WATER RESOURCES: INDIAN SCENARIOS

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Four Days Training Course on

HYDROLOGICAL INVESTIGATIONS FOR CONSERVATION AND MANAGEMENT OF LAKES

(15-18 January, 2013)

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INTRODUCTION

Water plays a major role in our lives as it play major role in agriculture, hydropower generation, livestock production, industrial activities, forestry, fisheries, navigation and recreational activities etc. India has plenty of fresh water. Most of the fresh water is received during monsoon months unlike land; availability of water varies from place to place and time to time. Bulk of rain fall, is confined to a brief period of 3-4 months and this large part of the country takes, supply of water for a greater part of the year.

National Water Policy (2002) stresses the need for multi-sectoral integrated water resources development and management considering drainage basin as a whole or a sub-basin as a hydrological unit taking into account both surface and ground water for sustainable development. All individual developmental projects and proposals should be formulated and considered within the framework of such an overall plan. Appropriate river basin organizations need to be established for the planned development and management of a river basin or sub-basins, wherever necessary Special multi-disciplinary units will be required to prepare comprehensive plan taking into account not only the needs of irrigation but harmonizing various other sectors, so that the available water resources are put to optimum use. As per the National Water Policy in planning and operation of systems, water allocation priorities should be broadly as: (i) drinking water, (ii) irrigation, (iii) hydropower, (iv) ecology, (v) agro-industries and non-agricultural industries and (vi) navigation. India receives annual precipitation of about 4000 km^3, including snowfall. Out of this, monsoon rainfall is of the order of 3000 km^3. The long-term average annual rainfall for the country is 1160 mm, which is the highest anywhere in the world for a country of comparable size (Lal, 2001). The annual rainfall in India however fluctuates widely. The highest rainfall in India of about 11,690 mm is recorded at Mousinram near Cherrapunji in Meghalaya in the northeast. In this region rainfall as much as 1040 mm is recorded in a day. At the other extreme, there are places like Jaisalmer, in Rajasthan, which receives barely 150 mm of rainfall. Though, the average rainfall is adequate, nearly three-quarters of the rain pours down in less than 120 days, from June to September and thus exhibits very high spatial and temporal variability.

India is endowed with a river system comprising of more than 20 major rivers with several tributaries. Many of these rivers are perennial and some of these rivers are seasonal. Apart from the water available in the various rivers of the country, the ground water is also an important source of water for drinking, irrigation and industrial uses etc. It accounts for about 80% of domestic water requirement and more than 45% of the total irrigation in the country. As per the international norms, if per-capita water availability is less than 1700 m^3 per year then the country is categorized as water stressed and if it is less than 1000 m^3 per capita per year, then the country is classified as water scarce. In India per capita surface water availability in the year 1991 and 2001 were 2309 and 1902 m^3 and these are projected to be reduced to 1401 and 1191 m^3 by the years 2025 and 2050 respectively. Hence, there is a need for judicious planning, development and management of the greatest assets of the country viz. water and land resources for raising standards of living of millions of people particularly in rural areas.

WATER POLLUTION

The environment and the human health are closely interrelated. The wellbeing of the people is the reflection of the healthy environment, but both can damage by pollution. Pollutants released into air, water and soil can find their way in to human body by breathing, eating and drinking. Growing urbanization, rapid industrialization without proper plan, excess use of chemical fertilizers, insecticides, pesticides in agriculture field has deteriorated the quality of water, causing water pollution. In broad perspective "Pollution" means such contamination of water or such alteration of the physical, chemical or biological properties of water or such discharge of any sewage or trade effluent or of any other liquid, gaseous or solid substance into water (whether directly or indirectly) as may, or is likely to, create a nuisance or render such water harmful or injurious to public health or safety, or to domestic, commercial, industrial, agricultural or other legitimate uses, or to the life and health of animals or plants or of aquatic organisms. (Govt. of India, 1974). Broadly, the major sources of water pollution can be divided as urban and domestic waste, industrial waste, agricultural sources, mining wastes, induced contaminated source, radioactive substances etc. In municipal areas the solid waste is produced at a rate of 0.33 kg/capita/day and thus the production of solid waste by the urban population of the country is around 23 million tons per year. Therefore, urban and domestic wastes play a significant role in polluting the water. Industrial wastes discharge plays an important role in the deterioration of water quality specially in urban and industrial areas. Besides several environmental guidelines for industries in India, there is lack of facilities to treat the solid and liquid waste and the same is generally dumped in low lying/open area by these industrial units, which moves downwards to lower reaches causing pollution in ground water regime. To increase the yield, indiscriminate use of fertilizers has also resulted into higher concentration of some constituents like Nitrates and Phosphate. Pollution is therefore considered as a major threat at the system level involving environmental implications and needs to make efforts for its control and remediation.

Various pollutants present in water are measured through water quality parameters and can be broadly classified into following categories:

Physical parameters: appearance, temperature, turbidity, colour, taste, odour
Chemical parameters: all inorganic and organic substances (e.g. pH, acidity, alkalinity, hardness, conductivity, chlorides, sulphates, nitrates, nitrites, ammonia, fluoride, boron, heavy metals, pesticides, detergents, phenols, cyanide, radioactivity, oil and greese, organics, BOD, COD, DO etc.
Biological parameters: Total Coliform, MPN, Total plate count (TPC)

Some of the pollutants are of serious concern and can not be neglected, are Heavy metals (zinc, copper, cadmium, lead, mercury, nickel, iron, manganese, arsenic, chromium) and Pesticides and Polynuclear Aromatics Hydrocarbons (PAH). Heavy metal pollution in its inorganic and organic forms is mainly caused by uncontrolled discharge of wastewaters of different types of industries. Leachates from landfill sites and mining waste dumps are other contributors of metal pollution. Organic pollutants (mostly organochloro and some persistent toxic substances in water bodies) got importance because of their carcinogenic character. They enter water bodies through point sources, non-point sources as well as through long range atmospheric transportation. The process of bio-accumulation and bio-magnification of these organic pollutants fresh water eco-system is of great importance.

The water is being used as multipurpose resource in India. The main uses of water are public water supply, outdoor bathing & recreation, fisheries & wildlife propagation, irrigation & other agricultural uses, cooling in power plants, navigation and disposal of wastes. The Central Pollution Control Board has classified all water bodies including coastal waters in the country according to their "designated best uses" as given in the Table 1. Most of these uses are often conflicting. In order for any water body to function adequately in satisfying any one of the above mentioned use, it must have corresponding degree of purity. In terms of quality, drinking water needs highest level of purity, whereas disposal of wastes can be done in any quality of water. Therefore there is great need to maintain the quality of water as it is as important as the quantity.

DRINKING WATER SPECIFICATIONS

The Bureau of Indian Standards (BIS) earlier known as Indian Standards Institution (ISI) has laid down the standard specifications for drinking water (BIS, 1991). In order to enable the users, exercise their discretion towards water quality criteria, the maximum permissible limit has been prescribed especially where no alternate sources are available. The national water quality standards describe essential and desirable characteristics required to be evaluated to ascertain suitability of water for drinking purpose. The important water quality characteristics as laid down in BIS Standard are given in Table 2.

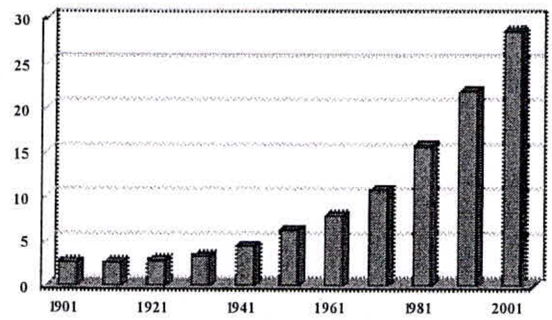
Table 1 : Designated Best Use Classification of Surface Water

Designated Best Use	Quality Class	Primary Water Quality Criteria
Drinking water source without conventional treatment but with chlorination	A	Total coliform organisms (MPN*/100 ml) shall be 50 or less pH between 6.5 and 8.5 Dissolved Oxygen 6 mg/L or more, and Biochemical Oxygen Demand 2 mg/L or less
Outdoor bathing (organized)	B	Total coliform organisms (MPN/100 ml) shall be 500 or less pH between 6.5 and 8.5 Dissolved Oxygen 5 mg/L or more, and Biochemical Oxygen Demand 3 mg/L or less
Drinking water source with conventional treatment	C	Total coliform organisms (MPN/100 ml) shall be 5000 or less pH between 6 and 9 Dissolved Oxygen 4 mg/L or more, and Biochemical Oxygen Demand 3 mg/L or less
Propagation of wildlife and fisheries	D	pH between 6.5 and 8.5 Dissolved Oxygen 4 mg/L or more, and Free ammonia (as N) 1.2 mg/L or less
Irrigation, industrial cooling and controlled disposal	E	pH between 6.0 and 8.5 Electrical conductivity less than 2250 micro mhos/cm, Sodium Absorption Ratio less than 26, and Boron less than 2 mg/L

Table 2: Drinking water specifications (IS:10500:1991)

S.No.	Characteristics	Desirable limit	Permissible limit
Essential Characteristics			
1.	Colour, Hazen units, Max	5	25
2.	Odour	Unobjectionable	-
3.	Taste	Agreeable	-
4.	Turbidity, NTU, Max	5	10
5.	pH value	6.5 to 8.5	-
6.	Total hardness ($CaCO_3$), mg/L, Max	300	600
7.	Iron, mg/L, Max	0.3	1.0
8.	Chlorides, mg/L, Max	250	1000
9.	Residual free chlorine, mg/L, Max	0.2	-
Desirable Characteristics			
10.	Dissolved solids, mg/L, Max	500	2000
11.	Calcium, mg/L, Max	75	200
12.	Magnesium, mg/L, Max	30	100
13.	Copper, mg/L, Max	0.05	1.5
14.	Manganese, mg/L, Max	0.1	0.3
15.	Sulphate, mg/L, Max	200	400
16.	Nitrate, mg/L, Max	45	-
17.	Fluoride, mg/L, Max	1.0	1.5
18.	Phenolic compounds, mg/L, Max	0.001	0.002
19.	Mercury, mg/L, Max	0.001	-
20.	Cadmium, mg/L, Max	0.01	-
21.	Selenium, mg/L, Max	0.01	-
22.	Arsenic, mg/L, Max	0.01	-
23.	Cyanide, mg/L, Max	0.05	-
24.	Lead, mg/L, Max	0.05	-
25.	Anionic detergents	0.2	1.0
26.	Chromium as Cr^{6+}, mg/L, Max	0.05	-
27.	PAH, mg/L, Max	-	-
28.	Mineral oil, mg/L, Max	0.01	0.03
29.	Pesticides, mg/L, Max	Absent	0.001
30.	Alkalinity, mg/L, Max	200	600
31.	Aluminium, mg/L, Max	0.03	0.2
32.	Boron, mg/L, Max	1	5

Figure 1: Urban Population Growth Trend



Contamination of water is certainly one of the key issues, as it can prevent water from being used for its intended purpose. Contamination can enter the water bodies through point sources and non-point sources. In India, fecal contamination is still the primary water quality issue for both surface and ground waters. Although this applies to the rural as well as urban areas, the situation is probably more critical in fast growing cities. Fecal contamination is a source of pathogenic organisms responsible for water borne diseases. It affects the health of the users as well as ecological health of the river.

Depletion of oxygen in natural water bodies due to discharge of high organic loads from domestic sector as well as agro based industries deteriorates the health of the water body. Due to such sudden oxygen depletion, survival of aquatic life becomes endangered, which is of concern.

Presence of organic pollutants (mostly organochloro compounds and some persistent toxic substances in water bodies) is also becoming an important water quality issue because of their carcinogenic character. They enter water bodies through point sources, non-point sources as well as through long range atmospheric transportation. The process of bio-accumulation and bio-magnification of these organic pollutants in fresh water eco-systems is of great importance. Uncontrolled discharge of industrial wastewaters often causes heavy metal pollution in its inorganic and organic forms. Leachates from landfill sites and mining waste dumps are other contributors of metal pollution. Increased mineral salts in rivers may arise from discharge from industrial/ mining wastewater, irrigation and surface run-off from arid and semi arid regions.

A vast majority of groundwater quality problems are caused by contamination, over-exploitation, or the combination of two. Most groundwater quality problems are difficult to detect and hard to resolve. The solutions are usually very expensive, time consuming and not always effective. An alarming picture of ground water deterioration is emerging in many parts of the country. Groundwater contamination due to nitrate, fluoride, iron, arsenic and mercury and intrusion of leachate from landfill sites are some of the glaring examples of this in India nowadays.

India is urbanizing very fast. With increasing urban population water supply and wastewater generation is also increasing steeply. However, the treatment facilities are lagging behind due to paucity of resources with the urban local bodies, who are responsible for sewage management. Discharge of untreated domestic wastewater is predominant source of pollution of aquatic resources in India. Urban centers contribute most of the sewage generation in the country. The smaller towns and rural areas do not contribute significant amounts of sewage due to low per capita water supply. The wastewater generated in these areas normally percolates in the soil or evaporates. CPCB carry out regular inventory of water supply, wastewater generation, collection and disposal in class-I cities and class_II towns of the country. As per the latest estimate, 423 class I cities and 498 class II towns of the country harbouring population of 20 crore generate about 26250 million litre per day (mld) of wastewater. It was observed that most of the cities do not have adequate organized water supply, as well as wastewater collection and treatment facilities. Out of which about 7000 mld of wastewater gets some kind of treatment. It was also observed that Maharashtra, Delhi, Uttar Pradesh, West Bengal and Gujarat are the major contributors of wastewater (63%). The facilities constructed to treat wastewater do not function properly and remain closed most of the time due to improper design and poor maintenance, together with a non-technical and unskilled approach. As per the latest information about 38300 MLD of wastewater generated from urban centres out of which treatment capacity exists for only about 11000 MLD. Thus, a large part of the untreated sewage is discharged into water bodies causing pollution. In many cases, there is no dilution water available resulting in severe pollution in the receiving water body (Trivedi, 2010).

STATUS OF WATER RESOURCES IN INDIA

India supports about 1/6th of world population, 1/50th of world's land and 1/25th of world's water resources. 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. India also has a livestock population of 500 million, which is about 20% of the world's total livestock population. More than half of these are cattle, forming the backbone of Indian agriculture. A brief description of availability of surface and groundwater water resources of India is given as follow.

In India, surface flow takes place through 14 major rivers systems. Between them they share 83% of the drainage basin, account for 85% of the surface flow and house 80% of the total population of the country. In addition to major rivers there are 44 medium and 55 minor systems. These are fast flowing and monsoon fed. The surface flow is further enlarged by addition of about 450 cubic kms. of fresh water from ground water flow while about 50 cubic kms are added to runoff from irrigated areas. Out of this surface water flow about same amount of water percolates down to the ground water deposits. Several organizations and individuals have made an attempt to estimate water availability for the country within the limitations of physiographic conditions and socio-political environment, legal and constitutional constraints and the technology of development available differently. As reported by the ministry of water resources of India, the basin-wise average annual flow in Indian river systems is 1869 km^3 and the utilizable annual surface water of the country is 690 km^3 (Website: MOWR, India). The details of available surface water resources are given in Table 3.

Ground water resources are abundant only in the northern and coastal plains. Underground reservoir of fresh water is called aquifers. Ground water are continuously reached through infiltration, seepage and evatranspiration. Presently about 25% of the ground water is being used by man. Agriculture uses maximum amount of ground water.

It has been found that excessive use of ground water depletes aquafers, lowers the water table and may lead to salivation, water logging and alkalization of the soils. According to the initial estimates of the Central Ground Water Board an additional quantity of about 10,081 km3 of static ground water can be exploited.

Generally static water is not regular replenished on annual basis; its one time use is only possible as a short time strategy. Further experience indicates that large scale use of static water or its mining is usually associated with surface settlement which may cause heavy damages to properties of land and soils and may, possibly, trigger seismic activities. Therefore, any appreciable use of static ground water on regular basis is not foreseen till the middle of the 21st century.

In our country, total replenishable groundwater resource is estimated 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).

Table 3: Basinwise average flow (in km^3/year)

S. No.	River Basin	Average Annual Flow
1	Indus	73.31
2	Ganga-Brahmaputra-Meghna Basin	
	2a Ganga	525.02
	2b Brahmaputra, Barak and others	585.60
3	Subarnarekha	12.37
4	Brahmni-Baitarani	28.48
5	Mahanadi	66.88
6	Godavari	110.54
7	Krishna	78.12
8	Pennar	6.32
9	Cauvery	21.36
10	Tapi	14.88
11	Narmada	45.64
12	Mahi	11.02
13	Sabarmati	3.81
14	West flowing rivers of Kachchh and Saurashtra including Luni	15.1
15	West flowing rivers from Tapi to Tadri	87.41
16	West flowing rivers from Tadri to Kanyakumari	113.53
17	East flowing rivers Between Mahanadi and Pennar	22.52
18	East flowing rivers Between Pennar and Kanyakumari	16.46
19	Area of Inland drainage in Rajasthan desert	NEG.
20	Minor River Basins Draining into Bangladesh	31.00
	Total	1869.35

Source: Website: Ministry of Water Resources, India

WATER REQUIREMENTS

Different sectors of society use water for different purposes: drinking, growing food, producing manufactured food removing or diluting waste, producing and using energy, and so on. Agriculture is the predominant occupation in India. Therefore, development of irrigation to increase agricultural production for making the country self-sustained and for poverty alleviation has always been of crucial importance for the water resources planners. In our country, irrigation sector was assigned a very high priority in the 5-year plans. In order to increase irrigation potential and maximize agricultural production, a number of schemes like the Bhakra Nangal, Hirakud, Damodar Valley, Nagarjunasagar, Rajasthan Canal project etc. were taken up. The production of food grains has increased from around 50 million tonnes in the fifties to about 203 million tonnes in the year 1999-2000 (National Water Policy, 2002). According to the estimates adopted by NCIWRD (1999), by the year 2025, the population is expected to be 1333 million in high growth scenario and 1286 million in low growth scenario. For the year 2050, high rate of population growth is likely to result in about 1581 million people while the low growth projections place the number at nearly 1346 million. Keeping in view the level of consumption, losses in storage and transport, seed requirement, and buffer stock, the projected food-grain and feed demand for 2025 would be 320 million tonnes (high demand scenario) and 308 million tonnes (low demand scenario).

The requirement of food grains for the year 2050 would be 494 million tonnes (high demand scenario) and 420 million tonnes (low demand scenario). Table 4 provides details of the population of India and per capita water availability as well as utilizable surface water for some of the years from 1951 to 2050 (projected). The availability of water in India shows wide spatial and temporal variations. Also, there are very large inter annual variations. Hence, the general situation of availability of per capita availability is much more alarming than what is depicted by the average figures.

Domestic Use Water Requirement

We use lot of water for our daily needs. Accordingely, community water supply is the most important requirement and it is about 5% of the total water use. About 7 km^3 of surface water and 18 km^3 of ground water are being used for community water supply in urban and rural areas. Along with the increase in population, another important change from the point of view of water supply is higher rate of urbanization. As per the projections, the higher is the economic growth, the higher would be urbanization. It is expected that nearly 61 percent of the population will be living in urban areas by the year 2050 in high growth scenario as against 48% in low growth scenario. Different organizations and individuals have given different norms for water supply in cities and rural areas. The figure adopted by the NCIWRD (1999) was 220 litres per capita per day (lpcd) for class I cities. For the cities other than class I, the norms are 165 for year 2025 and 220 lpcd for the year 2050. For rural areas, 70 lpcd and 150 lpcd have been recommended for the year 2025 and 2050. Based on these norms and projection of population, it is estimated that by the year 2050, water requirements per year for domestic use will be 90 km^3 for low demand scenario and 111 km^3 for high demand scenario. It is expected that about 70% of urban water requirement and 30% percent of rural water requirement will be met by surface water sources and the remaining from ground water.

Irrigation Water Requirement

Irrigated area in the country was only 22.6 million hectare (M-ha) in 1950-51. Since food production was much below the requirement of the country, due attention was paid for expansion of irrigation. The ultimate irrigation potential of India has been estimated as 140 M-ha. Out of this, 76 M-ha would come from surface water and 64 M-ha from ground water sources. The quantum of water used for irrigation by the last century was of the order of 300 km^3 of surface water and 128 km^3 of ground water, total 428 km^3. The estimates indicate that by the year 2025, water requirement for irrigation would be 561 km^3 for low demand scenario and 611 km^3 for high demand scenario. These requirements are likely to further increase to 628 km^3 for low demand scenario and 807 km^3 for high demand scenario by the year 2050.

Table 4: Per capita per year availability and utilizable surface water in India (in m^3)

S. No.	Year	Population (in million)	Per-capita surface water availability	Per-capita utilizable surface water
1	1951	361	5410	1911
2	1955	395	4944	1746
3	1991	846	2309	816
4	2001	1027	1902	672
5	2025 (Projected)	a. 1286 (Low growth) b. 1333 (High growth)	1519 1465	495
6	2050 (Projected)	a. 1346 (Low growth) b. 1581 (High growth)	1451 1235	421

Hydroelectric Power Water Requirement

The hydropower potential of India has been estimated at 84,044 MW at 60% load factor. At the time of independence (1947), the installed capacity of hydropower projects was 508 MW. By the end of 1998, the installed hydropower capacity was about 22,000 MW. The status of hydropower development in major basins is highly uneven. According to an estimate, India has plans to develop 60,000 MW, additional hydropower by the twelfth five year plan. It includes 14,393 MW during tenth five year plan (2002-2007); 20,000 MW during eleventh (2007-2012) and 26,000 MW during twelfth (2012-2017) five year plans. A potential of the order of 10,000 MW is available for development of small hydropower projects in the Himalayan and sub-Himalayan regions of the country. Therefore, it is not only desirable but also a pressing need of time to draw a master plan for development of small, medium and large hydro-schemes for power generation.

Industrial Water Requirement

Rough estimates indicate that the present water use in the industrial sector is of the order of 15 km^3. The water use by thermal and nuclear power plants with installed capacities of 40000 MW and 1500 MW (1990 figures) respectively, is estimated to be about 19 km^3. In view of shortage of water, the industries are expected to switch over to water efficient technologies. If the present rate of water use continues, the water requirement for industries in the year 2050 would be 103 km^3; this is likely to be nearly 81 km^3 if water saving technologies are adopted on a large scale.

Total Water Requirements

Total annual requirement of water for various sectors has been estimated and its break up is given Table 5.

Table 5: Annual water requirement for different uses (in km^3) (NCIWRD, 1999)

Uses	Year 1997-98	Year 2010			Year 2025			Year 2050		
		Lo w	High	%	Lo w	High	%	Lo w	High	%
Surface Water										
Irrigation	318	330	339	48	325	366	43	375	463	39
Domestic	17	23	24	3	30	36	5	48	65	6
Industries	21	26	26	4	47	47	6	57	57	5
Power	7	14	15	2	25	26	3	50	56	5
Inland Navigation		7	7	1	10	10	1	15	15	1
Environment – Ecology		5	5	1	10	10	1	20	20	2
Evaporation Losses	36	42	42	6	50	50	6	76	76	6
Total	399	447	458	65	497	545	65	641	752	64
Ground Water										
Irrigation	206	213	218	31	236	245	29	253	344	29
Domestic	13	19	19	2	25	26	3	42	46	4
Industries	9	11	11	1	20	20	2	24	24	2
Power	2	4	4	1	6	7	1	13	14	1
Total	230	247	252	35	287	298	35	332	428	36
Grand total	629	694	710	100	784	843	100	973	1180	100
Total Water Use										
Irrigation	524	543	557	78	561	611	72	628	807	68
Domestic	30	42	43	6	55	62	7	90	111	9
Industries	30	37	37	5	67	67	8	81	81	7
Power	9	18	19	3	31	33	4	63	70	6
Inland Navigation	0	7	7	1	10	10	1	15	15	1
Environment – Ecology	0	5	5	1	10	10	1	20	20	2
Evaporation Losses	36	42	42	6	50	50	6	76	76	7
Total	629	694	710	100	784	843	100	973	1180	100

With the increasing population as well as all round development in the country, the utilization of water has also been increasing at a fast pace. In 1951, the actual utilization of surface water was about 20% and 10% in the case of ground water. The utilizable water in river basins is highly uneven. For example in the Brahmaputra basin, which contributes 629 billion m^3 of surface water of the country's total flow, only 24 billion m^3 is utilizable.

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.

Effect of Climate Change on Water 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.

WATER QUALITY STATUS OF WATER RESOURCES IN INDIA

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.

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 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 (Source: CPCB Report, 2007):

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.

CONCLUDING REMARKS

India is one of the few countries in the world endowed with abundant land and water resources. In the major part of the country, rainfall is the only sources for water which is available mainly during the monsoon season lasting for less than 3 months. Due to tropical climate and it's geographical, location, the country experiences vast spatial and temporal variation in precipitation. About one- third of the country's area is drought prone. Due to spatial and temporal variability in rainfall and thus availability of water hundreds of millions of people in our conntry lack assess to sufficient amount of fresh water for their needs. Therefore, a first step towards sustainable water use would be to gurantee all humans the water needed to satisfy their basic needs.

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