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Integrated Stakeholder Approaches for Water Quality Management in the Ganga Basin

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Abstract

The Ganga River, one of India's most vital freshwater resources, is under increasing ecological stress due to rapid industrialization, urbanization, and unsustainable anthropogenic activities. This study investigates the integrated role of stakeholders in the conservation of the Ganga River, with a particular focus on water quality management. Stakeholders were categorized into five groups based on their relative power and interest in biodiversity conservation. Fieldwork was conducted along two major stretches of the river between December 2018 and April 2019 using a combination of field surveys, semi-structured interviews, and water quality assessments. The study identified key pollution sources, including industrial discharges, untreated domestic sewage, agricultural runoff, religious practices, and plastic waste, all contributing to a marked decline in water quality. A comparative analysis of Indian water quality standards with international benchmarks specifically those of the U.S. Environmental Protection Agency (EPA) and British Columbia revealed critical discrepancies, such as the absence of pesticide monitoring in Indian regulations. Findings emphasize the importance of interdepartmental coordination, targeted awareness campaigns, and participatory governance in strengthening stakeholder engagement. The study concludes that river conservation cannot be the responsibility of a single entity. Instead, a multi-stakeholder, inclusive approach integrating traditional ecological knowledge, scientific tools, and policy frameworks is essential for the long-term preservation of the Ganga's ecological health and cultural heritage.

Keywords: Ganga River, Water quality, Stakeholder analysis, River conservation, Environmental governance, Pollution sources

1. Introduction

Our survival on Earth depends on three basic resources – water, air and soil, nature's three valuable gifts to mankind. Among which water is the most important component as it forms the basic medium for origin of life (Postel, 1997), it is essential to all forms of lives from very microorganisms to very complex systems of plants, animals and human being. Its purity varies from place to place in nature. About 71 percent of the Earth's surface is water-covered, and the oceans hold about 96.5 percent of all Earth's water, Only 2.5–2.75% are in usable form and exists in the air as water vapour, in rivers and lakes, in icecaps and glaciers, in the ground as soil moisture and in aquifers, and even in you. Water is never sitting still. Thanks to the water cycle, our planet's water supply is constantly moving from one place to another and from one form to another (U.S. Geological Survey report,2016).

As assessed by the scientists of the National Environmental Engineering Research Institute (NEERI) Nagpur, nearly 70% of water in India is polluted (Martin, 1998). Some observers have estimated that by 2025 more than half of the world population will be facing water-based vulnerability, a situation which has been called a 'water crisis' by the United Nations (Kulshre-shtha 1998). Pollution can be called as human made problem as, industrialization and population increases around the globe, the problem of pollution had started increasing and came in history in 19th century before, that no one believed that pollution would ever become a serious problem. Polluted water not only affects the life of present generation but it also affects the life of upcoming generations because its effect remains for long (Khatun et al ,2017). Heavy metals are dangerous for living creature as, it can be bio accumulated in the food chain and can leads to human diseases through aquatic organisms. These accumulation of heavy metals depends upon various factors like environmental conditions, species and inhibitory processes etc. Cumulative effects or chronic poisoning of metals may occur as a result of long-term exposure or even to low concentrations (Mitra et al,2011).

Water pollution may be defined as alteration in the physical, chemical and biological characteristics of water which may cause harmful effects on human and aquatic life (Report,1965, president science committee, Washington USA). The environment, economic growth, and developments are all highly influenced by water-its regional and seasonal availability, and the quality of surface and groundwater (Halder et al, 2015). The water quality at any location reflects several major influences the lithology of the river basin, atmospheric inputs, climatic conditions and anthropogenic activities (Bricker and Jones, 1995). Statistical analysis of water quality index (WQI) and its parameters has shown to be effective, tool for the management of water resources. The study of the WQI and its parameter by descriptive analysis describe the behaviour of water quality indicators over time and its possible association with potentially polluting factors, this analysis can be of great importance in the management of water resources in the region(Konzen,2015).

UNEP report (2007) says that, there is no single measure that can describe overall water quality for any one body of water a composite index that quantifies the extent to which a number of water quality measures deviate from normal, expected or 'ideal' concentrations may be more appropriate for summarizing water quality conditions across a range of inland water types and over time. Although there is no globally accepted composite index of water quality, some countries and regions have used, or are using, aggregated water quality data in the development of water quality indices. Currently, India is at 120th position among 122 countries in the water quality index, as the report cited by NITI Aayog (2018). India is blessed with a large number of major, medium and small size rivers whose total catchment area is 252.8 million hectares(Basu,2015). River Ganga occupies a unique position in the cultural ethos of India. Millions of Hindus accept its water as sacred and count as river of faith, devotion and worship, it nourishes the mostly dense populated regions of the world. But in the last three decades the Ganges basin is among the most heavily populated areas in the world with an average density of 520 persons per square kilometre (Matta et al ,2014).

Pollution in water is the results of various causes, and factors which are been explained, Water pollution cause can be broadly divided into two Natural causes and Man-made causes: The biodegraded portions of plants and animals mix with water and pollute it. Many kinds of natural salts and other substances mix with rain water and finally fall in the rivers and ponds. The major portion of water pollution occurred by man-made causes. Industrial wastes, agricultural wastes, domestic wastes, excess use of fertilizer, pesticides are notable manmade pollutants. Water polluted by such types of pollutants is very harmful for both human and aquatic lives (Chakraborty 2013). Direct cause and Indirect cause are the two parts of classification which best describe the cause of water pollution in India, Direct Causes and Indirect Causes In direct category we can include those pollutants which directly enter into the water resources and pollute it. These are the main source of water pollution either surface water or ground water. When pollutants are carried from a place to the water resources, it can be called as indirect causes. Rainfall or snowmelt picks up pollutants as it moves over land or through the ground and then deposits them in water sources (Kumar et al,2017). The cause of water pollution in river Ganga can be based on different ways-

a) **Human waste-** A large numbers of the solid and liquid wastes (bathing, laundry and public defecation), sewage wastes, unburnt dead bodies are damped into Ganga river.

b) **Industrial waste-** Countless industries like chemical plants, textile mills, paper mills, fertilizer plants etc, Lies on the bank of the Ganga river from Uttarakhand to West Bengal. These industries are 20 % responsible to water pollution by solid and liquid waste in the Ganga river.

c) **Religious factors-** Kumbha Mela, regular cremations, Ganga Snans, disposing of materials like food, waste or leaves in the Ganga for spiritualistic reasons.

Being a dynamic river system, the Ganga river has far reaching impact on the people and their lives, Ganga river has significant cultural, religious, significance apart from providing resources. It also supports the uniqueness assemblage of aquatic diversity. Thus, stakeholders of Ganga river can be any individual or organisation who are directly or indirectly affecting or is affected by any decision concerning it. The Ganga river has multiple stakeholders at different spatial scales, each with its own unique relationship and role with respect to the river.

Stakeholders in the conservation of the Ganga River are classified into five categories based on their power and interest in biodiversity conservation. Key players have both high power and interest, enabling them to lead conservation efforts effectively; examples include National Mission for Clean Ganga (NMCG) and Central Pollution Control Board (CPCB). Context setters possess significant power but have low interest due to differing priorities—such as the Ministry of Power, Ministry of Shipping, and hydropower agencies. Subjects have high interest but low power; these include the Ganga River itself, aquatic life, and local community's dependent on the river for survival and livelihood. The crowd includes passive stakeholders with neither power nor interest in conservation. Finally, fence sitters are powerful but neutral actors whose interest varies depending on the situation, allowing them to shift roles among the other groups; this includes entities like tourists and Nuclear Power Corporation of India Limited (NPCIL). Understanding these categories is crucial for effective stakeholder engagement in river conservation efforts. (WII GACMAC, report, 2018).

2. Review of literature

Bhargav was pioneer to study the water quality parameter of Ganga river in 1977 at Rishikesh, Haridwar, Prayagraj(Allahabad), Kanpur and Varanasi, he approached to classify the river, proposed class of water for each beneficial use Ganga river. This study found that there is situation which can poses a serious threat to public health. He also studied that the Ganga water is suitable for agriculture and fish culture uses at most of its stretches. Tripathi et al, (1991) studied Physico-Chemical Characterization of city sewage discharge into Ganga river at Varanasi, at six sites, Assi ghat, Shiwala ghat, Harishchandra ghat, Chauki ghat, Rajendra Prasad ghat, and Rajghat was analysed for its physico- chemical properties such as temperature, pH, acidity, alkalinity, dissolved oxygen, BOD,COD, chloride, electrical conductance, nitrate and phosphate. It reveals significant variation in most of the parameters with respect to months as well as sites. The total pollution load discharged in the river Ganga through six nalas (sewage discharge points) was 25 082 kg per day in form of BOD, 54 170 kg of COD per day, 3919 kg of $CaCO3$ per day and 52 604 kg of CaCO s per day as acidity and alkalinity, respectively. Khawaja et al, (2001) discussed the influence of the wastes on the physicochemical characteristics of the Ganga water and sediments at Kanpur, there results reveal that most parameters increase such as BOD, COD, Cl^-, and total solids could be due to the domestic wastes as much as to the tannery wastes. Phenols and sulfides come from other sources, but their probability of coming from tanneries is higher. However, chromium is one parameter which can primarily tannery industry is higher. Khanna et al, (2007) studied Fish scales as bio-indicator of water quality of River Ganga. They observed during his course of study that in monsoon season because of higher velocity of river during flash floods, excess runoffs, soil erosion, landslide, and leaching effect there is an increase in some important physico-chemical properties such as the turbidity, total solids, decrease in the Dissolved Oxygen and increase in the BOD, COD, Hardness of water Some metals like Iron, Magnesium and Calcium also gets increased in the river water. Joshi et al, (2009) attempted to analyse the water quality of river Ganga in Haridwar district for irrigation purpose. Water samples were collected from 5 sampling stations in three different seasons. They studied that MC (Magnesium content), SAR ,RSC (Residual sodium carbonate) and PI (Permeability index) were found in the permissible range for Ganga river water in Haridwar. But Ec (Electrical conductivity), TDS (Total dissolved salt) are higher in rainy season. Hence Ganga river water in Haridwar is suitable for irrigation purpose except in rainy season. Kumar et al, (2010) studied Physical, Chemical and Bacteriological Study of Water from Rivers of Uttarakhand. In their study all samples were positive for E. coli, which indicates faecal pollution of water. The result showed that Brahma Kund in Haridwar, a famous tourist places, is most polluted. Temperatures ranged from 7.8 - 280C, pH from 7.02 - 8.16, turbidity from 1-15 NTU, DO from 6.3 – 10 mg/l and BOD from 1.4 - 4.5 mg/l. The rivers at Gangotri and Yamunotri showed nil BOD. COD ranged from 2.9 - 34.2 mg/L, total alkalinity from 32-118 mg/l and total hardness from 42 - 194 mg/L. Arora et al, (2013) analysis water quality parameters of Ganga river during Maha Khumba mela, their study summaries the water quality of River Ganga during mass bathing in Haridwar during Maha Kumbha of 2010 in terms of microbiological and molecular analysis (assessed for faecal indicator bacteria Escherichia coli along with Standard Plate Count (SPC) to determine total bacterial load in the river). They concluded that water is fit for bathing but not for drinking, On the basis of physio-chemical and microbiological analysis that the quality of river water deteriorated with the number of people taking dip. Mass bathing during Maha Kumbha mela – 2010, altered the physico-chemical and microbial nature of river Ganga. Mutiyar and Mittal (2013) reports the occurrences of organochlorine pesticides (OCPs) in the Ganga river basin covering 3 states, i.e., Uttarakhand, Uttar Pradesh and Bihar. Their results also revealed that different types of OCPs were dominating in different stretches in accordance with the land use practices and agricultural runoff generated from those stretches. HCHs were most frequently detected in mountainous stretch, Endosulfan were prominent in UP (detection rate=75%) stretch while Aldrin group in Bihar stretch. Naseema et al, (2013) Studied Seasonal Variation in the water quality among different ghats of Ganga river in Kanpur. They collected samples to analysis different Physico-chemical parameters viz.; temperature, pH, Total Alkalinity (TA), Dissolved Oxygen (DO), (BOD), Total Dissolved Solids (TDS), Chlorides, Electric Conductivity (EC), Nitrate, Phosphate, Magnesium and with respect to Chromium metal contamination. Sinha et al, (2015) studied Review on the contamination of Ganga, there aim was to review persistent organic pollutants (POPs) and other chemicals in the multi compartment Ganga River. He studied persistent organic pollutants (POPs) in Ganga river water along with sediments and organisms. He concluded that the Ganga River is highly contaminated by (DDTs),(HCHs) and heavy metals etc. Pandey and Singh (2015) studied, Heavy metals in sediments of Ganga River: up- and downstream urban influences in Varanasi, they found that metal concentrations increased consistently in downstream. Seasonally, metal concentrations in general were highest in summer followed by winter and rainy season. As the river flow declines in summer, the rate of sedimentation and consequently the concentration enhances. In rainy season, on the other hand, increased river flow causes a dilution effect, and consequently, metal concentration in sediment declines. Agarwal (2015) studied that having an extraordinary religious importance for Hindus, the river Ganga is affected from increasing level of pollution from urban and industrial areas. The level of natural contaminants such as fluoride and arsenic, and chemical pollutants specially pesticides and insecticides and industrial pollutants is high and rising at several places in Ganga River. He concluded that problem has arisen largely due to the discharge of untreated urban wastes and industrial effluents, crimination of dead bodies on the river bank etc., from the cascade of large and medium cities located along the course of Ganga and its tributaries. The use of poor water quality of Ganga River causes dysentery, cholera, hepatitis, as well as severe diarrhoea which continue to be one of the leading causes of death of children in India. Srivastava et al, (2016) studied, Physico-Chemical and Biological Parameters Investigation of River Ganga: from Source to Plain of Allahabad in India. Temperature in one of the most important physical factors which regulated natural process within the ecosystem. They found surface water temperature varies during different seasons in monsoon and post monsoon, pH of river Ganga varied from 7.1 to 9.6. It was observed that the pH of water was found to be higher mostly during monsoon period. The dissolved oxygen (DO) varied from 4.1 to 6.5 mg in monsoon and 5.4 to 8.2 mg in post monsoon season. The BOD values varied from 2.2 to 13.5 in pre-monsoon and 4.5 to 150 post-monsoon seasons. The concentration of sulphate ranged from 25 to 32 mg/l in pre-monsoon and 25 to 38 mg/l in post-monsoon season. They concluded that the pollution levels of the river and the river body was more polluted at Kanpur due to large quantity of sewage discharge and industrial discharge from leather and plating industries. Basu et al, (2016) studied Geographical and Microbiological Assessment of Ganga Water in and Around Dakhshineswar Area, West Bengal. He found that a large proportion of the sewage water with higher organic load in the Ganga is due to human waste, industrial waste and religious waste constantly being dumped in the river Ganga. They done geographical analysis by questionnaire schedule for the study of people's perceptions, array and statistical analysis of the information. LeBreton et al, (2017) says that, the top 20 polluting rivers, mostly located in Asia, account for 67% of the global total. There findings provide baseline data for ocean plastic mass balance exercises, and assist in prioritizing future plastic debris monitoring and mitigation strategies. Dwivedi (2017) concluded that the level of water pollution has reached to the alarming stage, we are unaware of the fact that we are consuming considerable amount of DDT, BHC, Aldrin and many other pesticides in addition to a variety of heavy metals along with our diet. The entry of these xenobiotic should be avoided.

3. Objectives of the Study

Objective 1: To explore the knowledge and attitude of the stakeholders of Ganga river towards the mitigation measures with the aim to enhance the water quality of the Ganga river.

Objective 2: To compare country specific water quality parameters.

Objective 3: To review water quality parameters used during the past half century, for the Ganga river.

Limitation of study –

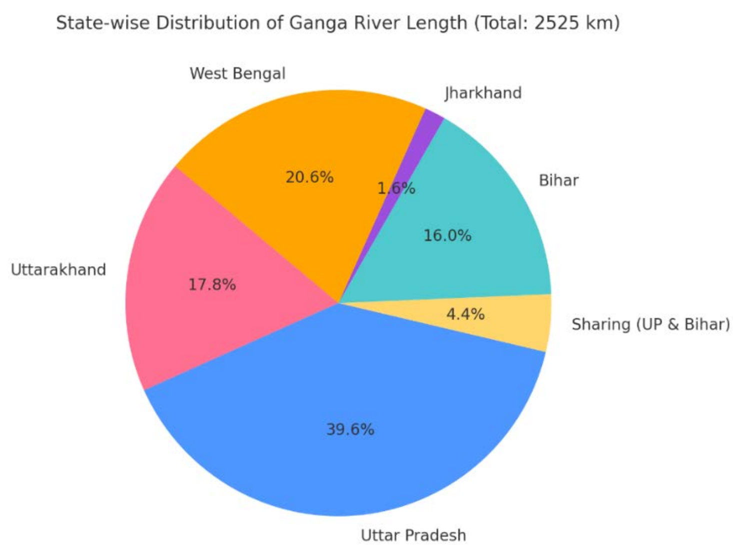
The present study does not encompass the full spectrum of stakeholders involved in the conservation of the Ganga River. The focus was primarily on key stakeholders located along the upper and lower stretches of the river, which may not fully represent the interests and perspectives of stakeholders in the middle stretch or across the entire basin. Additionally, the data collection was conducted over a limited period, from December 2018 to April 2019, which may not capture long-term trends or seasonal variations in stakeholder involvement and river conditions.

4. GANGA RIVER BASIN

The total length of river Ganga (measured along the Bhagirathi and the Hooghly) up to its outfall into Bay of Bengal is 2,525 km with 631 km navigable length, making it the 39th longest in the world, 20th longest river in Asia (Tandon et al,2008). Ganga river flows through states of Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal before merging into Bay of Bengal (Pradip Kumar et al,2015). The river Ganga is formed by the confluence of the rivers Alaknanda and Bhagirathi at Devprayag. Alaknanda originates30º44’29’’ N, 79º29’41’’E at a source near the Garhwal-Tibet border at an elevation of 7800 m. (Khawaja et al,2001). The main river stream originates in the Garhwal Himalaya (300 55’ N, 7907’ E) under the name of the Bhagirathi. The ice-cave of Gaumukh at the snout of the Gangotri glacier, 4100 meters above sea level, is recognized as the traditional source of Ganga river (CPCB 2011). The Ganga river basin is the largest of the basins of India with an area of 8,61,452 Sq.km in India, draining into the 11 states of the country, Uttarakhand, Uttar Pradesh, Haryana, Himachal Pradesh, Delhi, Bihar, Jharkhand, Rajasthan, Madhya Pradesh, Chhattisgarh and West Bengal, which is nearly 26.2% of the total geographical area of the country (Ganga Basin Report,2014).

The principal tributaries joining the river from right are the Yamuna and the Sone. The Rāmgangā, the Ghaghara, the Gandak, the Kosi and the Mahanadi join the river from left. The Chambal and the Betwa are the two important sub- tributaries join the river from left (Ganga Basin report, 2014). A headwater tributary of Alaknanda is the first to join at Mana Village, and flows about 5km to reach Badrinath. About 35km downstream of Badrinath, Dhauliganga joins Alaknanda. The river traverses about 150km to join Bhagirathi at Devprayag. The River descends to the lower Himalayas, the Shivalik’s, and reaches the town of

Rishikesh. Ganga then reaches Haridwar where the Bhimgoda barrage across the river diverts about 80% of the water. This lends the Ganga flowing in a braided manner, with dwindling discharge. The river heads down South, flowing past the city of Bijnore, and reaches Narora. Ganga heads South-East there on, with the Ramganga joining at Kusumkher and the Kali River joining at Kannauj (MOEF, 2009). Yamuna originates from the Yamunotri glacier in the Higher Himalaya and flows through the Ganga plain before merging with the Ganga at Allahabad. The River turns East and heads towards Varanasi, before reaching which; the River Tons joins Ganga at Sirsa. The River flows for about 1000km in the State of Uttar Pradesh (UP) and flows for 110 km forming the natural state borders between UP and Bihar. Nepal is the originate headwaters of the Ghaghra, the Gandak and the Kosi river. The Ghaghra merges with the Ganga upstream of Doriganj, the Gandak merges at downstream of Patna, and the Kosi at the upstream of Rajmahal (Singh et al, 2008). The Ganga travels 405km in Bihar, after which it enters the state of West Bengal. In west Bengal below 40 km in farrakka it divides into two arms, left arm flows into Bangladesh, right arm keeps flowing in West Bengal (Paul, 2017). The Ganga at this point splits, forming the Hooghly River and the Ganga-Brahmaputra complex. The Hooghly characteristically forms a delta while it terminates in the Bay of Bengal, and the region is home to one of the largest halophytic mangrove forests in the world - the Sundarbans. Gangasagar is one of the largest islands in the Sundarbans and marks the mouth of Ganga (NEERI, 2017). The entire Ganga Plain is divisible into three main units: (i) Upper Ganga Plain, (ii) Middle Ganga Plain, and (iii) Lower Ganga Plain. The Upper Ganga plain is the part of the Great Plains lying approximately between the Yamuna in the west covering the parts of Uttarakhand and Uttar Pradesh. The Middle Ganga Plain is the largest among the three plains of the Ganga. It covers the Bihar plains and the Eastern Uttar Pradesh lying on the entire side of the Ganga and the Ghaghara within the Himalayan and the peninsular ramparts on the north and the south respectively. The Lower Ganga Plain includes the Kisangani district of Bihar, whole of West Bengal excluding the Purulia district and the mountainous parts of Darjeeling district (Ganga Basin Report, 2014).



4.1 Biological Diversity of the Ganga River Basin

Ganga river is home to over 140 aquatic species, the river provides sustenance for over 500 million people living in its basin (WWF,2012). Ganga Basin is one the freshwater ecoregions of the world, with 214-322 freshwater fish species including 28-40 endemic fish species having percentage endemism- >10-15% (Abell et al, 2008). It supports about 375 fish species, of which 34 including Indian Major Carps, 11 species of amphibians, 27 of reptiles, amphibians are the least known group among vertebrates of the Ganga (Sinha,2015). Due to three ecological diverse biogeographical zone, the river is harbours important to faunal species such as Gangetic dolphin, gharial, otters, turtles and several water birds. Himalayan biogeographic zone is the upper stretch of Ganga which contain five type of forest Alpine forest (Junipers sp., Rhododendron campanulatum), Sub alpine forest (Betula utilis, Abies spectabilis, Abies pindrow), Himalayan dry temperate (Pinus gerardiana, Cedrus deodara), Himalayan moist temperate (Quercus floribunda, Quercus leucotricophora) and Sub-tropical pine forest (Pinus roxburghii). The Snow leopard (Panthera uncia), Himalayan Tahr (Hemitragus jemlahilcus), Musk deer(Moschus), Himalayan black bear (Ursus thibetanus langier), Himalayan monal (Lophophorus impajanus) are some terrestrial species and Golden mahaseer (Tot putitora), Snow trout (Schizothorax richardsonii), Smooth coated otter (Lutrogale perpicillata) are some aquatic faunal species of this stretch (WII-GACMC,2018). The middle stretch and most of the lower stretch of the Ganga river wind through the Gangetic plain, which is one of the largest biogeographic zones in India. This zone is dived into Upper Gangetic plain and lower Gangetic plain; this is the one of the most fertile area in the world. This region is harbour two major forest type, Tropical Dry deciduous forest (Dalbergia sisoo, Acacia nilotica, Madhuca indica) and Tropical Moist deciduous forest (Shorea robusta, Tectona grandis, Terminalaiese). Chital (Axis axis), and Sambar (Rusa unicolor) are the terrestrial representative of this stretch. Some example of the bird representative are Sarus crane (Antigone Antigone) and Indian skimmer (Rynchos albicollis) (Gopal &Chauhan,2006). Before merging into Bay of Bengal, the Ganga river flows mostly through Sundarbans delta, the vegetation of these area is swamp and littoral type. It is represented by species like fomes), sundari (Herititera fomes), mangrove plam Nypa fruticans) and tall-stilt mangroves. The Royal Bengal Tiger, leopard cat, barking deer, lesser adjutant stork, fishing cat are major fauna representative of these stretch, along with aquatic faunal species which includes northern river terrapin (Batagur baska), estuarine crocodile (Crocodylus porosus), Indian flapshell turtle (Lissemys punctate) and Indian soft shell (Trio Nyx gangaticus) (WII-GACMC,2018). The religious significance of the Ganges is physically manifested in Ghats (stepped landings) that form the land-water interface. Besides serving as a site for religious bathing and cremation (Das et al,2012). During festival seasons a lot of peoples come to Ganga Snans to cleanse themselves. After death of the people dump their asthia in Ganga river it is a tradition of India. Khumbha Mela is a very big festival of the world and billion peoples come to Ganga Snans at Allahabad, Haridwar in India. They through some materials like food, waste or leaves in the Ganga for spiritualistic reasons. (Rai,2013). Three towns holy to Hinduism – Haridwar, Allahabad, and Varanasi – attract thousands of pilgrims to its waters. Thousands of Hindu pilgrims arrive at these three towns to take a dip in the Ganges, which is believed to cleanse oneself of sins and help attain salvation. The rapids of the Ganges in Rishikesh also are popular for river rafting, attracting hundreds of adventure seekers in the summer months. During festival of Chatth, Ganga Ghats at Bihar attracts thousands of devotes and tourists (NGRBA,2011). The Ghats are also tied to people's livelihoods and are an inseparable part of their daily lives, pandit, pujaris, hawkers, stalls, shops all these are totally dependent on the Ghats of Ganga river. Today, the increasingly urbanized Ganga basin sustains more than

40 percent of India's population. Farmers or fisherman's largely dependent on the river Ganga to earn their livelihood, (Das et al,2012).

4.2 Intensive Study Area

The present study has been conducted on two stretches of the Ganga River, the upper stretch in Haridwar, Rishikesh and lower stretch in Kolkata, Hooghly, Howrah districts in West Bengal.

The State of Uttarakhand has three districts which fall in the main-stem of Ganga: Haridwar, Tehri Garhwal and Uttarkashi. These districts have a total population of 2,346,947. Of that total number, only 383,779 reside in some of Uttarakhand 's major towns which reside in the Ganga Basin. The largest of these towns are Haridwar, Tehri, Uttarkashi and Dhaluwala. There are some of the Class I cities are Haridwar, Roorkee, and Class II like Rishikesh which comes under Uttarakhand. (NGRBA,2011). The holy city of Haridwar is located in the north Indian state of Uttarakhand at the foothills of Shivalik. Haridwar extends from latitude 29°58′ in the north to longitude 78°13′ in the east (Matta et al, 2018). The city is situated at a height of almost 300 m above sea level and the temperature usually however around 40°C during summers and low as 6°C in winters (Joshi et al, 2010), with population of 2.29 lakhs (GOI, 2011). Haridwar is an important location both in terms of the change in flow of the River and anthropogenic activities. Haridwar is the location which has the most significant anthropogenic activity in Uttarakhand (Bhadula,2012).

With the progressing growth in the population, industrialization and the quality of Ganga water at this stretch is facing a risk of deterioration. The wastewater with various characteristics from industries, domestic places and recreational sources find their ultimate way to the river, Other than that human and animal carcasses, flowers, papers, clothes and plastic bags etc., are dumped in Ganga river. The bathing festivals like Makar shankranti, Guru Purnima, Ganga Dussehra, Vaisakhi and the Kumbha mela are the high times when lakhs of pilgrims take bath daily. All these have catalysed the chemical as well as the biological problems (Khanna et al,2007). The Bhimgoda barrage at Haridwar diverts about 10000 cusecs of water into the Upper Ganga canal, and greatly reduces the flow in the River. Bhimgoda Barrage is situated at Har Ki Pauri, Haridwar on the river Ganga. Irrigation is the primary purpose for the barrage, but it also serves to provide water for hydroelectric power production and control floods. The area behind the barrage is a popular destination for various water birds and tourists is known as the Neel Dhār Bird Sanctuary **(**Matta,2014). Rishikesh is a small serene town famous for meditation and yoga. The sacred River Ganga leaves the Shivalik Hills in the Himalayas and flows out into the plains of northern India. It is gateway to the Himalayas and being on the bank of River Ganga it is an ideal destination for adventure, it has elevation 372m population is 102138 (GOI, 2011). The average temperature of this area lies within the range around 5C- 39C with average rainfall is 9495 mm (Matta et al,2018).

The seven districts of West Bengal which is part of the Ganga basin are 24 Pargana South, 24 Pargana North, Hooghly, Howrah, Kolkata, Maldah, Medinipur. Bengal has 160 towns and cities, out of which 27 are class I and 27 are class II cities. Some of the Class I cities are, Kolkata, Haora, South Dumdum and some of class II cities are, Ranaghat, Bolpur, etc**.** The Bhagirathi flowing in West Bengal known as Hooghly, after reaching Diamond Harbour it spilt into two stream before reaching into Bay of Bengal(Paul,2017). At Kolkata in West Bengal, the Hooghly (Ganga) river basin is highly polluted as the waste from numerous industries as well as municipal sewage is dumped in the river. The Farakka Barrage, which was built originally to divert fresh water into the Hooghly River, has since caused an increase of salinity in the Ganga (Basu,2014). Kolkata is megalopolis capital of West Bengal lies at 22°82′N 88°20′E the downstream end of the Ganga basin with population of 45 lakhs (GOI, 2011). The city is at sea level, the average elevation being 17 feet. It was earlier also a major seaport and has many industries in and around it. The city has a significant impact on River Ganga, in all aspects such as discharge flow, industrial and domestic sewage (NMCG ,2017). The area receives an annual average rainfall of 1633.6 mm, 75% of which is contributed by southwest monsoon between June and September, average temperature lies between 9°C to 30°C (Ghose, 2009). Anthropogenic activities like mining, ultimate disposal of treated and untreated waste effluents containing toxic metals as well as metal chelates from different industries, e.g., tannery, steel plants, battery industries, thermal power plants etc., and the indiscriminate use of heavy metal-containing fertilizers and pesticides in agriculture resulted in deterioration of water quality in Hooghly river (Ammann et al, 2002).

Fig. Showing districts surveyed for studying attitude and knowledge of stakeholders

3.3 Pollution Load on the Ganga River Basin

4.3 (a) Domestic waste or solid waste

These are those that are produced by household's usage, Exposure factors such as washing clothes, bathing and lack of sewerage, toilets at residence, children defecating outdoors, poor sanitation generates solid and liquid wastes in Ganga river. Today, many people dump their garbage into rivers, thus making water bodies the final resting place of cans, bottles, plastics, and other household products (Groundwater Quality 2003). Most of today's cleaning products are synthetic detergents and most detergents and washing powders contain phosphates, which are used to soften the water among other things. These and other chemicals contained in washing powders affect the health of all forms of life in the water. A large number of dhobi Ghats are situated around the river Ganga, washer man washes their customer clothes with washing powder, bleaching powder, water etc. These chemicals, soap flow off into Ganga, this also increases the pollution of Ganga (Singh 2017).

4.3 (b) Plastic waste

The top 20 polluting rivers were mostly located in Asia accounting for 86% of the global annual input of plastic debris and representing 21% of the global population, From the Asian continent, with an estimated annual input of 1.21 (range 1.00–2.06) million tonnes per year. Chinese Yangtze River is the largest contributing catchment, with an annual input of 0.33 (range 0.31–0.48) million tonnes of plastic discharged into the East China Sea, followed by the Ganges River catchment, between India and Bangladesh, with a computed input of 0.12 (range 0.10–0.17) million tonnes per year (LeBreton et al,2017). Microplastic are called primary when they were intendedly produced at the microscale. They are used in consumer products such as personal care products or in industrial scrubbers and are mostly spherical in shape (beads). Secondary microplastics are produced by the weathering of larger plastic items, such as plastic films, fishing nets or household items and most often occur in irregular shapes, 28% microplastic concentrations were found in freshwaters from Asian countries (GESAMP 2015).

4.3 (c) Industrial waste

The major water polluting industries include chemicals, textiles, pharmaceuticals, cement, electrical and electronic equipment, glass and ceramics, pulp and paper board, leather tanning, food processing, and petroleum refining. Reportedly, which have toxic and non-biodegradable substances such as chromium, arsenic, chemical dyes etc. the discharge of sewage into the Ganga is responsible for 75% of its pollution with nearly 3000 mld (million litres per day) of sewage generated in the towns along the Ganga. This quantity is too large for self-purification by the Ganga. Nearly 50% of waste waters are discharged untreated (Hasan,2015). All the wastage materials of industries are solid and liquid waste materials, solid wastes are sometime metallic and polymers which never decompose and create pollution apart from this liquid waste is chemically treated causes imbalance to ecosystem. Radioactivity generated from nuclear power plants industries can pollute waters in a variety of ways, including discharge of mildly radioactive waste water or effluents from uranium mining (Mc Kinney and Schoch 2003).

4.3 (d) Agriculture waste

These are generated by the cultivation of crops and animals. Globally, agriculture is the leading source of sediment pollution which includes ploughing and other activities that remove plant cover and disturb the soil. Agriculture is also a major contributor of organic chemicals, especially pesticides. Some pesticides are applied directly on soil to kill pests in the soil or on the ground. This practice can create seepage of pesticides to groundwater or runoff to surface water. (Mc Kinney and Schoch 2003). Lots of agricultural activities are occurring in our country due to more demand and less production, peoples use dangerous chemicals and fertilizers which contaminates soil kill all its microbes and also pollute the water. These are also the major source to produce dangerous elements as a waste causing harm to ecosystem. Pesticides -like atrazine, Benomyl, Linuron etc. causes pollution on water. DDT which is common use fertilizer is biggest threat to Ganga river (Singh,2017). For agricultural and public health purposes, about 9,000 tons of pesticides are applied annually in the Ganga River basin. The pesticide use pattern in India is always dominated, followed by herbicides and fungicides (insecticide 52%, herbicide 33% and fungicide 15%). Among the insecticides, use organochlorines was 16%, organophosphates 50%, synthetic pyrethroids 19%, carbamates 4%, bioinsecticides 1% and others 10% (Ghose et al., 2009). HCH 0.1–17.6; DDT 0–12.3; endosulfan 0–85.4 and heptachlor 0–11.8 ng l−1 are found in the Ganga river stretch from its origin to the border of West Bengal. Agricultural use of endosulfan contributed to a great extent in the Uttar Pradesh stretch of the river. The Bhagalpur stretch was observed to be contaminated more with aldrin and related compounds (Mutiyar and Mittal, 2012).

4.3 (e) Tourists and Religious activities

Mass bathing in Ganga river during festivals is another environmentally harmful practice. The B.O.D goes up drastically when thousands of people come to Ganga snan. Dead bodies are cremated on the river banks, partially burnt bodies are also flung into the river. After religious worship of God people through some materials like flowers, ash and old figurine in the Ganges for spiritualistic reasons (Singh,2017). Kumbha Mela is a very big festival of the world and billion peoples come to Ganga Snan at Allahabad, Hardwar in India. They through some materials like food, waste or leaves in the Ganges for spiritualistic reasons. The pollution level in the sacred river has risen since Kumbha started at the historical city of Allahabad, the water is no fit for bathing purposes, latest evaluation by country's pollution board. The level of the BOD levels - used to measure of the level of organic pollution in the water - had increased to 7.4 milligram per litre at the main bathing place, known as Sangam, since the Kumbha started (Rai, 2013). Apart from holy dip, washing with detergents, pilgrims offer milk, curd, ghee, flowers, coins, idols, ashes of departed ones, body hairs and other religious materials into the water. Many a times such offerings are brought in polythene carry bags and in the absences of a proper disposable system, these polythene bags and other non-biodegradable materials are dumped at the site of river banks which remain either floating on the water surface or cover the river bed substratum, creating a noxious environment to aquatic life (Semwal and Akolkar, 2006).

5. Methodology

To assess the role of stakeholders in the conservation of the Ganga River, a combination of open-ended and close-ended questionnaires was employed. This mixed-method approach enabled a comprehensive understanding of stakeholders' perceptions, attitudes, and levels of engagement. Open-ended questions provided respondents the opportunity to express their views freely, allowing for an in-depth exploration of individual experiences and opinions. This flexibility was essential for capturing the broader socio-environmental context, as it avoided limiting responses to predefined options. The questionnaires facilitated both qualitative insights and quantitative analysis, enabling triangulation of data for more reliable findings. The interviews were semi-structured, allowing them to adapt based on the initial responses of participants. This format encouraged a conversational flow while ensuring that key themes were consistently addressed across interviews. Participants included a diverse range of stakeholders such as government officials, local community members, religious leaders, and representatives from various departments involved in river management. Only individuals who were willing to participate were interviewed, ensuring ethical research standards. As emphasized by Pretty (1995), effective communication and open exchange of information are central to the success of such surveys. Accordingly, efforts were made to create a participatory environment that fostered trust and encouraged honest responses.

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6. Results and Discussion

The stakeholder interviews revealed that 90.4% of respondents were male, while only 9.52% were female. In terms of geographic distribution, 60.7% of the participants were from Uttarakhand and 39.2% from West Bengal. Stakeholder roles in the conservation of the Ganga River varied considerably, reflecting the diverse priorities and objectives of each group. The Ganga River system involves a wide range of stakeholders operating at different spatial scales, each maintaining a unique relationship with and responsibility toward the river (WII GACMAC Report, 2018). The Fisheries Department contributes to conservation through the release of Indian Major Carp (NMCG report, 2021), while the Agriculture Department promotes organic farming as an eco-friendly agricultural practice. Sewage and solid waste management responsibilities are shared among the Tourism Department, Pollution Control Board, Municipal Corporation, and Jal Nigam. Among all, local communities were identified as playing the most significant role in biodiversity conservation, followed by religious groups and the tourism sector, according to respondents. Various government departments—particularly the Tourism, Irrigation, Rural Development, Agriculture, and Fisheries departments—are adversely impacted by the increasing pollution load in the Ganga. Approximately 17.7% of respondents reported being affected primarily due to loss in production, followed by waste dumping and tourist-related activities. Water quality monitoring focuses on key parameters such as pH, total suspended solids, acidity, and turbidity. In the lower stretch of the Ganga in West Bengal, fishermen regularly monitor water quality—mainly pH and temperature—on a daily basis. The Fisheries Department provides training to local fishers and conducts periodic water quality assessments as needed. The study observed that water quality parameters are not uniform across locations, indicating spatial variation in pollution levels. Waste management practices were found to be limited, with composting and vermicomposting being utilized solely by the Rural Development Department for solid waste treatment. Water usage in the study areas was predominantly for domestic and agricultural purposes. Water allocation is time- and area-specific, and often influenced by cropping patterns. Notably, in West Bengal, stakeholder discussions precede water distribution decisions, ensuring alignment with user priorities. Finally, while organic farming emerged as a promising strategy for reducing chemical input agriculture, it suffers from challenges such as lack of market access and low production levels, limiting its widespread adoption despite its ecological benefits.

A comprehensive literature review using Google Scholar compared aquatic water quality standards across different countries. British Columbia features the most extensive physical criteria—monitoring temperature, turbidity, total suspended solids (TSS), pH, and dissolved oxygen (DO)—while the U.S. EPA includes only alkalinity in its physical measures. Ireland tracks just pH and DO; India includes temperature, color, pH, DO, and total dissolved solids (TDS); and Japan covers TSS, nitrogen, phosphorus, pH, and DO. In terms of inorganic minerals, British Columbia again leads with chlorine, cyanide, sulfate, nitrite, fluoride, benzene, and phenols; India follows with chloride, cyanide, sulfate, nitrite, fluoride, and ammonia; Ireland includes sulfate, nitrite, nitrate, phosphate, ammonia, biochemical oxygen demand (BOD), and chlorine; the U.S. EPA lists chlorine, cyanide, chloride, and phenols; and Japan focuses on BOD, nitrogen, and phenols. For pesticides, the U.S. EPA offers the most comprehensive list—including PCBs, aldrin, endosulfan, chlordane, dieldrin, endrin, lindane, heptachlor, methoxychlor, parathion, heptachlor epoxide, acrolein, carbaryl, and toxaphene—while British Columbia regulates PCBs and sulfolane, and India, Japan, and Ireland do not specify aquatic pesticide criteria. Regarding metals, British Columbia again covers the widest range—arsenic, boron, cadmium, copper, cobalt, chromium, manganese, iron, lead, aluminum, mercury, molybdenum, naphthalene, selenium, silver, and zinc. The U.S. EPA includes arsenic, cadmium, chromium, lead, mercury, silver, nickel, and zinc; India lists copper, chromium, iron, and lead; Japan includes arsenic and zinc; and Ireland covers copper and zinc. Overall, British Columbia consistently applies the most exhaustive standards, the U.S. EPA leads in pesticide regulation despite limited physical parameters, and India, Japan, and Ireland maintain more targeted, specific criteria.

7. Conclusion

The ecological health of the Ganga River is significantly influenced by the actions—both individual and collective—of its diverse stakeholders. The three fundamental pillars of sustainable development—economic viability, environmental protection, and social equity—must be harmoniously balanced to ensure long-term conservation of the river. While society plays a role as vital as the economy and environment, the findings reveal that most stakeholders possess high power but low interest in Ganga conservation. Therefore, it is imperative to align stakeholder interests with conservation goals, integrating these with their departmental mandates. To foster a sustainable conservation pathway, emphasis must be placed on increasing stakeholder awareness, promoting water-saving technologies, and encouraging departmental engagement in the cleaning and preservation of the river. Additionally, stricter regulations and robust monitoring mechanisms are essential to control the indiscriminate dumping of solid waste and untreated sewage into the Ganga. Although departments widely acknowledge the contributions of local communities, religious groups, and the tourism sector, effective conservation of the Ganga River cannot be accomplished by any single group in isolation. Collaborative action—involving the exchange of information, sharing of resources, and coordinated efforts among all stakeholders—is crucial for meaningful and sustained conservation outcomes. Only through integrated and inclusive stakeholder engagement can the ecological sanctity of the Ganga River be restored and preserved for future generations.

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