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# Navigating India's Water Crisis: A Comprehensive Analysis of Depleting Water Quality & Resources, Contaminants and Urgent Conservation Measures

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**ABSTRACT**

Nowadays, in urban regions, increasing water pollutants are affecting water quality. Urban conglomerations are being identified, to understand the challenges faced, in examining water quality. This research aims to analyze the fundamental issue related to assessing water quality in the urban Indian context. The causes of water scarcity and the impact of pollutants on urban water are also studied. Water quality assessment and Physicochemical parameters show serious finding regarding water quality and contamination through tables and figures. The author tried to discuss the severity of the situation in India and the endangerment it brings if the issues and prospects are not taken into consideration. The paper discusses the readiness of the urban population for future challenges associated with water contamination and risk reduction.

**Keywords:** water pollutants, WQA, water scarcity, physicochemical parameters, risk reduction, water quality

## 1. INTRODUCTION

Water is the one entity upon which the survival of all species depends for sustenance and preservation. The amount of water available on earth is a fixed quantity; it can't be added to or reduced in any way. With a growing population, urbanization, and industrialization, the demand for water for different employments is expanding persistently, thereby decreasing per capita water accessibility. By 2025, the human population will reach 8 billion, which means rehabilitating and managing saline soils to fulfil the growing need for meals is necessary to prevent food shortages (ADRI, 2017 ) (Alcamo, Florke, & Marker, 2007). Thatswhy in future, current situation of water shortage will lead to severe hunger and poverty. On a global basis, groundwater accounts for approximately 30% of all resources used for human use (Arunbose, Srinivas, Rajkumar, Nair, & Kaliraj, 2021). The country's economic and social well-being of the developing world's city dwellers is dependent on groundwater (Wakode, Baier, Jha, & Azzam, 2018). When talk about accessibility of water supply, groundwater is the biggest storage of water, constituting 94% of all the fresh water supplies excluding glaciers and ice caps. India has 4% of the world's water resources despite having 18% of the world's population (Srivastava, Chaskar, & Mitra, 2017). Groundwater and surface water are interconnected and interdependent in all ecosystems, where the demand for safe drinking water and its requirement to maintain and sustain the health of the ecosystem are increasing (Glasser, Warinner, Gurrieri, & Keely, 2007). Many countries are facing increasing demands for fresh water and at the same time supplies are becoming increasingly contaminated (Simonovic, 2002). Globally, UNICEF and WHO (2017) estimated that 844 million people are lacking safe drinking water (Machiwal, Jha, Singh, & Mohan, 2018). Groundwater accounts for just 29.9% of global freshwater resources, with the remaining 0.26% concentrated in river systems, lakes, and reservoirs (Li & Qian, 2018). Management of water resources will be stressed in the next few decades by variety of factors, including climate change (Arnell, 1999). Changes in climate, population, economic growth, and technological progress should also be taken into consideration (Alcamo, Florke, & Marker, 2007). A variety of socio-economic factors, as demonstrated in river basin studies, can cause significant changes in water consumption and, as a result, numerous indicators of future water availability.

India is the world's most populated country with a population of 1.417 billion people, it has only 4% of the world's fresh water reserves. Population growth, along with urbanization and industrialization, is creating pressure on the country's limited water resources. Ground Water consumption in our country has dramatically increased over the span of the last few decades, and eventually, as time went on, groundwater became the backbone of the Indian economy in terms of both food security and water security. Figure 1, explain that per capita water availability is gradually decreasing, with an average annual per capita water availability of 1816 cubic meters in 2001 and 1545 cubic meters in 2011. For the year 2021, it is further estimated to be reduced to 1486 cubic meters. Geological and other factors allow for an annual utilizable water availability of 1122 BCM, which includes 690 BCM of surface water and 432 BCM of replenishable ground water. The water potential used is approximately 699 BCM, with 450 BCM of surface water and 249 BCM of groundwater. There is a high demand scenario for the years 2025 and 2050, which has been estimated to be 843 BCM and 1180 BCM, respectively (India, Annual Report, 2021-2022).

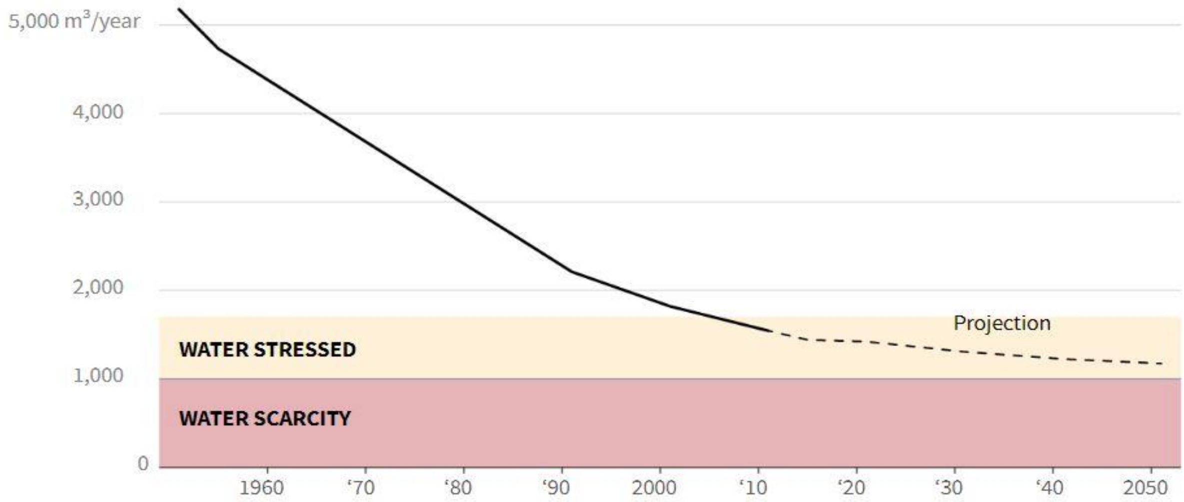



*Figure 1: India's water availability per person (m3/year), source: (Bhatia, 2019)*

1.1 Sources of Water in India: distribution of resources – land and water

Resources of water drives, industrial development, support tourism and recreation and play a role in climate regulation. However, to address the issues caused by population increase, urbanization, pollution, and climate change, sustainable management and conservation are required. Prioritizing conserving water and integrated management techniques are critical for ensuring the future availability and sustainability of water resources. Owing to its fresh water resources, India ranks among the top ten water-rich countries (Das, 2009). Despite having deposits of freshwater resources as compared to other countries, with the existing utilizable freshwater criteria, India is still classified as a 'water challenged region'.

Approximately 53% of Indian families are dependent on groundwater resources, whereas approximately 2% are dependent on surface water resources. Many purposes have relied on groundwater as their primary source of drinking water, including household, industrial, agricultural, recreational, and environmental activities (Selvakumar, Chandrasekar, & Kumar, 2017). Almost 43.5% of household units have access to tap water (treated and untreated) for consumption. Groundwater dependency is significantly higher (p 0.05), with over 65% of family's dependent on it. To emphasize the urban-rural divide, over 26% of urban family units rely on groundwater for their survival. For drinking purposes, though, tap water is available to almost 70% of urban families, compared to nearly 31% in rural areas. Table 1 and Table 2 explain about the water sources and their conditions in India (India, National Compilation on Dynamic Ground Water Resources of India, 2023).

Table 1: Assessment of Ground water Resources (2004-2023)

| No. | Evaluation of Ground Water Resources | 2004 | 2009 | 2011 | 2013 | 2017 | 2020 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Ground Water Recharge on an Annual Basis (bcm) | 433 | 431 | 433 | 447 | 432 | 436 | 438 | 449 |
| 2 | Annual Ground Water Extractable Resource (bcm) | 399 | 396 | 398 | 411 | 393 | 398 | 398 | 407 |
| 3 | Ground Water Extraction on an Annual Basis for Irrigation, Domestic, and Industrial Use (bcm) | 231 | 243 | 245 | 253 | 249 | 245 | 239 | 241 |
| 4 | Ground Water Extraction Stage (%) | 58% | 61% | 62% | 62% | 63% | 62% | 60% | 59% |

Source: (India, National Compilation on Dynamic Ground Water Resources of India, 2023)

Table 2: Assessment units' categorization (2004-2023)

| No. | Categorization of Blocks/ Mandals/ Talukas | 2004 | 2009 | 2011 | 2013 | 2017 | 2020 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Total Assessed units | 5723 | 5842 | 6607 | 6584 | 6881 | 6965 | 7089 | 6553 |
| 2 | Safe | 4078 | 4277 | 4503 | 4519 | 4310 | 4427 | 4780 | 4793 |
| 3 | Semi-critical | 550 | 523 | 697 | 681 | 972 | 1057 | 885 | 698 |
| 4 | Critical | 226 | 169 | 217 | 253 | 313 | 270 | 260 | 199 |
| 5 | Over-Exploited | 839 | 802 | 1071 | 1034 | 1186 | 1114 | 1006 | 736 |
| 6 | Saline | 30 | 71 | 92 | 96 | 100 | 97 | 158 | 127 |

Source: (India, National Compilation on Dynamic Ground Water Resources of India, 2023)

Over the past few years, the worsening water quality of Indian rivers has been widely reported. The physicochemical properties of river water are affected by pollution, which impacts public health and the food web (Setia, et al., 2020) (Moghtaderi, Alamdar, Seijo, Naghibi, & Kumar, 2020) (Dulaimi & Younes, 2017). Indian rains and the melting of glaciers are estimated to generate an annual runoff volume of about 1869 BCM on average. The only amount of surface water that can be effectively mobilized is about 690 BCM, or 37% of it. Rainfall variability across the country contributes to recurring floods and droughts in diverse locations (Kulinkina, et al., 2016). Gradients in rainwater quality are extremely sensitive processes whose characteristics are influenced by topography, microclimate, and human circumstances and which vary greatly from site to site (Khare, Goel, Patel, & Behari, 2004). India's annual average precipitation is almost 1,170 mm. The monsoon season's highest rainfalls occur from June to September, necessitating the construction of massive storage tanks in order to make the best use of rainwater.

Management of water resources and providing clean water are the two greatest challenges faced by current generation. People's care and concern regarding watershed activities as well as treatment, storage, and distribution make water safe (Saini, Khitoliya, & Kumar, 2014). The assessment of 'safe drinking water' sources include bore/tube wells, hand pumps, and untreated tap water. Various chemical and microbiological species commonly contaminate consumable water, according to UN standards for safe or improving water sources. So various initiatives have been taken by the Indian government to improve the quality and availability of potable water. Jal Jeevan Mission (JJM), Atal Bhujal Yojana, National Urban Drinking Water Mission, Swachh Bharat Mission, Pradhan Mantri Krishi Sichai Yojana and National Rural Drinking Water Program (NRDWP) schemes are working at present.

## 2. METHODOLOGICAL APPROACH

### 2.1 PRISMA Approach

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement was followed in this systematic review, and a flowchart was created to report the inclusion and exclusion of studies and the characteristics of all included studies (see figure 2). PRISMA method is systematic literature review process. So, in this process, Study of review paper was based on scientific papers, journals, and articles, authentic websites, and government reports that were published between 1998 and 2024. The selection criteria were determined by the independent reviewers. From the 793 records filtered, 95 papers met the selection criteria and were chosen to study in the review.

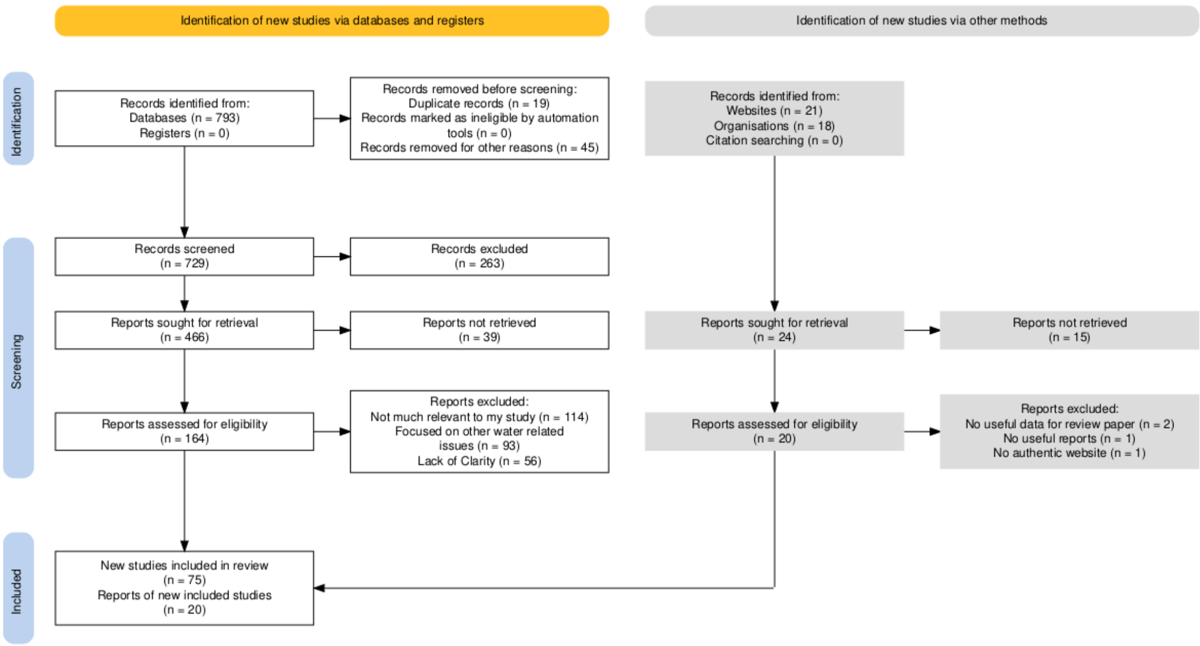



*Figure 2: Flowchart of the search process for included literature, PRISMA Tool; source: (Haddaway, Page, Pritchard, & McGuinness, 2022)*

2.2 Research strategy and selection

Preferred reporting items for systematic reviews and meta-analysis (PRISMA) guidelines state that, so this review paper was written on the basis of all published research papers, review papers, authentic websites, and government reports. Author used the keywords for searching the paper words combination for study area. These keywords include: international importance of water, urban water quality, day zero for urban water, hydrological cycle, solid waste management, water treatment process, UN/WHO guidelines, SDG goals for water in urban areas, etc. A comprehensive systematic literature search through Research Gate, Elsevier, Science Direct, and many more authentic journal websites for high-quality authentication. All literature describing exposure to water pollution and emerging water contamination outcomes in India and Indian cities All identified studies were screened for eligibility based on title and abstract, and potentially relevant studies were obtained, read in full text, and critically evaluated for inclusion by authors.

2.3 Data extraction and assessment

A prior data extraction form was used to retrieve information from all included studies to ensure a standardized procedure. The quality of the included studies was assessed by two separate authors. In the event of disagreement, a consensus was reached through discussion or, if necessary, through the consultation of a third reviewer.

### 2.4 Method

A method of designing a review paper based on the analysis of secondary databases. Data extraction from secondary sources is performed by SLR (PRISMA method). Collecting data on surface water bodies, groundwater, and treated water supplies and their sources of contamination. Using SLR method, Analyze the collected data. Study water quality parameters and contamination levels in India and cities to identify trends, patterns, and variations. Understand the pathways of contamination and environmental risk factors that contribute to the degradation of water quality by conducting a qualitative analysis. Based on the contamination levels and concentrations, assess the health risks to humans and the environment. Prepare policy recommendations based on the findings and analysis of the research. Result and discussion have done on the basis of finding data and analysis.

### 2.5 Outcome of the Approach

The approach of conducting a study on water quality assessment in India and selected urban conglomeration cities, focusing on sources, contaminations, and risk reduction following these outcomes.

- Identification of Water Quality Issues
- Understanding Contamination Pathways
- Evaluation of Risk Reduction Practices
- Policy Recommendations and Interventions

## 3. WATER CONTAMINATION IN INDIA

Water contamination is an issue that affects people all around the world. These might be either geological or artificial in nature (Fawell & Nieuwenhuijsen, 2003) (Sharma & Bhattacharya , 2016). There are two dominant categories of contamination sources: point sources and non-point sources shown in figure 3.

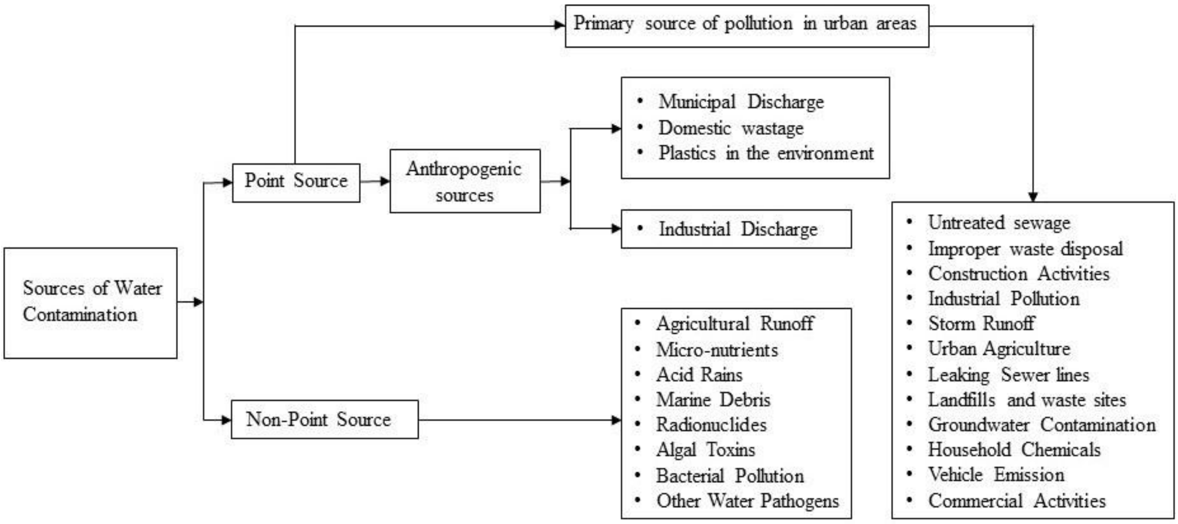



*Figure 3: Water Contamination Sources, Sources: (Schweitzer & Noblet, 2018) (Preeti, Reen, Thakur, Suman, & Kumar, 2018)*

A typical wastewater treatment plant does not entirely get rid of oestrogens and other endocrine disrupting compounds from sewage, and the effluents from these plants are extensively dispersed into water bodies (Vilela, Bassin, & Peixoto , 2018). As a result of water contamination modelling, we can improve human and environmental health and government operations by estimating pollution concentrations, speeds, and directions (Bahadur, Amstutz, & Samuels, 2013). Among the substances found in domestic waste water are substances used by humans, such as caffeine and other medicines (Seiler, Zaugg, Thomas, & Howcroft, 1999). The World Health Organization forecasts that providing basic water hygiene and sanitation will reduce diarrhoea by 35%; there are more than one billion people who depend on water sources that are hazardous to their health (Brick, et al., 2004). Flora-fauna is majorly affects by the anthropogenic activities. Surprisingly, untreated 80% of municipal waste water discharged into the river and approximately 70% of agrochemicals are also contributing contaminants into the water (Bashir, et al., 2020). The availability of fresh water, nature's gift, governs a large portion of the global economy. In order to produce food, consume energy, and perform industrial and recreational activities, adequate supplies of water are needed (Sharma & Bhattacharya, 2016).

The CPCB recognized extremely contaminated sections of 18 major rivers in 1995. It should come as no surprise that the majority of these sections were discovered in or near metropolitan areas. Examining the state of water quality, as mentioned in the report documented and presented by the CPCB in 2009, water quality monitoring was executed. WQI revealed that the water is deteriorating as oxygen-consuming compounds accumulate. Due to the widespread increase in water pollution sources, it is imperative to establish monitoring stations and continuously expand their numbers each year to effectively monitor water quality. India has 4456 monitoring stations for monitoring water pollution till 2022 (Central Pollution Control Board, 2021).

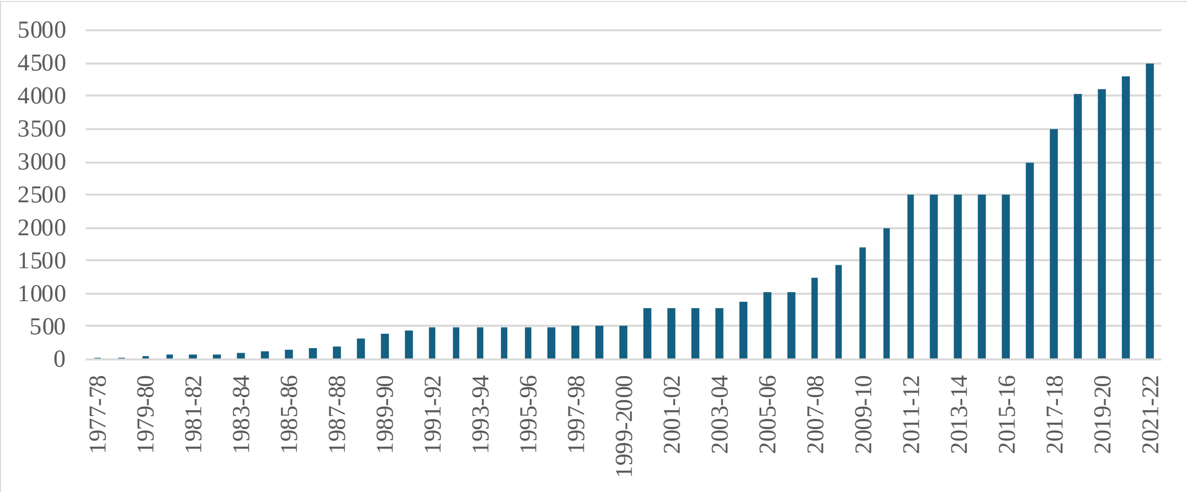



*Figure 4: Monitoring Water Pollution in India: Growth of Monitoring Networks, Source: Author, (Central Pollution Control Board, 2021)*

## 4. SYSTEM OF SEWAGE IN INDIA – A CAUSE OF CONTAMINATION: GOVERNMENT POLICIES, SEWAGE NETWORKS, SEWAGE PLANS ETC.

Production areas, landfills, dumps, waste storage and treatment sites, mine tailings sites, spill sites, chemical waste handling and storage sites are all examples of contaminated sites. Continuously disposing untreated water into the streams and dumping or spilling hazardous waste or chemicals is harming the environment, particularly the soil, surface water, and ground water (Budiman, Suharto, & Wahyunengseh, 2023). These areas are endangering human health and the environment. Contaminated sites can be found in a variety of settings, including residential, commercial, agricultural, recreational, industrial, rural, urban, and wilderness areas. Infrastructure and Efficiency play a significant role in the design of sewage system in India's urban conglomerations (Schellenberg, Subramanian, & Ganeshan, 2020). There are mainly two type of sewage systems i) separate system, ii) combined system that are often used[1] (Toffol, 2007).

### 4.1 Capacity of Sewage Treatment in India

[1] Sewage network (combined or separate) a network in which both residential sewage and stormwater runoff are collected in the same or separate pipes. Causes of sewage issues in Urban areas population growth, inadequate infrastructure, poor maintenance, lack of awareness, industrial discharge, illegal connections, non-biodegradable waste, urban agriculture, limited funding and lack of regulations etc. Groundwater Contamination and health hazards are often caused by poor maintenance, improper design, lack of regulations.

1.36 billion Indians generate 72,368 gallons of sewage per day, compared to 31,841 gallons per day of installed treatment capacity. In reality, only 26,869 MLD are operational out of 31,841 MLD. Underground pipes, pumping stations, and treatment plants are part of the centralized sewage systems in India's largest cities. Approximately 1,093 sewage treatment plants are operational in India, of which 578 enjoy compliance with the norms outlined by the SPCBs and PCCs, with a combined capacity of 12,200 MLD. Therefore, more infrastructure is needed to treat sewage. It is expensive and time-consuming to build and maintain centralized plants. Therefore, we can enhance sanitation in remote areas by considering decentralized systems (Jain, 2021). Treatment plant capacity in India during the time of 2008 showed that in Class-I cities (more than 1 lakh), only around 32% (11,553.68 MLD) of all wastewater produced is treated, while in those cities total water supply is 44,769.05 MLD and waste water generation is 35,558.12 MLD, and in Class-II towns (fifty thousand to 1 lakh), only around 8% (11,787.38 MLD) of all wastewater produced is treated, while in those cities total water supply is 3,324.83 MLD and waste water generation is 38,254.00 MLD. But recently in India, the total sewage generation capacity of all states is 72,368 MLD, the installed capacity is 31,841 MLD, and currently the total number of installed STPs is 1469, but the total operational treatment capacity is 26,860 MLD (Government of India, 2021). It is well known that there are several sources of pollution in India, including sewage, manure, and chemical fertilizers, mainly nitrates and phosphates. Deposition of atmospheric nitrogen causes nutrient-type water pollution (Clark, et al., 2013). Table 3 shows the comparative statistics and capacity of STPs in the country between 2014 and 2020 which are not sufficient to treat whole contaminated water. So, lack of STP's is the major reason to dump contaminated water in the streams also.

Table 3: STP condition in India

| No. | Status of STP | 2020 | | 2014 | |
|---|---|---|---|---|---|
| | | No. of STPs | Capacity (MLD) | No. of STP | Capacity (MLD) |
| 1 | Operational | 1093 | 26869 | 522 | 18883 |
| 2 | Actual Utilization | 1093 | 20235 | - | - |
| 3 | Compliance | 578 | 12197 | - | - |
| 4 | Non-operational | 102 | 1406 | 79 | 1237 |
| 5 | Under Construction | 274 | 3566 | 145 | 2528 |
| Total (no. 1+4+5) | | 1469 | 31841 | 746 | 22648 |
| 6 | Proposed | 162 | 4827 | 70 | 628 |

*Source:* (India, Ministry Of Environment, Forest and Climate Change, 2021-2022)

As per the CAG report (CAG, 2011-2012) on water pollution in India, millions of gallons of sewage, agricultural, and industrial waste are drained into 14 main rivers, 55 minor rivers, and countless local rivers. Industrial waste and sewage account for the most polluting sources of water pollution specially for rivers. In the current situation, just 10% of garbage gets processed, with the remainder being released into bodies of water, eventually polluting them (i.e., rivers, lakes, and ground water). Water discharged from households carries disease-causing microbes that are highly contaminated. With a project cost of Rs. 5961.75 crore approved, the National River Conservation Plan is currently repairing contaminated stretches in 34 main rivers across 77 towns in 16 states and creating a daily sewage treatment capacity of 2677 million liters. At a cost of Rs. 30458 crore, 353 projects were approved under the Namami Gange program, including 157 projects involving sewer network and sewage treatment construction.

Table 4: Post-Monsoon monitored drains discharging into river Ganga

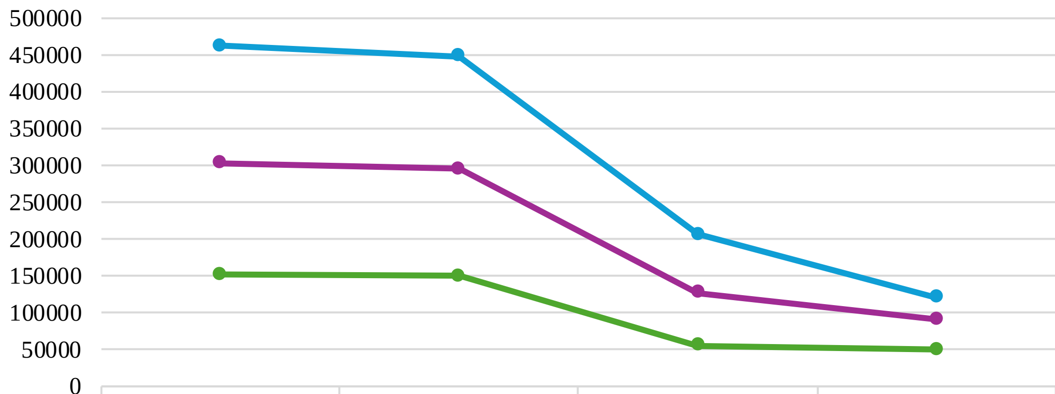
| Ganga's States | Years | Total Monitored Drains | Total flow (MLD) | Total BOD Load (TPD) | STP Outlet Drains |
|---|---|---|---|---|---|
| Uttarakhand | 2016 | 12 | 132.77 | 7.11 | - |
| | 2018 | 15 | 403.21 | 23.19 | - |
| | 2020 | 25 | 141.13 | 0.91 | 3 |
| Uttar Pradesh | 2016 | 59 | 1927.32 | 133.32 | - |
| | 2018 | 56 | 1704.54 | 121.66 | - |
| | 2020 | 154 | 2185.04 | 55.59 | 2 |
| Bihar | 2016 | 22 | 636.18 | 27.36 | - |
| | 2018 | 21 | 1087.18 | 39.47 | - |
| | 2020 | 19 | 609.48 | 9.09 | nil |
| Jharkhand | 2016 | 2 | 30.68 | 3 | - |
| | 2018 | 2 | 42.56 | 2.48 | - |
| | 2020 | 6 | 2.89 | 0.63 | nil |
| West Bengal | 2016 | 59 | 6419.14 | 190.41 | - |
| | 2018 | 58 | 7375.02 | 241.17 | - |
| | 2020 | 56 | 6627.45 | 169.84 | nil |

*Sources:* (Central Pollution Control Board, 2021)

Table 4, shows according to a report by the Central Pollution Control Board, three years of data are generated about waste dumped into the river Ganga through drains. The Ganga River flows in these five states, which are majorly known as West Bengal, Jharkhand, Bihar, Uttar Pradesh, and Uttarakhand. West Bengal is the maximum wastage generated state and that waste dump into the Ganga River and here Ganga River becoming more polluted by the urban wastage dumping. Uttar Pradesh is the second-largest waste-generating state, with a maximum drain of 154 in 2020, which directly goes into the river and pollutes it. Bihar is the third-largest waste-generating state and pollutes the Ganga River. The Ganga River is a major source of water in north India. And all over India's river majorly polluted through urban wastages which dump into the river directly.

### 4.2 Management of Solid waste in India

Figure 5, shows the solid waste generation over all states of India and their collected waste, treated waste, and landfilled waste. The graph shows how much solid waste is generated each year and how much of it is treated and disposed of. Solid waste generation rate is higher than treated rate and landfill rate is smaller than treated wastages. So, it is one of the major reasons for water contamination also.




| | Solid Waste Generation | Collected | Treated | Landfilled |
|---|---|---|---|---|
| 2020-2021 | 160038.9 | 152749.5 | 79956.3 | 29427.2 |
| 2019-2020 | 150847.1 | 146053.8 | 70973.2 | 40863.2 |
| 2018-2019 | 152076.7 | 149748.6 | 55759.6 | 50161.33 |

*Figure 5: Overall Solid Waste Management Status, Source: (CPCB, 2020-21)*

## 5. PARAMETERS TO ASSESS WATER QUALITY IN INDIA

Water quality management has primarily focused on nutrients, heavy metals, suspended sediments, and human pathogens in order to protect aquatic and human health (Sutherland & Ralph, 2019) (Pal, He, Jekel, Reinhard, & Gin, 2014). Rural India relies on untreated groundwater for 80% of household needs but increasing industrialization and urbanization are straining water supplies, leading to depletion and pollution of groundwater (Elangovan, Lavanya, & Arunthathi , 2017). In the figure 6 shown various type of parameters with the categories for water quality.

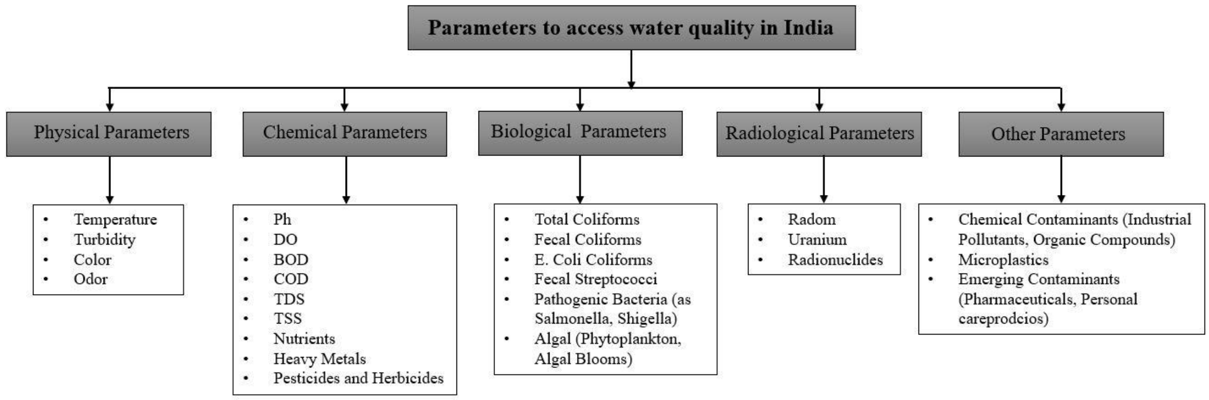



*Figure 6: Parameters to assess Water Quality, Source: (Maurya & Tripathi, 2023) (Rajendran, Sabarathinam, & Kamaraj, 2021)*

- The hydro chemical properties such as pH, alkalinity, total hardness, total dissolved solids (TDS), calcium, magnesium, nitrite, and sulphate can impact water portability (Solanki, Chitnis, & Bhavsar, 2012). Pharmaceuticals, personal care products (PPCPs) and artificial sweeteners (ASWs) are considered emerging contaminants (Petrie, Barden, & Horderna, 2015) (Brack, Dulio, & Slobodnik , 2012).
- Measurement of water quality also helps in developing policies and management practices related to water resources. The National Sanitation Foundation NSF developed the water quality index (WQI) in the early 1970s to describe supply water quality and monitor changes over time or compare water supplies globally or regionally (Prasad, Chaurasia, Sohony, Gupta, & Kumar, 2013).
- Surface water ways face extensive pollution with untreated sewage and industrial waste affecting around 40% of the population with water scarcity and 25% with low-quality water consumption. In India, 1.5 million children die annually from diarrhea and 73 million lost working days due to use of contamination water, causing significant economic losses (Pichura, Potravka, Skok, & Vdovenko, 2020) (Walton, 2018) (Kavya, Sevanan, & Harikumar, 2015).

5.1 Analysis of Water Contaminated Regions in India

Arsenic, EC, fluoride, iron, nitrate, and chloride are the most dangerous chemicals that pollute water and cause severe health issues for people. The author collected the data on a contaminated region from the Central Ground Water Board, 2018 (India, Central Ground Water Board (CGWB), 2018).

5.1.1 Arsenic Contamination: The main cause is the naturally high content of arsenic in deeper layers of groundwater. Poisoning from arsenic in the Ganges delta is a high-profile issue caused by deep tube wells used for drinking water. The Ganges delta in West Bengal is poisoning a large number of people with arsenic. Mainly affected regions are West Bengal, Bihar, Uttar Pradesh and Assam.

5.1.2 Electrical Conductivity Contamination: It is the thermophysical property of lake water that has a strong correlation with the pollution level. It is observed that electrical conductivity increases with an increase in TDS, which in turn indicates increased concentrations of sulphate and other ions. Mainly affected regions are Gujrat, Rajasthan and Panjab.

5.1.3 Fluoride Contamination: Fluoride reaches groundwater through weathering and leaching of fluoride-containing minerals from rocks and sediments. Fluorosis may occur at higher doses (71.5 mg/L). Fluoride in abundant supply in drinking water causes neuromuscular disorders, gastro-intestinal problems, tooth deformity, bone hardening, and skeletal fluorosis. Mainly affected regions are Andhra Pradesh, Gujrat, Rajasthan and Panjab.

5.1.4 Iron Contamination: Although not considered to cause health problems in harmony, its presence in potable water is rather unpleasant due to the bad Odors, rusty taste and color, and its feel on skin and hairs as well. Its tendency to leave stains on clothes. Mainly affected regions are West Bengal, Odisha, Chhattisgarh and Jharkhand.

5.1.5 Nitrate Contamination: In surface water and ground water, nitrates leach into the soil, contaminating water supplies from a variety of sources. Fertilizers can be found in irrigation water, waste water treatment, dairy products, and other natural environments. Nitrate in large amounts in drinking water reacts with haemoglobin to form non-functional methaemoglobin's, impairing oxygen transport (the Blue Baby Syndrome). Mainly affected regions are Panjab, Haryana, Rajasthan and Uttar Pradesh.

5.1.6 Chloride Contamination: Lakes, streams, and drinking water sources are contaminated by chloride from both de-icing salts and water softeners. One teaspoon of salt is enough to permanently contaminate 5 Liters of water. There is no way to eliminate the chloride once it is in the water. Mainly affected regions are coastal regions of Gujrat, Tamil Nadu and Andhra Pradesh.

## 6. METHODS TO REDUCE THE RISK OF WATER CONTAMINATION IN INDIA

### 6.1 Importance of reducing Water Contamination and the need for Water Conservation

Life depends on water and sanitary facilities, and industrial processes, all require plenty of fresh and pure water. So, it is a major issue in the 21st century (Hussain & Wahab, 2018). Therefore, everyone should understand the need and the importance of this precious resource, which is the bloodline for all living beings. Water conservation is a necessity for the present and future. As a result of the industrial revolution, global warming, climate change, and droughts, access to clean water is becoming increasingly problematic due to a rapidly growing population. Studies on the sustainable use of water resources are needed to fulfil food demands and maintain food security for future generations (Ertek & Yilmaz, 2014). According to rural respondents, farmers are not consulted in the development of rules, nor is their practical expertise considered (Comito, Wolseth, & Morton, 2013). Globally, around 5 to 7 million hectares of land suitable for maintaining agricultural production are lost each year owing to land degradation, putting the world's food security at risk. Conservation and management of soil and water resources are critical for human well-being (Bashir, Javed, Bibi, & Ahmad, 2017). As new technologies have been developed, non-conventional water treatment techniques have evolved. Treatments are classified into three types: phase-changing technologies, biological processes, and advanced oxidation processes (Narvaez, Hernandez, Goonetilleke, & Bandala, 2017).

### 6.2 Government Action Plans to reduce Water Contamination

In cross-border waterways waste framework and major catchments, the role of the centre is to ensure the expansion of the economical administration of stream frameworks, guaranteeing that the interface of all States must utilize common assets for the state's advancement in a sensible, secure, and harm-free way (Kumar & Bharat, 2014). The honourable Prime Minister has written a letter to all 'Sarpanches' (village heads) of the nation and motivated all of them to start conserving water activities such as cleaning of water bodies, de-silting, rainwater harvesting, etc. with the participation of people. As per the information furnished by states on the IMIS (Integrated Management Information System), 81.03% of rural habitations are fully covered (getting more than 40 L/capita/day), 15.61% are partially covered, and 3.36% are quality-affected (affected by chemical contamination) (Unstarred question no. 4259, Ministry of Jal Shakti, Department of Drinking Water and Sanitation). Under Jal Shakti Abhiyan, total of 10592 blocks have been selected in 256 groundwater stressed districts.

The National Water Policy (NWP) of 2002 was therefore provided in relation to the rapidly changing situation in the water sector in order to address growing challenges and provide essential approach suggestions. NWP 2002 emphasized biological and ecological viewpoints on water allocation for the first time. To oversee the arrangements and management of water resources, the National Water Policy (NWP) (2012) proposes a common coordinated viewpoint. Such a viewpoint would be environmentally sound, and the surroundings, territories, and regions would also be taken into account. Under the Open Practice tenet, the state is accountable for the guidance and management of water as a system of common pool community assets that ensures equity for all. Under the provisions of the Environment (Protection) Act of 1986 and the Water (Prevention and Control of Pollution) Act of 1974, industrial units are required to install effluent treatment plants (ETPs) to treat their effluents and to comply with stipulated environmental standards before discharging their effluents into rivers and other water bodies. Consequently, the Central Pollution Control Board (CPCB), State Pollution Control Boards (SPCBs), and Pollution Control Committees (PCCs) monitor industries and take enforcement action when effluent discharge standards are not met (Sasakova, et al., 2018).

### 6.2.1 Zero Liquid Discharge Initiative

Zero Liquid Discharge is a process where an industrial plant discharges zero wastewater (Shah). Water is recycled, and solids, which normally contain some moisture, are discarded as by-products or waste. The need for ZLD was identified due to environmental constraints, where it is clearly understood that water as a resource is scarce. Apart from just the need for ZLD, the primary benefit is that the process of ZLD will reduce the demand for fresh water as water conservation via ZLD will generate the supply and meet the need for water conservation.

## 7. RESULT AND DISCUSSION

### 7.1 Future Projection of Water Quality

Clean water accessibility trends and targets have been summarized in the World Water Development Report (WWDR) of the United Nations (UN). Water security refers to a population's capacity to secure their water supply and to get enough quantities of high-quality water is already facing numerous hazards, and the circumstance will end up more awful within the following few decades (Burek, et al., 2016). The water request and water quality estimate depend on numerous geopolitical variables that are difficult to anticipate (Boretti & Rosa , 2019). Access to clean water is closely connected to economic growth and poverty reduction (Bassi, Tan, & Goss, 2010). Since India's independence, water has played an essential part in the country's growth, and it is crucial for the lives and livelihoods of all citizens. Water demand now exceeds availability due to population expansion and uneven water distribution. Figure 7, depicts the water demand distribution wise in India. According to the Government of India, water availability per capita is now about 1,170 $m^3$/person/year, highlighting that India is only slightly over the water-stressed criterion of 1,000 $m^3$/person (Pandit, 2021) (Gebrehiwot & Gebrewahid, 2016). Water sector speculations have met every requirement in India's development plans.

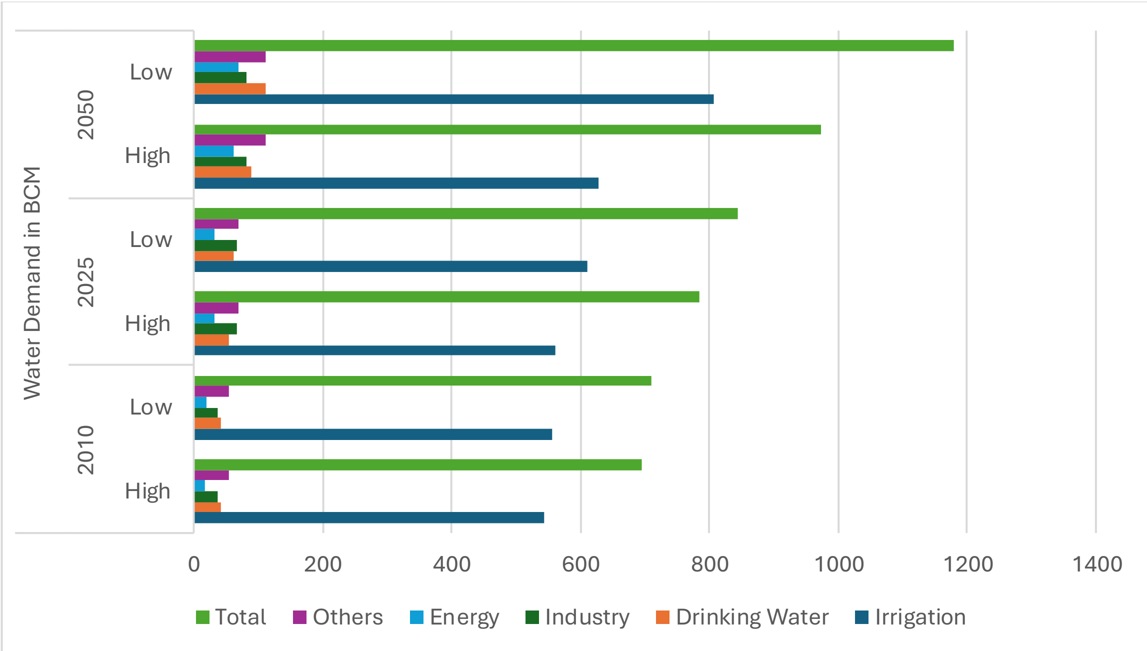



*Figure 7: Division Wise Anticipated Water Demand in India, Source: (ADRI, 2017 )*

Table 5: Ground Water Resources

| no. | Urban Cities | Recharging of Ground Water: Monsoon Season: Rainfall recharging (BCM) | Recharging of Ground Water: Monsoon Season: Other sources of recharge (BCM) | Recharging of Ground Water: Non-monsoon Season: Rainfall recharging (BCM) | Recharging of Ground Water: Non-monsoon Season: Other sources of recharge (BCM) | Total Annual Ground Water Recharge (BCM) | Total Natural Discharges (BCM) | Annual Ground Water Extractable Resource (BCM) | Extraction of Current Annual Ground Water: Irrigation (BCM) | Extraction of Current Annual Ground Water: Industrial (BCM) | Extraction of Current Annual Ground Water: Domestic (BCM) | Extraction of Current Annual Ground Water: Total (BCM) | Annual GW Allotment for Domestic Use on 2025 (BCM) | Groundwater Net Availability for Future Use (BCM) | Ground Water Extraction Stage (%) (BCM) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | New Delhi (NCR) | 1246.96 | 713.78 | 83.98 | 1353.34 | 3398.06 | 339.8 | 3058.26 | 714.92 | 2.2 | 2996.02 | 3713.14 | 2996.02 | 0 | 121.41 |
| 2 | Kanpur Nagar | 41794.84 | 13990.1 | 918.52 | 29910.55 | 86614.01 | 7392.37 | 79221.64 | 53988.75 | 346.27 | 7912.55 | 62247.55 | 8284.77 | 16601.87 | 78.57 |
| 3 | Bhopal | 32718.14 | 2401.7 | 0 | 6591.06 | 41710.9 | 2848.89 | 38862.01 | 23916.38 | 679.14 | 5011.46 | 29606.96 | 5584.57 | 8681.94 | 76.18 |
| 4 | Pune | 93292.27 | 19431.62 | 1186.25 | 67959.96 | 181870.1 | 10683.24 | 171186.9 | 112066.9 | 0 | 8174.04 | 120240.9 | 8174.07 | 59685.6 | 70.24 |
| 5 | Chennai | 8624.4 | 1099.76 | 0 | 862.01 | 10586.17 | 1058.67 | 9668.1 | 258.5 | 1189.5 | 11410.14 | 12858.12 | 13715.11 | 968.88 | 133 |
| 6 | Ahmedabad | 25027.78 | 8169.57 | 0 | 13736.33 | 46933.68 | 3632.52 | 43301.16 | 32678.1 | 3350.95 | 1003.03 | 37032.07 | 3225.83 | 12976.88 | 85.52 |
| 7 | Jaipur | 65004.12 | 2226.68 | 834.46 | 7420.55 | 75485.81 | 7548.59 | 67937.22 | 109776.5 | 1662.05 | 38927.03 | 150365.6 | 38927.03 | 0 | 221.33 |
| 8 | Hugli | 80580.07 | 35790.08 | 16644.65 | 19490.23 | 152505 | 15151.62 | 137353.4 | 47638.6 | 2067.41 | 10298.35 | 60004.35 | 11034.87 | 77395.45 | 43.69 |

*Source:* (India, Water Quality Reports, 2022)

Analysis of table 5 will in turn be followed by a discussion on the state of groundwater resources in some of the urban cities in India with the emphasis on localized factors such as recharge, extraction and resource availability. The numbers also expose the dire necessity of urban groundwater management adopting sustainability as the necessary, sufficient and possible mode of operation.

Groundwater resources in urban cities of India, as analyzed are brought to light in this article, primarily focusing on challenges in over-extraction and contamination. New Delhi, Chennai, and Jaipur are staring at a water apocalypse, in sharp contrast to cities like Bhopal and Hugli which have kept their groundwater table almost intact. This means that we need a wide-ranging strategy to address this issue, including:

• *Increasing the Regulation of Water Extraction and Monitoring Activities:* The monitoring of groundwater levels is part of regular water quality, as well as the enforcement of the regulations on groundwater extraction.

• *The Implementation of Technological Solutions:* This can be achieved by using some sophisticated technologies that save water or installing recharge structures to increase recharge.

• *Public Awareness and Community Participation* – Raising awareness about sustainable water use in communities by engaging them in sustained groundwater management programmes.

• *Sources Of Alternative Water Supply* – search for alternative water supplies such as desalination, wastewater recycling, and rainwater harvesting to reduce reliance on groundwater.

7.2 Emerging Challenges

The last few decades have seen a sensational rise in the demand for water in India due to an assortment of socio-economic forms and statistical patterns. Groundwater resources are over-exploited in numerous bone-dry and semi-arid regions, leading to falling water levels, breaking down groundwater quality, causing a groundwater shortage, and Surface supplies are quickly exhausted due to siltation from mechanical effluents and municipal waste (Kumar & Ballabh, 2000). Approximately 10 million people will die annually due to these resistant bacteria by 2050, and 28 million will be forced into poverty, according to the World Bank (Singh, 2017). Human health can be adversely affected by antibiotics (Laxminarayan, et al., 2013). Emerging contents (acidic pharmaceuticals—ketoprofen, naproxen, etc.—and pesticides—picloram, clopyralid, etc.) have not been focused on their chronic effects (Taheran, Naghdi, Brar, Vermaa,

& Surampallib, 2018). Inadequate waste management, surface water pollution, and shallow groundwater contamination pose the greatest threats to ecosystem health and human wellbeing (Lapworth, et al., 2018). Emerging organic contaminants detected in groundwater certainly have a negative impact on human health and aquatic ecosystems. Researchers have become increasingly interested in the fate and potential toxicity of these so-called "micro-organic pollutants" in terrestrial and aquatic environments in recent decades (Lapworth, Baran, Stuart, & Ward, 2012). The majority of the water is discharged as wastewater, such as municipal and industrial effluents, as well as agricultural drainage water (Rojas & Horcajada, 2020). Preventing and managing wastewater and solid wastes (biosolids) associated with water recycling plants, septic systems, and other water treatment plants are among the global environmental sustainability challenges (Cance, et al., 2018).

**8. CONCLUSION**

Having the maximum population, India is facing serious threats to its water resources. Changes in the patterns of rainfall are affecting the recharge of groundwater storage. Water contamination due to industrial and domestic waste is also increasing and adding a serious threat to the health and sanitation. Sewage treatment facility needs to be improved and should be installed in every district with proper mechanisms for solid waste management. The study reveals that water pollution and the lack of clean drinking water are major problems in India, as are declining groundwater levels. The discharge of agricultural and domestic wastes, urbanization, and the overuse of pesticides and fertilizers all contribute to severe water pollution. To control pollution and conserve water, educational and awareness programs should be organized. According to a recent report by the World Bank, this type of upstream contamination reduces economic growth in downstream areas by up to a third, reducing GDP growth by up to a third in various regions. To make matters worse, the impact is nearly half of GDP growth in middle-income countries such as India, where water pollution is a major issue. The impact of water pollution on agricultural revenues in India is estimated to be 9%, and the impact on yields is 16% downstream of polluted stretches. There is an estimated cost of INR 3.75 trillion a year associated with environmental degradation in India. Approximately 470–610 billion rupees are spent on health-related costs associated with water pollution, particularly regarding diarrheal deaths and morbidities among children under the age of five. 400,000 lives are lost as a result of the lack of safe drinking water, sanitation, and hygiene every year in India, apart from the economic cost. Various master plans for rivers and lakes have been conceptualized, but the progress is minimal, and we have a long way to go in that perspective as well. The role of governments (the Centre and States) is very important to making and implementing effective legislation for the maintenance and preservation of water resources. The centre-state relationship and different levels of administration must have the ability to perform their duties effectively in order to make the water resources clean and safe. Managerial and stakeholder management efficiency at regional levels should be assessed and monitored so that the need for water conservation may be calculated and planned for in the future.

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