Impact of land-use change on groundwater in the Punjab-Haryana plains, India

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Abstract In order to fulfil the requirements for agricultural, domestic and industrial purposes, the dependency on groundwater in Punjab-Haryana plains is rapidly increasing. Agriculture is the main source of livelihood of the rural population and the heavy dependence on groundwater is evident in that groundwater is used for irrigation in 95% of the total irrigated area. Several questions which the planners and decision makers are confronted with relate to the quantity and quality of groundwater and how the groundwater resource is affected by the location of recharge areas, the temporal and spatial variability of recharge, the inter-linkage between groundwater and surface water, existing hydraulic gradients, and the water table situation, and regional groundwater flow. Major groundwater resource problems result from indiscriminate exploitation, particularly for irrigation, and contaminant inputs from a variety of sources such as urban runoff, fertilisers used in agriculture, seepage from contaminated industrial sites, and industrial discharges. Improved water availability and safe water supply can be guided by effective public policies, plans, and local technologies, in addition to political, socio-economic, and other factors.

Key words groundwater depletion; groundwater monitoring; India; land-use change; quality assessment; socio-economic dimensions

INTRODUCTION

About 75–80% of human requirements for water are fulfilled by groundwater. In recent studies it was observed that of the use of inorganic fertilisers has resulted in increasing nitrate and related pollution in groundwater. The Punjab-Haryana plains (India) are one of the most agriculturally productive regions in the world. The plains are rich in natural resources, including deep productive soils, adequate water supply, and favourable climatic conditions for agriculture resulting in two or more crops per year. Increased production and productivity that characterized the green revolution of the 1970s and 1980s came about due to a combination of factors including expansion of irrigated areas by the development of surface and groundwater resources and increased use of inputs, such as fertilisers, herbicides, and pesticides. Since then, water supply has been threatened due to degradation of water quality. Uncontrolled disposal of urban waste into water bodies, open dumps, and poorly designed landfills cause groundwater contamination (Singh, 1999, 2000). Groundwater pollution has become one of the most important toxicological and environmental issues in India. In January 1994 the Central Pollution Control Board (CPCB), Delhi, undertook the first major groundwater quality monitoring exercise. The report, published in December 1995, identified 22 locations in 16 states of India as "critical" sites of groundwater pollution, and the CPCB found industrial effluents to be the primary reason for groundwater pollution (CPCB, 1998). Many of the critical regions have to depend on groundwater resources for various needs due to scarcity of surface water. In the industrial and urban fringe zones of cities, the subsoil water in the area has already been polluted by industrial effluents. Industries release high concentrations of toxic substances. The wells in many residential areas are contaminated with nitrate and detergents. The high fluoride content of groundwater has negative effects and is suspected to be a severe health hazard in the surrounding region. The main objective of this paper is to assess the critical areas which face groundwater contamination and to identify various sources and types of pollutants discharged in one of the most agriculturally advanced regions of India. Data from the District and Statistical Handbooks of the Punjab and Haryana states, publications of Central Ground Water Board (CGWB) and CPCB were used for the analysis.

ANALYSIS AND FINDINGS

Groundwater development and problems in the Punjab-Haryana plains

The green revolution in the states of Punjab and Haryana brought prosperity to the region, but problems of soil and water degradation emerged and have become increasingly important because these states make a significant contribution to national food security. The irrigated area in these states more than doubled between 1965 and 1995. Consequently, the major crops, which include rice, wheat and cotton, are totally irrigated in the region. The number of tube wells in the region has increased during the last three decades. Groundwater pumping has resulted in over-exploitation and groundwater table declines of up to 2 m in the last 20 years (Table 1). The groundwater table decline has forced farmers to lower the pumps and further deepen the wells, increasing the costs of pumping and energy use and thus decreasing the profitability and efficiency of agriculture. The government policy of providing a highly subsidized power supply to rural areas further aggravates the problem. The quality of the deep groundwater aquifers in most parts of Haryana is marginal and highly saline. Pumping water from greater depths could, therefore, result in the use of saline water for irrigation. Precaution in the use of groundwater is thus essential for a long-term sustainable agriculture (ICAR, 1998).

Impact of land use on soils and nutrient quality

There has been a marked change in soil fertility caused by changes in agricultural land use and practices during the green revolution (Singh, 2000). For example, 3% of the soil in 1980 had a low P content, and by 1995, 73% of soil had a low P content, whilst the area of soil with a low N content only increased from 89 to 91%. Soils with a high K content decreased from 91% in 1980 to 61% in 1995 (ICAR, 1998). The rotation of crops, wheat and rice, is disturbing the balance of available nutrients in the soil and also is causing a deficiency of micronutrients, particularly zinc and copper. This process has a large implication for ground water quality.

Table 1 Groundwater development in Punjab and Haryana (units = 10^6 m^3 $year^{-1}$).

State	Name of the district	Total replenishable resources	Use of resources for irrigation	Net draft	Balance: potential available for exploitation	Present development (%)
Punjab	Amritsar	1918.8	1630.9	1647.3	–16.3	101.0
	Firozpur	3588.3	3050.0	1509.8	1540.2	49.5
	Gurudaspur	1620.8	1377.7	832.5	545.2	60.6
	Jalandhar	827.2	703.1	1491.7	–788.6	212.3
	Kapurthala	392.7	333.8	668.4	–334.6	200.3
	Ludhiana	1686.5	1263.5	1953.6	–690.1	154.6
	Patiala	1365.9	1161.0	2376.7	–1215.6	204.7
	Sangrur	1511.9	1285.1	2190.0	–904.9	170.4
Haryana	Ambala	1057.5	898.8	585.2	313.7	65.1
	Karnal	1281.9	1089.6	1411.6	–322.0	129.9
	Kurukshtra	774.1	658.0	1253.3	–595.3	190.5

Source: various reports and statistical handbooks.

Impact of agrichemicals on groundwater quality

The use of agrichemicals in Punjab and Haryana is the highest in India. In Haryana fertiliser use has increased from 3 to 130 kg ha^{-1} in the last 30 years. Fertiliser use for rice and wheat is 160 and 170 kg ha^{-1}, respectively. There is an imbalance in the N, P, and K consumption ratio in rice–wheat crops. The use of K is also low in this region. In addition, nitrate concentrations have increased to toxic levels in the groundwater. In particular, of the wells sampled before the monsoon, 32%, 48%, 16%, and 4% have NO_3-N concentrations of <10, 10–15, 15–20, and >20 mg l^{-1}, respectively, and after the monsoon, 16%, 49%, 29%, and 6%, respectively (ICAR, 1998).

Groundwater quality: other challenges and responses

Disposal of untreated mercury-contaminated effluent from caustic manufacturers has contaminated groundwater. Dumping of effluent and hazardous waste is common in industrial areas of India. Industries and factories release untreated effluents directly into the ground, contaminating underground aquifers. The mercury concentration in one sample was more than 270 times higher than the World Health Organization's drinking water standard (0.001 mg l^{-1}). Groundwater in the industrial areas of northern India is unfit for even agricultural use. Groundwater pumped from a tube well bored to a depth of about 61 m by Suruchi Dyeing Udyog, a factory south of the GT Road in Ghaziabad, Uttar Pradesh, was yellow-coloured and contained 0.54 mg l^{-1} para-nitrophenol (an organic compound), a concentration much greater than the water quality standard of 0.001 mg l^{-1}. It is likely that a factory in that area pumped untreated effluent into the groundwater. Because 80% of the country's drinking water is supplied by groundwater, the Facility for Ecological and Analytical Testing of the Indian Institute of Technology, Kanpur, conducted a groundwater survey to evaluate the extent of the groundwater contamination. There were traces of the heavy metals iron and zinc in all samples, cadmium in five samples and lead in three samples (Down to Earth, 1999). All samples had very high mercury concentrations, which among other effects, can cause neuropathy, a severe impairment of the nervous system (CGWB, 1998).

The chemical oxygen demand (COD, which is the amount of oxygen required by chemicals in the water to oxidize) of the water was 360 mg l^{-1}. The maximum permissible COD level for industrial effluents is 250 mg l^{-1}. The chemical content of contaminants in the groundwater was more than that permitted for industrial effluents. Effluent with COD levels as high as 2400 mg l^{-1} was pumped into the aquifer. The municipal corporation is pumping groundwater from 80 wells to provide water supply. In addition, most residents and industries pump groundwater. The units responsible are 1311 thriving industries, including textiles and foundries. According to CGWB (1998), the industries discharge about 50 000 m^3 day^{-1} of industrial effluents—mostly toxic—into the Budha Nala, a stream that recharges the city groundwater supply. CGWB's report on Ludhiana's groundwater status indicates that many industrial units are deliberately pumping effluents into the aquifers. The CGWB reports that the concentrations of heavy metals, such as cadmium, cyanide, lead, and chromium, exceed permissible limits in the shallow aquifers, but arsenic concentrations were within the permissible limit. Small quantities of these heavy metals were also traced in the deeper aquifers. In the absence of suitable modes of disposal, indiscriminate discharge of effluents has caused serious pollution of groundwater. The indiscriminate discharge of mercury along with industrial pollutants may result in significant accumulation of the metal in the aquatic environment.

POLICY AND MANAGEMENT DEVELOPMENTS AND FUTURE CONSIDERATIONS

In order to address the issue of long-term policy on water-use, the following strategies are important: (a) technologies or strategies are needed to restore the water table to 1970 levels and to establish an appropriate use of fertilisers; (b) the water supply in areas with groundwater level declines needs to be replenished through artificial groundwater recharge. The rainy season surplus water, which typically is transported as stormflow, may be an appropriate source for the additional recharge; (c) on-farm irrigation water management should be given top priority to enable maximum productivity per unit of water and to avoid the development of waterlogging and soil salinity. This will require use of surface water in conjunction with groundwater. Between April and June, the recommended cropping pattern should include only crops that have a low water consumption, particularly in those agro-climatic irrigation zones where groundwater is over exploited. Regional groundwater resources planning is needed for a 50 horizon. Aquifers may also be recharged by collected rainwater. The continuing change in the water quality status needs to monitored and evaluated and to this end, remote sensing techniques in pollution detection provide a promising new technology that is most effectively used in conjunction with traditional frequent sampling and continuous monitoring.

Residents of the surrounding areas were unaware of the danger related to groundwater contamination, though they could see that something was wrong. The pollution control boards are either unwilling to deal with the offenders or are simply ineffective at implementing the anti-pollution laws. On 10 December 1996, India's Supreme Court directed the Union Ministry of Environment and Forests to empower the CGWB under the Environment Protection Act, 1986, against overexploitation of groundwater, resulting in the formation of the CGWA. Pollution control authorities are not capable of dealing with the groundwater crisis alone. It is very important to involve the local people and society to evaluate the pollution status of our groundwater, because they are the most important stakeholders of the country's natural resources and are the users most affected by pollution. Groundwater extraction should not exceed recharge over the long term. Groundwater recharge projects should be initiated for augmenting the available supply. A phased programme should be implemented for improvement in water quality. Urban development and related activities should be planned with due regard to the constraints imposed by the configuration of water availability. Where water demand exceeds supply, water zoning is needed and economic activities should be regulated in accordance with such zoning.

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