Water Resources in India: Its Demand, Degradation and Management

Atanu Bhattacharyya[1*], S. Janardana Reddy[2], Manisankar ghosh[3] and Raja Naika H[4]

[1]. Nanotechnolgy Section, Department of Biomedical Engineering, Rajiv Gandhi Institute of Technology and Research Centre , Cholanagar, R.T. Nagar Post, Hebbal , Bangalore-560 032. India.
[2]. Department of Fishery Science and Aquaculture, Sri Venkateswara University, Tirupati-517 502, India
[3]. Department of Textiles (Sericulture), Government of West Bengal, Ganesh Chandra Avenue,Kolkata-13
[4]. Dept. of Studies and Research in Environmental Science, Bharatha Ratna Prof. C.N.R. Rao Block, Lab. No. 104, First Floor, Tumkur University, Tumkur- 572103, Karnataka, India

Abstract- Water is a prime natural stockpile, a basic human need and a treasured national asset. Planning, development and management of water manoeuvre need to be governed by national perspectives. We are all too familiar with the problems of water on earth in both qualitative and quantitative aspects. India receives annual precipitation of about 4000km^3, including snowfall. Out of this, monsoon rainfall is of the order of 3000km^3. Rainfall in India is relying on the south west and north-east monsoons, on shallow cyclonic depressions and disturbances and on local storms. The latest estimate of total water resources of India as assessed by NCIWRDP is 1952.87 BCM. The (NCIWRD) estimated the total basin wise average annual flow in Indian River systems as 1953 km^3. The annual potential nature of ground water recharge from rainfall in India is about 342.43 km^3 .The total utilizable water resources of India, according to the CWC are 1110 BCM. According to NCIWRD, the population of India is expected to be 1333 million and 1581 million in high growth scenario by the year 2025 and 2050 respectively. This eventually would be major cause of water crisis and water quality deterioration. An ideal water management technique and awareness of people could help to save the life on earth.

Index Terms- Water resources, Groundwater, degraded water, surface water, water management

I. Introduction

Water bedaubs more than two-thirds of the Earth's surface. But fresh water represents less than 0.5% of the total water on Earth. The rest is either in the form of seawater or locked up in icecaps or the soil, which is why one often hears of water sparseness in many areas [**1**].

There are about 97 percent of all water is in the oceans and three percent of all Earth's water that is freshwater. The majority, about 69 percent, is locked up in glaciers and icecaps, mainly in Greenland and Antarctica. It might be surprised that of the remaining freshwater is remained as ground water. No matter where on Earth you are standing, chances are that, at some depth, the ground below you is saturated with water. Of all the freshwater on Earth, only about 0.3 percent is contained in rivers and lakes-yet rivers and lakes are not only the water we are most familiar with, it is also where most of the water we use in our everyday lives exists [**2**].

Water is finite in quantity, tangible in nature, and un-equally distributed throughout the world. Only 2.5% of 1386 million cubic kilometers of water available on earth is fresh water and one-third of this smaller quantity is available for human use [**3**]. The per capita annual water resource(AWR) has been used to classify countries with respect to the water scarcity[**4**]. According to international norms ,countries with an AWR per capita of 1700 cu m and above have been termed as countries where shortage will be rare; if per capita water availability is less than 1700 cu m per year then the country is categorized as water stressed , if it is less than 1000 cu m per capita per year, then the country is classified as water-scarce; and those with an AWR per capita of 500 cu m and below as countries where availability of water is a primary constraint to life [5**]**. Water is essential for sustaining all forms of life, food production, economic development and for general well being. It is impossible to substitutes for most of its uses, difficult to de-pollute, expensive to transport and it is truly a unique gift to mankind from nature [**6]**. In India, per capita surface water availability in 1991 and 2001 was 2309 and 1902m^3 respectively and these are projected to reduce further to 1401 and 1191m^3 by the years 2025 and 2050 respectively [**7]**. India receives annual precipitation of about 4000km^3, including snowfall. Out of this, monsoon rainfall is of the order of 3000km^3. Rainfall in India is reliant on the south west and north- east monsoons, on shallow cyclonic depressions and disturbances and on local storms (Figure-1).

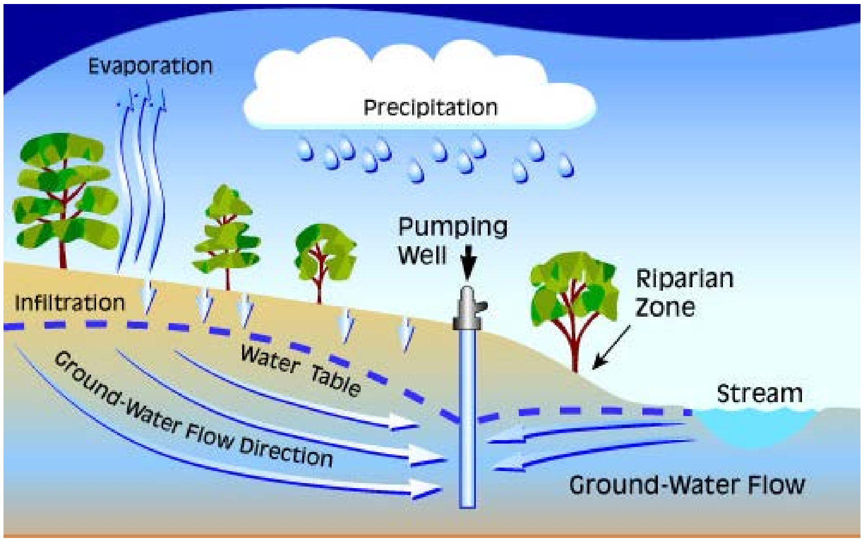

Figure-1: Ground water Direction, Flow and Availability

Population of our country is increasing with an alarming rate. It has an adverse impact on water resources in our country. In order to fulfill water demands in the future, we will need to rationalize on various means of capturing and storing water. A good management system may save the quality of water and protect it from deterioration.

II. WATER AVAILABILITY AND WATER DEMAND IN INDIA

According to the National Water Policy of India [**7**]. "Out of the total precipitation, including snowfall, of around 4000 billion cubic meters(BCM) from surface water and replenishable ground water is put at 1869 billion cubic meters. Because of topographical and other constraints, about 60% of this, i.e.690 billion cubic meter from surface water and 432 billion cubic meters from ground water, can be put to beneficial use. (Table-1). "The latest estimate of total water resources of India as assessed by NCIWRDP is 1952.87 BCM, but this cannot be fully put to beneficial use because of topographical and other constraints [**8-9**].

There are four main sources of water:

- **(i)** Surface water
- **(ii)** Underground water
- **(iii)** Atmospheric water, and
- **(iv)** Oceanic water.

In our daily life we use only surface water and underground water. Let us study them in detail. (A) Surface water – The main source of surface water is precipitation. About 20 percent part of the precipitation evaporates and mixes with the environment. A part of the running water goes underground. The large part of surface water is found in rivers, riverlets, ponds and lakes. Remaining water flows into the seas, oceans. Water endowed on the surface is called surface water. About two – third of the total surface water flows into three major rivers of the country – Indus, Ganges and Brahmaputras. The water storage capacity of reservoirs constructed in India so far is about 17400 billion cubic meters. At the time of independence, the water storage capacity was only 180 billion cubic meters. Hence water storage capacity has increased about ten times [**10**].

i) Surface Water: India's average annual surface run-off generated by rainfall and snowmelt is estimated to be about 1869 billion cubic meters (BCM). However, it is estimated that only about 690 BCM or 37 per cent of the surface water resources can actually be mobilized. This is because (i) over 90 per cent of the annual flow of the Himalayas rivers occur over a four month period and (ii) potential to capture such resources is complicated by limited suitable storage reservoir sites.

The average annual precipitation over the entire surface of the earth is estimated to be about 100cm.amounting to a total volume of about 5x105km^{3}**.**This is about 39 times the total quantity of all water in the atmosphere, implying that the average residence time of water in the atmosphere is about 9.4 days [**9**]. Yet, this atmospheric circulation is dynamically linked to the much larger time scales of circulation of surface water and ground water and has influenced the earth's evolution over billions of years.

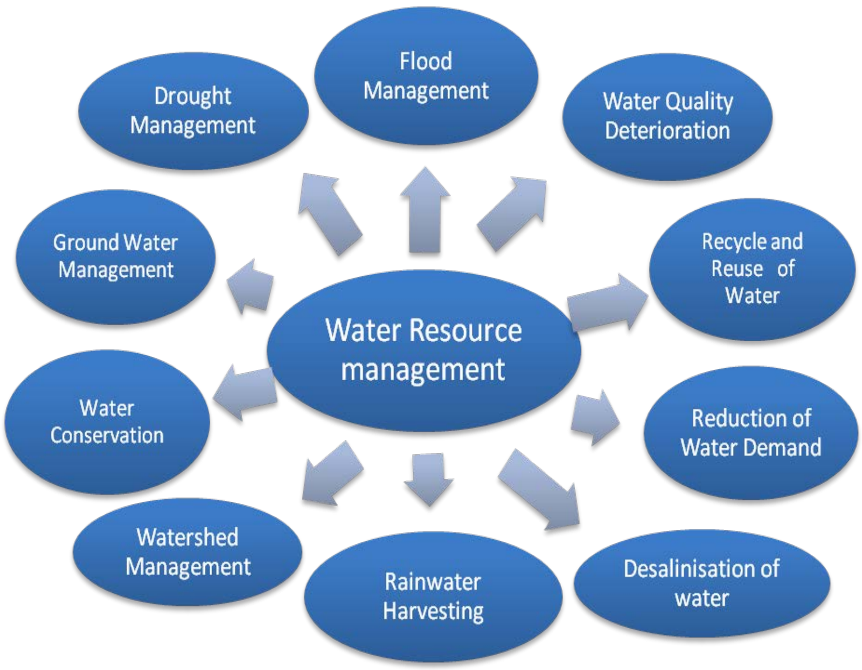

Figure-2: Water Resource Management and Procurement Methods

India is gifted with many rivers. As many as twelve of them are classified as major rivers whose total catchment area is 252.8 million hectares and an average annual potential in rivers is 1570.98 BCM. Another 48 rivers are classified as minor **[11]** rivers whose total catchment area is 24.9 million hectare **[12-13]**.

Many of these rivers are perennial, though few are seasonal. This is because precipitation over a large part of India is strongly concentrated in the summer monsoon season during June to September/October and tropical storm season from May to October[13]. Recently, the National Commission **[14]** for Integrated Water Resources Development (NCIWRD) estimated the total basin wise average annual flow in Indian river systems as 1953 km^3.The details is given in **Table 1.**

Table-1: Basin wise average flow of utilizable water (in km^3/year) [**7**].

Sl.No.	River Basin	Average annual flow	Utilizable flow
1.	Indus	73.31	46
2.	Ganga-Brahmaputra-Meghna Basin 2a.Ganga 2b. Brahmaputra sub-basin 2c. Meghna Sub -Basin	 525.02 629.05 48.36	 250 24
3.	Subarnarekha	12.37	6.81
4.	Brahmni-Baitarani	28.48	18.3
5.	Mahanadi	66.88	49.99
6.	Godavari	110.54	76.3
7.	Krishna	69.81	58
8	Pennar	6.32	6.86
9.	Cauvery	21.36	19
10.	Tapi	14.88	14.5
11.	Narmada	45.64	34.5
12.	Mahi	11.02	3.1
13.	Sabarmati	3.81	1.93
14.	West flowing rivers of Kachchh and Saurashtra including Luni	15.1	14.98
15.	West flowing rivers south of Tapi	200.94	36.21

16.	East flowing rivers between Mahanadi and Godavari	17.08	
17.	East flowing rivers between Godavari and Krishna	1.81	13.11
18.	East flowing rivers between Krishna and Pennar	3.63	
19.	East flowing rivers between Pennar Cauvery	9.98	16.73
20.	East flowing rivers south of Cauvery	6.48	
21.	Area of North Ladakh not draining into Indus	0	NA
22..	Rivers draining into Bangladesh	8.57	NA
23.	Rivers draining into Mayanmar	22.43	NA
24	Drainage areas of Andaman,Nicobar and Lakshadweep Islands	0	NA
25.	Total(rounded)	1953	690

Average water yield per unit area of the Himalayan rivers is almost double that of south peninsular river systems, which indicates the importance of snow and glacier melt contribution from high mountains. Average intensity of mountain glaciations varies from 3. 4% for Indus to 3.2% for Ganges and 1.3 for Brahmaputra. The tributaries of these river system show maximum intensity of glaciations [**9**].

It is estimated that the Himalayan Mountains cover a surface area of permanent snow and ice in the region which is about 97,020 km^2 with 12930 km^2 volume. In these mountains,10 to 20% of the total surface area is covered by glaciers, while an area ranging from 30 to 40% has seasonal snow cover [**12**]. These glaciers provide snow and the glacial melt waters keep the Himalayan rivers perennial [**14**].

ii) Underground Water: The term underground water refers to all water below the water table to great depths. In the soil, both water and air coexist in the pore spaces. A profound consequence is that the capillary water in the soil can only be extracted by plant roots, within certain range of conditions. Ground water, on the other hand can be extracted by humans through wells. Ground water and soil water together constitute the lower part of the hydrological cycle [**15**].

The annual potential natural of ground water recharge from rainfall in India is about 342.43 km^3, which is 8.56% of total annual rainfall of the country. The annual potential ground water recharge augmentation from canal irrigation system is about 89.46km^3.Thus, total replenishable ground water resource of the country is assessed as 431.89%. After allotting 15% of this quantity for drinking and 6 km^3 for industrial purposes, and the remaining can be utilized for irrigation purposes. Thus the available ground water resource for irrigation in India is 361km^3, of which utilizable quantity (90%) is 325km^3.The estimates by the central Groundwater Board (CGWB) of total replenishable groundwater resource, provision for domestic, industrial and irrigation uses and utilizable ground water resources for future use are given in **Table-2.**

Table-2: Ground water resources of India (in km^3/year)

Sl.No	Groundwater sources	Amount(km^3/yr)
1.	Total replenishable groundwater resource	432
2.	Provision for domestic, industrial and other uses	71
3.	Available groundwater resource for irrigation	361
4.	Utilizable groundwater resource for irrigation(90% of sl.3	325
5.	Total Utilizable groundwater resource(sum of sl.nos 2&3	396
	Total	1575

India's rechargeable annual groundwater potential has been assessed at around 431 BCM in aggregate terms. On an all India basis it is estimated that about 30 per cent of the groundwater potential has been tapped for irrigation and domestic use. The regional situation is very much different and large parts of India have already exploited almost all of their dynamic recharge. Haryana and Punjab have exploited about 94 per cent of their groundwater resources. Areas with depleting groundwater tables are found in Rajasthan, Gujarat, most of western Uttar Pradesh and in all of the Deccan states. Occurrence of water availability at about 1000 cubic meters per capita per annum is a commonly threshold for water indicating scarcity (UNDP). Investment to capture additional surface run-off will become increasingly more difficult and expensive in the future. Over time, both for surface and groundwater resources, a situation where resources were substantially under utilised and where considerable development potential existed, has transformed in little more than a generation to a situation of water scarcity and limited development options [**16**].

Figure-3: Women carrying Ground Water far from Residential Places.

India faces an increasingly urgent situation: its finite and fragile water resources are stressed and depleting while various sectoral demands are growing rapidly. Historically relatively plentiful water resources have been primarily for irrigated agriculture, but with the growth of Indian economy and industrial activities water demands share of water is changing rapidly. In addition increase in population and rapid urbanisation also put an additional demand on water resources. Summing up the various sectoral projections revealed a total annual demand for water increasing from 552 billion cubic meter (BCM) in 1997 to 1050 BCM by 2025 [**17]**.

iii) Atmospheric Water: The Earth is a truly unique in its abundance of water. Water is necessary to sustaining life on the Earth, and helps tie together the Earth's lands, oceans, and atmosphere into an integrated system. Precipitation, evaporation, freezing and melting and condensation are all part of the hydrological cycle **-** a never-ending global process of water circulation from clouds to land, to the ocean, and back to the clouds. This cycling of water is intimately linked with energy exchanges among the atmosphere, ocean, and land that determine the Earth's climate and cause much of natural climate variability. The impacts of climate change and variability on the quality of human life occur primarily through changes in the water cycle [**18]**.

The hydrological cycle is largely driven by solar energy. Of the total solar energy received on the Earth's surface, about 40% is returned to the atmosphere as latent heat of evaporation, and another 18% as sensible heat. Within the atmosphere, water plays a significant role in the redistribution of energy through meridional or longitudinal convection cells, as well as through zonal or latitudinal circulation patterns. The average annual precipitation over the entire surface of the Earth is estimated to be about 100 cm, amounting to a total volume of about 5, 105 km3. This is about 39 times the total quantity of all water in the atmosphere, implying that the average residence time of water in the atmosphere is about 9.4 days. Yet, this atmospheric circulation is dynamically linked to the much larger time-scales of circulation of surface water (years to decades) and groundwater (decades to centuries), and has influenced the Earth's evolution over billions of years.

iv) The Oceanic Water: The Ocean plays a key role in this vital cycle of water. The ocean holds 97% of the total water on the planet; 78% of global precipitation occurs over the ocean, and it is the source of 86% of global evaporation. Besides affecting the amount of atmospheric water vapor and hence rainfall, evaporation from the sea surface is important in the movement of heat in the climate system. Water evaporates from the surface of the ocean, mostly in warm, cloud-free subtropical seas. This cools the surface of the ocean, and the large amount of heat absorbed the ocean partially buffers the greenhouse effect from increasing carbon dioxide and other gases. Water vapor carried by the atmosphere condenses as clouds and falls as rain, mostly in the ITCZ, far from where it evaporated, Condensing water vapor releases latent heat and this drives much of the atmospheric circulation in the tropics. This latent heat release is an important part of the Earth's heat balance, and it couples the planet's energy and water cycles [**18]**.

RAINFALL

The average annual rainfall in India is about 1170 mm. This is considerable variation in rain both temporarily and spatially. Most rain falls in the monsoon season (June-September), necessitating the creation of large storages for maximum utilisation of the surface run-off. Within any given year, it is possible to have both situations of drought and of floods in the same region. Regional varieties are also extreme, ranging from a low value of 100 mm in Western Rajasthan to over 11,000 mm in Meghalaya in North-Eastern India. Possible changes in rainfall patterns in the coming decade, global warming and climate change and other predicted or observed long-term trends on water availability could affect India's water resources [**19]**.

TOTAL WATER DEMAND OF INDIA

The population of the country has already crossed the 1 billion mark and is expected to reach 1.64 billion by the year 2050. Towns and villages are expanding rapidly, new hamlets are coming up and existing ones are turning into villages – all requiring and demanding drinking water for sustenance of life. India has been traditionally an agriculture based economy. Hence, development of irrigation to increase crop production for making the country self sufficient and for poverty elevation has been the crucial importance for the planners. At present, available statistics on water demand shows that the agriculture sector is the largest consumer of water in India. About 83% of the available water is utilized in agriculture alone. The quantity of water required for agriculture has increased progressively through the years as more and more areas were brought under irrigation. Since 1947 the irrigated area in India rose from 22.60 to 80.76 mha up to June 1997.Contribution of surface water and ground water resources for irrigation has played a significant role in India attaining self-sufficiency in food production during the past three decades, but it is likely to become more critical in future in the context of national food security [**20]**.

The population of India is growing day by day. With the increase of population the demand of people also reaching sky-high. A number of agencies have estimated the likely population of India by the year 2025 and 2050. According to NCIWRD [2**1]**, the population of India is expected to be 1333 million and 1581 million in high growth scenario by the year 2025 and 2050 respectively. 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 and 2050 would be 320 million tons and 494 million tons respectively (high demand scenario).So, the annual water demand for irrigation purposes, domestic use, hydro-electric power sector, industrial sectors and for others purposes are mentioned in table 3.Much of the future demand needs to be met from the ground water resources.

Rain water percolates into the earth's surface and becomes underground water. The process of percolation also take place from the surface water. Large amount of water gets collected under the Earth's surface by these two methods. This is called underground water. According to Central Underground Water Board renewable underground water capacity in India (1994-95) was about 4310 billion cubic metre per year. Out of this about 3960 billion cubic metres water is available for use. The distribution of undergrounds water is not the same everywhere.

Availability of underground water depends upon the amount of rainfall, nature of rainfall, nature of land and its slope. In the areas of high rainfall where the land is almost plain and has porous rocks, the water easily percolates there. Therefore underground water is available in plenty at shallow depths in these areas. In the areas like Rajasthan where the land is plain and has porous sandy soil, the underground water is available in lesser amount at greater depths due to lack of rainfall. In the north-eastern areas of the country, where the land is sloppy, the conditions are not suitable for percolation of water inspite of more rainfall. With the result underground water is available in less quantity at greater depths in these areas also. There are large resources of underground water in the plains of Ganga – Brahmaputra and in coastal plains. The availability of underground water is less in peninsular plateau, Himalayan region and desert areas. Use of underground water capacity Underground water is used on a large scale in the areas where the rainfall is comparatively less. Underground water is used on a large scale in Punjab, Haryana, Rajasthan, Tamil Nadu, Gujarat and Uttar Pradesh whereas Andhra Pradesh, Madhya Pradesh, Maharashtra, Karnatake and Chhattisgarh are such states where inspite of less rainfall, the use of underground water is less. There is a great need to develop underground water resources here.

WATER BUDGET

Water Budget means – the balance between the available water in the country and the water under use. There is a great variation in the distribution of water resources in space and time. Water is available in sufficient quantity during rainy season. As the dry season sets in, there is a shortage of water. The reserves of our surface and underground water are about 23840 billion cubic metres. Out of this only 10860 billion cubic metre water is required for use. The unit of measurement of amount of water is cubic metre or hectare metre. If water standing one metre deep on a perfectly level area of one square metre, then the total volume of whole of that water would be one cubic metre. In the same way, if water standing one metre deep on a perfectly level area of one hectare then the total volume of water would be one hectare metre [**22**].

Table-3: Annual Surface water requirement for different uses[27] (in km^3)

Sl.No	Use(Surface water)	Year 2010	Year 2025	Year 2050
1.	Irrigation	339	366	463
2.	Domestic	24	36	65
3.	Industries	26	47	57
4.	Power	15	26	56
5.	Inland navigation	7	10	15
6.	Environment-Ecology	5	10	20
7.	Evaporation Losses	42	50	76
	Total	458	545	752
	Use(Ground water)			
8	Irrigation	218	245	344
9	Domestic	19	26	46
9	Industries	11	20	24
10	Power	4	7	14
	Total	252	298	428
	Grand Total	710	843	1180

In India, 90 percent rainfall takes place during the short period of three months from june to August. There is a great variation in the number of rainy days in India. Average number of rainy days on the western coast is 137. In Rajasthan average number of rainy days is reduced to less than 10. There is a variation in the nature of rainfall also. The rainfall may be heavy and continuous in the areas of more rainfall where as the rainfall may be low and intermittent in the areas of less rainfall. Hence, there is a great variation in the regional distribution of rainfall. About 8 percent areas of the country receive more than 200 cm rainfall, 20 percent areas receive rainfall between 125 to 200 cm. and remaining 30 percent areas, receive less than 75 cm, rainfall. Uneven distribution of rainfall is responsible for the uneven distribution of surface and underground water.

The average annual precipitation received in India is 4,000 km^3, out of which 700 km^3 is immediately lost to the atmosphere, 2,150 km^3 soaks into the ground and 1,150 km^3 flows as surface runoff. The total water resources in the country have been estimated as 1,953 km^3. Nearly 62% or 1,202 km3 of the total water resources is available in the Ganga-Brahmaputra-Meghna basin. The remaining 23 basins have 751 km^3 of the total water resources [**22**].

The annual water availability in terms of utilizable water resources in India is 1,122 km^3. Besides this, the quantity of 123 km^3 to 169 km3 additional return flow will also be available from increased use from irrigation, domestic and industrial purposes by the year 2050 (Table-3).

The per capita availability of utilizable water, which was about 3,000 m^3 in the year 1951, has been reduced to 1,100 m^3 in 1998 and is expected to be 687 m^3 by the year 2050 **(Table-4).**

Table- 4: Per Capita Availability of Water

Year	**1951**	**1991**	**2010**	**2025**	**2050**
Population (10^6)	**361**	**846.3**	**1,157**	**1,333**	**1,581**
Average Water Resources (m^3/person/year)	**3,008**	**128.3**	**938**	**814**	**687**

WATER RESOURCES AT A GLANCE

The total volume of water in the hydrosphere is estimated to be about 1.36×10^9km3, of which 97.3% is locked up in the oceans as sea water, and another 2.1% in ice caps and glaciers[21].Freshwater, essential for sustenance of terrestrial life (plants, animals, and humans) constitutes about 0.6% of the total water inventory. A bulk of this freshwater occurs as ground water and as soil water, which can be extracted only by plants. Freshwater in lakes streams and the atmosphere constitutes less than 0.05% of all water on the Earth. Atmosphere alone contains only 13000km^3 or 0.001% of Earths water inventory.

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Table-5: Water resources in India [23].

Sl.No	Water resources	Quantity
1	Annual Precipitation	4000 BCM
2	Available water resources	1869
3	Utilizable a)Surface water (Storage and diversion) b)Groundwater (Replenishable)	1122 690 432
4	Present utilization(Surface water 63%,groundwater37%	605
5	Irrigation	501
6	Domestic	30
7	Industry, energy and other uses	74

It is observed that most of the studies estimate the water resources of India as 1880 BCM **[23]**, while the total utilizable water resources vary considerably. The NCA has estimated the total utilization as 1050 BCM. The total utilizable water resources of India, according to the CWC are 1110 BCM while NCIWRDP estimated the same as 1086 BCM plus additional return flows (123 BCM) for low demand scenario or 169 BCM for high demand scenario). Thus, the total utilizable water resources of 1086 BCM would be further enhanced to 1209 or 1255 BCM depending upon low or high demand scenario, in according to NCIWRDP. Water resources in India are represented in **Table 5.**

WATER QUALITY DETERIORATION

Groundwater accounts for more than 80% of the rural domestic water supply in India [**24]**. Data collected in 1998 for the 54^{th} round of the National Sample Survey showed that 50% of rural households were served by a tubewell, 26% by a well, and 19% tap [**22]**. In most parts of the country**,** however, the water supplied through groundwater is beset with problems of quality [**26]** .The over dependency on groundwater has led to 66 million people in 22 states at risk due to excessive fluoride(table 5) and around 10million at risk due to arsenic in six states [**27].** Indias Tenth Five Year Plan lists excess fluoride concentration as one of the major hurdles to the sustainable supply of safe water for domestic use. Twenty Indian states have excess fluorides in the ground water [**28]** .Nearly six million children below the age of 14 suffer from dental, skeletal and non-skeletal fluorosis [**23]**.

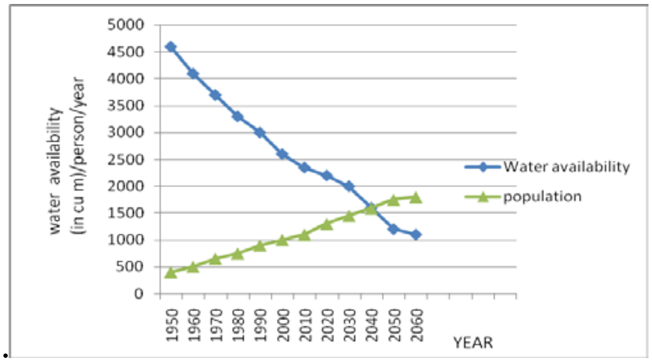

Figure-3: Clearly denotes that the availability of water per person/year is reducing with the rapid increase of population in our country. It is very much alarming for our future production, development and prosperity.

The presence of arsenic in water is geogenic. The entire gangetic delta plain, which consists of alluvial soil, contains arsenic in the deeper aquifers. Bacteriological contamination, especially fecal coliform, is the most widespread groundwater problem in India [**24]**. Groundwater itself doesn't inherently contain fecal coliform. Most of the ground water coli forms come from the leaching of solid (human and animal) and liquid waste. In addition, there are problems due to excessive salinity, especially in coastal areas, iron, nitrates and others. Around 195,813 habitations are affected by poor water quality due to chemical parameters [**25]** (Table-6)

Table-6: Water quality problem in rural areas[32]

Nature of problem	No of habitation affected
Excess fluoride	36988
Excess arsenic	3553
Excess salinity	32597
Excess iron	138670
Excess nitrate	40003
Other reasons	1400
Total	217221

WATER MANAGEMENT

India occupies over three million km^2, with enormous diversity of climate, landscape, geology, flora and fauna. Here, water played a critical role during the last part of the previous century and it promises to play an even more critical role in India's future. So, after six decades of independence, India's water situation is characterized by scarcity and lack of coordinated planning. Large tracts of India are vulnerable to vagaries of floods and draught. In many parts of the country, ground water levels continue to decline due to overdraft. Assured clean water supplies are lacking in urban centers and in rural villages. Currently, two major themes are receiving attention to overcome India's woes; rain-harvesting and interlinking of major rivers **[4].**

In Indian conditions, the availability of water is highly uneven in both space and time. The total average annual flow per year for Indian rivers is estimated as $1953km^3$.The total annual replenishable ground water resources are assessed as 432km^3.The annual utilizable surface water and ground water in India are estimated at 690 km^3 per year respectively[26].With rapid increase in population and improved living standards, the pressure on our water resources is also increasing, while availability of water resources is declining day by day. Production of food grains has increased from around 50 million tons (mt) in 1950s to about 208 mt in the period (1999-2000).This will have to be raised to around 350 mt by the year 2025.The drinking water needs of people and livestock also have to be met. In this hot situation management of water resources in all spheres are essential.

Water resources management is not just about moving water any more. The water resources management practices may be based on increasing the water supply and managing the water demand under the stressed water availability conditions. Data monitoring, processing, storage, retrieval and dissemination constitute the very important aspect of the water resources management.

III. FLOOD MANAGEMENT

As per the report of Central Water Commission (CWC) [**27**] under the Ministry of Water Resources, Government of India, the annual average area affected by floods is 7.563Mha.This observation is based on the data for the period 1953-2000 published by Indian Water Resources Society (IWRS) [**24**] .Thirty three million people have affected during this period. The main causes of floods in India are river bank erosion, silting of silver beds and inadequate capacity of river banks to contain high flows. Sometimes landslides often obstruct the river to flow and make its diversion in course. Poor natural drainage in flood prone areas, heavy rainfall, cyclonic effects, snow melt and glacial outburst also responsible for flood.

As stated by Mahapatra and Singh [**29**], Flood management programme were launched at the nation level by the Government of India after the devastating flood of 1954. The government of India has setup many committees since1954 and received several valuable recommendations from the committees regarding flood management issues [**30**]. Various types of structural and non-structural measures have been taken up to reduce the damages of flood plains. As structural measures, construction of embankments, levees, spurs have been implemented in some of our states. At present 16,800km embankments, 32,500km drainage channels have been constructed. A total of1040 town and 4760 villages are currently protected against flood. The non-structural measures, such as flood forecasting and warning are also being adopted and this system commenced in India in 1958 for the river Yamuna in Delhi. The CWC has established a flood forecasting system covering 62 major rivers with more than 157 stations for issuing flood forecasts covering almost all the flood prone states. Ministry of Water Resources constituted satellite based remote sensing for flood risk areas in 1999 with a view of giving thrust towards implementation of flood plain zoning measures [**31**].

IV. DRAUGHT MANAGEMENT

The planning and management of the effects of draught appear to have a least priority due to associated randomness and uncertainty in defining the start and end of draught. Presently, the draught prone area assessed in our country is of the order of 51.12 Mha. Most of the draught planning and management schemes are generally launched after persisting draught conditions. Food fodder agriculture inputs and water banks may be established in vulnerable zones instead of their storage in surplus regions to avoid transport bottlenecks during draught. Robust and rainfall independent off-farm livelihood opportunities may be targeted in the draught mitigation strategy. For draught management there is a need for development of decision support system(DSS)for the monitoring and management of draught on basin scale utilizing the advanced capabilities of remote sensing, geographical information system and knowledge based systems [**30**] .

V. GROUNDWATER MANAGEMENT

According to National Water policy [**8**], the detrimental environmental consequences of over exploitation of ground water need to be effectively prevented by the Central and State Governments. Over exploitation of groundwater should be avoided, especially near the coasts to prevent ingress of seawater to freshwater aquifers. In critically over exploited areas, borewell drilling should be regulated till the water table attains the desired elevation. Artificial recharge measures need to be urgently implemented in these areas [3**2**]. Amongst the various recharge techniques percolation tanks are least expensive in terms of initial construction costs. Many such tanks already exist but a vast majority of these structures have silted up. In such cases cleaning of the bed of the tank will make them reusable.

Shah [**16**] mentioned that three large scale responses to ground water depletion in India have emerged in recent years in an un-coordinated manner, and each presents an element of what might be its coherent strategy of resources governance as: a) Energy-irrigation nexus- Inter-basin transfers to recharge unconfined alluvial aquifers, and c) Mass-based recharge movement. Shah mentions the following workable solutions for management of ground water resources:

- Banning private well in futile; croud them out by improving public water supply
- Regulating final users is impossible, facilitate mediating agencies to emerge, and regulate them.
- Pricing agricultural groundwater use is infeasible; instead, use energy pricing and supply to manage agricultural groundwater draft.
- No alternative to improved supply side management: better rain- water capture and recharge, imported surface water in-lieu-of groundwater pumping.
- Grow the economy, take pressure off land, and formalize the water sector

VI. WATER CONSERVATION

Water conservation implies improving the availability of water through augmentation by means of storage of water in surface reservoirs, tanks, soil, and groundwater zone. It emphasizes the need to modify the space and time availability of water to meet the demands. There is a great potential for better conservation and management of water resources in its various uses. On demand side, a variety of economic, administrative and community-based measures can help conserve water. Also it is necessary to control the growth of population since large population since large population is putting massive stress on all natural resources [**33].**

Since agriculture accounts for about 69% of all waters are withdrawn, the greatest potential for conservation lies in increasing irrigation efficiencies. Just 10% improvement in irrigation efficiency could conserve enough water to double the amount available for drinking.

VII. WATERSHED MANAGEMENT

Watershed is the unit of management in Integrated Water Resources Management (IWRM), where surface water and groundwater are inextricably linked and related to land use and management. Watershed management aims to establish a workable and efficient framework for integrated use, regulation and development of land and water resources in a watershed for socio economic growth [**36]**. Local communities play a central role in the planning, implementation and funding of activities within participatory watershed development programmes. In these initiatives, people use their traditional knowledge, available resources, imagination and creativity to develop watershed and implement community centred programme.

VIII. RAINWATER HARVESTING

Rainwater harvesting is the capture, diversion and storage of rainwater for a number of different purposes including, but not limited to, landscape irrigation. Rainwater harvesting may also include land based systems with man-made landscape features to channel and concentrate rainwater in either storage basins or planted areas.

An old technology is gaining popularity in a new way. It is rainwater harvesting. There is a need to recharge aquifers and conserve rainwater through water harvesting structures. Even in ancient days, people were familiar with the methods of conservation of rainwater and had practice them with success. Different methods of rainwater harvesting were developing to suit the geographical and meteorological conditions of the region in various parts of the country [**36].** Those are capturing runoff from rooftops, capturing runoff from local catchments, capturing seasonal floodwaters from local streams, conserving water through watershed management etc. These techniques can serve the following the following purposes: provide drinking water, provide irrigation water ,increase groundwater recharge ,reduce storm water discharges, urban floods and overloading of sewage treatment plants, Reduce seawater ingress in coastal areas. Traditional rainwater harvesting; which is still prevalent in rural areas, is done by using surface storage bodies like lake, ponds, irrigation tanks, etc. Kul (diversion channels) irrigation system, is an example of such type. This system carries water from glaciers to villages.

In urban areas, rain water will have to be harvested using rooftops and open spaces. Harvesting rainwater not only reduces the possibility of flooding but also decreases the community dependence on groundwater for domestic uses. Apart from bridging the demand supply gap, recharging improves the quality of ground water, raises the water-table in wells, bore-wells and prevents flooding and choking of drains.

Rain water harvesting generally means collection and precipitation of rain water. Its special meaning is a technique of recharging of underground water. In this technique water is made to go underground after collecting rain water locally, without polluting the same. With this, water during the time of scarcity local domestic demand can be met. Now the question arises – After all why do we need water harvesting? Three main reasons are responsible for this: 1. Scarcity of surface water; 2. Growing dependence on underground water; and 3. Increasing urbanization.

(A) **Urban Scenario –** Total amount of rain water recovered in an area is called 'rain water reserve'. Effective management of rain water reserve is called 'potential water harvesting'. Think for a while the area of the roof of your house is 100 square metres and the 'average rainfall' of this area is 60 cms. Suppose the water on the roof has neither flowed, percolated nor evaporated then there will be 60 cms, high water on the roof.

Volume of water = Area of the roof X Amount of annual rainfall

= 100 x 60 cms = 100 x .6 = 60 cubic metres.

In other words, a family can collect 60,000L water in a year. All water related needs of this family can be met with this. On an average a person needs 10 L water for drinking daily. If your family consists of 6 members, then you need = 6 x 10 x 365 = 21900 L of water. Remaining (60,000 – 21,900) = 38,100L water can be used in dry weather when there is a scarcity of water.

(B) **Rural Scenario –** The tradition of water harvesting is very old in India. But the utility of water harvesting has never been felt so much as it is today. Even today the people living in the areas of water scarcity try to do their domestic work by adopting old methods. Deepening and dredging of wells, tanks and ponds are included in these methods. Water harvesting in the small channels (locally known as bawli) is an important traditional method in the areas of water scarcity. Now we can be in a better and secure situation by adopting new technique of water harvesting. Think for a while. If the people living in 5,87,000 village engage themselves for harvesting rain water of their 2000 lakh hectare area, there will be lot of water available for use. On an average a village comes under the radius of 37,500 lakh cubic metre rain water reserves. By this calculation we come to know that there is great potential of rain water harvesting.

Advantages of Rainwater Harvesting

Rainwater harvesting systems can provide water at or near the point where water is needed or used. The systems can be both owner and utility operated and managed. Rainwater collected using existing structures (i.e., rooftops, parking lots, playgrounds, parks, ponds, flood plains, etc.), has few negative environmental impacts compared to other technologies for water resources development. Rainwater is relatively clean and the quality is usually acceptable for many purposes with little or even no treatment. The physical and chemical properties of rainwater are usually superior to sources of groundwater that may have been subjected to contamination. Rainwater harvesting can co-exist with and provide a good supplement to other water sources and utility systems, thus relieving pressure on other water sources. Rainwater harvesting provides a water supply buffer for use in times of emergency or breakdown of the public water supply systems, particularly during natural disasters. Rainwater harvesting technologies are flexible and can be built to meet almost any requirements. Construction, operation, and maintenance are not labour intensive.

IX. RECYCLE AND REUSE OF WATER

According to Gupta et al. [**34]** recycling of water is not practiced in India and there is considerable scope and incentive to use this alternative. They estimated that recyclable water is between 103 and 177km3/year for low and high population projections.

Reduction of water demand and management of resources

Due to population pressure demand of water is gradually increasing in India. The water demand could be reduced through the practices which require less water and reduce wastage of water and misuse of water. First of all there should be a balance between water demand and water supply [**37].** For ideal water management, economic incentives or penalties to be applicable to the users. Water rationing system may also be introduced. These may be based on strategies that include legal restrictions, economic incentives and issuance of public appeals.

Desalinization of water

About 70% of the earth's water resources are saline water. Since 1970, different desalinization technologies have been developed including distillation, reverse osmosis and electrolysis. Especially these technologies are suitable in coastal areas where less drinking water is available and more saline water is available. As desalinization costs are now coming down and it is about Rs.50/m3 the afore said technologies may be followed in coastal areas enormously.

X. MANAGERIAL PRECAUTIONS

There should be proper organizational arrangements at the national and state levels for ensuring the safety of storage dams and other water-related structures consisting of specialists in investigation, design, construction, hydrology, geology, etc.

For effective and economical management of our water resources, the frontiers of knowledge need to be pushed forward in several directions by intensifying research efforts in various areas, including the following [**38]**.

- better water management practices and improvements in operational technology;
- surface and ground water hydrology;
- river morphology and hydraulics;
- assessment of water resources;
- water conservation;
- hydrometeorology;
- snow and lake hydrology;
- water harvesting and ground water recharge;
- water quality;
- evaporation and seepage losses;
- recycling and re-use;
- crops and cropping systems;
- soils and material research;
- use of sea water resources;
- prevention of salinity ingress;
- risk analysis and disaster management;
- use of remote sensing techniques in development and management;
- environmental impact;
- Regional equity.
- use of static ground water resource as a crisis management measure;
- sedimentation of reservoirs;
- seismology and seismic design of structures;
- the safety and longevity of water-related structures;
- economical designs for water resource projects;
- prevention of water logging and soil salinity;
- reclamation of water logged and saline lands;

XI. CONCLUSION

Water is life on earth. It is one of the most essential natural resources for sustaining life and it is likely to become critically scarce in the coming decades, due to continuous increase in its demands, rapid increase in population and expanding economy of the country. Variations in climatic characteristics both in space and time are responsible for uneven distribution of precipitation in India. It is posing a challenge to the existing water resources and to those who are responsible for the management of water resources. Hydrological studies are required to be taken up for assessment of water resources under changing climatic scenarios. For safe drinking water it is essential to generate reliable and accurate information about water quality. To sustain life on earth in all its totality, water should be carefully managed in its natural habitats.

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AUTHORS

First Author – Atanu Bhattacharyya, Nanotechnolgy Section, Department of Biomedical Engineering, Rajiv Gandhi Institute of Technology and Research Centre , Cholanagar, R.T. Nagar Post, Hebbal , Bangalore-560 032. India.

Second Author – S. Janardana Reddy, M.A., M.Sc., Ph.D.,, Department of Fishery Science and Aquaculture, Sri Venkateswara University, Tirupati-517 502, India. E-mail ID: sjanardanareddy@gmail.com.

Third Author – Manisankar ghosh, M.Sc., Ph.D., Department of Textiles (Sericulture), Government of West Bengal, Ganesh Chandra Avenue,Kolkata-13;E-mail ID: manisankar1@yahoo.com

Fourth Author – Raja Naika H , M.Sc., Ph.D., Dept. of Studies and Research in Environmental Science, Bharatha Ratna Prof. C.N.R. Rao Block, Lab. No. 104, First Floor, Tumkur University, Tumkur- 572103, Karnataka, India

Correspondence Author – Atanu Bhattacharyya, E-mail ID:atanubhatt@rediffmail.com, Contact Number: +91 9433848234
S. JANARDANA REDDY, E-mail: sjanardanareddy@gmail.com, Contact Number: +91 9949786291