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Water Quality Status of India in Changing Environment

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Abstract : Water is a central resource supporting human activities and ecosystems. The hydrologic cycle, a fundamental component of climate, is likely to be altered in important ways by climate change. Significant changes in average temperature, precipitation, and soil moisture caused by climate change are very likely to also affect demand in most sectors, especially in the agriculture, forestry, and municipal sectors. Changes are also likely in the timing, intensity, and duration of both floods and droughts, with related changes in water quality. Although a full understanding of, or appreciation for, the magnitude and consequences of climate change is yet to emerge, and therefore there is no consensus on how to best adapt or mitigate its impacts at a local, regional, national or global level. Due to increase in urbanization and industrialization in India, both surface and ground water resources are being contaminated day by day. The decline in quantity and deterioration of water quality are directly attributable to the increasing demands of water by various sectors of water uses, indiscriminate disposal of wastes from different sources including urban settlements, industries and agricultural activities. In the present paper, the status of water quality of surface water resources and groundwater resources in India has been discussed. Further probable effect of climate change on water quality parameters and their consequences have also been discussed. Suggestions have also been given to preserve the water quality of water resources for different designated uses.

INTRODUCTION

Water is essential for sustaining all forms of life, food production, economic development, and for general well being. It is Impossible to substitute for most of its uses, difficult to de-pollute, expensive to transport, it is truly a unique gift to mankind from nature. Although, India occupies only 3.29 million km^2 geographical area, which forms 2.4% of the world's land area, it supports over 15% of the world's population. The population of India as on 1st March 2001 stood at 1,027,015,247 persons (Census, 2001). Thus, India supports about $1/6^{th}$ of world population, $1/50^{th}$ of world's land and $1/25^{th}$ of world's water resources. National Commission for Integrated Water Resources Development (NCIWRD, 1999) estimated the basin-wise average annual flow in Indian river systems as 1953 km^3 and the utilizable annual surface water of the country is 690 km^3. Total replenishable groundwater resource of the country is assessed as 433 km^3. Out of which, annual natural ground water recharge from rainfall in India is 67% and the rest is from other sources. After allotting 15% of this quantity for drinking, and 6 km^3 for industrial purposes, the remaining can be utilized for irrigation purposes. Thus, the available ground water resource for irrigation is 363 km^3 of which utilizable quantity (90%) is 327 km^3. The basin wise per capita water availability varies between 13,393 m^3 per annum for Brahmaputra-Barak basin to about 300 m^3 per annum for Sabarmati basin. The state-wise estimates of dynamic ground water (fresh) resource have been made by the Central Ground Water Board (CGWB, 2006; IWRS, 1998).

CLIMATE CHANGE AND ITS IMPACT ON ENVIRONMENT

Water is a central resource supporting human activities and ecosystems. The hydrologic cycle, a fundamental component of climate, is likely to be altered in important ways by climate change, which will result in (i) more rainfall in lesser time; (ii) decrease in number of rainy days; (iii) overall increase in precipitation; (iv) increased glacial melt-runoff initially and then afterwards decrease; (v) increase in runoff but less ground water recharge?; (vi) increase in flood events particularly of flash floods; (vii) increase in drought like situations; and some other related issues like (viii) increase in landslide events in hilly areas etc.

India is a vast country with diversified climate from region to region. Any significant change in the climate specially in temperature will ultimately affect the water quality of our water resources thereby affecting river's self purification capacity and aquatic life system. In general, an annual mean global warming has been reported. In Indian context, the analysis of seasonal and annual air temperatures, using the data for 1881 to 1997 has shown a warming trend of 0.57 degree C per hundred years (Pant and Kumar, 1997). Lal (2001) stated that globally averaged precipitation is projected to increase, but at the regional scale both increases and decreases are projected. The increase in annual mean precipitation over the Indian sub-continent is projected to be 7 to 10% by 2080s. Winter precipitation may decrease by 5 to 25% in the Indian sub-continent. An increase of 10 to 15% is projected in average summer monsoon rainfall over the Indian sub-continent. Over northwest India, during monsoon season an increase of about 30% or more is suggested by 2050s. The western semiarid margins of India could receive higher than normal rainfall in the warmer atmosphere. It is likely that date of onset of summer monsoon over India could become more variable in future (CWC and NIH, 2008). IPCC (2001) has indicated that variability in Asian summer monsoon is expected to increase along with changes in the frequency and intensity of extreme climate events in this region. All climate models simulate an enhanced hydrological cycle and increases in annual mean rainfall over South Asia (under non-aerosol forcing). As recharge of groundwater is mainly governed by the precipitation and therefore, ground water quality in alluvial aquifers will be mostly affected. More basic studies to determine the trend of temperature and rainfall on basin, regional and country scales are required to be carried out. Global mean sea level is likely to rise by 0.14 to 0.80 meters from 1990 to 2100. There is probability of increased saline water intrusion in coastal and island aquifers due to rising sea levels if this trend will remain continued and thereby degrading the water quality of coastal and island aquifers.

EFFECT OF CLIMATE CHANGE ON QUALITY OF WATER RESOURCES

The probable effects of climate change on water quality of water resources can be summarized as follows (http://www.epa.gov/climatechange/effects/water/quality.html):

- Higher water temperatures and changes in the timing, intensity, and duration of precipitation can affect water quality. Higher temperatures reduce dissolved oxygen levels, which can have an effect on aquatic life. Where streamflow and lake levels fall, there will be less dilution of pollutants; however, increased frequency and intensity of rainfall will produce more pollution and sedimentation due to runoff (IPCC, 2007).
- Flood magnitudes and frequencies will very likely increase in most regions — mainly a result of increased precipitation intensity and variability — and increasing temperatures are expected to intensify the climate's hydrologic cycle and melt snowpacks more rapidly (IPCC, 2007). Flooding can affect water quality, as large volumes of water can transport contaminants into water bodies and also overload storm and wastewater systems.
- Higher temperatures, particularly in the summer, earlier snowmelt, and potential decreases in summer precipitation could increase risk of drought. The frequency and

intensity of floods and droughts could increase, even in the same areas, which will further the water quality problem.

- Sea level rise may also affect freshwater quality by increasing the salinity of coastal rivers and bays and causing saltwater intrusion, movement of saline water into fresh ground water resources in coastal regions.
- Changes in water quality could have implications for all types of uses. For example, higher temperatures and changes in water supply and quality could affect recreational use of lakes and rivers or productivity of freshwater fisheries. Certain species of fish could find temperatures too warm and migrate to more northern or higher altitude locations where water is cooler.

QUALITY STATUS OF WATER RESOURCES IN INDIA

i) Water Quality of Surface Water Resources

In view of the growing threat to our water resources, conservation of rivers, lakes and other water bodies is an important priority of the Government of India. Central Pollution Control Board has been monitoring water quality of national aquatic resources in collaboration of with SPCBs at designated monitoring stations. CPCB has worked out riverine length for different Biochemical Oxygen Demand (BOD) values, in mg/L, as indicator of organic pollution after analysing 10 years of data, is as given below:

- Length of river for BOD > 6 mg/L (severely polluted): 6086 km (14%)
- Length of river for BOD 3-6 mg/L (moderately polluted): 8691 km (19%)
- Length of river for BOD < 3 mg/L (relatively clean): 30242 km (67%)
- Total length of the river including tributaries: 45019 km

Based on the outcome of CPCB's studies on water quality and identification of polluted stretches of major rivers, the Government of India launched an ambitious river conservation plan named Ganga Action Plan (GAP) in 1986 for pollution abatement of river Ganga. Later in 1995-96, the conservation of another 17 rivers was added to this programme renamed as National River Conservation Plan (NRCP). The water quality of river Ganga is regularly monitored under this plan since April 1986 (Trivedi, 2006).

The river water quality has shown improvement over the pre-GAP period water quality. It was observed that in 1986, the bio-chemical oxygen demand (BOD) which is an indicator of pollution of river water quality was ranging from 5.5 to 15.5 mg/L in the critical stretch of Ganga from Kannauj to Varanasi. As against this, the values of BOD in 2009 in the stretch of Kannauj to Kanpur is (1.5 – 4.8 mg/L) and Allahabad to Varanasi (3.10 – 6.25 mg/L) respectively. This is based on average of four months (March to June 2009). Similarly, Dissolved Oxygen (DO) levels which indicate the health of the river, were in the range of 5.6 to 6.6 mg/L in 1986 in the Allahabad-Varanasi stretch and in 2009 the range improved from 7.72 to 8.13 mg/L. (Source: http://envfor.nic.in/nrcd/NRCD/Ganga3.htm).

The quality of Yamuna river water was maintained all through in Haryana as per the water quality standards with DO values above 5.0 mg/l and BOD values less than 3.0 mg/I. The DO value at Kalanaur (2009) is 9.1 and BOD values is 2.33. The Yamuna water at Delhi was always poor with DO values < 5.0 mg/l and BOD values >3.0 mg/l. The poor quality trend continued downstream also with values of DO fluctuating upto Majhawali. The values were again fluctuated d/s Agra. However, the values improved at Auraiya. The same trend was indicated by BOD values. The Critical stretch of Yamuna in 2009 extended from Delhi to Udi as against Delhi to Majhawali and again, Agra d/s to Etawah in (1996), there was no improvement in water quality and the effect of NRCD schemes was not positive (Source: http://envfor.nic.in/nrcd/NRCD/Yamuna.htm).

Presently NRCP programme has been expanded to cover 29 rivers in 22 states. In addition to the pollution abatement of rivers, the conservation of lakes has also been included since June 2001 under the NRCP. The Central Government, by a notification dated 20.2.2009, has set up 'National Ganga River Basin Authority' (NGRBA) as an empowered planning, financing, monitoring and coordinating authority for the Ganga river, in exercise of the powers conferred under the Environment (Protection) Act,1986. The functions of the Authority include all measures necessary for planning and execution of programmes for abatement of pollution in the Ganga in keeping with sustainable development needs.

The decline in quantity and gradual deterioration in quality are observed due to over exploitation of water resources as a result of wide demand-supply gap, indiscriminate disposal of wastes from urban and industrial sectors and runoff from agricultural activities. Class I and Class II cities generate about 23,000 MLD of wastewater of which only 26% receives some form of treatment. Industrial sector on the other hand produces 13,500 MLD wastewater and only 8000 MLD of wastewater are disposed after treatment. The rest of the untreated wastewater either finds its way into surface water or leads to groundwater contamination (Trivedi, 2006).

Generally, water quality status (trophic state) of lakes is studied using Carlson's index (Carlson's 1977). The trophic state is defined as the total weight of biomass in a given water body at the time of measurement. The Carlson Index is used with lakes that have relatively few rooted plants and non-algal turbidity sources. Three independent variables can be used to calculate the Carlson Index: chlorophyll pigments, total phosphorus and Secchi depth. Three independent equations can be used to calculate the TSI, which are given as below:

$$TSI(TP) = 14.42 \ln(TP) + 4.15 \quad .....(Eq. 1)$$

$$TSI(SD) = 60 - 14.41 \ln(SD) \quad ....(Eq. 2)$$

$$TSI(CHL) = 9.81 \ln(CHL) + 30.6 \quad .....(Eq. 3)$$

The eutrophication status of lakes was studied based on Carlson's Trophic State Index (Carlson, 1977) using phosphate concentration of the lakes pertaining to summer months. The concentration of phosphate of various lakes of India is given in Table 1.

Eutrophic condition of Mansar, Surinsar, Renuka and Tsomoriri lakes for the epilimnion zone is given in Table 2. However, Dal and Tsokar lakes were found to be under hypertrophic condition. A eutrophic body of water, commonly a lake or pond has high primary productivity due to excessive nutrients and is subject to algal blooms resulting in poor water quality. The bottom waters of such bodies are commonly deficient in oxygen, ranging from hypoxic to anoxic. Eutrophic waters commonly lack fish species like trout which require cold, well-oxygenated waters. This oxygen deficiency is most apparent in shallow lakes, owing to the smaller hypolimnetic volume. The process of eutrophication may occur naturally or be the result of anthropogenic influences (Campbell & Reece, 2005). Since, it is evident that the eutrophication of water bodies is primarily attributed due to nutrients input either in-situ or from the lake catchment through various anthropogenic activities. It would be necessary to adopt an integrated approach for effective conservation and restoration of the polluted water bodies utilizing input from scientific field investigations.

Water Quality of Groundwater Resources

Groundwater situation in different parts of India is diversified because of variation in geological, climatological and topographic set-up. The prevalent rock formations, ranging in age from Archaean to Recent, which control occurrence and movement of groundwater, are widely varied in composition and structure. Further, significant variations of landforms from the rugged mountainous terrains of the Himalayas, Eastern

Table 1. The Concentration of Phosphate in various lakes

S.No.	Name of Lake	Phosphate, µg/l	Year
1	Mansar	14 (Surface)	Zutshi, 1989
		80 (Surface)	June, 1999 (Rai et. al., 2001)
		100 (Surface)	May, 2004
		150 (Bottom)	May, 2004
2	Surinsar	50	1995, Omkar and Sharma, 1994-95
3	Dal	115	1985, Handa et al., 1991
4	Tsomoriri	30	2000
5	Tsokar	300	2000
6	Renuka	222 (Surface)	1983, Singh, et.al., 1987
		365 (Bottom)	
		230 (Surface)	2004, Anonymous, 2004
		250 (Bottom)	
		200 (Surface)	
		230 (Bottom)	2006 (Anonymous, 2006)
		120 (Surface)	2007
		170 (Bottom)	
		90 (Surface)	2008
		110 (Bottom)	

Table 2. Eutrophication status of the various lakes

S.No.	Lake	TSI (TP)	Trophic Status	Year
1	Mansar	42.20	Mesotrophic	1989
		67.00	Eutrophic	1999
		70.00	Eutrophic	2004
2	Surinsar	61.00	Eutrophic	1995
3	Dal	72.00	Hypertrophic	1985
4	Tsomoriri	53.00	Eutrophic	2000
5	Tsokar	86.00	Hypertrophic	2000
6	Renuka	69.0	Eutrophic	2008

and Western Ghats to the flat alluvial plains of the river valleys and coastal tracts, and the aeolian deserts of Rajasthan are also responsible non-uniform distribution of ground water. The rainfall patterns too show similar region-wise variations. The topography and rainfall virtually control run-off and groundwater recharge (Master Plan, 2002).

Growing demand of water in various sectors viz; agriculture, industrial and domestic sectors, has brought problems of over-exploitation of the groundwater resource, continuously declining groundwater levels, sea water ingress in coastal areas, and groundwater pollution in different parts of the country. The falling groundwater levels in various parts of the country have threatened the sustainability of the groundwater resource, as water levels have gone deep beyond the economic lifts of pumping. The Central Ground Water Board has established more than 15,000 network monitoring stations in the country to monitor groundwater level and its quality. Water levels in major parts of the country generally do not show any significant rise/fall. However, significant decline in the level of groundwater has been observed in certain pockets in Andhra Pradesh, Assam, Bihar, Chhattisgarh, NCT Delhi, Gujarat, Haryana, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal. Delhi, Haryana, Punjab, Rajasthan, Chandigarh and Diu have recorded high level of groundwater development (more than 85%) (Mall et al., 2006).

Groundwater in certain geological formations may not be of desired quality for specific uses. Naturally occurring fluorides, arsenic and salinity are known to adversely affect the quality of water for drinking water supplies. Under certain hydrogeological conditions, unsewered domestic waste can cause severe groundwater contamination by pathogenic bacteria, nitrate and other pollutants. In India, the percentage of sewered population is nearly negligible in most of the rural areas and is quite meager (0 to 50%) in most medium and small towns. As a result, the contamination of groundwater by pollution from unsewered areas is one of the most important environmental problems facing the country. Studies carried out in India reveal that one of the most important cause of ground water pollution is unplanned urban development without adequate attention to sewage and waste disposal. Industrialisation without provision of proper treatment and disposal wastes and affluent is another source of ground water pollution. Unsystematic use of synthetic fertilizers couple with improper water management practices have resulted in deterioration of ground water quality in many parts of the country.

Recently a study on assessment of ground water quality in metropolitan cities of India was carried out by National Institute of Hydrology, Roorkee sponsored by CPCB, Delhi. Findings in general and recommendations of the study has been summarized below:

Groundwater Quality of Metropolitan Cities Agra, Meerut, Lucknow, Ludhiana, Vijaywada, Madurai, Chennai, Coimbatore (Source: CPCB Report, 2007)

A) Findings in general

i) The groundwater quality problems are mainly due to a) contamination by geogenic and man-made sources; and b) sea water intrusion due to over-abstraction of groundwater along the coasts. The geogenic contamination can be attributed to over-abstraction causing lowering of water table and disturbing the contaminated geological structures. The man-made contamination is mainly due to large-scale urbanisation, industrialisation and agricultural activities.

ii) Groundwater quality is being increasing threatened by agricultural, urban & industrial wastes, which leach or are injected into underlying aquifers. With fast urban growth and increasing standard of living the waste generation has steeply increased in India, especially in large urban centres. Due to paucity of resources the local authorities, who are responsible for waste management are not able to adequately address the problem. This has resulted in a large amount of wastes, both solid and liquid, not being collected, treated or disposed properly. The un-collected wastes are largely accumulated in the city areas, percolate or leach in the ground and pollute the groundwater.

iii) A large number of industrial activities are taking place in urban areas, especially in congested, populated areas. The wastes generated by industrial activities in urban areas get mixed with domestic wastes and pollute the groundwater.

iv) The groundwater is only source of drinking in many urban centres of the country. Thus, a large urban population is at risk of consuming polluted water and the major problem is urban areas are related to increasing salinity, nitrate, coliform (indicators of pathogen), fluoride and in some cases micro-pollutants.

v) The quality of groundwater with respect to bacteriological parameters in some of the pockets of metropolitan cities showed bacterial contamination at few locations during pre-monsoon season. This can be attributed to in-adequate collection of sewage, garbage leading to accumulation of wastewater and garbage, inadequate maintenance of hand pumps, improper sanitation and unhygienic conditions around the structures and in the city limit may be responsible for bacterial contamination at few locations during the pre-monsoon season.

vi) In some of the metro-cities like Agra and Meerut, the salinity is increasing at a fast rate. This can be attributed to percolation of accumulated salts in intense irrigated areas and industrial activities.

vii) With respect to physico-chemical properties of the samples collected, it is either conforming to desirable or permissible limits. The quality of ground water from a few shallow tube wells has been impaired in some of the areas. However, the deep bore/tube wells have not yet been affected. Percent violation against drinking water standards in eight metropolitan cities is given Table 3.

CONCLUDING REMARKS

- More basic studies to determine the trend of temperature and rainfall on basin, regional and country scales are required to be carried out to apprehend the impact of climate change on water resources.
- As recharge of groundwater is mainly governed by the precipitation and therefore, ground water quality in alluvial aquifers will be mostly affected due to climatic change. Further, possibilities of construction of artificial recharge structures should be explored to augment the ground water recharge.
- The most common method of disposal of solid municipal waste in India is by deposition in landfills. In order to minimise

Table 3. Percent violation against drinking water standards in eight metropolitan cities

S. No.	Agra	Meerut	Lucknow	Ludhiana	Vijaywada	Madurai	Chennai	Coimbtore
TDS	36	-	-	-	18	10	22	32
Nitrate	54	14	-	-	-	-	-	28
Fluoride	34	4	-	-	8	8	14	4
Total Coliform	8	2	20	-	-	-	2	-
Faecal Coilform	6	-	28	-	-	-	-	-
Fe	74	30	10	-	12	4	32	2
Cu	96	-	-	-	-	-	-	-
Cr	-	-	-	-	-	-	-	4
Mn	10	8	10	-	12	16	42	-

the impact of such landfills on groundwater quality and the environment in general it is necessary to properly design and build these facilities to prevent pollution and put in place strict management controls to ensure they are operated correctly.

- The untreated sewage and sewerage flowing in various open drains are one of the causes of ground water quality deterioration. Proper under ground sewage system must be laid in all inhabited areas and the untreated sewage and industrial wastes should not be allowed to flow in open drains.
- Disposal of hazardous waste or biomedical waste should be prohibited in the city limit to avoid any leaching process in to the groundwater or to provide engineered landfill, if it is within the city limit.
- More R&D is required to develop low cost, economic viable and easy to implement techniques for consumers for removing hardness, total dissolved solids arsenic, fluoride, coliform, nitrate and heavy metals in water where the value exceeds the permissible limit of drinking water.
- The mass awareness should be generated about quality of water, its effect on human health and responsibilities of public to safeguard water resources.

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