changes in the pH of River Yamuna from 2012-2021

During the last ten years, the pH of the Yamuna River has been in the acceptable drinking water range of 6.5 to 8.5 and has fluctuated minimally from 7.56 to 7.88. The small fluctuation shows a generally stable, slightly basic condition, indicating minimal exposure to acidic or basic contaminants capable of upsetting the pH balance. Such stability is important to aquatic life since drastic changes in pH can harm biodiversity and influence water quality. The minor increase in pH in 2015 might be related to greater rainfall and soil erosion during that year, which both contribute mineral-loaded sediments to the river, increasing alkalinity. In addition, the basic quality of the river could also be due to eutrophication, where the overgrowth of vegetation enhances photosynthesis, lowering dissolved carbon dioxide (an acidic gas) content from the water and thus elevating pH levels. These combined contribute to the river's relatively stable, mildly alkaline conditions, which are conducive to aquatic life and ensure its continued suitability for drinking and irrigation.

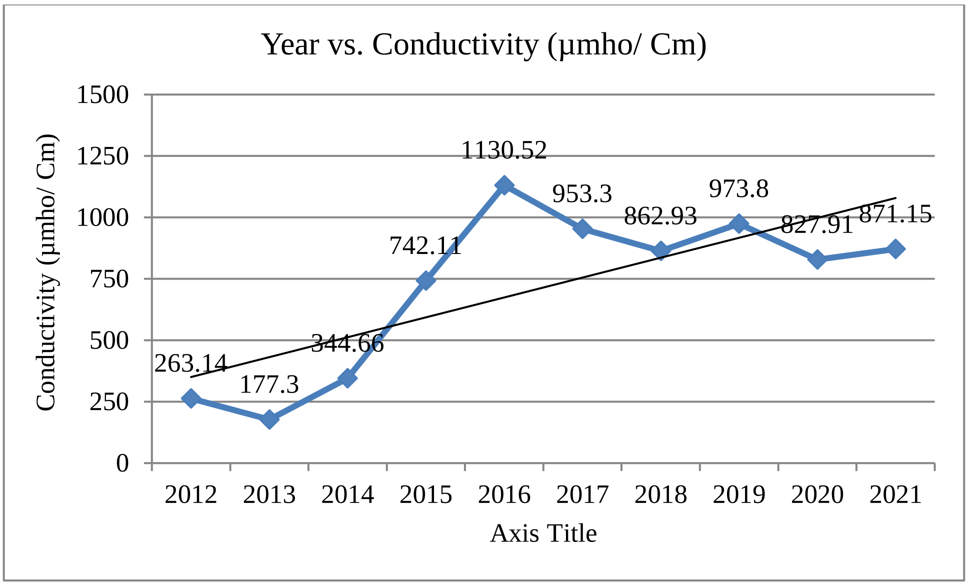


Fig. 4 Changes in the Conductivity of River Yamuna from 2012-2021

Conductivity, a measure of the ionic content of a water body, indicates the dissolved ions' concentration, e.g., salts, metals, and other inorganic substances. The acceptable level of conductivity in drinking water is 200–800 µmho/cm, ensuring ionic content at safe levels for drinking. The conductivity levels in Yamuna River in 2012, 2014, and 2015 were all within this range, indicating stability in ionic concentration. Nevertheless, a sharp surge during 2016 propelled conductivity above safety levels, suggesting a very high level of dissolved ions.

This spurt indicates greater concentrations of dissolved salts, heavy metals, chemicals, and inorganic wastes, likely because industrial discharge, farming runoff full of fertilizers and pesticides, and untreated residential wastes are reaching the river in large quantities. Such pollutants have the potential to raise conductivity, indicative of decreased water quality and predicting possible danger to aquatic environments as well as to human health if not tackled.

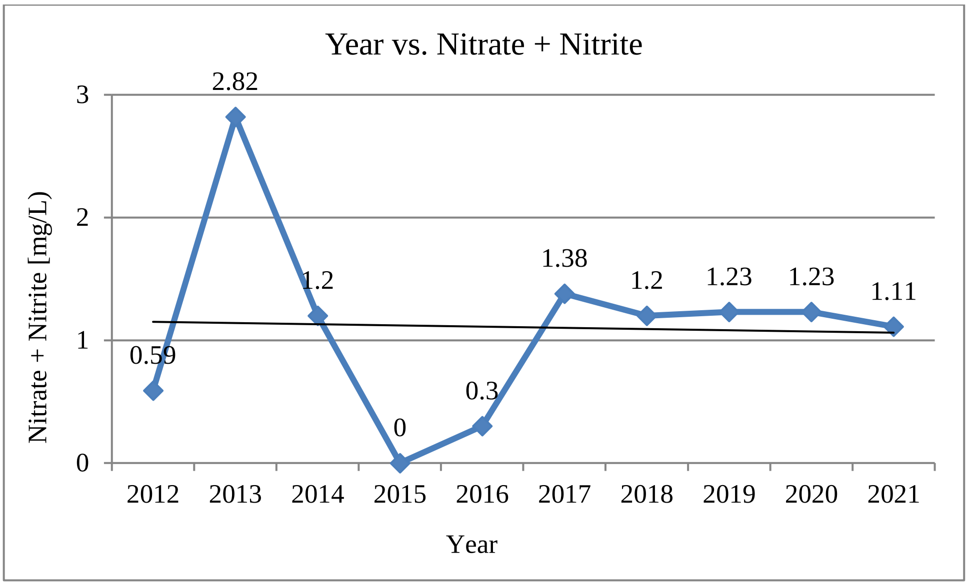


Fig. 5 Changes in the Nitrate + Nitrite levels of River Yamuna from 2012-2021

Nitrate levels must be below 1.2 mg/L for safe and good-quality drinking water. However, the nitrate levels of River Yamuna ranged from 0.3 mg/L - 2.82 mg/L. The peak in 2013 and 2017 can be attributed to increased anthropogenic activities. Agricultural runoff containing nitrogen fertilizers and domestic waste containing nitrates, like detergents, lead to such activities. Elevated nitrate levels lead to health hazards. Nitrate causes the haemoglobin in the human blood to change into methemoglobin, a condition called methemoglobinemia.

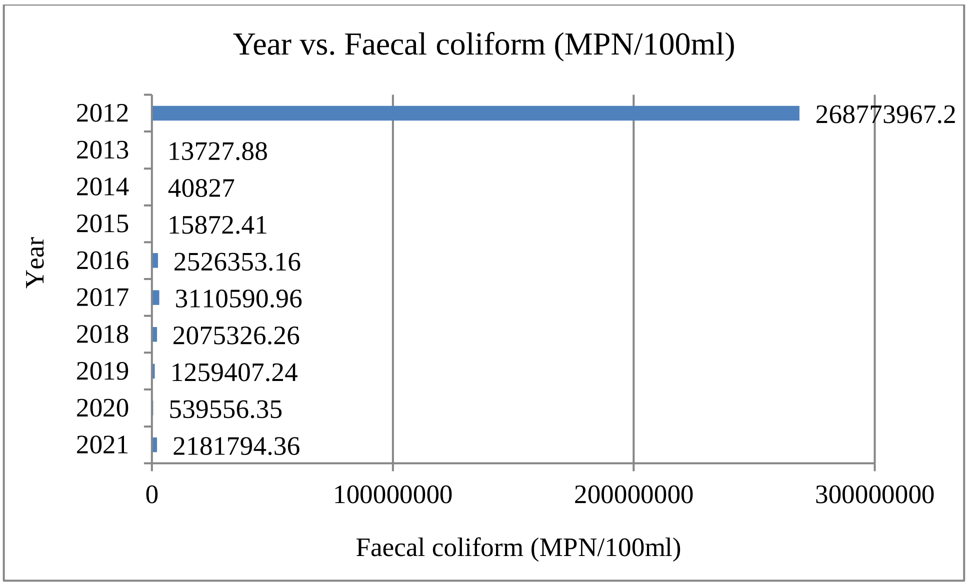


Fig. 6 Changes in the Faecal Coliform levels of River Yamuna from 2012-2021

The permissible limit of faecal coliform in drinking water is 0 MPN/100 mL, essential for maintaining safe water quality. However, the Yamuna River has reported extraordinarily high faecal coliform levels, indicating severe pollution and contamination from waste sources. In 2012, the fecal coliform concentration soared to an alarming 268,773,967.2 MPN/100 mL. Such elevated levels raise significant public health concerns due to the presence of pathogenic bacteria that can lead to waterborne diseases.

The sudden rise in faecal coliform counts may be due to several reasons, such as poor sewage treatment, agricultural runoff, and industrial waste. These microorganisms can also harm aquatic life, compromising the biodiversity of the water bodies and degrading the quality of water. An increase in the growth of disease-causing bacteria directly threatens rural communities that get their drinking and recreational water supplies from the river.

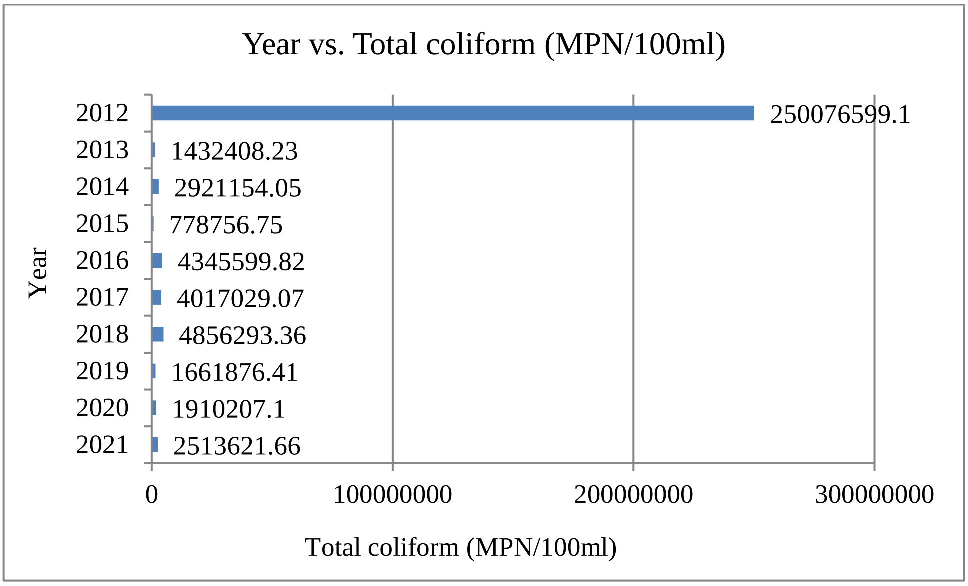


Fig. 7 Changes in the Total Coliform levels of River Yamuna from 2012 to 2021

Like faecal coliform, the acceptable threshold for total coliform in drinking water is similarly 0 MPN/100 mL. River Yamuna has recorded extremely high levels of total coliforms, from 778,756.75 to 250,076,599.1 MPN/100 mL. High contamination levels are a cause for concern and are mainly contributed by agricultural runoff and untreated sewage, which could introduce pathogenic microorganisms into the river. Such contamination makes the water dangerous to drink and unsafe for recreational activities, and it presents severe health consequences to the residents of the areas.

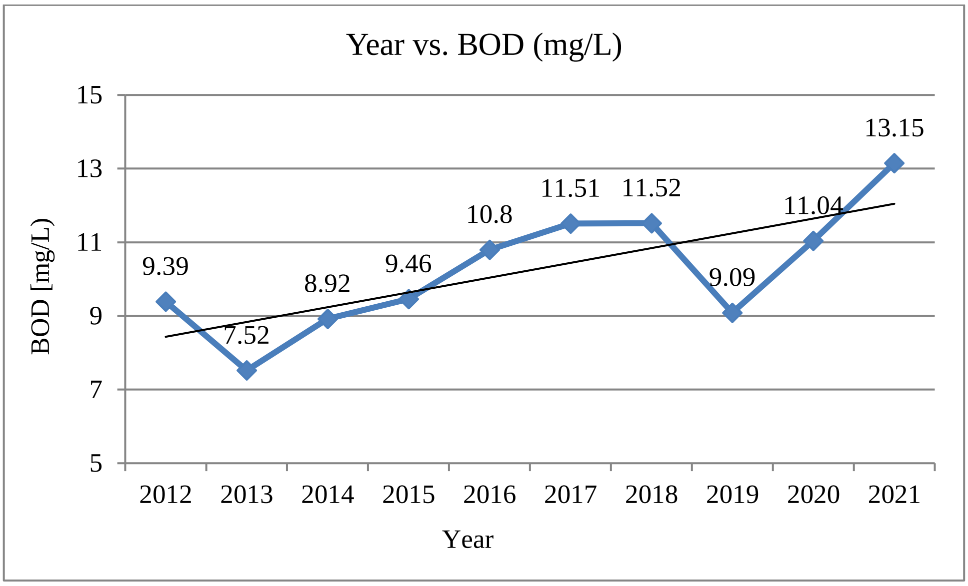


Fig. 8 Changes in the B.O.D. of River Yamuna from 2012-2021

BOD should be less than 3 mg/L for the water to be safe and healthy. The BOD of River Yamuna has been consistently ranging from 7.52 to 13.15 mg/L, which is much higher than the safety threshold by at least 4-10 mg/L. Higher BOD values indicate more microbial activity in the water. This increased activity depletes the water's oxygen, killing fish and other aquatic life.

There were considerable reductions in BOD levels in 2013 and 2019, showing that fewer organic wastes were entering the river through agricultural runoff and untreated sewage during these years. This indicates that activities aimed at reducing pollution can lead to the improvement of water quality. There is a need to continue striving to reduce such sources of pollution to salvage the river and its ecosystem.

5. Conclusion

The water quality assessment of River Yamuna for the period between 2012 and 2021 indicates a severe decline in different types of pollutants. The study indicates that the river is unsuitable for consumption and general use, and local communities' health risks have increased significantly. This is an obvious sign that environmental problems should be tackled at once, and it reflects the importance of proper control of pollution to protect this valuable source of water. Effective management of sewage, industrial waste, and agricultural runoff is crucial for improving the water quality of River Yamuna. Ensuring ecological flow, preventing solid waste disposal, and enforcing pollution control regulations can enhance its suitability for drinking, irrigation, and fisheries. Improved water quality will mitigate health risks, support agricultural productivity, and sustain livelihoods while contributing to tourism and economic growth. Implementing these measures is essential for long-term environmental sustainability and socio-economic development.

The research does have some weaknesses, mainly because it is based on secondary data collected from government databases that might not necessarily reflect the actual changes in real-time or localized pollution concerns along the river. Even mean yearly figures may be hiding some major water quality variations that occur during specific time frames, and excluding seasonality does not enable us to get the whole picture of how various weather conditions affect the river's health. To overcome such limitations, more studies must be conducted on-site by gathering first-hand information from the river itself, allowing for a better estimation of its present condition. Seasonal variation of data analysis by periodic sampling, say weekly or monthly, would set up the role of seasonal variations on water quality. Regularly comparing past and present data would facilitate tracking pollution sources and trends over time. Finally, establishment of the effectiveness of clean-up measures targeted for the River Yamuna would make possible derivation of meaningful lessons for enhancing conservation and public health protection.

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