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Water flux and facts

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Abstract
Any environmental imbalance directly affects sustainable development. Most of the issues on various dimensions of sustainable development directly or directly depend on the availability of water. Pre-existing tensions can be exacerbated by resource scarcity or invite new ones, and water is no exception. Within a decade, water could overshadow oil as a scarce and precious commodity at the centre of conflict and peacemaking. Hence, the then UN Sectary General Boutros Boutros Ghali (Egypt's Minister of State for foreign affairs in 1985) warned that the next war in the Middle East will be fought over water, not politics. The already evident symptoms of an imminent environmental crisis like severe water resource depletion and ecological degradations at all levels is not just ecological phenomena alone. While the persisting demographic pressure on natural resources and the increasing reliance on resource/energy-intensive technologies have aggravated the environmental crisis, the real cause of the problem lies in the very world view and the meaning of development underlying a purely material growth-cantered development paradigm and its attendant social, economic, and legal policies and institutions. Unless the present development paradigm and its associated institutions and policies are reoriented to focus on the neglected ecological and equity dimensions of human development, the environmental crisis will eventually culminate in still more diabolic economic, social, and even, political crises. It is with this kind of diagnosis, sustainable development has been proposed as an alternative development paradigm. Adoption and implementation of the new paradigm of sustainable development, i.e., development that simultaneously ensures ecological security, economic efficiency, and social equity, demands far-reaching changes in two major directions. First, to have an altogether new concept of development rooted in the principles of co-existence and mutual dependence on the one hand, and ethical commitments in man-nature relationships on the other hand. Envisioning sustainable development is a strategy to achieve immediate economic gains while maintaining indefinitely the productive potential of the renewable resource base. The main focus is on the development, management and utilization of water resources in harmony with environmental conservation and the concept of sustainability.

Keywords: Environment, sustainable development, water, water reserves, water cycle, water flux

Introduction
Water: An Inescapable Necessity
The statement, many of the wars in 20th century were about oil, but those of the 21st century will be over water, by Ismail Serageldin[5] not only highlights the importance of water, but is also a warning for the present generation. Environment has been linked with development since 1960s. It is only in the recent years, an effort is being made to link environment and development to be seen from a water perspective because, the inhabitants on the water planet are infact living at the mercy of WATER CYCLE [6]. Considering all the natural resources which have to do with health, comfort and prosperity, there is only one which approaches in great importance, the most common of all our minerals and the only one vital to life is, water. Water is so common; its use is intimately associated with every necessity and comfort. But like most common things, its importance is overlooked [7].

The World's Water
Samuel Taylor Coleridge (1772-1834) in his classic poem, The Rime of the Ancient Marines, effectively described the principal characteristic of the earth's water resources when he said: Water, water, everywhere, not any drop to drink.

The planet has 1,385,984,610 cubic kilometre of water out of which, 96.54 per cent of all the water on the earth is brackish (Salt water), comprising a total volume of 1, 338, 085, 400 cubic kilometre, unsuitable for drinking or growing crops (includes, volume of water in the ocean and salt-water lake). A total volume of 12,870,000 cubic kilometres comprising 0.93 per cent is stored in underground aquifers too deep to tap under current and foreseeable technology. Remaining 2.53 per cent is fresh water, comprising a total volume of 35,029,210 cubic kilometres, (Vide Table 1) to cater the needs of 6.3 billion people of the globe.

Table 1: The World Water Reserves

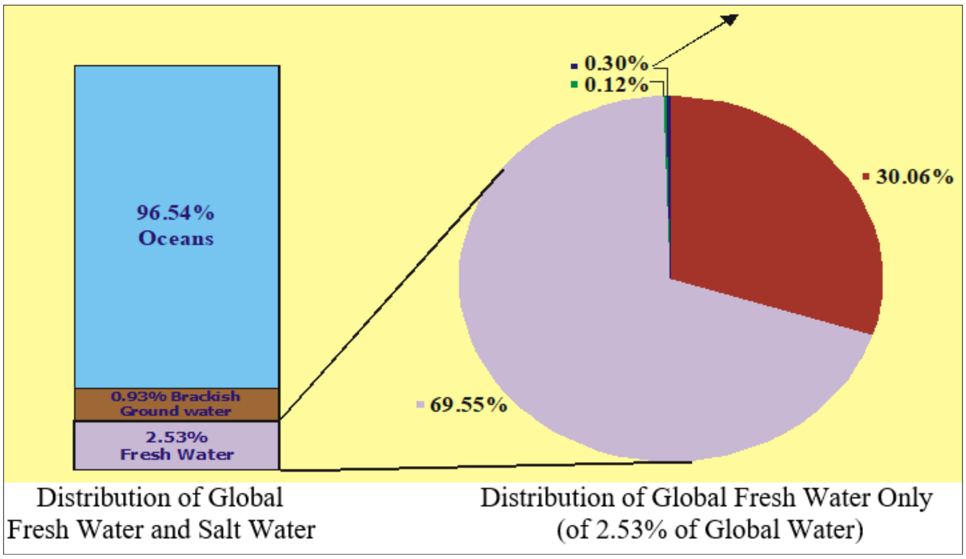
Form of Water	Area Covered (Square kilometer)	Volume (Cubic kilometer)	Share of World Reserves (%)	
			Of total Water Reserves	Of reserves of fresh water
World Ocean	361,300,000	1,338,000,000	96.5379	-
Total Ground Water	134,800,000	23,400,000	1.6883	-
1. Brakish ground water	134,800,000	12,870,000	0.9286	-
2. Fresh ground water	134,800,000	10,530,000	0.7597	30.061
Soil Moisture	82,000,000	16,500	0.0012	0.047
Glaciers and Permanent Snow Cover	16,227,500	24,364,100	1.7579	69.554
1. Antarctica	13,980,000	21,600,000	1.5585	61.663
2. Greenland	1,802,400	2,340,000	0.1688	6.680
3. Arctic islands	226,100	83,500	0.0060	0.238
4. Mountainous areas	224,000	40,600	0.0029	0.116
5. Underground ice zones of permafrost	21,000,000	300,000	0.0216	0.856
Water Reserves in Lakes	2,058,700	176,400	0.0127	-
1. Fresh water lake	1,236,400	91,000	0.0066	0.260
2. Salt water lake	822,300	85,400	0.0062	-
Marsh water	2,682,600	11,470	0.0008	0.033
Water in rivers	148,800,000	2,120	0.0002	0.006
Biological water	510,000,000	1,120	0.0001	0.003
Atmospheric water	510,000,000	12,900	0.0009	0.037
Total Water Reserves	510,000,000	1,385,984,610	100	-
Total Fresh Water	148,800,000	35,029,210	2.53	100

Note: Numbers of world ocean, brackish ground water, salt water lake and total fresh water adds to Total Water Reserves.
Numbers of fresh ground water, soil moisture, glaciers and permanent snow cover, freshwater lake, marsh, river, biological and atmospheric water adds to Total Fresh Water

Source: 1. Korzun, 1978, Ghassemi Fereidoun, in Anthony J. Jakeman and Herry A. Nix, Salinisation of Land and Water Resources: Human Causes, Management and Case Studies, CAB International, UK, p 5
2. Rick Weiss, 2003, *Hydrology* in Deccan Herald, Science and Technology Column, Bangalore, P i

Of the 2.53 per cent of the fresh water were spread out evenly over the surface of the earth, it would make a layer of 70 meter thick. Yet, almost all of this fresh water is effectively locked away in the glaciers and permanent snow cover (69.55 per cent of 2.53 per cent) in Antarctica, Greenland, Arctic Islands, Mountainous areas, and Underground ice zones of permafrost. This constitutes 1.76 per cent of the total water reserves. The fresh water found in soil moisture, marsh water, biological and atmospheric water (0.12 per cent of 2.53 per cent), constitutes 0.04 per cent of the total water reserves. Though total groundwater comprises 1.69 per cent of the total water reserves, only 0.76 per cent of the total water reserves constitute fresh groundwater, which accounts to fresh water (30.1 per cent). Less than 100,000 cubic kilometres (just 0.3 per cent) of the total fresh water reserves on earth is found in the rivers and lakes that constitute the bulk of our usable supply, which is renewable. This adds up only to a meagre of 0.007 per cent of the total water reserves. These statistics are presented in the Graph A.

The World's Water Flux: Fresh water is a renewable resource made continuously available by the constant flow of solar energy, which evaporates water from the oceans and land, and redistributes it around the globe. More water evaporates from the oceans than falls on them as precipitation. Thus, there is a continuous transfer of fresh water from the oceans to the continents. This water runs off in the rivers and streams that sustain our natural ecosystem and societies, and recharge our aquifers. In calculating how much fresh water is available for human use, what counts is not the sum total of global freshwater supplies, but the rate at which fresh water resources are renewed or replenished by the global hydrologic cycle (Movement of water in the land). This cycle powered by the sun, deposits about 113,000 cubic kilometre of water on the world's continents and islands as rain and snow each year. Of that, about 72,000 cubic kilometres evaporates back into the atmosphere. That leaves 41,000 cubic kilometres a year to replenish aquifers, or to return to the ocean as the river and ground water runoff. Only about 3,500 billion meter of the 18,000 billion cubic meters that falls as rain is used by living organisms (Vide Figure I).



Graph 1: The World's Water

2.53% is the proportion of the World's Fresh Water that is Renewable
69.55% Glaciers and Permanent Snow Cover (243,641,000 cubic kilometres)
30.06% Fresh Ground Water (10,530,000 cubic kilometres)
0.30% Rivers and Lakes (2,120 and 91,000 cubic kilometres)
0.12% Soil Moisture, Marsh, Biological and Atmosphere water (41,990cubic kilometres)
Note: Percentage figures do not add up to 100% due to rounding
Source: Table 1

For human use, not all of this 41,000 cubic kilometre can be captured whereas, more than half flows unused to the sea as flood waters and as much as an eighth fall in areas too far from human habitation to be captured for use. Thus, accessible fresh water makes up less than 0.01 per cent (out of 2.53 per cent) of the earth's fresh water supply, i.e., approximately 3,503 cubic kilometres, which constitutes 0.0003 per cent of the total world water reserves.

Water Cycle Facts

As per calculations, for the renewal of ice caps on the land it takes 16,000 years, for glaciers 16,000 years, freshwater lakes it ranges from 10 to 100 years (which varies with the depth), rivers 12 to 20 days, and salt water lakes from 10 to 100 years (which varies with the depth). In the sub-surface, soil moisture's renewal time is 280 days, ground water to half a mile depth 300 years, and beyond half-mile depth around 4,600 years. Other forms like atmospheric water takes 9 to 12 days and world's ocean takes 37,000 maximum years.[10] A document prepared for the United Nation's World Water Conference held in Argentina in March 1977 stated that, if the entire world's water were represented by half-a-gallon bottle, the quantity of freshwater would be about half-a-teaspoon full. And a single droplet would suffice to represent the surface flowing water, the rest being groundwater [11]. This signifies the importance and abundance of ground water.

Groundwater

Of all the fresh water below the surface, about 90 per cent satisfies the description of ground water, that is, water that occurs in saturated materials below. Global ground water is estimated to be 23,400,000 cubic kilometre. But, most of the ground water lies too deep to be accessible and ground water is only renewable to the extent it is withdrawn, no faster that it recharges. Ground water acts as a reservoir by virtue of large pore space in earth materials and as a conduit, which can transport water over long distances. It also acts as a mechanical filter, which improves the quality of water bodies from bacterial contamination. It is the source of water for wells and springs, that is the recommended source of rural domestic use. It is replenished by precipitation through rain, snow and hail. When surface water supplies are insufficient, humanity has traditionally mined some of the vast resources naturally stored underground. But ground water is also unequally distributed, if only a little of it is economically exploitable, tapping it consumes liquid capital. Thus, we not only realize the abundance and scarcity of fresh water in nature but also its preciousness [12].

Water and Population

Two major problems relating to water as a resource are: (i) its availability and (ii) its quality [13]. With the increase in human and animal population, freshwater has become increasingly less and less available whenever and wherever needed. Average annual per capita water consumption of the planet is estimated to be 800 cubic meter. Given the increase in the world population (80 million per year), the demand for water is growing by 63 cubic kilometre a year.

If the population growth rate remains more or less the same, the projected population growth in the future along with the per capita availability of water and the annual renewable fresh water available for selected countries are given in the Table 2. The Table reveals that, the per capita availability of water for India is quite disheartening next only to Egypt and Nigeria.

China and Canada, for example, receive similar amounts of precipitation, both in total and per hectare. But with 42 times more than that of Canada's population, each person in China has an access to only 2.2 percent of what each Canadian claims. As population grows unevenly in the world, such inequities will tend to increase. Since much of the world's urbanization, industrialization and irrigation are characterized by unsustainable patterns of fresh water use, the situation threats to grow worse.

Table 2: Population and Per Capita Water Availability for Selected Countries (1994 - 2050)

Selected Countries	Population (In millions)			Population growth rate % per annum 1985-94*	Annual renewable freshwater available (Cubic Kilometer)	Per capita Freshwater Availability (1000 cubic meter)		
	1994	2025	2050			1994	2025	2050
Argentina	34.2	46.1	53.1	1.4	994	29.06	21.56	18.71
Bangladesh	117.8	196.1	238.5	2.0	2357	20.00	12.02	9.88
Brazil	150.1	230.3	264.3	1.8	6950	46.30	30.18	26.30
Canada	29.1	38.3	39.9	1.3	2901	99.69	75.74	72.70
China	1190.9	1526.1	1606.0	1.4	2800	2.35	1.83	1.74
Egypt	57.6	97.3	117.4	2.0	59	1.02	0.60	0.50
India	913.6	1392.1	1639.1	2.0	2085	2.28	1.50	1.27
Indonesia	189.9	275.6	318.8	1.6	2530	13.32	9.17	7.94
Japan	124.8	121.6	110.0	0.4	547	4.38	4.50	4.97
Mexico	91.9	136.6	161.4	2.2	357	3.88	2.61	2.21
Nigeria	107.9	238.4	338.5	2.9	308	2.87	1.29	0.91
Turkey	60.8	90.9	106.3	2.1	203	3.34	2.23	1.91
UK	58.1	61.5	61.6	0.3	120	2.07	1.95	1.95
USA	260.6	331.2	349.0	1.0	2478	9.51	7.48	7.10
World					41022			

Note: *1994 population estimates and population growth rates are from the World Bank Atlas (1996) population projections (medium variant) for 2025 and 2050 are from United Nations (1994)
Source: 1. Biswas Asit K., 1997, Water Development and The Environment, in Water Resources Development, Vol. 13, No. 2, p. 147
2. The World Bank, 1997, Clear Water Blue Skies: China's Environment in the New Century, Washington D.C., p. 88 (compiled).

Based on per capita availability of renewable water, India - the second most populous country in the world is said to have enough water to meet the needs of its people. But despite the availability of an estimated 2,280 cubic meters per person per year, many of its nearly 900 million people are suffering from severe water shortages in part, as a result of uneven availability of water. Freshwater availability is dictated in large part by climate particularly by the timing and evaporative demand. A measure of how much moisture the atmosphere can absorb is chiefly determined by average temperature. Some arid countries in the Middle East and North Africa have such low precipitation and high evaporation that only a small amount of fresh water can be captured for human use. Change in global climate brought about by the green-house effect is likely to cause great disruption, because rainfall patterns will change as the earth heats up. Rain being the purest form of naturally occurring water, constitutes one of the most important and largest sources of water.

Climate and Rainfall

Rainfall in many desert areas amount to a few millimetres a year and all that may fall, within few days. By contrast, nations such as Sweden or Iceland, where precipitation is high and evaporative demand is low, enjoy abundant water resources. Water availability can vary tremendously from season to season, causing distinct wet and dry seasons in well-watered regions. Bangladesh is inundated with rainfall during its two to three months monsoon season, but lacks rainfall for the rest of the year. Water availability also varies from year to year, making even semi-arid regions vulnerable to a succession of dry years, such as drought that gripped 20 Sub-Saharan African nations from 1981 to 1984 and California recently. Moreover to be useful, fresh water supplies must be close to the population that needs it. For example, three quarters of Mexico's population lives in its dry central highlands, while four-fifths of the surface water lies in the wet coastal regions.
The case of Rajasthan, a state in northwest India, situated in one of the most inhospitable arid zones in the World well illustrates India's vulnerability to regional water scarcity. Rajasthan's northwest corner extends into the Thar Desert with a wide range of temperatures and an unpredictable monsoon climate. Drought and desertification are common; and water is a scarce commodity. Home to eight percent of India's population, Rajasthan has only one percent of the country's water resources in the form of ground water, limited rainfall, and a restricted share of water that straddle state boundaries. Most of the rainfall is during the monsoon season (from June to September), and a level of precipitation is about 100 millimetres a year. In 1990, the per capita water use in the state accounted to 562 cubic meters, a level nearly commensurate with absolute scarcity. With the projected increase in human numbers in the decades to come, acute shortage of water is imminent. Ground water that can be used annually is estimated to be about 416 cubic kilometre.
In contrast, the region of Cheerapunji in Meghalaya, in the north east of India, receives the highest level of rainfall recorded in the world (over 9,000 millimetres). But, due to clearance of forest during the past few decades (to meet growing demands for agricultural land and housing), much of the runoff of intense seasonal rainfall cannot be captured. Soil is compacted and most rainfall runs off before it can percolate into the ground, leading to increase in floods. The region not only suffers from excessive flooding for three or four months but also faces frequent droughts for the rest of the year. With a rapidly growing population of 1.8 million in the region, Cheerapunji's water shortage and desertification is likely to worsen. Generally, higher population size, the demand for agriculture and industrialization together boost the demand for finite quantities of water and intensify competition and tension among users.

Access to Water

Socio-economic factors have a great influence on access to water. Developing countries may lack the capital and technology to tap potential water resources. Within a country, powerful industrial or agricultural interests may claim a disproportionate share of water resources. When supplies are limited, people with the least status and wealth often suffer disproportionately.

Water for Agriculture

Life is tied to water as it is tied to air and food, whereas food is tied to water, since plant growth depends on its (Water) flow from roots to foliage. Since ancient times, agriculture has depended on fortuitous combinations of good soil, adequate and predictable water supply. Worldwide, agriculture is the single biggest drain on water supplies, accounting for about 69 percent of all uses. One third of the total global harvest of food comes from the 17 per cent of the world's irrigated cropland. Much of the world's irrigated land for example, at least a fifth in the United States is supported by water extracted from aquifers and lakes thousands of times faster than it can be recharged and thus said to have been literally stolen from the future. The situation is similar in many other regions of the world, including parts of China, Middle East and India.

Although much of the world's farming still relies on the renewable water that falls as rainfall, irrigation explains agriculture's thirst, and the watering of crops has grown in tandem with rising population. Without dependable water supplies, growing food for the earth's population is a marginal affair. A few countries such as Malta and Botswana have adopted to rely on imported food, in part to save water, despite the risk of imported food becoming expensive.

In India, the requirement of freshwater is increasing year after year. The freshwater consumption has increased from 540 cubic kilometres in the year 1985 to 750 cubic kilometre in 2000, and is projected to increase to 1050 cubic kilometre by 2025. The Green Revolution of the 20th century in India was accomplished in large part by greatly expanding the availability and use of irrigation technology and water. India being an agrarian economy, the demand for freshwater for irrigation is more than 80 per cent followed by the industrial and domestic use. It is observed that the pressure on groundwater development is increasing steadily (Vide Table 3). Worldwide, if 69 per cent of fresh water is used for agriculture, about 23 per cent of water withdrawals go to meet the demands of industry and energy, and just 8 per cent to domestic or household use.

Table 3: Annual requirement of fresh water for various uses in India (in cubic km)

	1985 A.D.		2000 A.D.		2025 A.D.	
Water Use For	**Surface**	**Ground**	**Surface**	**Ground**	**Surface**	**Ground**
1. Irrigation	320	150	420	210	510	260
2. Other uses	40	30	80	40	190	90
a. Domestic / Livestock	16.70		28.70		40.00	
b. Industries	10.00		30.00		120.00	
c. Thermal Power	2.70		3.30		4.00	
d. Miscellaneous	40.60		58.00		116.00	
Sub-Total	360	180	500	250	700	350
Total*	540		750		1050	

Note: *Approximate requirement is inclusive of both surface and ground water.

Source: 1. Chitale M.A., 1992, Population and Water Resource of India, in Vasant Gowariker, (ed). Science, Population and Development,. Unmesh Communications, Pune, p. 113

2. Sharma E.S. and K.R. Khan 1995, Water Management in Major Rivers of India -Strategies for Sustainable Management, in Water Resources Journal, ESCAP, March 1995, p. 18

3. Phadre P.N, Rain Water Harvesting Structures, p. 9

4. Hasan Zafarul, Water Pricing Policies and Structures in India, in Water Resource Series No. 76, UN, ESCAP, p. 47

5. Rao Vidyasagar R., 1997, Water and Sustainable Development: India's Scenario, in Water Resources Journal, Sep. 97, p. 85

6. Saleth R. Maria, Water Institutions in India: Economics, Law and Policy, Common Wealth Publishers, New Delhi, p. 11

Patterns of use vary greatly from country to country, depending on levels of economic development, climate and population size. In Afghanistan and Sudan, it is estimated that 99 per cent of all the water is used for agriculture. Africa for instance, devotes 88 per cent of water to agriculture (Mostly irrigation), while in industrialized Europe, more than half is allotted to industry and hydroelectric energy production.

Water for Industry

Dependable sources of abundant water have played a prominent role in the industrialization of Europe and North America. Industry, a category that includes energy production uses water for processing, cooling, cleaning and removing industrial wastes. Nuclear and fossil fuel power plants are the single largest industrial users, applying staggering amount of water for cooling. While most of the water used for industrial purposes goes for recycling, where chemicals and heavy metals often contaminate it, or its temperature is increased to the detriment of water ecosystems. Water used for Industries vary from less than 5 per cent of withdrawals (In many developing countries) to as much as 85 per cent (In Belgium and Finland). Only in Europe, where reliance on irrigation is relatively low, water used for industries is equal the sum of water applied to agricultural and domestic uses. The proportion of water used for industrial purposes is often seen as an indicator of economic development.

Water for Energy and Energy for Water

Water is used to produce the energy, and energy is used in agriculture, industry and transport, besides domestic needs. Limitations on the availability of fresh water in some regions of the world may restrict the type and extent of energy development. Limitations on the availability of energy will constrain our ability to provide adequate clean water and sanitation facilities to millions of people who lack these basic services. The vulnerability of the energy systems is due to fluctuations in water supply. The severe drought in California, between 1987 and 1991, greatly reduced hydroelectric production, and forced electrical utilities to burn more fossil fuel than normal. This led to an added cost to electricity consumers (Approximately $ 3000 million), and carbon dioxide emissions increased by 25 per cent. Similarly, the decade-long drought in North-eastern Africa in the 1980s caused a reduction in hydroelectric generation from the Aswan Dam in Egypt, which meets nearly half of Egypt's demand for electricity.

Energy helps to make use of water that was previously considered undrinkable or unobtainable, by the process of desalination, wastewater treatment techniques and pumping water from deep underground aquifers or distant sources. As a result, understanding the links between water supply, its quality, and energy will help us evaluate constraints on meeting future water needs.

Water for Household

In most countries, water used for domestic purposes *viz*., drinking, preparation of food, washing, cleaning, gardening and service industries such as restaurants and Laundromats, accounts for only a small portion of total. The amount of water people use for household purposes is said to increase with rising standards of living. However, variations in domestic water use are substantial.

In the United States, each individual approximately uses more than 700 litres each day, or 185 gallons for domestic tasks. In Senegal, an individual on an average uses just one twentieth of that, i.e. 29 litters (7.6 gallons), to meet household needs. In countries' rich or poor, that has little agriculture or industry domestic needs account for a greater share of overall use. In both Kuwait and Zambia, nearly two out of every three litters of water used is for domestic purpose [22]. The essence of sustainable development is that natural resources must be used in ways that will not limit their availability to future generations. Sustainable development of water resources requires that we respect the hydrologic cycle by using renewable water resources that are not diminished over the long period. As of now, most easily accessible renewable fresh water resources - rivers, smaller streams and lakes, and aquifers that recharge quickly have been already developed. The growing use of fossil fuels to pump water from deep underground aquifers has expanded the access to fresh water today, but at the cost of its access in the future. There is nothing inherently unsustainable about the uses of groundwater per se; people have been drawing water from wells since the dawn of civilization. But to ensure that wells continue to provide sufficient water even in the future, there is the need for water to be drawn at a rate that permits water table levels to remain stable over time. Although all natural water resources are replenishable through the natural hydrologic cycle, their renewal ranges from days to millennia.

Last Resort - A Costly Affair

Desalination of seawater could theoretically be a sustainable source of freshwater - at least for wealthy nations with access to seawater. In 1990, through desalination just over 13 million cubic meters of fresh water were being produced per day in some 7,500 facilities around the world. This represented a 13 fold increase in global capacity of fresh water over 20 years. Yet, the supply of desalinated water is just one thousandth of the fresh water used worldwide, according to calculation by Peter H. Gleick, (An expert on water issues, from the Pacific Institute for Studies in Development, Environment and Security in Oakland, California).

Due to high capital and energy requirements, desalinated water costs several times, more than water supplied by conventional means. It is driven almost entirely by the combustion of fossil fuels. These fuels, inextensive but still finite in supply, pollute the air, and contribute to the risk of global climate change. At present, solar powered desalination plants which use renewable energy to take the salt out of sea water account for only 5, 240 cubic meters a day, though it is a negligible proportion of all desalinated water, but is a source of hope and promise for the future. With world population growing by 1.6 per cent a year, the feasibility of this technology contributing to meet water needs of the people around the world is hard to imagine. Sustainable development of water resource means working with 41, 000 cubic kilometre of water provided by the water cycle each year.

Therefore, we need to develop water supplies in ways that assure every human being abundant and renewable quantities of clean and healthy water for life, prosperity and well-being. Besides, there is a need to stabilize the population in the world at a level just to the quantities of water which can be produced today to meet their needs, but also that the earth can provide ever.

Present Situation

Either as a result of over exploitation of available water resources for limited localized purposes, or due to inadequate and ill-informed management strategies, water shortage is the current scenario in almost all the countries. About one-third of the world's population lives in countries experiencing moderate-to-high water stress. The Committee of the Economic and Social Council of the United Nations on Natural Resources noted with alarm that some 80 countries, comprising 40 percent of the world's population are already suffering from serious water shortages. In many cases, the scarcity of water resources has become the limiting factor to economic and social development, because there is greater demand on fresh water resources by the burgeoning human population; diminishing quality of water resources because of pollution; and additional requirements of spiralling industrial and agricultural growth [23]. For each person, water is among the absolute necessities of life. People are now facing a global fresh water crisis, where human demand is out stripping local water supplies in many regions. There is, therefore, an immediate need to develop a better understanding of, and management system for freshwater resources to ensure its conservation and sustainable use.

It is important to know the distinctions between water scarcity, water shortage and water stress. Water Scarcity is a relative concept intended to capture the imbalance between supply and demand under the prevailing legal, institutional, regulatory, and applicable arrangements. Water shortage is an absolute concept indicating low level of water supply relative to minimum level necessary for basic needs. Whereas, water stress signifies acute water shortages for prolonged periods.

Malin Falkenmark, a widely respected Swedish hydrologist, pioneered the concept of a water stress index based on an approximate minimum level of required water per capita, in a moderately developed country in an arid zone to maintain an adequate quality of life. To maintain good health and for basic household needs, Malin Falkenmark began with the calculation that 100 liters per day is a rough minimum per capita requirement. Falkenmark suggests specific thresholds of water stress and water scarcity based upon these findings.

On an annual per capita basis, a country whose renewable fresh water availability exceeds about 1,700 cubic meters will suffer only occasional or local water problems. Below this threshold, countries begin to experience periodic or regular water stress. Where fresh water availability falls below 1000 cubic meters per person per year, countries experience chronic water scarcity, in which case, the lack of water begins to hamper economic development, human health and well-being. When renewable fresh water supply falls below 500 cubic meters per person per year, countries experience absolute scarcity.

These levels can be considered as rough benchmarks, but not as precise thresholds. The exact level at which water stress sets in, varies from region to region as it is a function of climate, level of economic development and other factors. The 1,000 cubic meters per person per year as a bench mark has been accepted as a general indicator of water scarcity by the World Bank and other analysts. Peter. H. Gleick, considered this as an approximate minimum necessity for an adequate quality of life in a moderately developed country. Falkenmark's higher stress benchmark of about 1,700 cubic meters per capita per year is a "warning light" to nations whose population continues to grow.

India is one among those countries projected to fall into the water stress category before 2025 A.D. In 1990, the annual per capita water availability was 2464 cubic meters. Now according 2001 census, India's population is estimated to be 103 crores indicating decreasing per-capita availability of water. By 2025 A.D, India's population is expected to exceed 1.4 billion according to the United Nation's projection, and the chronic water scarcity that already plagues many regions of the country now, is certain to intensify with finite water resources available for India. The water resources available for India are given in Table 4.

Table 4: The Water Resources Available for India

Sl. No.	Water resources	Quantity
1	Rainfall	4000 cubic kilometer
2	Average annual flow in the rivers	1880 cubic kilometer
3	Utilizable water	1140 cubic kilometer
	a. Surface water	690 cubic kilometer
	b. Ground water	450 cubic kilometer

Source: Chitale M.A., 1992, Population and Water Resources of India, in Vasant Gowariker, (ed), Science, Population and Development, Unmesh Communications, Pune, p 111

Though India receives 4000 cubic kilometre of rainfall, more than half of it is lost in evaporation and soil moisture. Only 1880 cubic kilometre of the total rainfall flows in the river. But, out of 4000 cubic kilometre of rainfall only 690 cubic kilometres is available as surface water for utilization and the rest of 450 cubic kilometre of utilizable fresh water is from the groundwater. This indicates that, all that falls as rain is not being or cannot be utilized. Though the statistics reveal that the projected requirement of freshwater for 2025 will increase to 1050 cubic kilometre, (Vide Table 3) there is sufficient utilizable water (1140 cubic kilometre). But, due to lack of management of water resources, it has not been made available when and where it is needed the most.

Conclusion

As the demands of growing population approach the limits of renewable resources, water could provide the flash point for conflict in region with long standing ethnic and political rivalries. Indeed, the same analysts have suggested that within a decade, water could overshadow oil as a scarce and precious commodity at the centre of conflict and peacemaking. In 1985, United Nations' then Secretary General Boutros Boutros Ghali warned as, the next war in the Middle East will be fought over water, not politics. Tensions over control and use of water resources are mounting around the globe. Besides water becoming scarcer, its quality is also in peril.

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