Sustainable Water Resource Development in the Indian Scenario

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Abstract A period of increasing competition for water supplies has increased the risk of water contamination and environmental deterioration, and rising social, economic, and environmental expenses are all affecting water resources. The water shortage in India seems to be becoming worse rather than better. In order to meet the challenges posed by this situation, water professionals and managers need to adapt their thinking about water in a way that is sustainable. Due to the distinctive characteristics of water, which include its necessity for human existence, economic growth, and environmental conservation, as well as the large number of stakeholders involved, this is particularly challenging. A number of difficulties confront those in charge of these essential resources today, highlighting the significance of managing water resources sustainably. This study aims to provide an overview of water scarcity and its sustainable development in the context of India. The significance of this study is to avert this crisis by applying sustainable development, a water management concept that emphasizes the significance of using less water than could be produced or replaced, maximizing positive economic benefits, minimizing negative social and environmental impacts, protecting natural systems, and ensuring that future generations will not have to compromise on their water needs.

Keywords Water Resources, Water Policy, Sustainable Development, Indian Scenario, Water Pollution, Environmental Deterioration

Cite This Article Saha S. Strategies Sustainable Water Resource Development in the Indian Scenario. Cross-Border Trade and E-commerce. 2023, 2(2): 37-47. https://doi.org/10.55571/cte.2023061

Received: June 12, 2023 / Accepted: June 24, 2023 / Published: July 30, 2023

Introduction

Water is a precious natural resource that is being depleted more quickly than it can be replaced. As demand for this essential commodity continues to grow, the available water is decreasing at an alarming rate. India

leads the world in terms of irrigated land, but one-eighth of its land is flood-prone, and one-sixth experiences drought. The main culprit behind India's water shortages is the monsoon season. Crops need a lot of water to grow, especially during the summer, and as a result, urbanization, industrialization, and modernization all contribute to increasing demand for this essential liquid. Along with household waste removal needs, issues such as sewerage infrastructure have made it difficult to meet demands without compromising our water supply. According to the World Bank, despite making some progress on poverty reduction in recent years, a shocking 52% of India's population still lives below the middle-class income level.

The excessive privatization of government solutions has also made them vulnerable as a result of India's rapid urbanization. Even if the quality of drinking water has improved, many more water sources are contaminated with chemical and biological contaminants, and over 21% of illnesses in the country are connected to water. Moreover, just 33% of the population has access to traditional sanitation. One worry is that India may not have sufficient long-term access to replenishable water supplies. As with other countries with substantial agricultural output, overuse of water for food production depletes the entire water table. Drilling wells is sometimes the only option for many rural villages in India located on the periphery of urban sprawl to access groundwater sources. However, any water system contributes to the overall loss of water. Increased corporate privatization, industrial waste, and personal waste are frequently blamed for India's water shortages.

There are still areas with a fairly rainy climate in India's driest regions. Nevertheless, the majority of the water is either lost through transfer or evaporation since there are no rain collection plans in place. In these areas, rainwater harvesting may be one method of obtaining water. With better filtration techniques to reduce the risk of water-borne infections, the collected water can also be made promptly available for human consumption.

Water Resources in India

One of a nation's most important resources is its water supply. India receives roughly 4000 BCM (Billion Cubic meters) of precipitation every year (Figure 1). The absurdity of the situation is that Mousinram, which is next to Cherrapunji and receives the highest rainfall worldwide, also experiences a water shortage during the dry season almost every year. India's rainfall is incredibly variable both geographically and temporally. 1953 BCM is thought to be the average annual flow for all Indian rivers. 432 BCM is estimated to be the total yearly replenishable groundwater resources (Pathak *et al.,* 2014). Surface water and groundwater resources that can be used annually in India are estimated to be 690 BCM (Figure 11.1) and 396 BCM, respectively.

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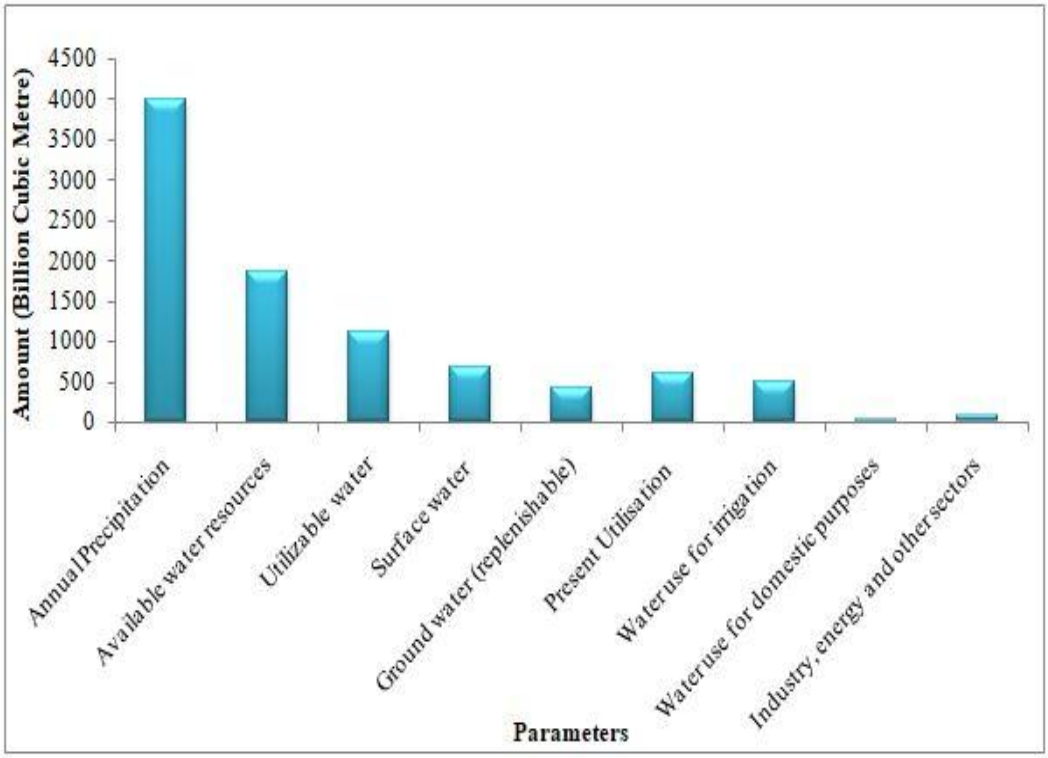

Figure 11.1. Indian water resources

There is increasing pressure on our water resources as the population continues to grow and economic conditions improve. The per-person availability of resources is decreasing day by day (Figure 3). Due to regional and temporal variations in precipitation, the issue of flood and drought syndrome exists throughout the country. The overuse of groundwater is causing groundwater supplies to decline, rivers to flow more slowly, and saltwater intrusion in aquifers near the coast. Waterlogging and salinity have occurred as a result of excessive canal irrigation in some of the command regions. Rising pollution loads from point and non-point sources are deteriorating the quality of both surface and groundwater resources. Precipitation and water availability are expected to be impacted by climate change (Kumar *et al.,* 2005).

Water holds a special place among all renewable resources in the world. It is necessary for the continuation of all living forms, the production of food, the growth of the economy, and overall health. Since it can be diverted, transported, stored, and recycled, water is also one of the most manageable natural resources. All of these characteristics provide water with tremendous human benefit. Agriculture, hydropower generation, livestock production, industrial activities, forestry, fisheries, navigation, leisure activities, etc. heavily rely on surface water as well as groundwater resources of the nation. According to National Water Policy (2012), irrigation, drinking water, hydropower, agro-sectors, ecology, non-agricultural industries, and navigation should be given priority in the development and operation of systems.

India receives 4000 BCM of precipitation annually, including snowfall. Rainfall during the monsoon is approximately 3,000 BCM. India's rainfall is influenced by the southwest and northeast monsoons, local storms, and shallow cyclonic depressions and disturbances (Bhattacharyya *et al.,* 2015). Except for Tamil Nadu, which is influenced by the northeast monsoon during October and November, the majority of rainfall occurs between June and September under the influence of the southwest monsoon. India has a river system that includes more than 20 major rivers and several tributaries. Some of these rivers are seasonal, while others are perennial (Gangwar, 2013). The Himalayas are the source of rivers like the Ganges,

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Brahmaputra, and Indus, which transport water all year round.

The Himalayan snow and ice melt, as well as the base flow, are responsible for the flows during the lean season. According to Lal (2001), the many tributaries of these river systems contain more than 50% of India's water resources. The average water supply per unit area of the Himalayan rivers is about twice as great as that of the southern peninsular river system, highlighting the significance of the high mountains' contribution to snow and glacier melt. In addition to the water found in the nation's numerous rivers, groundwater is another significant supply of water for drinking, agriculture, industrial applications, etc. It supplies more than 73% of all irrigation in the nation, as well as around 5% of the water needed for domestic use (Figure 11.2).

Water for irrigation is just as important as water for drinking since both are necessary to increase food production, care for livestock, and ensure enough food for the expanding population. Population expansion is a major concern, as everyone is aware, because it will further reduce future per capita water supplies (Kumar *et al.,* 2005) (Figure 11.3). Despite having a reasonable distribution of rainfall, the country currently struggles to effectively utilize rainwater due to a lack of understanding and inadequate infrastructure for building dams and reservoirs. In order to harvest 1-2 crops every year, just 35-40% of the cropland is irrigated. Numerous rivers in India are used for hydropower generation in addition to irrigation. Due to challenging sites, concerns about protecting forests, interstate problems, subpar execution, and a lack of commitment, the country is currently having a tough time realizing its full potential. It is also feasible to create projects with multiple uses, such as those for irrigation and power generation, which can increase water supply while enhancing project viability.

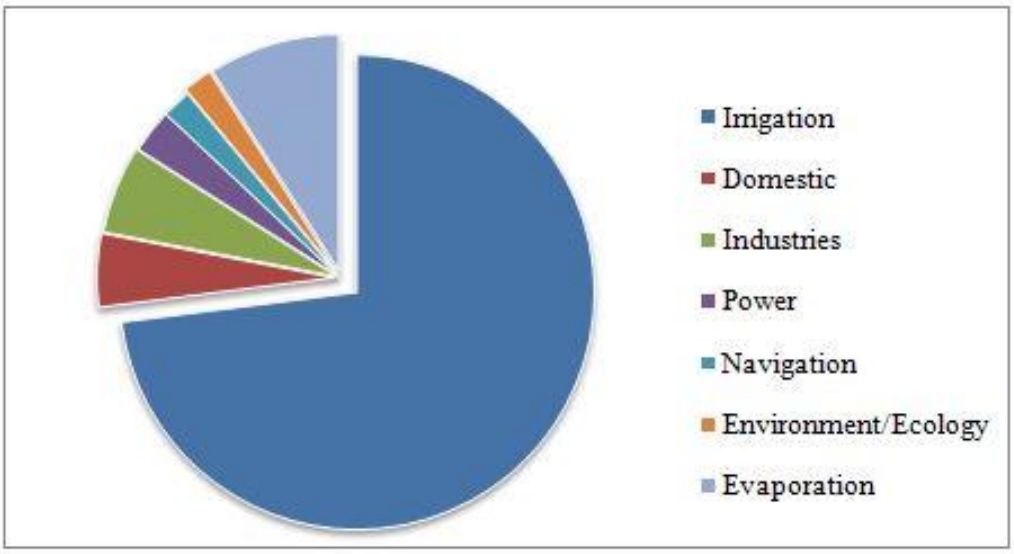

Figure 11.2. Demands of water for several uses in India

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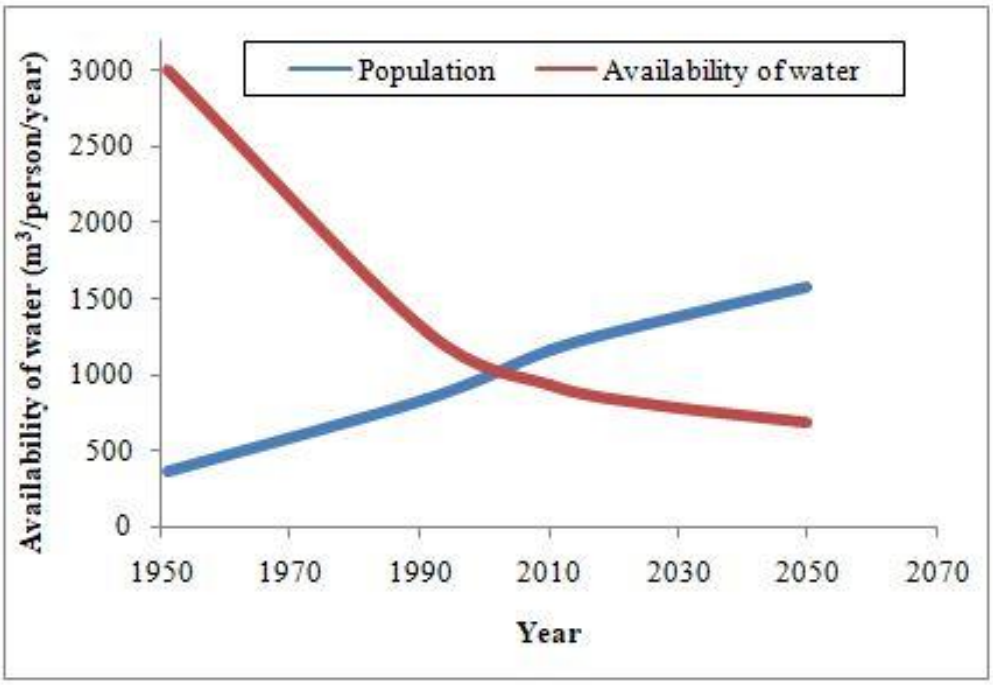

Figure 11.3. India's per-person water availability

human health and water supply. Although only 5% of the country's entire water is utilized for household purposes, 27% of India's villages and 4-6% of its urban population lack access to clean drinking water. In addition to the insufficient water supply, there is a big concern about water quality, which is negatively affecting people's health. The main contributors to water pollution are the release of untreated sewage as well as industrial pollutants into rivers, excessive use of fertilizers in agricultural land, and the inclusion of salts and minerals from lower soil profiles in groundwater. According to estimates, daily sewage production in New Delhi alone is 36 million tonnes, of which only 50% is treated before being released into the Yamuna River. The same is true for other remaining cities. 23 significant cities produce sewage, yet only 31% of it is treated; the remainder pollutes 18 significant rivers across the nation. Additionally, various hazardous metals, nitrites, and fluorides are present in the majority of the nation's rivers. More than 66 million individuals currently have fluorosis as a result of drinking water with a fluoride content of more than 1.5 ppm (Ayoob and Gupta, 2007). Another factor contributing to the contamination of drinking water sources is poor sanitation, both in urban and rural regions.

The amount of groundwater that has been contaminated by the excessive use of chemical fertilizers and pesticides cannot be determined with any degree of accuracy. Increased fertilizer application is simply one aspect of the issue; excessive irrigation water use is another. Because of this, nearly all well water utilized for drinking purposes in irrigated areas is contaminated. Due to water reaching lower soil layers and salts contained in this area being diffused in water, over-irrigation has also been reducing soil productivity. These salts then go through capillary action to the topsoil. High concentrations of such soils transform them into desiccated wastelands unsuitable for agricultural use. Currently, more than 9 million ha of rich irrigation-based lands have degenerated into wastelands, where the water is highly salinized and unsuited for both human consumption and agricultural productivity. The prevalence of ailments is great because those who live in these communities use such hard water in a helpless manner.

Water Resources Development

Water is essential for life, as it is necessary for the survival of both plants and animals. Water serves various purposes, including food security, livestock care, maintaining organic life, conserving biodiversity, and preserving the environment. Without it, life on Earth would not exist. Geological evidence suggests that water has never dried up on our planet, and it exists in different forms, including as plant life. However, due to reckless human behavior, many areas around the world face severe water shortages. Without appropriate corrective measures, India alone will soon experience a crisis in food and water security. Due to the burgeoning human population and various other factors, water has become increasingly scarce in India. This necessitates swift action by those responsible for managing the country's water resources. Water has been abundant for centuries, but with population growth and technological advances, water consumption has become more rampant, and a shortage of good-quality water is now looming. The world is facing a water crisis, with some countries having too much water while many others are running out. This problem is only going to get worse as the population continues to grow in different parts of the world. Over the years, water usage has been largely dependent on culture, lifestyle, and industrial development, and water was never seen as a serious concern. In addition to being used for fisheries, hydropower generation, transportation, conserving biodiversity and ecological balance, agriculture, industrial production, and home uses account for the majority of water usage (Integrated water resources development (1999).

The National Water Policy (NWP)

India updated NWP in 2012 (National Water Policy, 2012) with key elements listed below:

(i) Facilitating the conversion of existing water resources into usable water

(ii) Establishing data banks at the national and state levels to track demand and supply.

(iii) In order to ensure sustainable development, water should be wisely allocated for different uses and prices.

(iv) Groundwater extraction should be regulated, and the water table should be closely monitored utilizing the latest scientific approaches.

(v) All interested parties and neighborhood groups should be included in maintaining the current water bodies.

(vi) PPP (Public Private Partnership) for water projects should be used.

(vii) A comprehensive flood control strategy that promotes soil conservation measures and links several rivers.

(viii) Improvement of drought-prone areas through the creation of watersheds, reforestation, and sustainable agricultural methods

(ix) A policy for interstate water sharing and prompt resolution of issues.

The environment has radically changed over the past ten years, and the water sector's development has not kept pace with expectations. Therefore, it was deemed necessary to make additional revisions to the policy, especially in the following areas:

Proposed modifications to NWP

1) ***Agriculture Industry***

(a) Increasing the efficiency of water use

(b) Acquisition of watershed management and rainwater collection as well as storage strategies

(c) Reducing subsidies for electrical supply, especially for water pumping

(d) Groundwater exploitation can be stopped by implementing differential prices, incentives, and penalties.
(e) The National River Link project is now being implemented. The project will connect 30 rivers as well as canals in order to provide water amounting to 175 trillion liters.
2) ***Industrial Sector***
(a) Encourage the development of new water-saving technology
(b) Promote industrial wastewater recycling as well as treatment through regulations and financial incentives.
3) ***Domestic Sector***
(a) The acquisition of legislation mandating that cities collect rainwater
(b) Spreading water efficiency
(c) Raising public awareness of the need for water conservation

Elevation of Water Resources

The majority of people, particularly those who depend on agriculture and live in poverty, will be most negatively impacted by India's increasing water use. The ecosystem, biodiversity, and food production will all be affected by water scarcity. The degradation of the environment will accelerate global warming, which will in turn worsen the water crisis. This deadly cycle exists, and the only way to solve this problem is to utilize every accessible source of water, save it for future use, and improve water use efficiency. The aforementioned can be accomplished by attending to innumerable issues and launching appropriate activities for the creation of new sources of water, the expansion of current resources, the protection of water from contamination, and the enhancement of water usage efficiency across all provinces. According to Integrated Water Resources Development (1999), the following projects should get underway in order to increase the availability of water resources.

Growing the Storage Capacity of Water

Percolation tanks, farm ponds, small and medium-sized dams, water reservoirs, and rivers can hold additional surface water during groundwater recharge, which increases. A series of contour bunds, especially in sloping landscapes, will enhance the groundwater table and promote water percolation through the soil while lowering soil erosion. Insufficient soil and water conservation efforts are causing acute erosion of soil, silting of riverbeds, and reservoirs, and recurrent flooding throughout the nation, since precipitation cannot be collected in forests and deforested high terrains. Serious deforestation is one of the main causes of soil erosion and river silting. Many rivers have been altering their courses virtually annually as a result of soil erosion, harming productive agricultural fields. A notable example is the Brahmaputra, whose breadth varies from 3 to 4 km in the summer to 10 to 12 km in the wet season. The aforementioned demonstrates the amount of river flooding and harassment of those who live along the river. 22 billion m3 of this river's water only can be utilized, however, more than 607 billion m3 of water are squandered as a result of inadequate management (National Water Policy, 2012). Other rivers, like the Ganga, Mahanadi, Godavari, Narmada, etc., are subject to comparable conditions.
The country's water distribution will be improved while floods are prevented by connecting the rivers. Soil erosion can be avoided by controlling floods and water flow. Currently, our forests and valuable agricultural fields are losing billions of tonnes of rich soil together with priceless nutrients. In actuality, the quantity of nutrients lost as a result of the erosion of soil is about equal to the amount of artificial fertilizers made in the nation. This demonstrates how controlling soil erosion affects food output. Reforestation of damaged forests and the creation of wastelands through afforestation will assist in soil and water

conservation. Water scarcity can be avoided by a careful distribution of water among various users. Strong lobbyists and entrenched interests have an influence on how water is distributed for various reasons. At the expense of other sectors, many receive more water than is necessary. The sites for framework development are frequently impacted by individuals who possess political clout and have vested interests, even in the same industry, such as agriculture irrigation, depriving others in poor regions. Proper investment strategies must be created based on demands and profits from investing to combat such inefficiencies and resource waste. With the implementation of a program with a transparent procedure and frequent quality control checks, the projects' pace and quality can be boosted.

Efficient Irrigation Practices

If a nation desires to address the dilemma of the crisis of water, irrigation efficiency is crucial. Over 70% of the water utilized for irrigation is lost because flood irrigation is used to irrigate the majority of crops. Farmers also have the propensity to flood the field with excessive amounts of water without incurring any additional costs because the water provided is not metered. Such a method has an adverse effect by increasing the cost of leached nutrients, contaminating groundwater, increasing soil salinity, and increasing pests and illnesses. The farmers should use micro-irrigation techniques, which will expand the area irrigated while lowering production costs and reducing the amount of water needed. Metered irrigation water supplies, cost recovery for water usage, promotion of micro-irrigation techniques, and participation of users' groups for water in the distribution of water would all greatly improve the efficiency of water use while lowering agricultural production costs.

Watershed Development

To maximize the application of rainwater for agricultural output while enhancing soil and biodiversity conservation, watershed development is a crucial initiative. Under the watershed development program, a basin's catchment area is treated as a group in an endeavor to treat the soil from the ridge to the valley to capture rainfall. It is projected that more than 63% of the land area used for agriculture in rain-fed regions needs to be included in the development of watersheds to conserve soil and water, increase agricultural yields and groundwater levels. In the final year of the tenth five-year plan, the watershed development program, which was first implemented nearly thirty years ago, covered more than 51 million acres. However, due to subpar soil conservation work done in the past and the deficiency of coordination to further agricultural development operations, a significant number of watersheds continue to experience high soil erosion.

Water Pollution Management

Excessive use of water in homes, industries, and agriculture is contributing to water contamination as this extra water is converted into effluent, sewage, or saltwater. Therefore, it is important to design rewards and penalties to motivate people to make judicious use of the few water resources available. In addition to pursuing and enforcing wastewater recycling, it is required to forbid the discharge of effluent and sewage into bodies of water and rivers. This will keep water sources clean and reduce the future need for water. Agriculture and industrial output can benefit from the use of treated sewage and effluent.

Desalination of Sea Water

 https://doi.org/10.55571/cte.2023061

The looming shortage of freshwater can be addressed by economically desalinating seawater, especially for human consumption, as more than 70% of the world's water resources are already salty. Seawater desalination (Figure 11.4) is currently costly and unpopular. However, desalination can be a practical solution with solar power to address water needs in coastal locations.

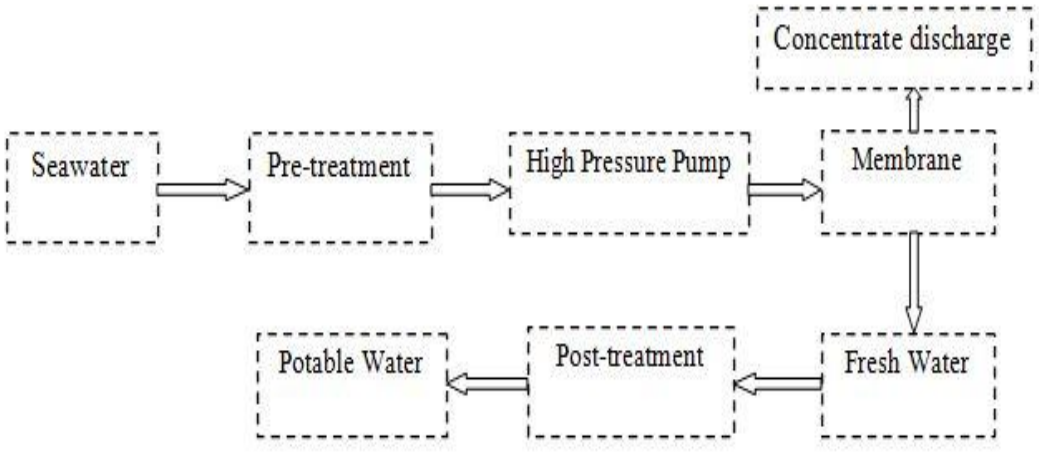

Figure 11.4. Flow chart of desalination of seawater

Research and Development

In order to create crops and varieties that can withstand the changing climatic circumstances brought on by global warming, it is important to fund studies on weather prediction, breeding water efficient as well as drought-resistant crops, and groundwater monitoring.

Actionable areas of Priority

The following actions must be taken immediately because time is running short:

(i) Irrigation projects should be carefully designed, and a number of programs should be started at the same time, such as providing aid as well as rehabilitation to project-affected populations, managing land usage at the microscale, and enhancing farmer capacity.

(ii) To encourage the conservation of soil, recharge of groundwater, and prevent flooding of rivers, and silting of water reservoirs, priority should be given to replanting on degraded wastelands, riverbanks, and woodlands.

(iii) If careful forethought is placed into water meter distribution, water is priced sensibly to cover costs, and investments are made in micro irrigation systems, irrigation efficiency can be increased with ease. Farmers should be educated on the necessity of water judicious use and conservation, which is required for achieving sustainability.

(iv) Development of the 80 million hectares of wastelands, which is accelerating erosion of soil, and surface runoff water, as well as increasing productivity in these arid regions, will aid in water conservation while enhancing food production and biodiversity.

(v) Enhancing local capacities by training the next generation of water management managers and professionals to carry out various innovative projects more successfully. Additionally, there is a need to support multidisciplinary researchers that are interested in researching several facets of water resources, including conservation, effective storage, loss reduction, and sustainable use.

(vi) Both Farmers' Organizations and Civil Society Organizations can assist small farmers in implementing cutting-edge technologies and creating the forward and backward linkages necessary to boost their income.

(vii) Diverse developmental programs coming together can increase outputs. The Ministries of Water Resources Development, Agriculture, and Rural Development carry out several development programs that are coordinated at the local level by a single organization to promote efficient resource use and greater impact.

Conclusions

India's water supply is going to present significant challenges for several reasons. The biggest worry is the population growth, which is expected to reach 1.66 billion by 2050. Another issue is excessive groundwater use. In many coastal areas, fertile agricultural grounds have been rendered unsuitable for cultivation due to the excessive intrusion of seawater. Even though India has enough water resources to meet the country's expanding demand, it is nevertheless imperative to solve these pressing challenges that are limiting the supply of water. According to estimates, more than 70% of irrigation water is lost since other dry areas aren't given irrigation. To significantly alleviate water shortage, it is important to move from flood irrigation to micro irrigation and to enhance water usage efficiency (Rosegrant *et al.,* 2002). Water scarcity can be avoided by carefully distributing water among various users. India falls well short of the majority of affluent nations when it comes to the efficiency of water use in agriculture. This is caused by a variety of factors, including inefficient water conservation techniques, crop varieties that require more water, flood irrigation, and overwatering. Crops will require more water because increased evapotranspiration will come from global warming. The nation's denuded wastelands and forestlands, which total more than 60–80 million ha, are unable to collect rainwater, which would have ensured groundwater replenishment and biodiversity preservation. Because of this, the rivers that run from these mountains are unable to maintain their water flow all year long. Heavy soil erosion is causing floods, which have also forced rivers to modify their paths. In the future, such rivers won't be able to support agricultural development.

Therefore, it is essential to avert this crisis by utilizing all available technology and resources to preserve water resources already in place, transform them into usable forms, and effectively utilize them for human consumption, industrial production, and agricultural usage. Water conservation will benefit from the implementation of legislative restrictions to stop water waste and the introduction of rewards and penalties to promote wise water use. It is also necessary to conduct hydrological studies to evaluate water resources under different climatic situations. The country can eventually weather the water crisis if all water consumers are made aware of it and encouraged to adjust their lifestyles to conserve water. The difficulty can be overcome as long as we have effective policies and tools to urge our population to change their way of life.

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