Journal of Environmental Studies [JES]
An International Journal
https://jesj.journals.ekb.eg/
doi: *10.21608/jesj.2025.373568.1121*

Economic Evaluation of Water Resources in Industrial Development in India

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Citation: *Ali, I.A.S. (2025). Economic Evaluation of Water Resources in Industrial Development in India. Journal of Environmental Studies, Vol. 38(1): 51-60.*

Article Information

Received 7 April 2025,
Revised 16 April 2025,
Accepted 16 April 2025,
Published online. 1 June 2025

Abstract:

Water is a vital natural resource essential for life and the survival of humanity, supporting various social and economic activities, particularly in industry. Unlike other natural resources, water is stable in quantity on Earth and is continually renewed through the hydrological cycle. In India, water resources include both fresh and saline resources. Freshwater is found in rivers, lakes, and groundwater, while saline water is crucial for fishing, transportation, and can be desalinated for drinking in water-scarce areas. Water plays a significant role in industry, which consumes less water than agriculture but has a direct relationship with national income growth. As a key element of economic development, industrial water usage highlights the importance of optimizing resource management for sustainable growth.

Keywords: Economic Evaluation, Water Resources, Industrial Development, India, Industrial Water Use.

1.Introduction

Water is considered one of the most important natural resources related to life and the survival of humanity and all its social and economic activities in various fields, especially in the field of industry. This resource is distinguished from other natural resources by the fact that its quantities are stable on Earth and are constantly renewed over a limited period of time thanks to the hydrological cycle.

Water resources in India are diverse, including fresh and salty water resources. As for fresh water resources, they are represented by rivers, lakes and groundwater, while salty water resources are important for India to exploit in fishing and transportation or by desalinating salty water to benefit from it for drinking in areas with little water.

Water resources in India have a clear role in industry, as industry with its various activities represents a participating consumer of available water resources, although its share of these resources is much less than what agriculture consumes, and there is a close relationship between the rate of increase in national income and the rate of increase in water consumption in industry, as industry is a pillar of economic development and an essential element for the optimal exploitation of the resources and wealth of different countries.

2.Location

India is located in the southern part of the continent of Asia, and includes most of the lands of the Indian subcontinent. It is bordered to the north by China, Nepal, and Bhutan, to the northwest by Pakistan, to the east by Bangladesh and Myanmar (formerly Burma), and to the east by Sri Lanka, the Maldives, and Indonesia on the Indian Ocean, and close to the Arabian Sea to the west and the Bay of Bengal to the east, Figure (1). India is divided into 28 states and seven federal territories, including the city of Delhi. The capital is New Delhi. The largest cities are Bombay, Delhi, Madras, and Hyderabad. According to World Bank estimates, India's population reached 1.44 billion people in 2023.

India occupies a large area of South Asia, amounting to about 3.2 million km2, which constitutes about 6.9% of

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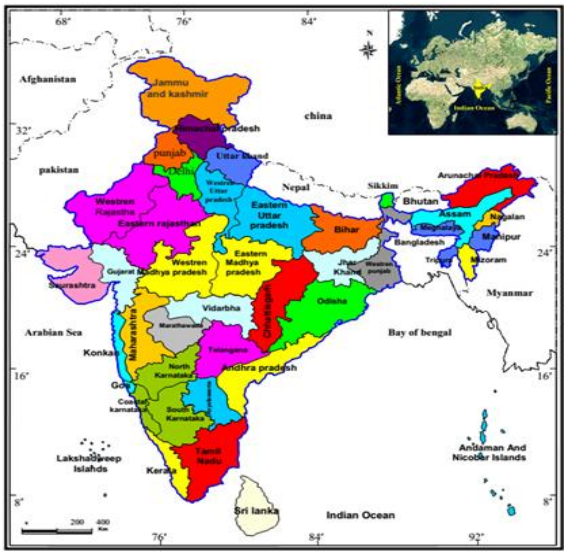
the total area of the continent, making it the second largest Asian country after the People's Republic of China, with about 9.6 million km2 (Gharib, 2005).



Source: https://ar.wikipedia.org/wiki/%D8%A7%D9%84%D9%87%D9

Figure (1): Administrative borders of the Indian states

3.Previous studies:

- Panda & Kumar (2018): Economic Impact of Water Scarcity on Industrial Productivity in India Summary: This study evaluates the economic impact of water scarcity on industrial productivity in India. It highlights how water availability directly influences operational costs and output in manufacturing sectors, suggesting that efficient water management could enhance industrial growth.
- Sharma & Bhattacharya (2020): Water Pricing Policies and Industrial Water Use Efficiency in India Summary: This research focuses on the relationship between water pricing policies and industrial water use efficiency in India. The authors argue that implementing tiered pricing can motivate industries to adopt water-saving technologies, thereby leading to sustainable industrial development.
- Ghosh & Roy (2019): Economic Benefits of Water Conservation Technologies in the Textile Industry Summary: This study assesses the economic benefits of investing in water conservation technologies in the textile industry. By analyzing case studies, the authors demonstrate that upfront investments in water-efficient processes lead to long-term cost savings and increased competitiveness.
- Kumar & Singh (2017): Impact of Industrial Water Pollution on Local Economies Summary: This paper evaluates the impact of industrial water pollution on local economies. It discusses how water contamination from industries affects agricultural productivity and public health, emphasizing the need for stricter regulations and water quality management.
- Joshi & Verma (2021): Cost-Benefit Analysis of Integrated Water Resource Management in Industrial Zones
  Summary: This study explores the cost-benefit analysis of integrated water resource management (IWRM) in industrial zones. The authors find that IWRM can significantly reduce water wastage and enhance economic returns for industries, advocating for policy shifts towards integrated management strategies.

4.Study objectives:

The study aims to identify the water resources available for industrial development and the most water-consuming industries in India, as well as to identify areas of water abundance and deficit and their effects on the energy sector in the Indian states.

5.Water resources in India:

India depends on three main sources for its water resources: rain, surface water, which is represented by rivers and water storage projects, and groundwater, which can be studied as follows:

5.1.Rainfall:

India's seasonal climate is characterized by its frequent changes, which clearly affect its rainfall system from one year to the next, whether in terms of the amount that falls on the country or in terms of the length of the rainy season, which leads to serious damage to agricultural production and urban centers.

Heavy rains fall on the southeastern and southern parts of India during the period extending from October to March. The climatic conditions change during the summer months, as heavy rains fall from June to October on the northern mountain ranges and the slopes of the Western Ghats and the Eastern Ghats. The most abundant areas of India are the mountain slopes of the Western Ghats, where the annual rainfall exceeds 150 inches, and in some regions, such as the Cherrapunji region in Assam, it reaches about 400 inches per year. This amount ranges between 100-150 inches in some areas of the Western Ghats, between 50-100 inches in the northern ranges and the northern Deccan, and between 30-50 inches in the rest of the country, with the exception of the Thar Desert in the northwest, where the annual rainfall is less than about five inches (Al-Zouka, 2004). Table (1) shows a variation in the amount of rainfall, as the Indian states can be divided into categories in terms of the amount of rainfall in each state as follows:

Table (1) and Figure (2) show the following:

-The first category is less than 400 mm: This category includes the western state of Rajasthan and Tamil Nadu.

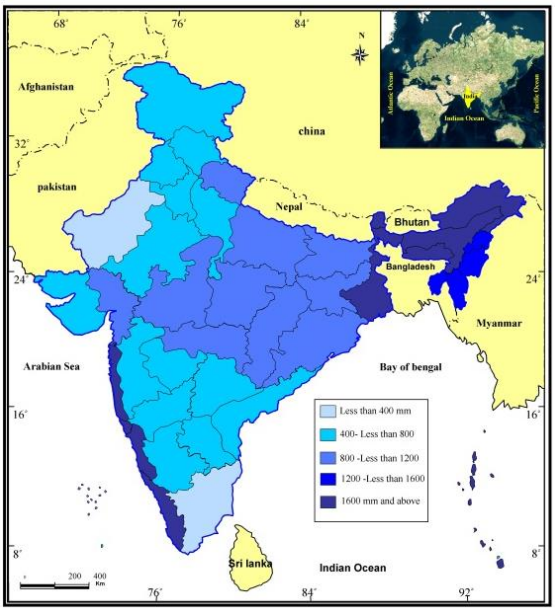
Table (1): Distribution of rainfall in Indian states in 2021

State/City	Rainfall Amount (mm)				
	June	July	August	September	Total
Andaman and Nicobar Islands	413.7	402	409	429.1	1653.8
Arunachal Pradesh	490.7	523.8	360.6	351.5	1726.6
Assam and Meghalaya	496.9	557.7	404.3	314.8	1773.7
Nagaland, Manipur, Mizoram, Tripura	398	389.5	355.4	283.8	1426.7
West Bengal and Sikkim	483.3	625.9	480.7	380.9	1970.8
Odisha	217.7	344.6	366.4	226.6	1155.3
Jharkhand	199.9	322.3	297.8	234.7	1054.7
Bihar	167.7	349	285.2	215.3	1017.2
Eastern Uttar Pradesh	108.2	281.2	263.8	186.2	839.4
Western Uttar Pradesh	76	243.9	256.7	144.7	721.3
Uttarakhand	177.8	407.7	397.7	193.7	1176.9
Haryana, Chandigarh, Delhi	48.1	156.8	159.2	79.9	444
Punjab	50.4	176.2	160	80.7	467.3
Himachal Pradesh	100.5	273	262.3	127.7	763.5
Jammu and Kashmir	74	203.7	185.4	102.9	566
Western Rajasthan	36.9	101.7	88	38.7	265.3
Eastern Rajasthan	66.8	218.9	222.2	95	602.9
Western Madhya Pradesh	105.9	287.2	303.8	160.8	857.7
Eastern Madhya Pradesh	140.4	342.4	366.2	199.4	1048.4
Gujarat	138.6	340.1	295.3	148.9	922.9
Saurashtra	94	195.6	141	76.6	507.2
Konkan and Goa	689.7	1068.1	759	358.5	2875.3
Madhya Maharashtra	157	240.8	197.1	156.3	751.2
Marathwada	138	179.1	186.5	165.2	668.8
Vidarbha	170.6	307.1	306.6	158.8	943.1
Chhattisgarh	193.5	375.5	364.2	208.9	1142.1
Coastal Andhra Pradesh	105.2	157.9	162.1	161.7	586.9
Telangana	130.4	232.7	225.5	163.3	751.9
Rayalaseema	70.9	92.6	108.5	139.6	411.6
Tamil Nadu	51.7	73.3	92.8	118.3	336.1
Coastal Karnataka	866.7	1116.3	806.3	305.8	3095.1
Northern Karnataka	107.1	123.5	122	144.5	497.1
Southern Karnataka	144.1	213.3	178	146.4	681.8
Kerala	643	720.1	426.7	259.5	2049.3
Lakshadweep	330.3	294	223.2	165.6	1013.1
Total	7883.7	11937.5	10219.5	6724.3	36765

Source: Government of India, India Meteorological Department, 2021, pp145,146

- The second category is from 400 mm to less than 800 mm: This includes the states of (Eastern Uttar Pradesh, Haryana, Chandigarh, Delhi, Punjab, Jammu and Kashmir, Eastern Rajasthan, Saurashtra, Madhya Pradesh, Marathawada, Coastal Andhra Pradesh, Telangana, and Northern and Southern Karnataka).
- The third category is from 800 mm to less than 1200 mm: This includes the states of Orissa, Jharkhand, Bihar, Eastern Uttar Pradesh, Uttarakhand, Western and Eastern Madhya Pradesh, Gujarat, Vidarbha, Chhattisgarh, and Lakshadweep Island.
- Category IV of 1200 mm - less than 1600 mm: It includes the states of Nagaland, Manipur, Mizoram and Tripura.
- Category V of 1600 mm and above: The coastal state of Karnataka comes first among the Indian states in terms of the amount of rainfall, which is estimated at about 3095.1 mm, representing 8.4% of the total amount of rainfall in the Indian states during the monsoon season extending from June to September of 2021. This category also includes the state of Arunachal Pradesh, the Andaman and Nicobar Islands, Assam and Meghalaya, West Bengal and Sikkim, Konkan and Goa, and Kerala.

It is clear from the above that the areas that receive the largest amount of rainfall during the season extending from June to September 2021 are the southwest of India, represented by the coastal state of Karnataka, Konkan and Goa, Kerala, and also the far northeast of India, Arunachal Pradesh, Sikkim and West Bengal, Assam and Meghalaya.



Source: Prepared by the researcher based on Table No. (1)

Figure (2): Total amount of rainfall in the Indian states during the season (from June to September) 2021.

5.2.Rivers:

Rivers are the main source of water in India, as it has 1/25 of the world's water resources, and therefore the amount of water used annually is about 1086 billion m3 (Algalaly, 2017).

Indian rivers are classified based on topography and river systems into:

- Himalayan rivers
- Deccan Plateau rivers
- Coastal rivers
- Internal drainage basin rivers

Table (2) shows the size of river basins in India, their annual flow and the flow used.

Table (2) and Figure (3) show the following:

The Central Water Commission estimates the total water resource potential of India, measured as natural flow within river systems, at about 1999 billion cubic metres, taking into account the contributions of surface and groundwater. Of this total, the exploitable water resources are expected to reach 1126 billion cubic metres annually, with surface and groundwater constituting 690 billion cubic metres and 436 billion cubic metres respectively.

As shown in Table (2) which summarizes the catchment areas of the basin, average water resource potential and usable water capacity, the Ganga-Brahmaputra-Meghna (GBM) basin dominates the watershed, covering a catchment area of over 1.1 million square kilometers. Additional major basins with catchments exceeding 100,000 square kilometers include the Indus, Godavari, Krishna and Mahanadi systems. It is worth noting that the Brahmaputra basin alone contributes about 1,123 billion cubic meters per annum to the national water resource potential, which is about 56.2% of the total 1,999 billion cubic meters.

Table (2): Area of river basins in India (km^2) and available and usable water resources (BCM)

River Basin	Catchment Area (km^2)	Average Water Resources Potential(BCM)	Utilisable Surface Water Resources(BCM)
Indus	317708	45.53	46
Ganga	838803	509.52	250
Brahmaputra	193252	527.28	24
Barak & others	86335	86.67	--
Godavari	312150	117.74	76.3
Krishna	259439	89.04	58
Cauvery	85167	27.67	19
Subarnarekha	26804	15.05	6.8
Brahamani & Baitarni	53902	35.65	18.3
Mahanadi	144905	73	50
Pennar	54905	11.02	6.9
Mahi	39566	14.96	3.1
Sabarmati	31901	12.96	1.9
Narmada	96659.79	58.21	34.5
Tapi	65805.8	26.24	14.5
West Flowing Rivers from Tapi to Tadri	58360	118.35	11.9
West Flowing Rivers from Tadri to Kanyakumar	54231	119.06	24.3
East Flowing Rivers between Mahanadi & Pennar	82073	26.41	13.1
East Flowing Rivers between Pennar and Kanyakumari	101657	26.74	16.5
West Flowing Rivers of Kutch and Saurashtra including Luni	192112	26.93	15
Area of Inland drainage in Rajasthan	144835.9	-	---
Minor River Draining into Myanmar (Burma) & Bangladesh	31382	31.17	---
Total	**3271953**	**1999.2**	**690.1**

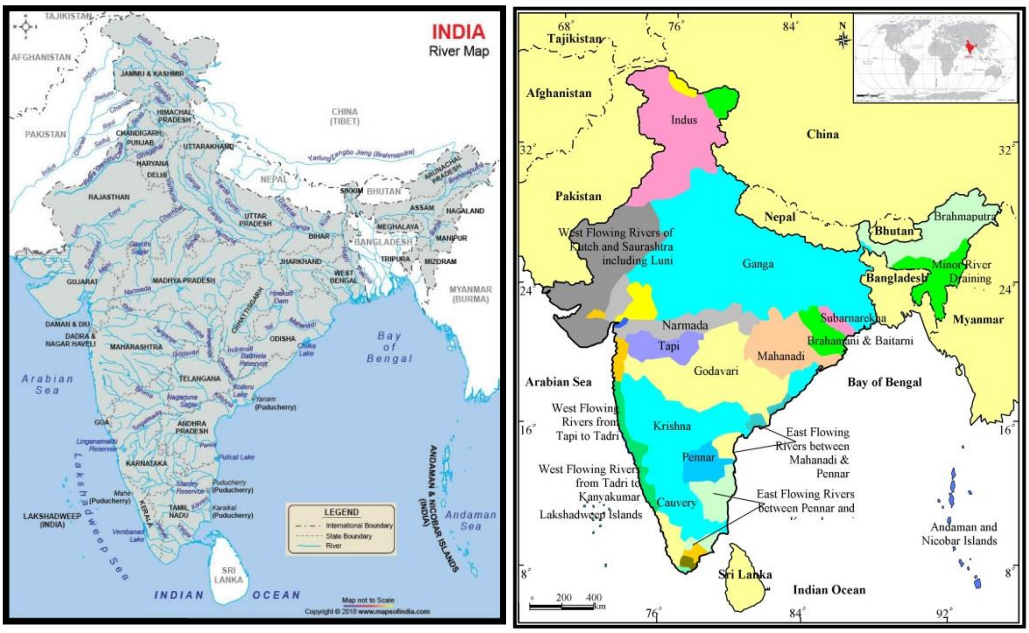
Source: Water Related Statistics Directorate Information System Organisation Water Planning & Projects Wing Central Water Commission, October, 2021, P6 .

Analysis of usable surface water reveals high ratios of usable resources to total potential in smaller basins, with exceptions in the Mahi and western river basins flowing from Tapi to Tadri and Tadri to Kanyakumari. In contrast, the Brahmaputra sub-basin exhibits the lowest proportion of usable surface water compared to its average water resource potential, highlighting the inefficiency in resource access within this region.

5.3. Groundwater:

Groundwater is the main source of water for wells, springs, tube wells or artesian wells, and this water is used for many domestic purposes, agriculture, industry, mining, and engineering operations.

The volume of groundwater is estimated at approximately 8.4 million km2,which is equivalent to 97.7% of the total fresh liquid water in the world, which highlights its level of importance and the great



Source: International Water Management Institute, Colombo, Sri Lanka, 2007

Figure (3): River basins in India (km2) and available and usable water resources (b m3)

role it can play in providing part of the human need for water, especially in dry and semi-dry regions where surface water sources are scarce or almost non-existent (Al-Zouka, 2002, p. 213).

It is estimated that there are 21 million tube wells in India, of which 16 million are in use, extracting about 231 billion m^3 of water, of which 213 billion m^3 is used for irrigation, and about 18 billion m^3 for domestic and industrial use, while the amount of groundwater available in India is estimated at about 399 billion m^3 (Institute for Defense Studies and Analyses, New Delhi, 2010, p26). The volume of groundwater resources for recharge in India is estimated at about 431.43 km^3/year, and according to information from the Indian states, the volume of groundwater resources available in India is 433.882 billion m^3/year, of which 71.08 billion m^3/year is used for industry and domestic use, and 360.35 billion m^3/year for irrigation (Sharad, et al., 2007, p32). Table No. (3) shows the amount of groundwater available and used in the Indian states in 2009.

Table (3) shows that the Indian states can be divided in terms of the net annual amount of available groundwater into:

- The first category is less than 5 billion m^3: It includes the states of Arunachal Pradesh, Delhi, Goa, Himachal Pradesh, Haryana, Jammu and Kashmir, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Uttarakhand, Andaman and Nicobar, Chandigarh, Dadra and Nagarhaveli, Daman and Diu, Lakshadweep Islands, Puducherry, Ladakh, Rajasthan, Punjab, Jharkhand, Kerala.

- The second category is 5 billion m^3 - less than 15 billion m^3: It includes the states of Chhattisgarh, Karnataka, Maharashtra, Madhya Pradesh, Orissa, Tamil Nadu, Telangana, West Bengal.

- The third category is from 15 billion m^3 - less than 30 billion m^3: The state of Uttar Pradesh comes in first place, followed by the states of Andhra Pradesh, Gujarat, Assam, and Bihar.

6. Uses of water resources in the industrial sector:

Water used in industrial production is an intermediate commodity, and 23% of water is used for this purpose globally. Water uses for industrial purposes vary from one region to another. Asia uses only 9% of its water for industry, Africa uses only about 5%, Australia and the Pacific Islands (2%), while the percentage rises to 55% in Europe, North and Central America (42%), and South America (23%). The reason for this disparity is due to the dependence of the economies of developed countries on industry, unlike developing countries whose economies depend mostly on agriculture (Sadiq & Barghouthi, 1997). The availability of fresh water is one of the most important factors that determine the choice of industrial sites. Industrial water consumption exceeds that used for domestic purposes and sometimes agricultural purposes. For example, a coal-burning machine used to generate electricity requires an amount ranging between 600 and 1000 tons of water for every ton of coal burned. The amount of water needed to cool a 2000 kilowatt power plant is 1000 million gallons per day, which is enough to consume a large urban complex. The production of a ton of aluminum requires 120 thousand gallons of water, a ton of steel 80

thousand gallons, and a ton of paper 64 thousand gallons. There are some other industries that consume large amounts of water in production processes (Abu Al-Ezz, 1989). Industry is the second largest consumer of water in India, with rapid growth in various industries. The current use of water in the industrial sector is about 15 km3 of water, and thermal and nuclear power plants operating with a capacity of 40,000 MW and 1,500 MW need this water at an estimated rate of 19 km3. In light of the water shortage, factories are expected to search for water resources using technology. If the current rate of water use continues at this rate, ranging between 15 km3 and 19 km3, the water needs of manufacturing will reach 1030 km3, i.e. the required deficit is 81 km3 in the event that there is no development in manufacturing technology (Youssef, 2013).

Table (4) shows that the sector with the highest water consumption in 2000 was the spinning and weaving industry, with an estimated water quantity of 8,153.72 million m3, representing 37.4% of the total water used in all industries. The distillation industry came in second place in terms of water consumption, with a percentage of 29.1% of the total water used in the previous industries, followed by the iron and steel industry in third place, with about 17.5% of the total water used in the industry. The medium-water-consuming industries are leather products, food industries, cement, fertilizers, inorganic chemicals, and pharmaceuticals, followed by the industries with the lowest water consumption, which are smelters, caustic soda, rubber, pesticides, paper and pulp, and engineering industries. Also in 2025 and 2050, the most consuming industries, as well as the medium and least consuming ones, will remain the same, with the difference being in the increase in the amount of water used in various industries, with the expected total reaching 44987.1million m3 and 67412.36 million m3 in 2025 and 2050 respectively. Table (4) shows the amount of water required for the production unit (m3) and the production volume (million tons) of various industries during the years 2000, 2025 and 2050.

Table (5) and Figure (4) show that the largest quantity of water required per production unit is 200 m3 in the most water-intensive industries, such as the paper and pulp industry, the inorganic chemicals industry, and the spinning, weaving, and jute industry. This represents an increase of 197.8 m3 over the least water-intensive industries per production unit in these industries, such as the sugar industry and engineering industries.

The table also shows that in 2000, the largest production industry was the iron and steel industry, with a production volume of 174.1 million tons, followed by the cement industry, with a production volume of 120 million tons for the same year. Food processing ranked last in terms of production volume, estimated at 0.1 million tons. In 2025, the cement industry is expected to produce the largest amount, 395.0 million tons, followed by the iron and steel industry with 273.3 million tons. The textile and jute industry is expected to produce 183.5 million tons, while smelters will rank last with 0.4 million tons. The cement industry will maintain its lead among Indian industries in 2050, with a production of 749.0 million tons, followed by the iron and steel industry with a production of 547.1 million tons. Smelters will remain at the bottom of the list from 2025, with a production of only 0.5 million tons. The following is a review of some of the industries.

Table (3): The amount of groundwater available and used in the industrial sector in India in 2023 (billion m^3/year)

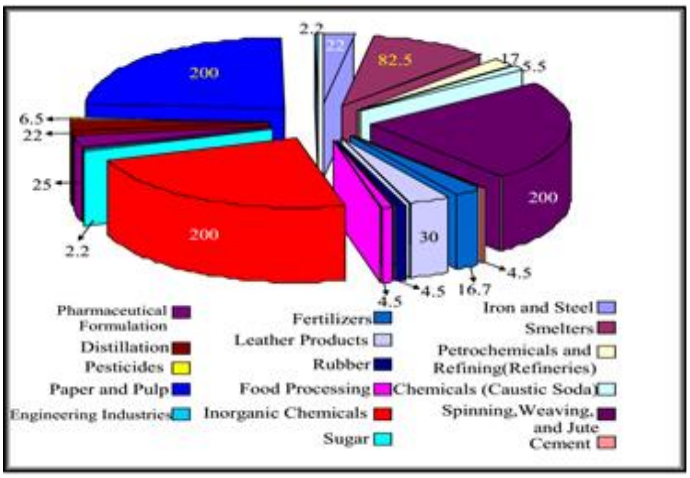
State/City	Net annual available groundwater quantity	Annual groundwater withdrawal for industrial use	Groundwater available for future use
Andhra Pradesh	26.45	0.14	19.09
Arunachal Pradesh	4.16	0.0003	4.15
Assam	20.93	0.01	18.27
Bihar	30.72	0.37	17.02
Chattisgarh	12.18	0.13	6.51
Delhi	0.34	0.0007	0.03
Goa	0.317	0.005	0.247
Gujarat	25.41	0.17	12.86
Haryana	8.69	0.62	1.0
Himachal Pradesh	1.01	0.05	0.66
Jharkhand	5.73	0.21	3.95
Karnataka	17.08	0.13	7.29
Kerala	5.01	0.01	2.02
Madhya Pradesh	32.85	0.17	14.45
Maharashtra	30.95	0.03	14.81
Manipur	0.47	0.0002	0.42
Meghalaya	1.51	0.0003	1.43
Mizoram	0.2	0.0	0.19
Nagaland	0.54	0.00002	0.52
Orissa	15.94	0.18	8.49
Punjab	16.98	0.24	1.82
Rajasthan	11.25	0.13	0.9
Sikkim	0.219	0.001	0.206
Tamil Nadu	19.51	0.15	6.86
Telangana	20.92	0.35	12.83
Tripura	1.09	0.0003	0.98
Uttar Pradesh	65.57	0.44	20.04
Uttarakhand	1.85	0.12	0.89
West Bengal	23.9	0.15	13.07
Andaman and Nicobar	0.557	0.001	0.549
Chandigarh	0.048	0.002	0.012
Dadra and Nagarhaveli	0.08	0.09	0.01
Daman and Dio	0.033	0.055	0.0
Jammu and Kashmir	4.46	0.05	3.36
Ladakh	0.08	0.0002	0.05
Lakshadweep Islands	0.005	0.0	0.002
Puducherry	0.18	0.01	0.05
Total	**407.219**	**4.01602**	**195.036**

Source: Central Ground Water Board, Department of Water Resources, National Compilation on Dynamic Ground Water Resources Of India, 2023, p135.

Table (4): Water requirements of various Indian industries in the years 2000/2025/2050 (million m3/year)

No.	Industry	Quantity of water required (million m^3)		
		2000	2025	2050
1	Iron and Steel	3829.1	6012.6	12035.1
2	Smelters	16.76	32.31	44.35
3	Petrochemicals and Refining (Refineries)	23.47	37.76	55.61
4	Chemicals (Caustic Soda)	8.65	12.67	19.07
5	Spinning, Weaving, and Jute	8153.72	36701.4	46923.5
6	Cement	600	1.778	3.371
7	Fertilizers	220.11	1105.09	1192.75
8	Leather Products	1244.65	93.08	147.83
9	Rubber	3.04	6.41	9.54
10	Food Processing	992	9.443	12.298
11	Inorganic Chemicals	165	3.346	615
12	Sugar	46	334	637
13	Pharmaceutical Formulation	124	276.15	429.15
14	Distillation (Required per 1,000 liters)	6357.2	318	5203.92
15	Pesticides	6.67	4.82	8.38
16	Paper and Pulp	1.26	10.24	19.49
17	Engineering Industries	1.433	28.0	56.0
Total		**21793.06**	**44987.1**	**67412.36**

Source: Government Of India, Ministry of Water Resources, Comprehensive Mission Document, 2008, P Iv37.



Source: Researcher's work based on Table (5)

Figure (4): Quantity of water required for the production unit (m3)

6.1. Sugar Industry:

The Indian sugar industry plays a leading role in the global sugar market. India is the world's largest sugar producer after Brazil, producing approximately 15% and 25% of the world's sugar and sugarcane production, respectively. It contributes significantly to the country's social and economic development. The sugar industry comprises 597 factories, 309 distilleries, and 213 cogeneration plants. The area under sugarcane cultivation is approximately 5 million hectares, which is approximately 3% of India's total arable land. This

Table (5): The quantity of water required for the production unit (m3) and the production volume (million tons) from various industries in the years 2000, 2025 and 2050

Industry	Amount of water required per unit (m^3)	Production quantity (million tons)		
		2000	2025	2050
Iron and Steel	22	174.1	273.3	547.1
Smelters	82.5	0.2	0.4	0.5
Petrochemicals and Refining(Refineries)	17.0	1.4	2.2	3.3
Chemicals (Caustic Soda)	5.5	1.6	2.3	3.5
Spinning, Weaving, and Jute	200	51.2	183.5	234.6
Cement	4.5	120	395	749
Fertilizers	16.7	17.3	66.2	88.4
Leather Products	30	1.3	3.1	4.9
Rubber	6.6	0.5	1	1.4
Food Processing	6.8	0.1	1.4	1.8
Inorganic Chemicals	200	3.7	16.7	30.1
Sugar	2.2	19.5	152	289.5
Pharmaceutical Formulation	25.0	5.0	11.0	17.2
Distillation (Required per 1,000 liters)	22.0	1.8	4.5	6.0
Pesticides	6.5	0.2	0.7	1.3
Paper and Pulp	200	5	51.2	97.5
Engineering Industries	2.2	6.5	12.6	25.3

Source: Government of India, Ministry of Water Resources, Comprehensive Mission Document, 2008, PIV38 .

area produces 300 to 350 million tons of sugarcane and 23 to 25 million tons of white sugar to meet domestic sweetener needs. This is in addition to approximately 2.9 billion liters of alcoholic beverages, 2,330 megawatts of power, and the production of numerous chemicals. The sugar industry is capable of exporting approximately 1,300 megawatts to the local grid. The Indian sugar industry is considered capable of meeting the demand for edible alcohol. For drinking as well as 10% of the gasoline mix, this industry also produces other than sugar, bio-electricity, bio-ethanol, bio-fertilizer, chemicals, and contributes about 1.1% of the GDP, the turnover of sugarcane, sugar and related economic activities is around 80-85 thousand crores, of which about 55-60 thousand crores are dues to sugarcane farmers, all of which made the Indian sugar industry have a major role in the global market (Solomon, 2014).

6.2. Pulp and Paper Industry:

The pulp and paper industry is one of the most water-intensive industries. India's paper industry accounts for 2.6% of global paper production. However, per capita paper consumption in India is 9 kg per year, which is

significantly lower than the global average of 58 kg per year and lower than the Asian average of 21 kg per year. Paper production in 2000 amounted to approximately 4.87 million tons, increasing to 10.11 million tons in 2010, an increase of 107.6% (Sharma, 2015). 6-3- The Indian Cement Industry:

India is the second largest producer of cement in the world, and the Indian cement industry is expected to achieve a compound annual growth rate of 8.96% during the period from 2014 to 2019. The housing sector is the largest cement consumer, consuming approximately 67% of India's total cement consumption. Infrastructure consumes approximately 13%, commercial construction 11%, and industrial construction 9%. An additional 56 million tons are expected over the three years following 2014/2015. Production will reach 395 million tons by the end of 2016, and is expected to reach 421 million tons by the end of 2017. Per capita consumption is approximately 190 kg. Large cement plants produce approximately 97% of India's total cement production, representing 188 plants, while 365 small plants collectively produce the remaining 3%. Large plants are concentrated in the states of Andhra Pradesh, Rajasthan, and Tamil Nadu produce approximately 350 million tons of India's total cement production (http://www.indianmirror.com/indian-industries/2015/cement-2015.html).

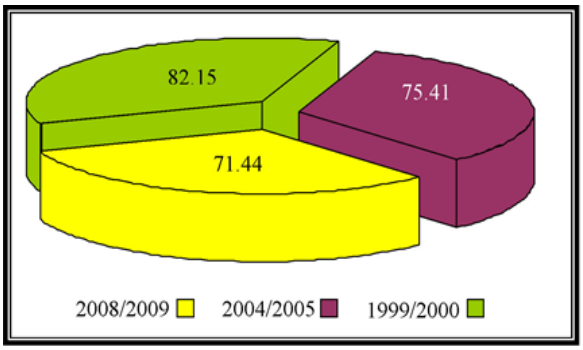
6.4. Textiles:

Textiles account for 14% of India's industrial production and approximately 17% of export earnings. The textile industry covers a wide range of economic activities. India is one of the world's largest exporters of yarn, contributing approximately 22% of the world's cotton yarn trade. Textile exports were valued at approximately Rs. 15,483.62 crore in 1992/93. Textile exports reached Rs. 51,337.34 crore in 2001/02, an increase of 231.5%, and reached Rs. 63,024.18 crore in 2005. In 2004/2005, textile exports accounted for approximately 28.84% of India's total exports in 1992/1993, declining to 16.79% of total Indian exports in 2004/2005 (Narayanan, 2009). Indian cotton textiles are characterized by their low prices, as most production is allocated to domestic marketing, while limited quantities are exported to neighboring Southeast Asian markets. Mumbai, Ahmedabad, and Madras are the country's most important cotton manufacturing centers (Al-Zouka, 2004). Industry plays an important role in the GDP, accounting for 26.4% in 2011. The iron and steel industry is one of the important industries that contributed to the industrial development witnessed by India, by meeting the needs of the country's large industries, such as the automobile, train, and military equipment industries. India has many factories for textiles, chemicals, food processing, transportation equipment, machinery, software, pharmaceuticals, cement factories, food industries, and textiles (Ibrahim & Abdul Wahid, 2015).

Table (6): shows the share of manufacturing exports in total Indian exports (million US dollars) for the years 1999/2000, 2004/2005, and 2008/2009.

Year	Manufacturing exports	Total Exports	Percentage of Manufacturing Industries in Total Exports(%)
1999/2000	30161	36715	82.15
2004/2005	62993	83536	75.41
2008/2009	130468	182631	71.44

Source: Handbook of Industrial Policy and Statistics, 2008-2009, p201



Source: Researcher's work based on Table (6)

Figure 5: Percentage of manufacturing exports to total Indian exports

Table (6) and Figure (5) show an increase in the volume of manufacturing exports from $30,161 million in 1999/2000 to $130,468 million in 2008/2009, an increase of 332.6%. The share of manufacturing exports declined from 82.15% in 1999/2000 to 71.44% in 2008/2009, a decrease of 10.71%.

Manufacturing contributes approximately 25% of the GDP and creates 100 million jobs by 2022. The annual growth rate of the manufacturing sector reached 18.4% of India's total industrial production in 2007/2008 (Algalaly, 2019).

Water use in industry is similar to domestic consumption in India. Water demand in industry increases with industrial development, and economic growth favors industry, which leads to increased demand for water. Rivers are the primary source of industrial water (41%), followed by groundwater (35%) and municipal water (24%). There are no accurate estimates of industrial water consumption. However, it is projected that industrial water requirements in 2050 will be 103 billion cubic meters. This could be reduced to 81 million cubic meters if water-saving technologies are widely adopted across industries. Industrial water prices also vary from state to state in India. The cost of water supply varies widely

and can range from Rs. 0.9 to Rs. 50/m3. In India, the cost of water consists of three components: excess water that pays for pollution, control panels, the cost of purchasing water from suppliers (municipalities), and the cost of extracting water from rivers and groundwater. There is no consensus on the range of industrial water demand, price elasticity, and the sensitivity of water demand to other factors, such as input prices and production levels. Analyzing the economic value (shadow price) of water, the average shadow price of water was found to be Rs. 7.21/kL. It varies between companies, from Rs. 1.4/kilometer for petrochemicals to Rs. 30.54/kilometer for paper and paper products. Industries are not only water consumers but also pollute water resources. On average, every liter of pollutant discharged pollutes approximately 5-8 liters of water, increasing water demand by 35-40%. Furthermore, there are no clear environmental policies and responsibilities are fragmented to control industrial pollution. This inevitably puts pressure on available freshwater resources, resulting in future water demand (Palanisami, et al., 2015).

7. indings and Recommendations

7.1. Findings:

- Traditional water resources contribute significantly to economic development.
- Regions that use effective water management practices reported higher productivity and resilience in industrial sectors.
- Many traditional practices promote sustainability, helping to maintain water quality and availability.
- Regions with strong traditional systems showed less vulnerability to water scarcity than those relying solely on modern infrastructure.
- Employment opportunities associated with water management and conservation practices increased, enhancing economic stability.
- Economic benefits varied significantly across regions, with states with richer traditional water management practices outperforming others in industrial growth.
- Water pollution and over-extraction threaten the sustainability of traditional resources.
- Lack of awareness and investment in traditional systems hinders their effectiveness in modern industrial sectors.

7.2. Recommendations

- Governments should integrate traditional water management practices into industrial policy frameworks to promote sustainability and economic efficiency.
- Develop policies that incentivize industries to adopt traditional water conservation techniques.
- Invest in infrastructure that supports traditional systems, such as rainwater harvesting and watershed management.
- Encourage public-private partnerships to finance sustainable water resource projects.
- Implement awareness programs that highlight the benefits of traditional water management.
- Educate the population about the economic advantages of sustainable water practices.
- Encourage research into integrating traditional practices with modern technologies to improve efficiency.
- Support innovation in water-saving technologies that are compatible with traditional methods.
- Establish monitoring systems to assess the health of traditional water resources and their impact on industrial development.
- Use data-driven methods to improve and enhance traditional water management practices based on observed results.
- Involve local communities in decision-making processes related to water resource management.
- Encourage community initiatives focused on sustainable water use and conservation.

References

Abu Al-Ezz, M., Safi al-Din, (1989). Economic Resources, *Dar al-Nahda al-Arabiya, Cairo*.

Algalaly, I. A., (2017). Water Resources Economics and its Impact on Economic Development in India, Master's Thesis, *Institute of Asian Studies and Research, Zagazig University*.

Algalaly, I. A., (2019). Water Resources and Their Economic Role in the Energy and Industrial Sectors in India, *Journal of the Faculty of Arts*, Port Said University, Issue 13.

Al-Zouka, M.Kh. (2002). Water Geography, Second Edition, *Dar al-Ma'rifah al-Jami'ah, Alexandria*.

Al-Zouka, M. Kh., (2004). Asia, A Study in Regional Geography, *Dar al-Ma'rifah al-Jami'ah, Alexandria*.

Central Ground Water Board, Department of Water Resources, *National Compilation on Dynamic Ground Water Resources of India*, 2023, p135.

Data.Worldbank,2023.

Gharib, S.R., (2005). The Role of Agrarian Reform in Economic Development in India, Master's Thesis, *Asian Institute, Zagazig University*.

Government of India, India Meteorological Department, (2021), p145,146

Handbook of industrial policy and statistics, new delhi, 2008-2009.

Institute for Defense Studies and Analyses, water security for India (2010). *the external dynamics, new Delhi*.

International Water Management Institute, Colombo, Sri Lanka, (2007).

Narayanan, K., (2009). The Indian Textiles and Clothing Industry and Innovation Policies, Innovation Policies and International Trade Rules, The Textiles and Clothing Industry in Developing Countries, *Palgrave Macmillan, UK*.

Palanisami, K., Kakumanu, K. Reddy, Ravinder P.S. Malik, (2015). Water Pricing Experiences in India: Emerging Issues, Water Pricing Experiences and Innovations, *Springer International Publishing Switzerland*.

Sadiq, A.K., and Barghouthi, Sh., (1997). Water Resources and Uses in the Arab World, Kuwait, p. 482.

Sharad, K.J., Pushpendra, K.A., Vijay, P.S. (2007). Hydrology & Water Resources of India, *Water Science and Technology Library*, *Dordrec*ht, The Netherlands.

Sharma, A. K., (2015). Potential of Solar Energy Utilization for Process Heating in Paper Industry in India: *A Preliminary Assessment*.

Solomon, S., (2014). Sugarcane Agriculture and Sugar Industry in India: At a Glance, Sugar Tech, *Indian Institute of Sugarcane Research*, Lucknow 226 002, 16(2).

Water Related Statistics Directorate Information System Organization Water Planning & Projects Wing Central Water Commission, October, 2021, P6

Youssef, H. El-Sayed, (2013). The impact of water resources on agriculture and tourism in the Republic of India, PhD thesis, Asian Institute, Zagazig University.

Websites:

http://www.indianmirror.com/indian-industries/2015/cement-2015.html.

https://ar.wikipedia.org/wiki/%D8%A7%D9%84%D9%87%D9