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Research Article

Growing Industrialization and Management of Water Resources in India

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Abstract:

Water is an essential element of life on Earth and is critical to all aspects of development. The principles related to water and development serve as a guide to achieving environmental, social and economic balance. India has undergone economic liberalization since 1991, and this has indeed accelerated the pace of industrialization. During these years, there has been a significant increase in the industrial sector, rapid expansion of urban areas, and the emergence of new industries, service sectors, and manufacturing hubs. While this industrial boom has certainly boosted the country's economic progress, it has also had its environmental and social impacts. A major problem is the stress on water resources. The decline in surface water availability, increased exploitation of tributaries, and pollution of rivers and reservoirs have led to uneven water availability. The increasing demand for water from industries, urban centres, and industrial clusters has increased the pressure on these important resources. Industrial activities in sectors such as textiles, chemicals, power generation and manufacturing are major contributors to problems such as wastewater discharge, salinity and thermal pollution. The increasing demand for industrial water, coupled with challenges in wastewater management and increasing water pollution have led to overuse and contamination of our water resources. For example, waste from chemical industries has significantly damaged water quality. In response, various policy and technical measures have been devised. Initiatives such as water conservation, rainwater harvesting, water reuse, water distribution management, and improvements in industrial water management have helped to some extent. Managing water resources in the future calls for a comprehensive, well-coordinated approach that fits the specific needs of each region. This means getting local communities involved, leveraging technology effectively, using natural methods, and planning strategically for the long haul. While industrialization is increasing the demand for water, we can still halt the over-exploitation of water resources. By implementing the right management practices, policies, and technologies, we can ensure that water remains available for everyone in a way. This research paper examines into the relationship between industrialization and water resource management in India from 1991 to 2019. It explores how industrial growth has affected water resources, the ways in which these resources have been exploited, the pollution that has resulted, and the effectiveness of policies aimed at promoting management.

Keywords: Water resources, Industrialization, Water Pollution, Water conservation.

Introduction:

Water and development are interdependent. Water management is not a technical process but a social institution and a moral duty. In 1991, India hit a major milestone in its economic journey, stepping onto the path of liberalization, privatization, and globalization. This pivotal choice sparked a wave of industrial growth, giving rise to new industrial hubs, speeding up urbanization, and transforming the way production and distribution worked. While this industrial boom certainly steered the economy in a new direction, it also brought along some serious environmental and social

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challenges, particularly concerning water resources. The rapid pace of industrialization put a heavy strain on surface water, tributaries, rivers, and reservoirs. As industries, urban areas, and agriculture ramped up their water needs, the management of these vital resources lagged behind. Consequently, we started seeing issues like water resource over-exploitation, pollution, and uneven distribution cropping up. This stark reality highlights the significant challenges we face in managing our water supply. With rapid industrialization and urban growth, water pollution has become an even bigger problem. The demand for water has increased, but unfortunately, our efforts in water distribution and conservation have not kept pace. In many cities and industrial centres, systems for water distribution, recycling, wastewater management, and resource conservation have failed, posing a serious threat to the long-term conservation of our water resources.

Objectives:

- To study the nature and pace of industrialization in India from 1991 to 2019.
- To analyse the problems caused by industrialization on water resources.
- To observe the policies and technologies used at the industrial level for sustainable water resource management.

Hypothesis:

- During the period 1991-2019, increasing industrialization in India has increased pressure on water resources and reduced the quality and effectiveness of water resource management.

Research Methodology:

This study is both qualitative and quantitative. Statistical data as well as descriptive data have been analysed to understand the trends in industrial growth and water resource utilization in various states of India. The study mainly uses secondary data. This information is from reports of the Ministry of Jal Shakti, Central Water Commission, NITI Aayog, Central Pollution Control Board. This research covers the period from 1991 to 2019. This period is after India’s economic liberalization, globalization and privatization, during which the pace of industrialization increased and the challenges in water resource management intensified.

Summary of the review of Literature:

Industrialization and water resource management in India have been studied in depth by various researchers, government agencies and international organizations. This section provides a brief review of those studies and reports that have shed a clear picture of the theoretical and practical aspects of the problem. Since 1991, India has embraced liberalization, privatization and globalization. This change has boosted industrial development, but it has also increased pressure on water resources, which has created a serious challenge of water pollution. Although the industrial sector accounts for about 10-15% of total water consumption, the pollution it generates is high. The quality of groundwater near industrial areas is steadily declining, and excessive use of groundwater for industrial purposes has led to acute shortage of drinking water in rural areas. To address these problems, balanced regulation of groundwater is of utmost importance. Unfortunately, there is a lack of coordination in the ownership, distribution and management of water resources in India. Water use policies vary widely from state to state, resulting in unbalanced water planning between industrial and agricultural sectors. In ancient India, local and community-based water management practices were very effective. However, in today's modern era, these traditional methods have become outdated. Integration of traditional knowledge with modern technology is necessary today. Approaches like water reuse, rainwater harvesting and revitalization of local water sources can still be effective. If these traditional methods are adopted along with modern technology, long-term conservation of water resources is possible.

Analysis and Discussion:

Water resource development means managing our water supply in a way that meets today's needs and ensures that future generations can do the same. This means we must focus on ensuring that we have enough clean water for drinking, agriculture, industry and to keep our ecosystems healthy. It is crucial to use water wisely, protect our water resources from overuse and pollution, and carefully manage our watersheds and aquatic ecosystems. Some key principles include promoting water conservation, reducing waste, and implementing effective water policies. Although industrialization plays an important role in development, it significantly affects the balance of our water resources. Therefore, industrial progress must be compatible with water practices. Without which we cannot achieve future water security.

Nature and Pace of Industrialization in India:

The year 1991 marked a significant turning point in India's economic journey. It was during this time that India embraced of transformative policies: economic liberalization, privatization, and globalization. This shift propelled the country from a controlled economic framework to free, competitive, and market-driven. Major changes were also seen in the process of industrialization during this period.

The liberalization of economic policies in India brought about radical changes in the industrial sector. The government abolished the licensing system known as "Parwana Raj", which gave freedom to private investors and multinational companies to set up various industries. This change led to rapid expansion in sectors such as manufacturing, services, information technology, automobiles and electronics. With the relaxation of foreign direct investment (FDI) norms, global giants such as Coca-Cola, Honda, Samsung and Tata-Microsoft set up production and research facilities in India, which gave a boost to the country's industrial infrastructure.

During this period, along with traditional manufacturing, industries such as information technology, telecommunications and financial services became important for the country's industrial economy. Cities such as Bengaluru, Pune and Hyderabad developed into bustling industrial and technological hubs. Meanwhile, micro, small and medium enterprises (MSMEs), which play a key role in employment generation in rural areas, were encouraged. However, their growth and productivity remained limited compared to large industries. Therefore, while the post-1991 industrial boom took India to new heights in the global industrial arena, it also created regional disparities and challenges in resource management.

The period from 1991 to 2019 was crucial for laying the groundwork for liberalization in India. During this time, industrial growth averaged between 6% and 7%, private investment surged, and the public sector's dominance began to wane. Moving into the 2000 to 2010 phase, India experienced a boom in manufacturing, particularly in sectors like automobiles, steel, energy, and IT, with industrial growth hitting an impressive 8% to 10%. This era marked India's emergence as a global manufacturing powerhouse. From 2010 to 2019, the focus shifted to integration and innovation, with initiatives such as Make in India, Digital India, and Start-up India driving advancements in manufacturing and technology.

Problems caused by industrialization on water resources:

Overexploitation of Water Resources:

The rapid pace of industrialisation has led to a significant increase in water demand in various sectors such as textiles, automobiles, power generation and chemicals. Unfortunately, this has led to over-extraction of groundwater and surface water, which has upset the natural balance of our water resources. In states like Maharashtra, Gujarat and Tamil Nadu, the water table has dropped, leading to water scarcity for agriculture and drinking. This overuse of water not only creates ecological imbalances but also adds to long-term water stress.

Industrialisation in India has led to a significant increase in water consumption. The demand from industries has upset the natural balance of water resources, resulting in: water depletion in rivers,

groundwater depletion and salinity in reservoirs. Also, water conflict arises between industry, agriculture and domestic use. According to the Central Ground Water Board 50% and above of groundwater blocks in India are overused, with Maharashtra, Gujarat, Punjab, Haryana and Tamil Nadu being the most affected. Industrial water consumption in India is about 8 to 10%. For example, a 1000 MW thermal power plant uses 15 to 30 million litters of water per day. The textile industry uses about 200 to 250 litters of water per day, while the chemical and fertilizer sectors use 5,000 to 20,000 cubic meters of water per unit per day. The automobile manufacturing industry uses 1000-5000 (m^3) litters of water per unit.

Water Pollution:

One of the major causes of water pollution in India is industrialization. A large amount of untreated wastewater from various sectors such as chemicals, textiles, tanneries and thermal power plants is discharged into rivers and groundwater. According to the Central Pollution Control Board (CPCB), about 70-75% of industrial wastewater in India is discharged without proper treatment. This polluted water contains heavy metals (lead, mercury, chromium), dyes and toxic chemicals that have serious impacts on aquatic life and human health.

Industries located on the banks of the Ganga, Yamuna, Godavari and Mithi rivers are known to be major contributors to water pollution. Industrial clusters in Maharashtra, Gujarat, Uttar Pradesh and Tamil Nadu are among the most polluted regions.

Major Polluting Industries and Their Pollutants

Industry	Major Pollutants	Environmental Impact	Regions
Textile & Dyeing	Dyes, detergents, salts, acids	Alters pH of water, affects aquatic life	Gujarat, Tamil Nadu, Maharashtra
Chemical & Fertilizer	Ammonia, nitrates, phosphates, acids	Eutrophication and toxicity in rivers	Maharashtra, Gujarat, Uttar Pradesh
Leather Tanneries	Chromium, sulphides, organic waste	Heavy metal contamination in groundwater	Tamil Nadu, Uttar Pradesh, West Bengal
Thermal Power Plants	Fly ash, suspended solids, hot water	Thermal pollution, oxygen depletion	Maharashtra, Chhattisgarh, Jharkhand
Paper & Pulp Industry	Lignin, chlorinated compounds, organic matter	High BOD/COD levels, oxygen depletion	Maharashtra, Punjab, Madhya Pradesh
Pharmaceutical	Antibiotics, solvents, organic compounds	Alters microbial balance, toxic residues	Hyderabad, Maharashtra, Himachal Pradesh
Sugar & Distillery	Molasses, organic matter, sulphates	High BOD, black water discharge	Maharashtra, UP, Karnataka
Food Processing	Oils, fats, organic solids	Odor and microbial contamination	Maharashtra, Gujarat, Punjab

Source: Central Pollution Control Board (CPCB) Centre for Science and Environment (CSE), NITI Aayog report 2018

The data indicates that, in India, many industries are responsible for water pollution, as they do not treat their wastewater. This creates harmful pollutants such as heavy metals, dyes and organic compounds, which can wreak havoc on the ecosystem and human health.

Thermal pollution

Thermal pollution is the increase in water temperature that occurs when used cold water from power plants, chemical factories and refineries is discharged into rivers or lakes. This increase in temperature reduces the amount of dissolved oxygen in the water, which can be fatal to aquatic animals. It also disrupts the reproduction of fish and other species, which disrupts the balance of the entire ecosystem. In India, this type of thermal pollution is found in rivers in Maharashtra, Tamil Nadu, and Uttar Pradesh, especially near thermal power plants and large industrial areas, where cooling systems are not adequate.

Industrial Wastewater and Salinity:
Textile, sugar and fertilizer industries are discharging large amounts of saline wastewater into our rivers. This wastewater is loaded with salts, acids and toxic metals, which increase the salinity and hardness of the water. As a result, it becomes unfit for drinking and agriculture. High salinity levels harm soil fertility and reduce crop yields. This salinity of groundwater is a significant problem in states like Gujarat, Maharashtra and Tamil Nadu, posing a long-term threat to the environment, ecosystem and human health.

Unequal Water Distribution:
Industrial development mainly uses water for industries and urban centres, which reduces the available water supply for agriculture and drinking water in rural areas. Industrial areas in Maharashtra (Pune, Nashik), Gujarat (Surat, Vadodara) and Karnataka (Bengaluru) have high water consumption. This leads to social conflict, rural-urban inequality and lack of safe drinking water.

Policies for sustainable water resources management at the industrial level:
Water (Prevention and Control of Pollution) Act, 1974
This Act makes industries responsible for treating and managing their wastewater. It mandates the reduction of chemical and biological pollution by using Effluent Treatment Plants (ETP). By doing so, this Act plays a vital role in reducing the stress on our water resources and ensuring that rivers and groundwater remain clean and safe.

Environment Protection Act, 1986
This Act is to control industrial water pollution. Industrial companies are required to comply with specific regulations regarding water use and pollution levels. The aim of this policy is to maintain a balance between industrial activities and our precious water resources, and to promote long-term sustainable water management.

National Water Policy (National Water Policy, 2012)
The National Water Policy provides guidance to industries to promote sustainable use of water. It highlights the importance of achieving water reuse, zero liquid discharge (ZLD) and conserving our precious water resources. The policy also encourages collaboration between industries and local communities to protect water supplies and ensure a healthy ecological balance in the long term.

Zero Liquid Discharge (ZLD) Rules
According to ZLD rules, industries are required to recycle all their wastewater and refrain from releasing any liquid pollutants. This approach not only helps industries save water but also reduces the strain on our natural water resources and supports ecological balance. This policy promotes sustainability in how industries manage their water usage.

Technology for sustainable water resource management on an industrial scale
Effluent Treatment Plants (ETP)
Effluent Treatment Plants, or ETPs, play a key role in treating wastewater. They effectively remove chemical, biological and solid pollutants from industrial wastewater, which helps reduce the strain on our natural water resources. The result is clean, purified water that can be reused in various industrial processes, contributing to the goal of Zero Liquid Discharge (ZLD).

Common Effluent Treatment Plants (CETP)
CETPs treat wastewater from multiple industries in a combined industrial cluster. CETPs play a vital role in managing wastewater from various industries. This approach is not only cost-effective for small and medium-sized businesses but also helps in reducing water pollution and conserving our precious natural water resources. Moreover, it makes a large amount of water available for reuse.

Reverse Osmosis (RO)
RO systems reduce heavy metals, alkalinity, and chemical and biological contaminants in water. This means that clean water can be reused in various industrial processes. In addition, RO systems play a vital role in helping businesses comply with water conservation and Zero Liquid Discharge (ZLD) policies, while reducing dependence on natural water resources.

Membrane Bioreactor (MBR)
Membrane Bioreactor (MBR) is a high-performance water treatment technology that effectively combines biological processes with membrane processes. This innovative approach ensures that industrial wastewater is treated so that it is safe for water resources. It increases recycling efforts, makes industrial water management efficient, and helps reduce pollution.

Multiple Effect Evaporators (MEE)
Multiple Effect Evaporators (MEE) filter industrial wastewater by evaporating water, leaving behind solids, effectively achieving zero liquid water discharge. This process not only promotes industrial water reuse, but also reduces pressure on our natural water resources and helps reduce pollution.

Corporate Social Responsibility (CSR) Projects
Industrial CSR projects include river conservation, reservoir recharge, ponds and water resource conservation. The key to effective water resource conservation lies in collaboration between industry, local communities and government agencies. This teamwork ensures that the management of our water resources is not only socially responsible but also environmentally sustainable.

Conclusion and Recommendations:

Industrialization is important for economic growth, but it has also created significant water pollution problems across India. Water resource management has become a challenge in India, especially at the industrial level. Since 1991, problems such as over-extraction of groundwater and pollution and degradation of river ecosystems have become acute. Every industrial sector releases its own pollutants, and the careless discharge of toxic chemicals, dyes and heavy metals into wastewater has seriously threatened water quality, affecting human health and biodiversity. In addition, the gap between rural and urban areas regarding industry, agriculture and domestic water users is widening. In this situation, strict enforcement of wastewater regulations and adoption of clean technologies are necessary.
Coordination between industry, government and society is very important for Water resource management at the industrial level. Regular water audits are important to ensure that industries are using water efficiently and to implement reuse systems. Wastewater should be treated and reused through a Zero Liquid Discharge (ZLD) policy, which significantly reduces the amount of industrial wastewater discharged into rivers. In addition, we need to mandate Effluent Treatment Plants (ETPs), Common Effluent Treatment Plants (CETPs), reverse osmosis (RO), membrane bioreactors (MBRs), Multiple Effect Evaporators (MEEs) and rainwater harvesting techniques for effective rainwater harvesting and groundwater recharge. In India, integration of traditional knowledge with modern technology is of utmost importance for effective management of water resources. In ancient India, water management was not just a government function but was considered a collective responsibility of every segment of society. At the local level, communities had developed various methods to plan, store and use water according to their needs. For example, the Johad in Rajasthan, the Bawdi in Gujarat, the tanks and dams in Maharashtra and the Ahar-Pen system in Bihar are prime examples of ancient and sustainable water management practices. Each of these methods focused on harvesting rainwater, recharging groundwater and increasing local water availability. They were designed to adapt to the geographical and climatic conditions of their area, which made

them highly effective. Notably, these systems were based on community work, which instilled a sense of social solidarity and environmental responsibility.

In today's modern industrial era, by combining traditional water management practices with cutting-edge technology, we can find long-term solutions to manage water resources. Industries should implement water conservation projects under CSR with local communities and train workers in effective water management. Governments should promote sustainable industrial water management through stringent regulations, incentives and tax breaks. Governments should ensure compliance with groundwater sustainability criteria while granting industrial licenses. Mapping of water resources, regulating extraction, encouraging recharge and monitoring of effluents is essential. Bringing transparency in water allocation decisions, industrial, urban, agricultural demands, climate risks and environmental needs should all be met within the water allocation framework, while increasing water use by industries should not compromise the health of rural communities, agriculture or ecosystems. Industrial growth should embed water management as a core value. By adopting all these measures, the industrial sector can effectively move towards water conservation, reuse and environmentally responsible development.

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