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Vulnerability and Sustainability of Groundwater Resource in India

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Abstract Water is a resource precious for life. The water cycle has significant role in the maintenance of ecosystems. Surface water and groundwater are important components of the hydrological cycle and are interdependent. The supply of water in suitable quality is steadily decreasing and the demand has increased significantly throughout the world. India has been found to be water stressed and is likely to be water scarce by 2050. The present study attempts to review the vulnerability and sustainability of groundwater resource due to its overexploitation dominated by agricultural sector. It has been revealed that groundwater is being consumed by human activities in these parts at a rate faster than replenished by natural processes. In the process, its quality has also deteriorated.
Keywords *Groundwater, Sustainability, Vulnerability, Quality*

1. Introduction

Water has always been perceived as a gift from God as it rained from heavens and provided the earth with the capacity of supporting life. The water cycle has significant role in the maintenance of life and ecosystems. Physical processes of evaporation, condensation, precipitation, infiltration, runoff, and subsurface flow are involved in the movement of water in the hydrologic cycle. In this process, the nature purifies the water and replenishes the land with fresh water. Fresh and clean water is of fundamental importance to the survival, protection and development of human needs, as well as for the conservation of the environment. The total amount of water on earth is estimated to be about 1400 million cubic kilometers which is enough to cover the earth with a layer of 3000 m depth. However, the reserve of fresh water in nature is limited and its spatial distribution is highly uneven. A small proportion of the quantity existing in rivers, lakes and aquifers is effectively available for consumption and other uses.

Surface water and groundwater are important components of the hydrological cycle and are interdependent. These resources fulfill most of the fresh water requirements in the world. Although water is a renewable resource, yet its supply in suitable quality is steadily decreasing. Moreover, the demand has increased significantly throughout the world due to population growth, socio-economic development, technological and climatic changes (Alcamo et al., 2007). During the last century, the

requirements have grown approximately at a rate twice that of population (UN, 2006). It is widely recognized that many countries are entering an era of severe water shortages. By 2050, about two-third of total population of the world is estimated to be living in water scarce areas (Wallace, 2000). India supports more than 16% of the world's population with only 4% of the total fresh water resources (Singh, 2003). The country has been found to be water stressed and is likely to be water scarce by 2050 (Gupta and Deshpande, 2004). The projections of annual demand for water in India are alarming (Table 1).

Table 1: *Projected Water Requirements of India in Billion Cubic Meters (BCM)*

Use of Water	1990	2000	2010	2025	2050
Domestic	32	42	56	73	102
Irrigation	437	541	688	910	1072
Industry	-	8	12	23	63
Energy	-	2	5	15	130
Others	33	41	52	72	80
Total	502	634	813	1093	1447

Source: Compendium of Agricultural Statistics, 2002, Ministry of Statistics and Programme Implementation, Government of India

2. Groundwater

Groundwater is defined as water occupying all the voids within a geologic stratum. It is a replenishable resource and has several advantages over surface water (Aswathanarayana, 2001). Generally, it has convenient availability near the point of use, a superior quality, and a relatively low cost of development. Precipitation, stream flow, lakes and reservoirs act as principal sources of natural recharge. Other contribution, known as artificial recharge, occurs from excess irrigation, seepage from canals, and special structures installed for the purpose. Natural discharge occurs mostly as flow to the surface from springs and flow into surface-water bodies such as streams, lakes and oceans. Moreover, groundwater near the surface may return directly to the surface by evaporation from the soil and transpiration from the vegetation. Pumping from wells constitutes the major artificial discharge of groundwater (Todd and Mays, 2005).

Worldwide, agriculture accounts for 70% of the total water consumption, compared to 20% for industry and 10% for domestic use. The advent and rapid spread of energized pumping technologies have enabled speedy groundwater development. This has led to emergence of land use and cropping systems dependent on its reliability. In India, groundwater is used to fulfill more than 85% of domestic water supply in rural areas, about 50% of water requirements for urban areas and industries and more than 55% of irrigation water needs. Moreover, groundwater is predominant source of irrigation in drought years (Jain, 2009). Due to production from irrigated land, agriculture contributes around 30% of India's gross domestic product (GDP). Therefore, a large percentage of national GDP is closely dependent on the availability of groundwater. The continuous rise in groundwater use along with increase in intensity of surface-water supply has helped in bringing green revolution in India, particularly in the north-western region.

2.1. Exploitation of Groundwater and Its Sustainability

The groundwater is threatened by over-exploitation as its development has taken place without proper understanding of its occurrence in time and space (CGWB, 2006). An increase in demand has led to higher withdrawal of groundwater. The abstraction exceeding natural replenishment has generated stress in aquifers causing depletion of water table. Since groundwater is a limited resource, the

enormous development of bore-wells threatens aquifers and cases of declining water tables have been widely reported, particularly in densely populated areas (Narain, 1998).

There is a strong relationship between the development and management of groundwater resources because depletion of water tables, groundwater pollution, water logging and salinity are consequences of over-exploitation and intensive agriculture (Prabhakaran et al., 2009). Moreover, climate change also makes a direct impact on groundwater by way of change in recharge. The levels may take months or years to replenish once pumped for irrigation or other uses. Therefore, risks related to groundwater levels are a cause of serious concern (Custodio, 2002). Temporal delay, variability and change in spatial rainfall pattern is of great concern in tropical arid and semi-arid zones, since in these regions, natural vegetation and agricultural ecosystems are highly sensitive to small variations of rainfall (Singh et al., 1992).

The lowering of groundwater levels has resulted in reduction in individual well yield, growth in well population, failure of bore-wells, drying up of dug-wells, increase in power consumption, changes in the direction and velocity of groundwater flow, and ecological damage (Imtiyaz and Rao, 2008). Further, the environmental effects may also cause reduction of porosity, deterioration of water quality, loss of vegetation, land subsidence, inland ingress of saline water in coastal regions etc. (Figure 1.2). The formation of regional depressions of potentiometric levels in several aquifer systems have been observed due to excessive groundwater use (Biswas, 2003).

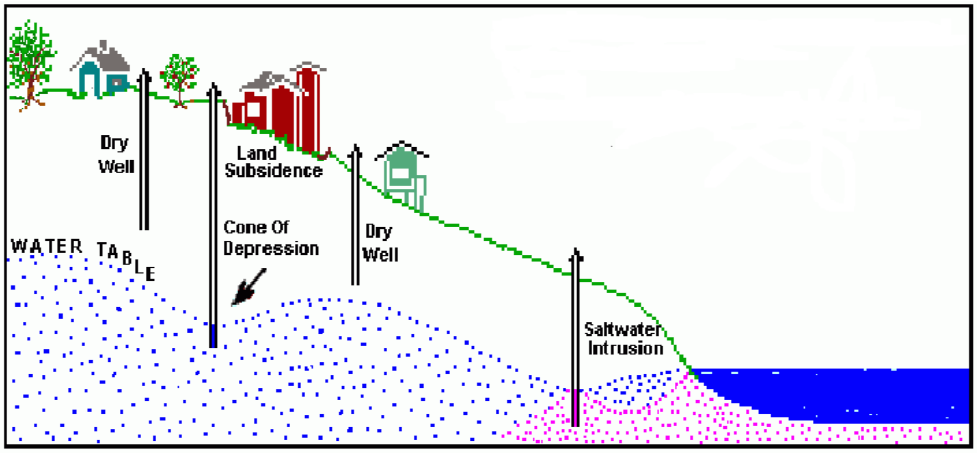

Figure 1.2: *Impacts of Overexploitation of Groundwater. Adapted from United States Geological Survey*

The factors contributing to unsustainable use of groundwater resources and its degradation in different forms are varied and spatially specific. Excessive withdrawal to meet the needs of increasingly intensive cropping is leading to lowering of water tables in several areas. This is also causing the rise in water table in areas where its use is restricted due to quality considerations, leading to spread of salinity problems. Thus, the problems of unsustainable use of groundwater resources are multifaceted. The optimal use of this resource for a range of diversified and increasing demands requires a good understanding of the issues involved.

2.2. Quality of Groundwater and Its Vulnerability

The quality of groundwater is the resultant of all the processes and reactions that act on the water from the moment it condensed in the atmosphere to the time it is discharged by a well or spring. It varies from place to place and with the depth of the water table (Jain et al., 1995). Due to its unique property of dissolving and carrying in suspension variety of materials with different chemical properties, the groundwater is vulnerable to contamination.

It may acquire minerals and salts from the aquifers during its movement or stay at a location (Todd and Mays, 2005).

Fresh water is essential for domestic, agricultural and industrial uses. The lack of clean drinking water is adversely affecting the general health and life expectancy of the people in many developing countries (Nash and McCall, 1995). Moreover, poor water quality for irrigation is a constant threat to crop yield as well as soil physical conditions (Ayers and Westcot, 1994; Patel et al., 2004; Marechal et al., 2006). Different processes in various industries require huge quantities of water with specific characteristics as water quality may affect their production performances, operational costs and the sustainability. Industrial processes also need good quality water for use as a solvent, a medium, a coolant and a cleansing agent.

Various investigations have shown that groundwater is highly susceptible to pollution from natural as well as anthropogenic factors (Kovar and Krasney, 1995; Appelo and Postma, 1996; Jain and Sharma, 2000). Uncontrolled extraction without commensurate recharge and heavy leaching of pollutants from pesticides and fertilizers to the aquifers has resulted in pollution of groundwater (Rajmohan and Elango, 2005). The changes in direction of groundwater movement due to excessive depletion of water table are causing intrusion of saline water into freshwater zones. Thus, the quality of groundwater has been undergoing a change to an extent that use of such water at certain places could be hazardous for domestic, agricultural and industrial purposes. Moreover, resultant adverse impact on human and livestock population and ecosystem health due to access to toxic elements from agricultural inputs (e.g. fertilizers, pesticides) and industrial effluents is extremely worrisome.

3. The Scenario

In India, a significant decline in the groundwater levels (by more than 20 cm per year) has been observed in 362 districts of the country during the decade 1995-2004 (CGWB, 2006). Moreover, there has been deterioration in groundwater quality due to over-exploitation, indiscriminate use of chemicals in agriculture, and untreated effluents from industrial and domestic sectors (Palaniswami and Ramulu, 1994; Datta et al. 2000). Between 1970 and 1994, the amount of farmland irrigated with groundwater in India increased by 105%, while the areas of land irrigated with surface water increased by only 28%. The rapid increase in groundwater irrigation is also illustrated by the soaring number of mechanized tube wells from less than 10^6 in 1960 to more than $19x10^6$ in 2000, making India the country with the maximum number of pump sets (Marechal et al., 2006). Expansion of irrigation led to significant shifts in cropping pattern. Rice followed by wheat emerged as a major cropping sequence. This practice paid off in terms of increased production. But, this has also led to unsustainable use of water resource which has posed a threat to sustaining agriculture and food security of the country.

4. Conclusion

The north-western region of India comprising the states of Punjab, Haryana and western Uttar Pradesh, which was at the centre stage of Green Revolution era during seventies and eighties, now faces serious challenges. It has been revealed that groundwater is being consumed by human activities in these parts at a rate faster than replenished by natural processes. If measures are not taken to ensure sustainable groundwater usage, consequences may include a collapse of agricultural output and severe shortage of potable water for 114 million residents of the region (Rodell et al., 2009).

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