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# India's Groundwater Crisis: The Consequences of Unsustainable Pumping

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**Key Points**

- India's groundwater usage is the highest in the world and supplies 85 per cent of drinking water in rural areas.
- Most groundwater is used for agricultural irrigation and an improvement in the industry's water efficiency is essential for reducing groundwater demand.
- The depletion of groundwater resources is affected by both demand-side practices and the specific hydrogeological settings of the aquifer. Depletion primarily occurs in north India's alluvial systems and peninsula India's crystalline systems.
- Despite major challenges, solar desalination, wastewater management and groundwater recharge provide opportunities for improving India's water security.

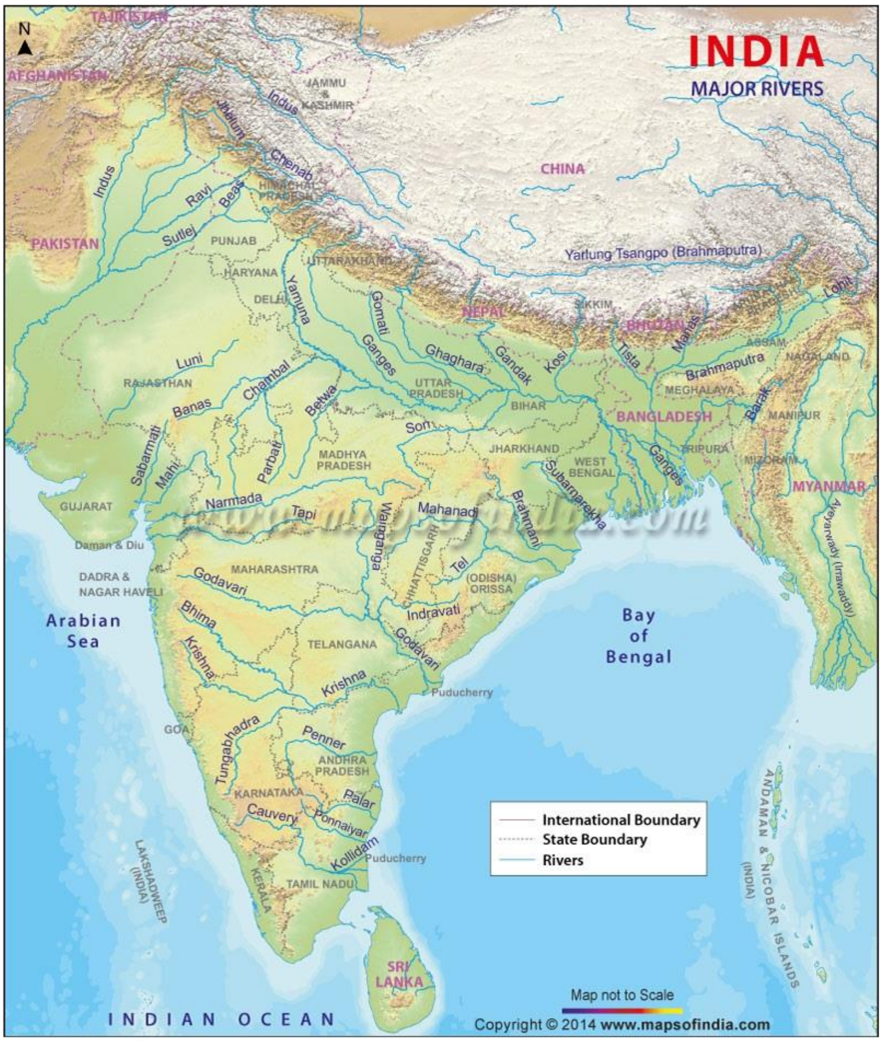
**Summary**

India is the largest consumer of groundwater in the world and, because its rate of extraction has remained high, groundwater replenishment has been unable to sustain water levels in many of the country's aquifers. At the same time, contamination is a serious problem throughout the country and many key agricultural regions suffer from both groundwater overexploitation and pollution. Water security problems have worsened with the ongoing drought that has been declared in eight states.

## Analysis

India is the world's highest user of groundwater. It consumes over a quarter of the global total - equivalent to 230 cubic kilometres per year. Groundwater from over 30 million access points supplies 85 per cent of drinking water in rural areas and 48 per cent of water requirements in urban areas. Most groundwater is used for irrigation, which accounts for 88 per cent of total groundwater usage. Groundwater is required for the daily needs of around 700 million Indians living in the country's villages. An assessment of 6,607 groundwater units in 2011 found that 1,017 were "overexploited", indicating the rate of groundwater extraction exceeded replenishment. Around one-third of all units in India were under stress. The World Bank predicts that by 2032, around 60 per cent of aquifers in the country will be in a critical state.

Groundwater resources in India are further deteriorating due to high levels of contamination, most prominently fluoride, arsenic and saline. Contamination and over-extraction are compounding problems, as over-exploitation causes a higher concentration of pollutants in groundwater resources. Regions with stressed aquifers are generally more susceptible to water quality problems. The socio-economic implications are severe in the long term, as groundwater problems are concentrated in provinces with large populations and high agricultural productivity. Groundwater is an essential component of India's water security, not only due to of its predominance in drinking water and agricultural irrigation, but also because groundwater becomes a critical water resource during periods of surface




*Source*: Maps of India

water scarcity. As a "buffer" water resource, groundwater will be increasingly important as monsoon rainfall patterns become more unpredictable due to the effects of climate change. Groundwater depletion, as a result, has severe consequences on India's water security, food security, health and the livelihoods of its population.

**North-west India**

The Indus and Ganga basin regions of north-west India experience a combination of high levels of groundwater dependency, aquifer stress and agricultural output. In 2015, a Water Resources Research study found that the Indus basin aquifer was the second-most overstressed in the world. In Delhi, Haryana, Punjab and Rajasthan, aquifer extraction exceeds the rate of recharge and groundwater is subsequently "overexploited". Haryana, Punjab and Uttar Pradesh also experience high levels of arsenic contamination.

The hydrogeological settings of groundwater in north-west India is made up primarily of alluvial aquifers in the Indo-Gangetic plains. Mountainous systems are also predominant in the northern-most states of Uttarakhand and Himachal Pradesh, but the alluvial systems experience the most significant extraction levels in the north-west region. In north-west India's alluvial systems, groundwater is stored in the unconsolidated sediments of the Indus-Ganga river basin. As these aquifers are large, many villages, towns and cities utilise and compete over the same groundwater resource. Users are able to tap into the Indus-Ganga aquifers through a generally uncontrolled system of wells and can make relative gains in groundwater extraction over neighbours by increasing pumping rates and digging deeper wells. Over the long term, however, the water security of all users is deteriorating as aquifer levels fall from overexploitation. Due to the aquifer's large storage size, a depleted alluvial source is difficult to revitalise as this can only occur through regional large-scale recharge. Elevated alluvial areas such as Punjab and Rajasthan have an additional groundwater challenge from the aquifer's deep water tables. Most of India's groundwater is less than ten metres below ground level, but in these areas groundwater can be up to 40 metres below ground level, requiring sophisticated pumping equipment.

The most dire groundwater problems are located in the states that India is most dependent on for agriculture. Since the Green Revolution of the 1960s, Punjab and Haryana have developed into India's "breadbasket". The proportion of overstressed groundwater units in Punjab and Haryana, however, are the first and third highest in India at 77 per cent and 59 per cent, respectively. Depletion in these agriculturally intensive areas is primarily due to the high rate of extraction for irrigation - around 95 per cent of groundwater is used for farming in north-west India. Water efficiency for agriculture in India is relatively poor. By comparison, China uses less than half the amount of water that India uses for the same output of rice, wheat and cotton. To secure India's food security in the long term, policies must address the low water efficiency of its agricultural sector.

**North-east India**

North-east India's groundwater is provided by the alluvial systems of the east Indo-Gangetic plains and the Brahmaputra basin, with mountainous systems in the most north-western areas and crystalline systems in Jharkhand and parts of West Bengal. North-east India has significantly lower levels of groundwater dependency and development than north-west and south India. In West Bengal, for example, only 19 per cent of units were found to be 'critical' or 'semi-critical'. Many of the state's groundwater resources are underutilised, largely due to high energy costs, high poverty rates and state regulation. The West Bengal Groundwater Resources Act 2005 states 'no user shall sink any well for extracting or using groundwater without obtaining a permit'. West Bengal is a unique state in India in which opportunities remain for sustainable groundwater expansion.

North-east India has particular problems with groundwater contamination. The region's groundwater has the highest iron concentration in India, according to tests by India's Central Ground Water Board in 2015 and 2016. The permissible limit of iron concentration is 0.3 milligrammes per litre; in Assam, concentration of iron was typically 1-3 milligrammes per litre and exceeded 3 milligrammes per litre in the Brahmaputra valley. A 2010 study of groundwater in Golaghat in Assam found that 76.4 per cent and 67 per cent of samples contained levels of iron and arsenic above the acceptable limits provided by the World Health Organisation, respectively. Contaminations of this level present serious health and water security risks to the population, including the heightened risk of cancer. While north-east India has large groundwater reserves, they might not be usable – without costly treatment – due to high levels of contaminants.

**South India**

South India's hydrogeological settings are varied between crystalline, volcanic and sedimentary systems. Peninsula India's groundwater depletion problems primarily occur in the crystalline systems of the Godavari, Krishna and Cauvery basins. This typology and its implications for groundwater differ greatly from the alluvial systems of northern India's Indus-Ganges-Brahmaputra basins. Crystalline aquifers are shallow with low storage, which results in a lower number of users per aquifer. The consequences of aquifer overuse are localised and the effects of depletion are more immediate than in alluvial systems. Contamination also occurs over a shorter period. Users of crystalline aquifers are more vulnerable to the effects of unsustainable competition, worsening the aquifer's inequitable usage. The rocks' low permeability and porosity means that groundwater recharge from rainfall is slow and limited. Addressing groundwater depletion in the crystalline systems requires a community-based approach; state-based approaches are likely to be ineffective due to the localised nature of the aquifers and the difficulty of managing the millions of wells in south India.

Prior to India's rapid increase in groundwater usage, crystalline aquifers were adequately recharged during the monsoon season. Water tables in southern India, however, have steadily fallen since 1980 from the shift towards greater groundwater usage. Tamil Nadu has experienced the worst water insecurity in the peninsula. According to a Water Resources Management study, the rate of groundwater depletion in Tamil Nadu between 2002 and 2012 was eight per cent higher than average annual recharge, largely due to the state's growth in groundwater usage for agriculture. In the state capital Chennai, groundwater levels fell 8-10 metres following the 2003 and 2004 drought. By 2004, 95 per cent of wells on small farms in Tamil Nadu were dry and in the years following, irrigated land area in the state has halved.

**Policy**

The severity of India's groundwater problems requires immediate and diverse solutions. India's water security will only be improved by addressing both demand and supply issues with policies ranging from top-down regulation to pragmatic approaches to the specific needs of individual communities. The varied hydrogeological settings of the country's overstressed aquifers require case-specific management policies. The large alluvial aquifers are best managed at a regional level, while community-based approaches are required for the smaller aquifers of south India's crystalline systems. Groundwater management is challenged by the urgent need to reduce the ratio of groundwater extraction to replenishment, while also recognising the resource's vital role in the water supply for millions of people, especially in rural areas.

Groundwater in India suffers from the "tragedy of the commons", in which there are little effective restrictions on overexploiting the largely unregulated common good. Unsustainable pumping through wells affects all users of the aquifer. The problem is worsened by existing rules on groundwater access that give landowners the right to pump on their land, while not being legally liable for the source's deterioration. This disproportionately affects the millions of Indians that do not own land but rely on groundwater for their water needs. India's Ground Water Board is responsible for identifying deteriorated groundwater units, but lacks the power to restrict the landowner's rate of extraction. In addition, enforcement of groundwater governance suffers from the overarching challenge of regulating over 30 million wells throughout India.

Regardless of enforcement challenges, groundwater regulations are needed to address the problem from a governance perspective. West Bengal's relatively low levels of overexploitation can be partly attributed to its existing groundwater regulatory regime. This model, however, cannot be simply transferred to into countrywide legislation. West Bengal has relatively low agricultural productivity and high poverty rates. Following a period of strong agricultural growth in the 1980s, growth slumped in the 1990s and the total number of groundwater units declined in the early 2000s. Enforcing groundwater legislation in West Bengal poses fewer complexities than in highly dependent states such as those in the north-west. Legislation, therefore, must be based on a pragmatic approach to the specific conditions of each state and municipality.

Demand for groundwater is dominated by agricultural irrigation, yet the industry is relatively water inefficient. Government policies of power subsidies and irrigation equipment credits for farmers, while acting as an enabler of India's agricultural growth, have contributed to the overexploitation of groundwater. Government policy to address this issue is politically sensitive. Any cuts to agricultural subsidies may reduce groundwater wastage from a purely economic perspective, but will likely target rural Indians who already suffer greatly from water insecurity. Despite these socio-political implications, India's unsustainable groundwater extraction requires demand-side measures to regulate usage. An improvement in irrigation technology and a shift towards efficient crops in overstressed areas are important measures to reduce demand for groundwater in agriculture.

Replenishing the aquifers in overexploited areas is essential for groundwater to become a reliable and sustainable water source in the long term. Artificial groundwater recharge is required because the natural recharge from rainfall is no longer adequate to sustain the water levels in many of India's aquifers. Groundwater recharge moves surplus surface water into the aquifer during the monsoon season by either maximising the excess water's contact with the surface above the aquifer, or with deeper water tables, directly pumping water into the ground, usually through wells. The primary challenge of groundwater recharge is similar to the problems of overexploitation, in which there is a lack of financial and legal incentive for individuals to recharge the common groundwater source. The issue is best addressed with top-down legislation. Authorities in water-scarce Chennai, where 91 per cent of rainwater flows into the ocean, have made rooftop rainwater harvesting compulsory for buildings over three stories. The captured water is directed into the ground to recharge the urban aquifer. In India, there also remains a significant risk of recharging with contaminated surface water and damaging the aquifer, posing additional costs to effective groundwater recharge.

India's untreated wastewater has serious water security and health implications. Almost 80 per cent of the scarce water supplied to households turns into wastewater, while only ten per cent is adequately treated. Wastewater pollutes the waterways and groundwater sources that India relies on for drinking water. According to the World Bank, 21 per cent of communicable diseases in the country are related to unsafe water. The treatment plants announced in Uttar Pradesh, Bihar and Delhi have the capacity to improve India's water security by protecting existing water resources and establishing new sources. Treated wastewater has the added potential to provide a safe source for groundwater recharge.

Desalination remains a challenging method for efficiently producing safe water, but nevertheless plays a significant role in India's water supply. Around one quarter of India's population live along the coastline. Desalinated seawater normally supplies 40 per cent of the water supply in Chennai in Tamil Nadu, a state currently experiencing its worst drought in 140 years. The desalination plants, however, do not solve the city's water shortages during times of scarcity. The city's four reservoirs have dried and on 26 June 2017, authorities announced that only half of the 830 million litres of water per day the city needs had been supplied. The current crisis displays how seawater desalination is a critical source of water during surface water shortages, but nonetheless is not the final solution to the country's water insecurity.

The primary challenge of desalination in India is its high cost and energy consumption. Electricity makes up 63 per cent of the operational costs of seawater desalination plants; Chennai's Minjur and Nemmeli plants produce water at Rs. 60 ($1.22) and Rs. 30 ($0.61) per kilolitre, respectively. The plants contribute to water security but add stresses to the energy security of the fuel-poor country. India does, however, have high solar energy potential. A 2011 study found that solar powered desalination is economically viable for small to medium capacity plants in India, improving energy and water security and lowering greenhouse gas emissions. A 2014 study in the *Desalination* journal suggested that solar powered electrodialysis was an appropriate method for groundwater desalination in rural villages, especially those without access to power grids. Given the country's high exposure to solar radiation and its extensive water problems, solar desalination has strong potential in India.

**Conclusion**

India's groundwater depletion problems are at a critical level that requires immediate solutions to improve water security and, in the long-term, avoid a countrywide agricultural disaster. The livelihoods of the millions of people that rely on groundwater for drinking water and agriculture are currently at risk and this situation will worsen if unsustainable practices remain. The alluvial Indo-Gangetic plains in north-west India are particularly overstressed, especially in the agriculturally intensive "breadbasket" areas in Punjab and Haryana. In south India, the low-storage crystalline aquifers are highly vulnerable to depletion from over-extraction, which has had severe consequences on states such as Tamil Nadu. While enforcing groundwater regulation is a significant challenge, the low stress levels in West Bengal display the importance of state legislation to address groundwater depletion. A multifaceted approach, by reducing the demand for groundwater in agriculture and addressing supply-side issues through aquifer replenishment, wastewater treatment and diversifying water resources, is critical for sustaining India's groundwater and avoiding a worsening water crisis.

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