CHAPTER 1

Water Resources: An Introduction

Water is a precious resource on the earth without which no living thing, plant, animal or human, can survive. It is also the most abundant commodity covering about 71% of the earth's surface making earth, the blue planet. Besides, huge amount of water is in circulation in a solar-driven hydrological cycle, which has no beginning and no end. Approximately 97% of water available on earth is salt water, which cannot be used unless treated to make it fit for any pre-defined activity. Besides, about 2% of the remaining fresh water is frozen at the Poles or is too deep to be harnessed using presently available technologies or too polluted to use. Only less than 1% is available as fresh water that can be used for human consumption and other uses. The water in circulation commonly referred as replenishable resource is finite, inelastic and has large spatio-temporal variations. With increasing population, urbanization and industrialization, this source of water is increasingly becoming scarcer and has gone beyond the reach of many people in under developed and developing countries. Two recent hot spots such as Cape Town in South Africa and Latur in India have glaringly brought forth the issue of water scarcity.

The problem of water inadequacy assumes greater significance and becomes more complex when water quality comes into picture. *The term water quality describes the chemical, physical and biological characteristics of water that decides its suitability for a particular use amongst many uses.* First and foremost water quality issue relates to the quality of water bodies. There should be no significant change in the ecological environment to adversely impact the animals within water bodies and flora and fauna therein. Besides, water supply should be pure, wholesome, and potable to minimize ill-effects on human health. Even for agriculture, it is necessary that the dissolved minerals and/or other toxic materials in the irrigation water should not exceed tolerance limits of cultivated crops. In the industrial sector, different kinds of industries such as textiles, paper, brewing, and others have their specific water quality needs that must be met for their efficient functioning.

It may not be out of place to mention that water has always been scarce and people by habit have been mismanaging the resource. Instances of water wastage and water pollution have been highlighted in ancient literature. In recent times, both the dimensions of water resource, its scarcity as well as its quality have assumed serious overtones making these issues quite topical subjects. It is now emerging that deterioration in water quality will impact the adequacy of water more than its physical

scarcity in future. The water may be available but will be unfit to use for a pre-decided activity especially the domestic sector. Few numbers from the World Bank study highlight this situation very well.

- 163 Million Indians lack access to safe drinking water
- 210 Million Indians lack access to improved sanitation
- 21% of communicable diseases are linked to unsafe water
- 500 children under the age of five die from diarrhea each day in India

Natural geogenic factors have been in operation since time immemorial and continue to impact the water quality. The current concerns on water quality have mainly emanated from anthropogenic activities that have resulted in the introduction of sediments, inorganic and organic constituents, nutrients, heavy metals, radio-active materials and pathogens. The perpetuating water pollution has made a considerable part of available water resources unfit for human use. It has made the situation on the water front even more precarious. It may be understood that water quality is not a question of simply saying good or bad, but one need to define it in terms of its best use with or without treatment. For example, water quality related to drinking is more stringent and different than that for aquatic life, or for that matter for industrial or agricultural use. Agriculture sector is capable of utilizing large quantities of conventionally categorized poor quality water with minimal or even without any treatment.

GLOBAL WATER RESOURCE

The total volume of water on the Earth is assessed at about 1.386 billion km^3 which is capable to cover it with a water layer of 3000 m above the land surface. The per cent distribution of this water is given in Table 1.1. The distribution of this water on the earth is also shown in a slightly different way in Fig. 1.1 (Shiklomanov, 1993). The volume of freshwater resources on the globe is around 35 million km^3 or 2.5% of world's water resource. Around 30.1% of the world freshwater is available as ground water (shallow and deep ground water basins up to 2000 m). Around 1.2% is mobile in the surface and atmospheric phases of the hydrologic cycle. Around 90% of it is ground ice and permafrost and in lakes (Fig. 1.1). The total usable freshwater supply for ecosystems and humans is about 200,000 km^3 of water - less than 1% of all freshwater resources. Freshwater lakes and rivers contain an estimated 105,000 km^3. As per World Health Organization (WHO) estimates, only 0.007% of all water on earth is readily available for human consumption. A glimpse of the global water balance on the land (30% of surface are) and the ocean (70% of the surface area) is given in Table 1.2 (Chow et al., 1988). Note that 47×10^3 km^3/yr of water leaving the oceans is balanced by 47×10^3 km^3/yr water on the land area.

WATER RESOURCES OF INDIA

With a geographical area of about 329 million ha (M ha), India accounts for 2.4% of the world surface area. On an average over space and time, annual rainfall including snow over the Indian sub-continent is estimated at 1200 mm. Most of the rainfall takes place under the influence of Southwest monsoon between June to September except in Tamil Nadu, where it is also under the influence of Northeast monsoon during October and

November. This precipitation constituting the main water resource is estimated at 4000 km^3 per annum (400 M ha-m per annum).

Table 1.1: A glimpse of water resource of the world

Source	% of total resource*
Oceans and other saline water	97.5
Ice sheets and glaciers	1.72
Ground water	0.62
Atmosphere	0.29
Lakes (Fresh)	0.01
Inland Seas and salt water lakes	0.05
Soil moisture	0.004
Rivers	0.001

* The sum may not be exactly 100%

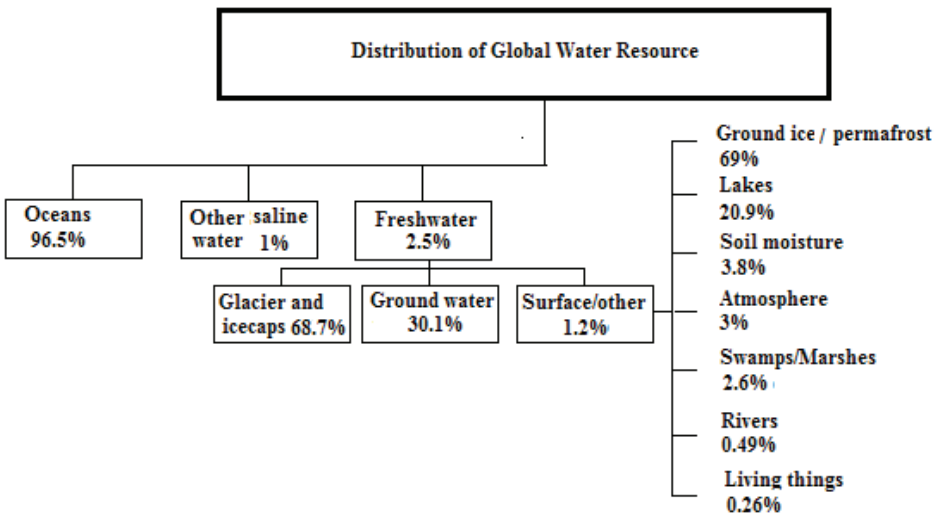

Fig. 1.1. Distribution of global total and fresh water resource

Table 1.2: The water balance on earth (Oceans and land)

Parameter	Ocean	Land
Area (10^6 km^2)	361.3	148.8
Precipitation (10^3 km^3/yr)	458 (1270)*	119 (800)
Evaporation (10^3 km^3/yr)	505 (1400)	72 (484)
Run-off to the ocean		
Rivers (10^3 km^3/yr)		44.7
Ground water (10^3 km^3/yr)		2.2

*Values in parenthesis are in mm/yr

After meeting interception, evaporation and soil moisture requirement, this resource gets distributed in surface and ground water resources. A glance at the various components of India's water resources is given in Table 1.3 (CWC, 2011). It shows an estimated deficit of 327 km^3 in 2050. A part of it may be compensated through interlinking of the Rivers.

SURFACE WATER RESOURCES

Surface water resources comprise water contained in any body of water found on the Earth's surface, including both the salt water in the oceans and the freshwater in rivers, streams, and lakes including ones flowing overland. The River system of India comprises more than 20 major rivers with several tributaries. While many of these rivers are perennial, some are seasonal in nature. From surface water resource point of view, India has been divided into 12 major basins each having a catchment area exceeding 20,000 km^2 and 8 composite basins suitably combining all the remaining medium and small river systems.

Table 1.3: A glance at India's water resources

Sl. No.	Item	Quantity (km^3)	Percentage
1	Annual precipitation (Including snowfall)	4000	100
2	Precipitation during monsoon	3000	75
3	Evaporation + Soil water	2131	53.3
4	Average annual potential flow in rivers	1869	46.7
5	Estimated utilizable water resources	1123	28.1
	Surface water	690	17.3
	Replenishable ground water	433	10.8
	Storage of utilizable water created	253.381	22.52
	Storage of utilizable water (under construction)	50.737	4.5
6	Estimated water need in 2050	1450	129
7	Estimated deficit	327	29
8	Additions estimated due to interlinking of rivers	200	17.8

The total water potential of these basins has been revised by Central Water Commission in 1993 to 1869 km^3 (Table 1.4, (CWC, 2010, Publication Division, 2011)). As per this estimate, a breakup of the resource reveals that 1050 km^3 is the run-off from rainfall that flows into rivers and streams including reservoir and tanks. Additional water is received from snow melt (100 km^3), flow from outside India (200 km^3), from ground water (370 km^3) and from irrigated areas (110 km^3) making a total of about 1830 km^3. New reports have revised the basin-wise average annual flow in Indian River systems as 1953 km^3 (Chitale, 1992, NCIWRD, 1999, Kumar et al., 2005). According to a recent study "Reassessment of Water Availability in India using Space Inputs" carried out by CWC (CWC, 2019), the average annual water resources of the 20 basins of the country have been assessed as 1999.20 km^3 (Table 1.4). The largest potential is available in the Ganga/ Brahmaputra/Barak basin making a total of 1120 km^3 followed by Godavari and by west flowing rivers from Tapi to Tadri and Tadri to Kanyakumari each having an

average annual potential of about 120 km^3.

The per capita water availability estimated by dividing the annual average water availability by the population in the year 2025 has also been assessed for each river basin with an average annual per capita water availability of 1434 m^3. Lowest per capita water available is in east flowing rivers between Pennar and Kanyakumari at 360 m^3 per capita. Highest per capita water is in the Brahmaputra basin at 10971.3 m^3 although a still higher figure of 12568.6 m^3 is emerging in minor Rivers basins draining into Bangladesh and Myanmar.

Table 1.4: River basin-wise water and per capita availability

Sr. No.	River basin	Average annual surface water availability (km^3)			Utilizable surface water resource (km^3)	Estimated per capita water availability in the year 2025 (m^3)
		Old	New			
1	Indus	73.31	45.53 (up to border)	26.49	46.0	657.95
2	Ganga-Brahmaputra-Barak					
	(a) Ganga	525.02	509.52	170.99	250.0	859.17
	(b) Brahmaputra	585.6	527.28	35.07	24.0	10971.29
	(c) Barak and others	Included in above two	86.67	Included in b above		8463.87
3	Godavari	110.54	117.74	40.65	76.3	1320.25
4	Krishna	78.12	89.04	26.41	58.0	886.70
5	Cauvery	21.36	27.67	12.30	19.0	571.81
6	Pennar	6.32	11.02	4.93	6.9	687.89
7	East Flowing Rivers (a) Between Mahanadi and Pennar	22.52	26.41	9.00	13.1	677.70
8	(b) Between Pennar and Kanyakumari	16.46	26.74	9.20	16.5	359.80
9	Mahanadi	66.88	73.00	16.46	50.0	1661.73
10	Brahmani and Baitarni	28.48	35.65	4.05	18.3	2203.34
11	Subarnrekha	12.37	15.05	1.82	6.8	969.72
12	Sabarmati	3.81	12.96	3.00	1.9	747.40

13	Mahi	11.02	14.96	4.20	3.1	862.80
14	West flowing Rivers of Kutch, Saurashtra including Luni	15.10	26.93	11.23	15.0	737.81
15	Narmada	45.64	58.21	10.83	34.5	2397.45
16	Tapi	14.88	26.24	8.27	14.5	1073.75
17	West flowing Rivers (a) Tapi to Tadri	87.41	118.35	8.70	11.9	2777.52
18	(b) Tadri to Kanyakumari	113.53	119.06	9.00	24.3	2211.37
19	Area of inland drainage in Rajasthan desert	Negligible	Negligible	-	-	
20	Minor Rivers basins draining into Bangladesh and Myanmar	31.00	31.17	18.80	-	12568.55
21	Andaman, Nicobar and Lakshadweep			Not estimated	-	
	Total	1869.37	1999.20	431.40	690.1	1434.13

A total storage capacity of about 253.4 km^3 has been created in the country due to the major and medium irrigation projects so far (CWC, 2013). The projects under construction will contribute to additional 51 km^3 (Table 1.3). Thus, the storage available will be only 304.4 km^3 upon completion of on-going projects against the total water availability of 1869 km^3. Factors like extreme variability in precipitation, non-availability of storage space in hills and plains, evaporation losses and water going to the Sea and outside India disallows assured storage of all the water. It is anticipated that utilizable surface water resources would be 690 km^3 which will be utilized by the year 2025 (Sharma and Paul, 1998). An upward revision in the utilizable flows may be expected on account of advancement in technology and on account of large scale inter-basin transfer of water (Table 1.3).

Ground Water Resources

Water that occurs below the surface of Earth, where it occupies all or part of the void spaces in soils or geologic strata is known as ground water. It is also called subsurface water that distinguishes it from surface water. The ground water resource is classified as static and dynamic. *The static ground water resource defined as the amount of ground water available in the permeable portion of the aquifer below the zone of water level fluctuation.* It has been assessed at 10812 km^3 (Duraiswami et al., 2016). *The dynamic resource, defined as the amount of ground water available in the*