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Research Paper

From Pollution to Preservation: Impacts of the Namami Gange Project on the Ganga River Ecosystem in the Varanasi Urban Area

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Abstract
The Namami Gange project was started by the Government of India, in 2014 as a mission to rejuvenate the Ganga River from acute pollution and environmental degradation, achingly throwing a plight on this holy waterway. This research paper explores the impact of the Namami Gange project on the holy river Ganga in Varanasi Urban Area, Uttar Pradesh. The study is based on a multi-disciplinary approach with the help of water quality monitoring, sources of pollution, and assessment of the measures followed under the Namami Gange Program.
For monitoring the water quality, the parameters adopted in the present research are temperature, pH, conductivity, DO (dissolved oxygen), BOD (biochemical oxygen demand), FC (fecal coliform), and TC (total coliform), before and after the Namami Gange program implementation. Results show a visible improvement in water quality with major reductions in BOD and coliform levels, reflecting better oxygenation and reduced organic pollution. In this direction, the work pertaining to the establishment of STPs (Sewage Treatment Plants) and upgrading of existing infrastructure has been extremely crucial for mitigating the inflows of untreated sewage and industrial effluents into the river.
The research also investigated the program's ecological effects on the restoration of aquatic habitats and biodiversity recolonization in a few river reaches. Public awareness campaigns and community participation programs were also completed with huge responses from the local population and pilgrims to enhance the sense of stewardship, which leads to greater sustainability and reduced pollution.
The research, however, portrays that some of the lingering challenges pertain to continuous monitoring, STP maintenance, and non-point sources of pollution. More importantly, this would call for a holistic invasive management approach so that these positive outcomes as potentials of the Namami Gange program do not go astray. Overall, the paper provides valuable insights into the efficacy of large-scale environmental interventions and their potential to revive and preserve vital water resources like the Ganga River in Varanasi.

Keywords: *Ganges River, Namami Gange Project, pollution control, biodiversity, Varanasi, river restoration, ecosystem.*

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I. Introduction

Being an important part of India's heritage and culture the River Ganga supports millions of people in its basin. The Varanasi city is one of the oldest continuously inhabited cities in the world, depending intensely on the Ganges for day-to-day living, religious routines, and the local economy (Singh G. et al. 2024). Due to the deterioration of its water quality the Ganga River, has been facing a severe crisis in recent decades. During the last decades, the increasing levels of pollution have turned the river into one of the most polluted water bodies in the world. The factors contributing for the degradation of water quality in this river are effluents from industries, untreated sewage, and religious activities. Varanasi, a holy city situated along the banks of the Ganga, has been at the epicenter of this environmental challenge. (Singh Y.V. et al. 2023). The lack of comprehensive understanding of the pollution load and the increasing amount of non-biodegradable pollutants at several locations along the

Ganga Ghats has been a significant concern (Jamal S. et al., 2021). The river is being polluted from various sources, including domestic sewage, industrial wastewater, and agricultural runoff (Mukherjee B. et al. 2015) These pollutants have a detrimental impact on the water quality, affecting the aquatic organisms that rely on the river ecosystem (Trivedi R. et al. 2010). The Indo-Gangetic plain, where the Ganga flows, is a heavily populated region and one of the largest groundwater repositories on Earth. The growing population, extensive urbanization, and industrialization in the region have exacerbated the problem, leading to serious concerns about the increasing levels of heavy metals in the Ganga River. The Ganga River basin covers a vast area, accounting for 26% of India's land mass and supporting approximately 43% of the Indian population. (Modi A. et al. 2023). Realizing the dire need for intervention, the Government of India launched the Namami Gange Project in 2014 to restore the Ganges through a multi-pronged approach. The present paper highlights one of the focal points of the project, Varanasi, evaluating the environmental and socio-economic outcomes of the NGP and exploring the success of the latter in bringing about sustainable preservation of the Ganges. The Namami Gange program, launched by the Government of India in 2014, aims to rejuvenate the Ganga River by improving water quality, reducing pollution, and promoting sustainable river management. In Varanasi, the religious and cultural epicentre along the Ganga, the program's efforts have focused on addressing the city's long-standing challenges with river pollution. Before the mission, Varanasi was infamous for raw sewage, industrial effluents, and solid waste polluting the Ganga. Under Namami Gange, the construction of STPs and development and re-development of the sewer network was done, coupled with the enforcement of standards for industrial effluents, thereby considerably reducing the direct discharge into the river. Apart from that, ghats and riverbanks were cleaned and maintained through Swachh Bharat and Namami Gange initiatives to increase hygienic conditions for the pilgrims and tourists visiting the holy rivers. Many reports showed improvement in the water quality indicators with less biological oxygen demand and coliform levels, indicating a healthy aquatic ecosystem. Afforestation along the river and public awareness campaigns also contributed to the sustainability of the program. However, challenges remain in fully controlling non-point source pollution and ensuring the consistent operation of STPs. Furthermore, community engagement remains essential to curbing local littering and maintaining cleanliness. Despite these ongoing challenges, Namami Gange has marked a positive shift in Varanasi, helping restore the Ganga's ecological balance while honouring its cultural significance. (Namami Gange Annual Report 2022-23; National Mission for Clean Ganga)

II. Pollution in the Ganges: A Historical Overview

2.1. Sources of Pollution

Pollution in the Ganges is multi-faceted, arising from untreated sewage, industrial discharges, agricultural runoff, and religious waste (Singh R. 1994). Varanasi, as a densely populated urban area, contributes significantly to this pollution. Pollution sources affecting the Ganga River of Varanasi are largely anthropogenic in origin and influenced by industrial effluent (Jamal S. et al. 2021). Untreated wastewater is a significant contributor. There are also several drainage systems dumping water directly into the river, including the Varuna River, that merge at Varanasi. The effects of this scenario have resulted in increased levels of biochemical oxygen demand (BOD) and fecal coliform bacteria, making the river unsuitable for drinking and recreation in many parts of the river basin (Singh Y.V. et al. 2023). Secondarily, heavy metals such as lead (Pb), cadmium (Cd), and chromium (Cr) plague the river's waters, primarily via industrial inputs. These pollutants remain in aquatic systems through water, sediments, and fish causing critical damage to marine habitats and human health (Rai P.K. et al. 2010). Along with this, the persistence of rituals and waste disposal lowers the level of water quality. In fact, pollution increases during the festive seasons as large populations gather at the ghats (Srivastava R.K. et al. 1996).

2.2. Previous Cleanup Efforts

Various efforts have been made over the decades to clean the Ganges, but most have failed due to a lack of coordination, insufficient funding, and inadequate implementation. The Ganga Action Plan (GAP) launched in the 1980s, for instance, met limited success due to mismanagement and inefficiencies, leaving the river highly polluted. This led to the creation of the Namami Gange Project, which sought to address the shortcomings of previous efforts with a more holistic and robust approach (Namami Gange Annual Report 2015-16). Restoring the Ganga River in Varanasi has taken an approach of embracing both state-implemented activities and grassroots efforts. Namami Gange has successfully driven down pollution with the installation of STPs, improvement in waste management, and public awareness campaigns (Modi A. et al. 2023). However, in studies considering the complexities surrounding the rehabilitation of the river, the call for sustainable practices and long-term measures becomes inevitable. A specific study highlights the secondary gains from cleanup operations from the cities upstream, like Kanpur, which simultaneously benefit Varanasi. This finding suggests that inter-city cooperative projects can achieve greater total outcomes. Theoretical models have also been developed to examine how social well-being can be enhanced by optimizing pollution cleanup strategies where water quality is aligned with economic and social gains (Xing S. et al. 2019). In addition, nongovernmental organizations such as Swatch

Ganga have traditionally started to stimulate numerous religious and community groups for river conservation goals; however, these efforts face challenges due to inadequate infrastructural facilities and a lack of funds.

III. Namami Gange Project: Scope and Implementation

3.1. Objectives of the Namami Gange Project

The Government of India launched a Namami Gange Programme in 2014 for effective measures to revitalize and conserve the Ganga River. Its primary focuses include a reduction of pollution through the establishment of STPs, improvement of waste management systems, and increased regulation towards industrial activities. The aesthetic and ecological value of the banks of the Ganga has been enhanced through the development of ghats; the promotion of tourism and the development of access to ghat areas. Cleaning efforts on the river surface remove floating littering debris and solid waste for hygiene; biodiversity conservation attempts to protect endangered species like the Ganga river dolphin by rehabilitating habitats and afforestation projects. It promotes organic farming that reduces chemical fertilizers to reduce agricultural runoff. It also raises public awareness so that local people become involved in conservational approaches to challenge themselves for sustainable activities in this region. Riverbank afforestation can protect the ecosystem and ensure water retention for a stream of groundwater, which is essential for the flow of the Ganga.

3.2. Implementation in Varanasi

The Namami Gange initiative in Varanasi has introduced various crucial steps to promote better sewage treatment systems and protect the Ganga River. STPs in places such as Dinapur, Goitha, and Ramana have significantly reduced the direct discharge of untreated sewage into the river and improved the urban city's sewage treatment capacity. Alongside these STPs, the project has revamped and expanded sewerage infrastructure through new underground pipelines connecting various districts of Varanasi. Such overhauling assures safe conveyance of waste water into treatment plants instead of exposing open drainage to the Ganga. Beautification and maintenance of the ghats have been another area of focus: cleaning operations have been undertaken regularly to remove solid waste and debris, much of which is generated from religious offerings and rituals of cremation. Effluent control from industries has been reinforced by stricter norms and checks to ensure that local industries treat their wastes before discharge. Public awareness programs involve educating the local community, schools, and religious leaders about keeping the river clean and refraining from using non-biodegradable products. Surface cleaning programs have also been sent out to clear the river of floating wastes. Efforts that achieve biodiversity consist of tree planting along the river banks and the safeguarding of local wildlife, as in the case of the Ganga river dolphin, which is one of the most important indicators of the ecosystem's health.

IV. Methodology

4.1 Study Area:

The Varanasi Urban Area is located in the northern state Uttar Pradesh of India stretching from around 25º13′26″ N to 25º24′07″ N latitudes and 82º52′01″ E to 83º10′55″ E longitudes. According to Varanasi-Ramnagar-Mughal Sarai Mahayojna-2031 the Varanasi Urban Area has been divided in two zones: Zone A comprising of the area to the left of River Ganga (Varanasi Mahayojna 2031) and Zone B along the right bank of river Ganga (including area of Ramnagar-Mughal Sarai Mahayojna 2031). The Study area has a tropical monsoon climate, with hot summers and cold winters. The region receives most of its rainfall during the monsoon season, which lasts from June to September. The plains of Varanasi consist of younger alluvium which rests over the Precambrian basement. The unconfined and leaky type of aquifers are found in Varanasi.

4.2 Data:

The Water quality data of the Ganga River for the study area has been collected from the published annual report from of the Central Pollution Control Board (CPCB) and Central Water Commission (CWC). Some of the recent water quality data has been verified from the RTWQM (Real Time Water Quality Management) portal of the Central Pollution Control Board and the web portal of India WRIS. The parameters used in this research work for assessing the impact of the Namami Gange project on Ganga River water quality are temperature, pH, Conductivity, D.O. (Dissolved Oxygen), B.O.D. (Biochemical Oxygen Demand), Nitrate (NO□), Fecal Coliform and Total Coliform. The data has been taken for the two stations namely Assi Ghat (Upstream) and Raj Ghat (downstream) from 2012 to 2022. The comparison of each water quality parameter between the two stations has been represented by the help of bar graphs.

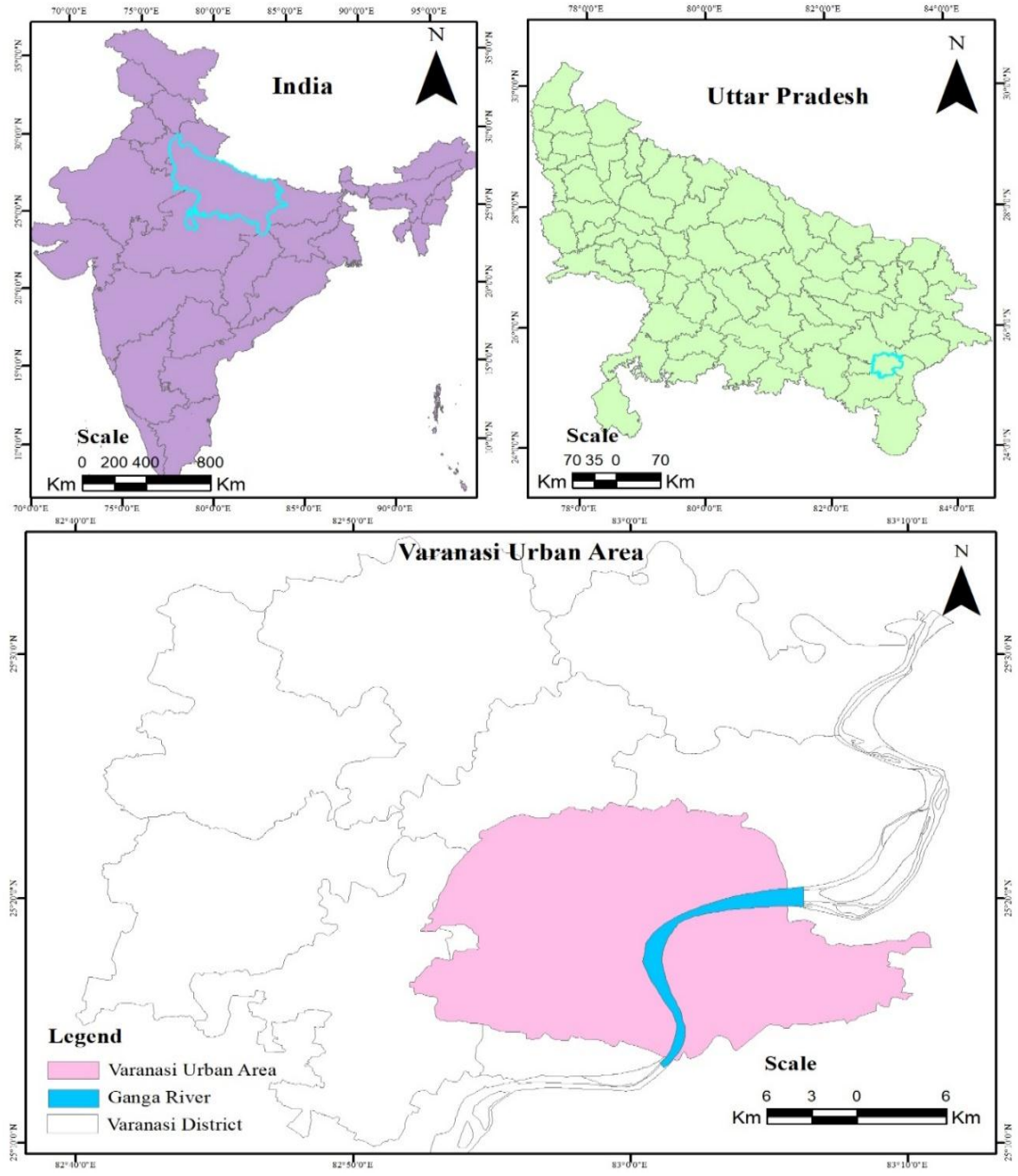

Figure 1. Study Area Map

Table 1. Water quality parameters for the Ganga River at Varanasi Urban Area

	Name of Station															
	Assi Ghat (U.S.)								Rajghat/Malviya Bridge (D.S.)							
Year	Temp. (ºC)	pH	Cond. (µS/cm)	D.O. (mg/L)	B.O.D. (mg/L)	NO3 (mg/L)	F.C. (MPN/100ml)	T.C. (MPN/100ml)	Temp. (ºC)	pH	Cond. (µS/cm)	D.O. (mg/L)	B.O.D. (mg/L)	NO3 (mg/L)	F.C. (MPN/100ml	T.C. (MPN/100ml
2012	25	8.2	251	7.9	3.2	1.1	6783	16467								
2013	23.2	8.2	291	8.4	3.0	0	5500	8833	23.2	8.5	327	7.9	4.6	1.64	34500	49500
2014	22.5	8.2	338	8.3	2.9	0	2617	3950	22.5	8.5	385	7.8	4.5	0	31167	47333
2015	21.5	8.35	510.5	8.1	5.5	0	2250	3850	22.5	8.6	406	7.4	4.75	0	28000	44500
2016	26	7.95	408	8.6	3.15	0	1800	2900	26	7.95	441	7.5	5.5	0	27500	48500
2017	24.5	8.2	437.5	8.15	3.05	0.30	1750	12200	25.5	8.45	481.5	7.05	5.7	0.35	36000	56500
2018	25.5	8.3	416.5	8.30	2.85	0.21	1350	2250	25.5	8.2	477	6.95	5.15	0.34	32500	48500
2019	25.75	8.25	438	8.6	2.5	0.18	1100	2250	25.75	8.3	460	7.2	3.8	0.28	17000	30000
2020	24.5	8.25	377	8.45	4.3	0.3	950	2250	24.5	8.25	400	7.65	3.85	0.35	12000	22500
2021	24.5	8	405	8.4	2.25	0.78	900	2550	24.5	7.85	417	7.8	3.7	0.91	10000	7950
2022	25	7.8	378	6.5	2.3	0.67	820	1700	25	7.21	416	6	2.4	0.82	8800	1100

V. Results and Discussions

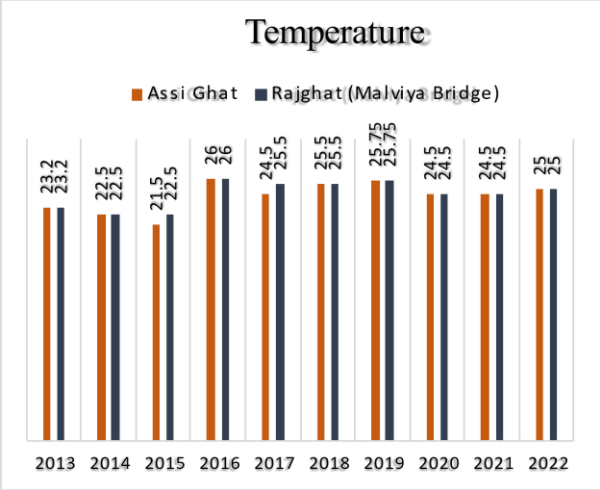

Figure 2. Temperature

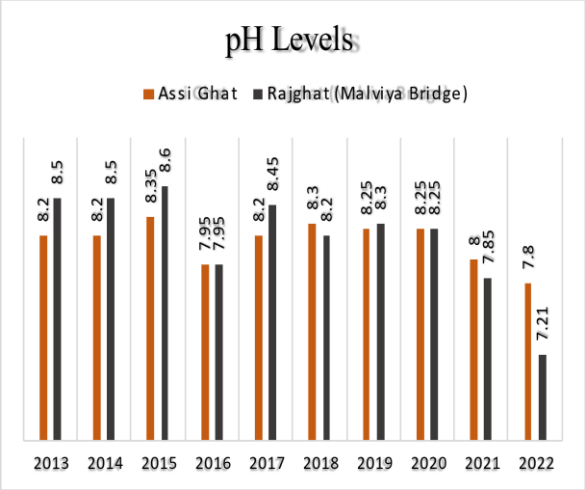

Figure 3. pH

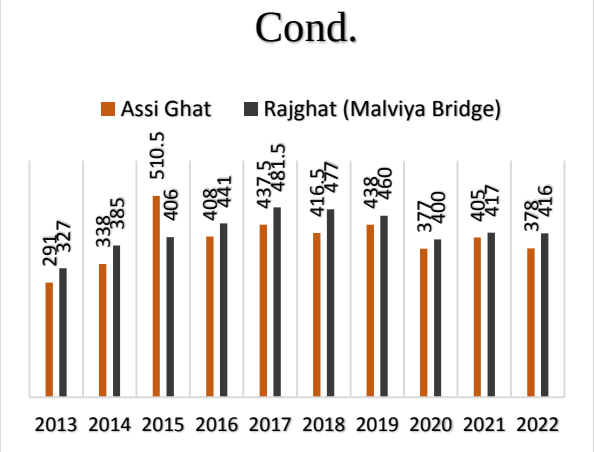

Figure 4. Conductivity

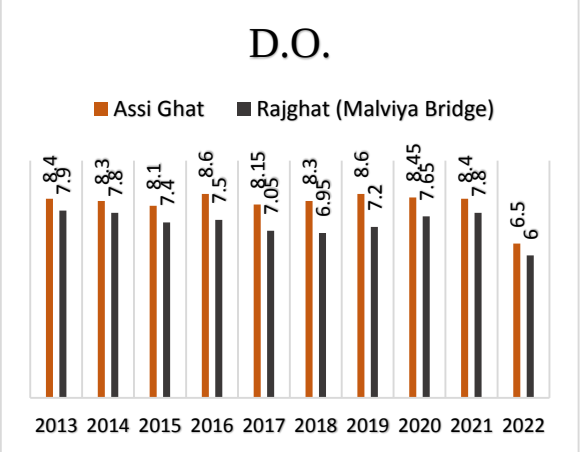

Figure 5. Dissolved Oxygen

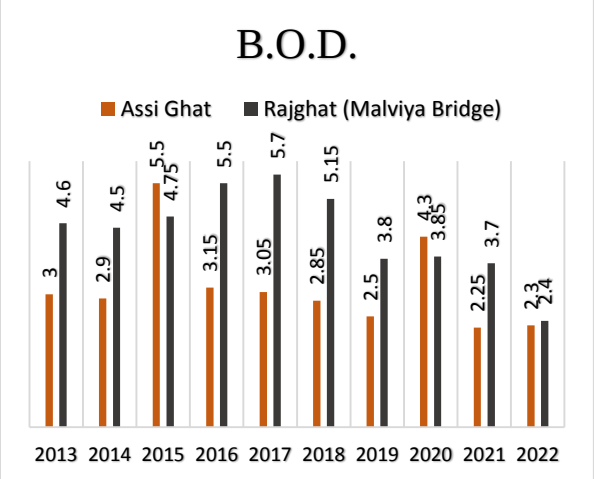

Figure 6. Biochemical Oxygen Demand

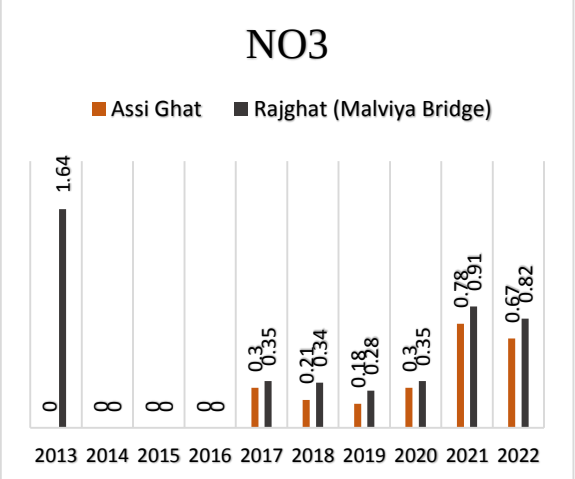

Figure 7. Nitrate

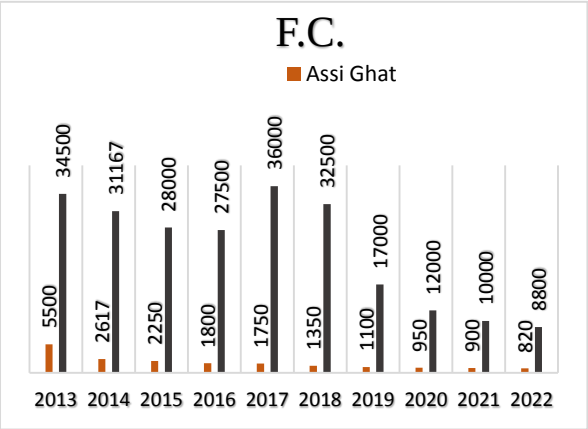

Figure 8. Fecal Coliform

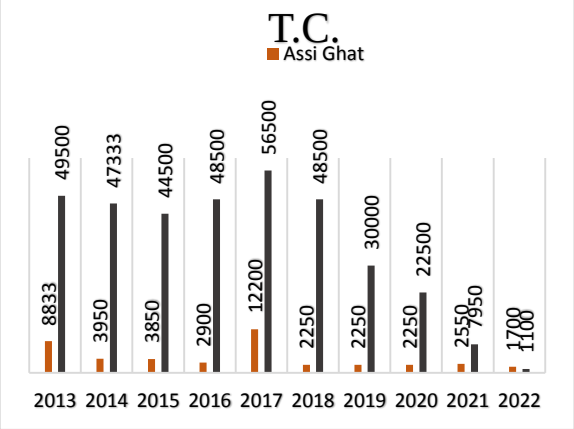

Figure 9. Total Coliform

From the data represented in Table 1 and the bar graphs, we can see that there are minor fluctuations in temperature which shows seasonal and climatic changes. The gradual increase in pH values across all stations is observed showing the changing of water to alkaline nature which is suitable for aquatic life and helps restore the river ecosystem. Dissolved Oxygen (D.O.) has a visible improvement after 2017, indicating better oxygenation in the water. A slight decline in conductivity values after 2019, indicates reduced salinity and dissolved solids. Noticeable decrease in B.O.D. values post-2016, indicating lower organic matter and improved water quality. Nitrate has stable levels, with some minor reductions in recent years. A significant decline in Fecal Coliform and Toal Coliform has been observed especially after 2017 which suggests that improved sewage treatment and sanitation efforts have been implemented under the Namami Gange Project.

VI. Outcomes and Impact in Varanasi

6.1. Pollution Reduction

The NGP was finally able to bring down the level of pollution in the Ganges to a bare minimum. Sanitation through modern STPs at local levels has reduced untreated sewage discharge to a considerable extent into the river. Until 2022, more than 120 million liters per day were reported being treated in Varanasi, showing visible improvements in water quality.

Water quality studies indicate a reduction in the predominant pollution parameters, BOD and COD, however, need further intervention to achieve the desired goal set by CPCB standards. Moreover, prophecies have been made to implement real-time monitoring systems at various locations in Varanasi for better management of water quality around those sites.

6.2. Biodiversity and Ecological Restoration

The Namami Gange Project has played a significant role in the rehabilitation of aquatic biodiversity. In Varanasi, initiatives aimed at conserving species like the Ganges river dolphin, various turtles, and fish populations have yielded favourable outcomes. Additionally, the ecological restoration of riverbanks through afforestation efforts has contributed to the stabilization of the river ecosystem. It has also initiated "bio-remediation" techniques; this is cleaning and restoring polluted sites through the use of plants and microorganisms, especially near heavily contaminated ghats.

6.3. Socio-Economic Impact

The socio-economic impact of the Namami Gange Project has been very significant in Varanasi. The construction of ecologically friendly ghats has upgraded the tourism infrastructures, provided safe drinking water for the residents as well as for holy purposes. The project has also offered employment by constructing sanitary structures and daily maintenance of the ghats. Increased consciousness-raising activities by engaging the local people have altered behaviour-in this case, fewer religious offerings now get dumped directly into the river. Changes in behaviour towards more sustainable practices-for example, using eco-friendly materials for religious rituals-have also been observed.

VII. Challenges and Limitations

Despite the said achievements, the Namami Gange Project faces a number of challenges. The scale of pollution in the Ganges remains substantial, and in some areas, the improvement in water quality has been slow. Varanasi continues to suffer from significant untreated sewage discharge due to gaps in the capacity of STPs. Challenges related to enforcing regulations on industries and religious activities continue to persist. Public participation, though increased, is still low. The very success of the project depends on a continuous change in the

behavior, especially towards the disposal of waste. Besides, its continuity also rests on sustained funding, political will, and coordination among all the stakeholders involved in the project.

VIII. Conclusion and Future Directions

The Namami Gange Program has achieved remarkable progress in restoring the ecological well-being and hygiene of the Ganges River at Varanasi. Reduction of pollution levels, restoration of biodiversity as well as socio-economic benefits prove that this ambitious project has a potential. However, there still are major challenges especially with regards to infrastructure capacity; compliance enforcement; and people's involvement. Hence forth, Namami Gange Program's success in Varanasi will depend upon the continuous improvement of sewage treatment facilities; stringent implementation of pollution control measures; and more community participation. For long-term sustainability, this project should keep changing with times embracing new technologies plus methodologies meant for safeguarding Ganges so that posterity can use it.

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