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Groundwater Sustainability - A Brief Review

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Abstract Groundwater is the water found under ground in the cracks and spaces in soil, sand and rock. It is stored in and moves slowly through geologic formations of soils, sand and rocks called aquifers. It is one of the Nation's most important natural resources. It plays a major role in ensuring livelihood security across the world, especially in economies that depend on agriculture. Ground water contains mineral ions which slowly dissolve from soil particles, sediments, and rocks named as dissolved solids. Continuous discharge of industrial effluents, domestic sewage use of fertilizers and pesticides, waste dump and over exploitation of the resource have badly impact on ground water sustainability. Though over utilization of ground water is the key factor for ground water depletion but there are other factors which have negative impact on ground water sustainability. The most important impact of groundwater depletion is loss of base flow; other impacts being severe crisis of safe drinking water and irrigated water. Lastly it is to be mentioned that protection of the water resource from depletion is not possible unless the users agree to cooperate and manage the resource themselves in a sustainable manner. Moreover the state also needs to play a key role of facilitating and fostering community action for sustainable management.

Keywords Groundwater, Aquifers, Depletion, Sustainability

1. Introduction

Groundwater is one of the extremely valuable renewable resources. Now a day's pollution of groundwater resources is a matter of serious concern. Groundwater quality comprises the physical, chemical, and biological qualities of ground water.viz Temperature, turbidity, color, taste, and odor are represent the physical quality whereas pH, E.C, N, P, K, Organic Carbon etc. represent the chemical quality and total microbial count etc. stand for biological quality of ground water. Naturally, ground water contains mineral ions which slowly dissolve from soil particles, sediments, and rocks named as dissolved solids.

Microbial components are also available in ground water. There are different forms where ground water is stored and human can withdrawal from there namely aquifer, wells etc. Aquifers are divided into two types (confined and unconfined) depending on the position relative to surface and other permeable and impermeable layers. Man made activities play a key role for depletion of natural composition of ground water through the disposal or dissemination of toxic chemicals and microbial matter at the land surface and into soils, or through waste water. In India, most of the population is dependent on groundwater as the only source of much clean drinking water supply than surface water. Continuous discharge of industrial effluents, domestic

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Table 1. Primary (major), secondary, and trace constituents in natural ground water (Harter T.)

Major	Secondary	Trace	Trace
Constituents	constituents	constituents	constituents
(1.0 – 1, 000 mg/l)	(0.01 – 10 mg/l)	(0.0001 – 0.1 mg/l)	(less than 0.001 mg/l)
		Antimony	beryllium
		Aluminum	bismuth
cations:	______	arsenic	cerium
sodium	potassium	barium	cesium
calcium	iron	bromide	gallium
magnesium	strontium	cadmium	gold
		chromium	indium
		cobalt	lanthanum
anions:	______	copper	niobium
bicarbonate	carbonate	germanium	platinum
sulfate	nitrate	iodide	radium
chloride	fluoride	lead	ruthenium
silica	boron	lithium	scandium
		manganese	silver
		molybdenum	thallium
		nickel	thorium
		phosphate	tin
		rubidium	tungsten
		selenium	ytterbium
		titanium	yttrium
		uranium	zirconium
		vanadium	
		zinc	

sewage use of fertilizers and pesticides, waste dump and over exploitation of the resource have badly impact on ground water sustainability (Harter T.). So, sustainable ground water management is a burning challenge for the 21st century because it ensured livelihood security across the world. Agriculture dependent countries (viz. India) are mostly relied on ground water.

Current status of ground water:

Table 2. Possible source of ground water entering and leaving a groundwater system under natural condition (source: Alley W. et al 1999)

Inflow (recharge)	Outflow (discharge)
Areal recharge from precipitation that percolates through the unsaturated zone to the water table.	Discharge to streams, lakes, wetlands, saltwater bodies (bays, estuaries, or oceans), and springs.
Recharge from losing streams, lakes, and wetlands.	Groundwater evapotranspiration.

Although ground water is mentioned as renewable resource but it does not recycle rapidly. The ground water recycling depends on aquifer depth, type, location and connectivity etc. Generally the average time of renewal of ground water is 1,400 years (World Water Balance, 1978). Significantly renewal rate of shallow groundwater are about 15 times less than deep groundwater (Jones, 1997).

Of all of the Earth´s water, fresh water is very limited (3%) compare to saline water (97%). Of all of the limiter and valuable fresh water, a huge amount of water(68.7%) is permanently stored in icecaps and glaciers and other huge amount of fresh water is stored as ground water. Approximately out of 37 million cubic kilometers of total fresh water about 8 million cubic kilometers of fresh water is stored as ground water. So ground water is a key source of fresh water.

2. Global Fresh Water Demand and Ground Water Depletion

Fresh water demand rise day by day especially for irrigation purpose. The percentage of total irrigation water withdrawal from ground water increased 23 percent in 1950 to 42 percent in 2000 (Hutson, 2004). Water shortage increased dramatically and it is projected that around 3 billion will be water stressed by 2025 (Engelman and LeRoy, 1993).

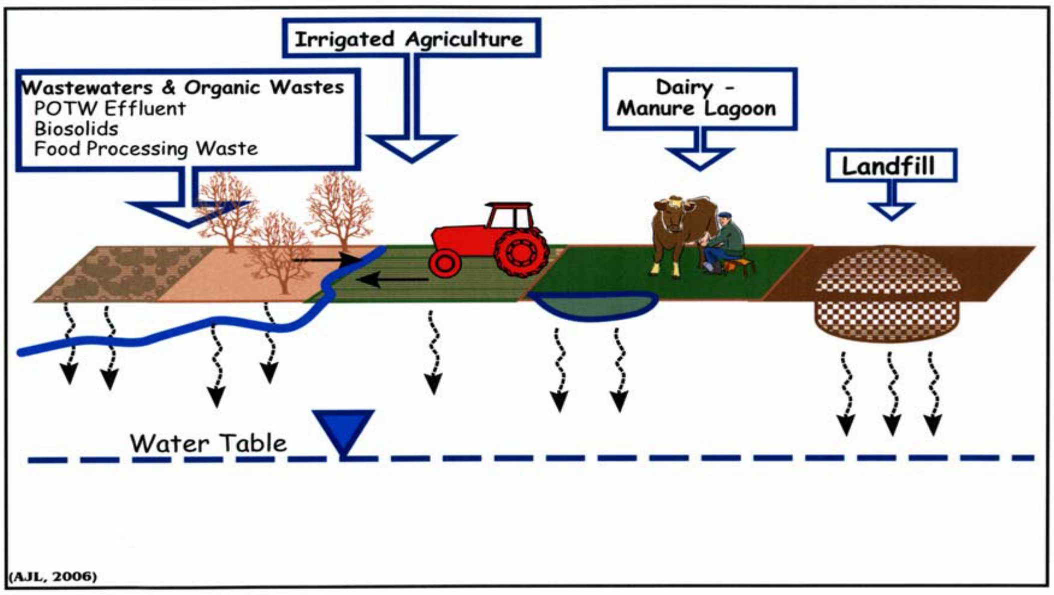
From the above table we can say that increasing demand of water and decreasing availability of water create a significant pressure on groundwater and this ultimately deplete the ground water quality. At present approximately 61% of total irrigation water is come from groundwater (Kulkarni et al).

Table 3. Per capita water availability by region, 150-2000 (Source: Ayibotele, 1992)

Region	1950 (thousand cubic meters)	1960 (thousand cubic meters)	1970 (thousand cubic meters)	1980 (thousand cubic meters)	2000 (thousand cubic meters)
Africa	20.0	16.5	12.7	9.4	5.1
Asia (excluding Oceania)	9.6	7.9	6.1	5.1	3.3
Europe (excluding the soviet union)	5.9	5.4	4.9	4.6	4.1
North America and central America	37.2	30.0	25.2	21.3	17.5
South America	105.0	80.2	61.7	48.8	28.3

Table 4. Average share (%) of various source in Net Irrigated Area in India (NIA), 1950-2007 (Source: Indian Agriculture Statistics, 2008)

Period	Surface water			Ground water			Other source	NIA
	Canal	Tank	Total	Tube well	Other well	Total		
1950/51 to 1959/60	41%	19%	60%	0%	30%	30%	10%	22287
1960/61 to 1969/70	42%	17%	58%	6%	27%	33%	9%	26735
1970/71 to 1979/80	40%	11%	51%	19%	23%	42%	7%	34361
1980/81 to 1989/90	38%	7%	46%	28%	21%	48%	6%	42418
1990/91 to 1999-00	33%	5%	38%	34%	22%	56%	6%	53083
2000/01 to 2006/07	26%	4%	30%	41%	20%	61%	9%	57410



From the above table we can say that expansion of agricultural field and decreasing pattern of usage of surface water accelerate the over exploitation of ground water. There are a various example of over usage of groundwater but a classic case is the water level in Borrego valley, Southern California have declined 2 feet per year over the past 20 years (Victor M. ponce, 2006). Though over utilization of ground water is the key factor for ground water depletion but there are also other important factors those have negative impact on ground water sustainability. Contamination or Presumption contamination also has adverse impact on ground water. Agricultural chemicals like N, P, K, pesticides etc. percolate through soil and contaminate the ground water. A sampling program in Wisconsin found that pesticides are present in 38% of their samples from wells in the state (Krohelski, 2004).

Naturally occurring constituents like arsenic fluoride, chloride etc. contaminate the ground water and made the water unsafe. Murshidabad district of West Bengal is an arsenic porn area. Increasing efforts to protect and enhance In-stream flow and aquatic ecosystems also limit the amount of ground water available for extraction.

3. Impact of Ground Water Depletion

The most important impact of groundwater depletion is loss of base flow. If the base flow is reduced then there are different crucial additional impacts take place. These are:

- Increased magnitude and frequency of flood
- Loss of wetland and riparian vegetation
- Changes in channel morphology
- Accelerate erosion
- Increased frequency of drought
- Loss of biodiversity

Other impacts of ground water depletion are severe crisis of safe drinking water and irrigated water.

4. Ground Water Management

Groundwater, as a valuable resource we should meet its sustainability for our basic needs. Firstly we should not exploit in an unsustainable manner. Ground water use policy should be sustainable and depend on basin´s recharge capacity. We should follow the groundwater basin´s mass balance equation

$$P-E-T-Q-G-D = 0$$

Where P = precipitation, E = evaporation, T = evapotranspiration, Q = surface runoff, G = groundwater runoff, D = deep percolation (Ponce. V. 2006).

In rural areas where ground water is the main source for drinking water, implementation of wellhead protection is necessity and secondly must control the waste water to percolating through soil and disposing of waste water to neighboring septic systems. Tapping primary deep percolation and secondarily shallow percolation are important measures for maintaining groundwater sustainability. Baseline and time dependent hydrological studies are necessary to monitor the ground water.

5. The Priorities for Ground Water Management

There are also some strategies to promote sustainable ground water supply. Conjunctive use of surface water and ground water, desalination, recycling and wastewater reuse, water harvesting, increase recharge to the ground water system are also a effective measure to promote sustainable ground water supply. Lastly awareness should be raise towards ground water sustainability.

Table 5. Vision statement of priorities for ground water management in the United Kingdom. (Modified from Downing, 1998)

⇒ Sustainable long term yields from aquifers
⇒ Effective use of the large volume of water stored in aquifer
⇒ Preservation of ground water quality
⇒ Preservation of the aquatic environment by prudent abstraction of ground water
⇒ Integration of ground water and surface water into a comprehensive water and environmental management system

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