TOPIC: -

HYDROLOGICAL CYCLE AND WATER BUDGET.

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INTRODUCTION: -

Water is the basic component of all the living beings including flora and fauna. It is well known that human and plant body consists of approximately 60% to 90% water, respectively (Kleiner, 1999; Pandey, 2003 and Ramesh & Soorya, 2012). After the oxygen water is one of the most essential natural resources for sustaining life on earth. It is impossible to think existence of life without water. We require 3 to 5 liter of water/day and it is the basis of life and is the foundation for human survival and development. Water is used for various purposes like drinking, washing clothes, bathing, cleaning, cooling, irrigation and in industry. Water is consumed, it is no longer available for reuse in the local area because of evaporation, storage in the living matter of plants and animals, contamination or seepage into the ground. Almost three-fourths of the water withdrawn each year throughout the world is used for irrigation. The remainder is used for industrial processing, energy production, cooling electric power plants, for domestic and industrial activities. The main sources of water on earth include: the precipitation, surface water i.e. streams, rivers, ponds, lakes and groundwater. The distribution of water varied from place to place and even varied from time to time at a particular place e.g. in India maximum fresh water is available during rainy season. The earth's water resources consist of the oceans and seas, the ice and snow of polar regions and mountain glaciers, the water contained in surface soils, and underground, the water in lakes, rivers and streams. These water resources collectively form hydrosphere. Less than 1% of these resources consist of freshwater, about 2% is freshwater ice located mainly in the Polar Regions and remaining 97% consists of sea water (Miller, 1997 and Bhattacharyya et al. 2015).

IMPORTANCE OF WATER: -

It is well known fact that early human civilizations have grown and flourished on the banks of rivers. We cannot think about life without water, the other name of water is life. It is assumed that life first appeared in the water (in the seas, 3.5 billion years ago). It is most important and abundant component of protoplasm in the cells of all living being. Moreover, metabolic and biochemical reactions in the body of all the living beings including human being occur in the presence of water. The green plants which act as producer in the ecosystem pick up nutrients from the soil transport to different parts with the help of water. After sun light water is second most important component required for photosynthesis. The huge amount of water present in the oceans act as a sink for carbon dioxide i.e. helps to control global warming likewise forests. These giant water bodies provide protein rich diet to the world's people in the form of fish. Water is habitat for aquatic animals and plants which run the food chain in aquatic ecosystem. It also helps in control of climate of a particular place. Beside this water is required for agriculture, domestic needs, navigation, industrial processing, recreational use, power generation and many more etc.

In India more than 70% of population depends upon agriculture for livelihood which uses maximum fresh water. According to Bhattacharyya et al., (2015) the per capita exploitable water availability in India in 1951 and 2010 was 3000 and 938m^3, respectively and these are projected to reduce further to 814 and 687m^3 by the years 2025 and 2050 respectively.

Water is a precious natural resource and limited in quantity and unequally distributed. Approximately three-fourth of the earth is covered by water so why, earth is also known as blue planet. It is the only known substance that can naturally exist as a gas, liquid, and solid state. Slightly more than 97% of water present in world's oceans that is saline in nature. Beside this, 2.5% to 3% is fresh water and less than 1% is easily accessible through rivers, lakes and from shallow aquifers (groundwater). The global distribution of water resources is shown in Figure: 1.

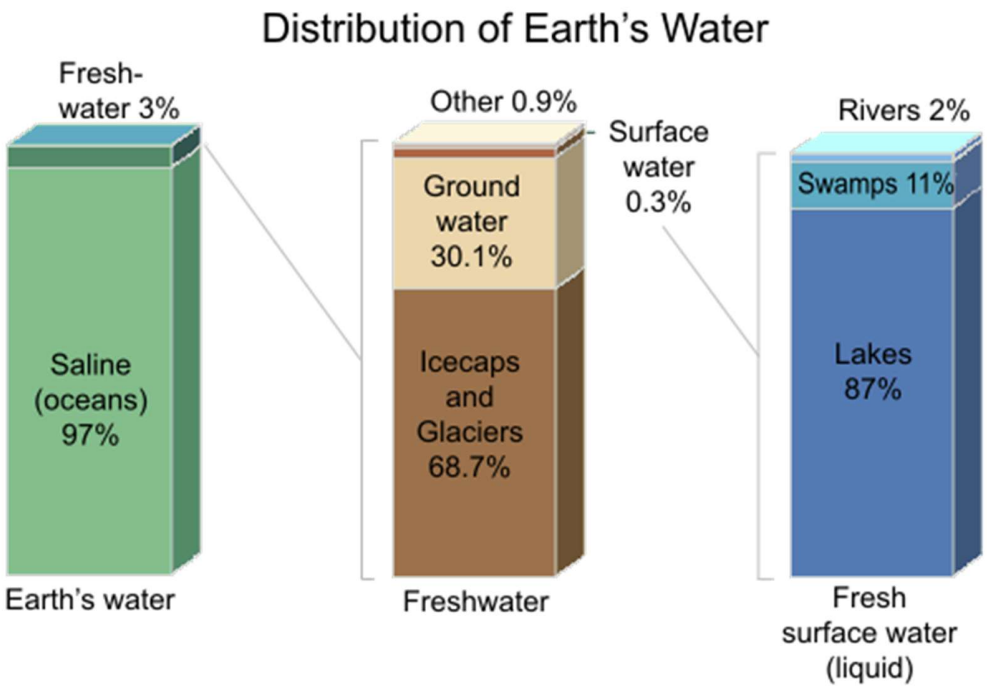

Figure: 1 Distribution of Earth Water Resources

It is evident from figure: 1 that groundwater is the biggest source of fresh water after the ice (including ice caps, glaciers, permanent snow, ground ice, and permafrost) however, exact estimation of groundwater is very difficult. It is stored in sediments and rocks below the surface of the earth.

WATER CYCLE: -

The movement of water from the earth's surface to the atmosphere and from atmosphere to earth' surface is known as hydrological or water cycle. Moreover, according to National Research Council (NRC, 1982), the hydrological or water cycle is defined as "the pathway of water as it moves in its various phases to the atmosphere, to the earth, over and through the land, to the ocean and back to the atmosphere". Thus, precipitation is the most important source of water on earth for terrestrial life (Cunningham and Cooper, 2001). The detailed approximate estimate of distribution of global water resources in biosphere in terms of volume and percentage is shown in table 1.

Table 1: Global water distribution in different segments of the Biosphere

Sr. No.	Segment	Volume of water in B.ham(billion hectare metres)	% age of total water	% age of fresh water
1.	Oceans	1,34,800	**97.3**	-
2.	Fresh water	3,750	02.7	100%
Total water		**1,38,550**	**100.0**	**100**
Distribution of fresh water among various sources:				
(i)	Polar ice and Glaciers	2820	2.03	75.2
(ii)	Groundwater (less than 800 m deep)	374	0.27	10.0
(iii)	Groundwater (800-4000 m deep)	471	0.34	12.6
(iv)	**Lakes and Rivers**	12.7	0.01	0.3
(v)	Other sources (soil moisture, biological water and atmospheric vapour)	72.7	0.05	1.9
Total fresh water		**3750**	**2.7%**	**100.0**

Source: The role of Dams in the 21st century, June 1992. United States Committee on Large Dams; as reported by CWC through its publication "water and Related Statistics, May, 2004".

From the Table 1 it can be seen clearly that 97.3% water is saline in nature and contained in oceans. It cannot be used for domestic purpose (drinking, washing, cooking, bathing), irrigation use, for industrial activities and energy production without prior treatment. The fresh water is only 2.7% of total water present on the earth. Out of this 2.7% of fresh water, about 2.03% is restricted to polar ice caps and glaciers, 0.61% is present underground known as groundwater. The reminder fresh water is present in rivers, lakes, ponds i.e. 0.01% of total water, and about 0.05% is available as soil moisture, biological water and atmospheric vapour (Garg et. al, 2006).

The evaporation of water from oceans, other open water bodies, soil and transpiration from plants contributes water close the cycle (Jain, 2012). Hence, evapotranspiration is the term used to describe

the return of water from the surface to the atmosphere. The wind then moves water vapor from place to place until it condenses to form rain clouds. The wind circulates these clouds to different parts of the earth. After condensation and precipitation these vapors falls on earth in the form of either dew, rain, snow or hail on the earth (Figure. 1).

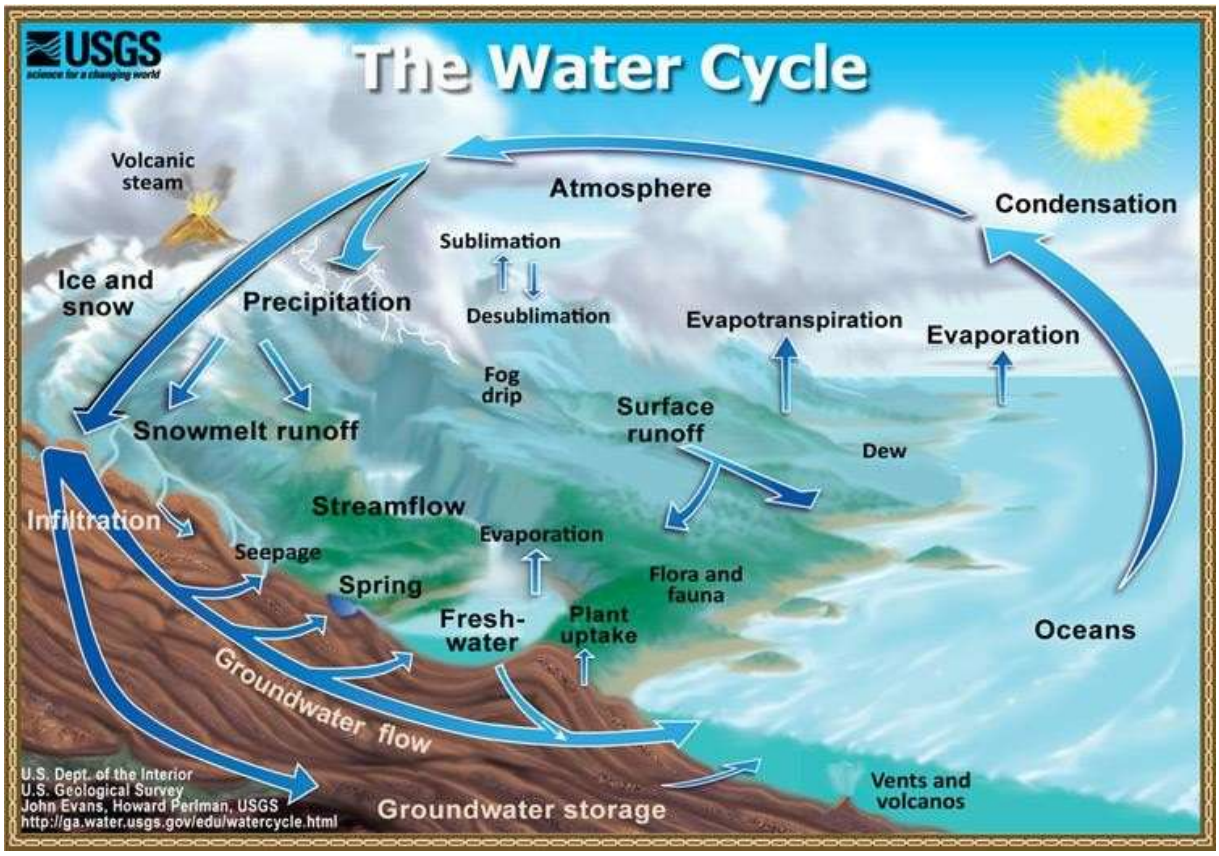

Figure: 2 The Hydrological Cycle

It is estimated that approximately 90% of moisture in the atmosphere is contributed by the process of evaporation from oceans, seas, bays and other open fresh water bodies i.e. rivers, lakes, ponds, streams etc. In addition to this, a very minute amount of water vapor is contributed to the atmosphere through the process of sublimation, the process by which water changes from a solid (ice or snow) to a gas. Beside, evaporation and sublimation process remaining 10% moisture in the atmosphere is contributed

by the process of transpiration from plants (Chang and Okimoto, 1970). The plants get water along with nutrients from soil with the help of root system and transport to their leaves. The water from leaves is released by tiny pores known as 'stomates' present on the undersides of leaves through the process of transpiration. Moreover, respiration by organisms and volcanic eruption may also contribute to moisture content of the atmosphere minutely. Hence, evaporation, sublimation, transpiration, respiration, and plus volcanic eruption accounts for overall moisture content present in the atmosphere.

MECHANISM OF WATER CYCLE: -

Hydrologic cycle is a very vast and complex cycle in which there are a large number of paths of unreliable time scale. The three main subdivisions of hydrological cycle are world's oceans, atmosphere and lithosphere. The oceans are the main source of water supply to hydrological cycle, atmosphere act as carrier and supplier of water to lithosphere, which act as consumer of water. The amount of water supplied by hydrological cycle at a particular place may vary due to weather conditions prevailing at that time. The various events involved during the process of water cycle are-

- Evaporation
- Sublimation
- Transpiration
- Precipitation
- Infiltration
- Percolation
- Runoff and
- Subsurface flow.

EVAPORATION: -

With the help of solar radiations oceans and other surface water bodies' water get warm up. Due to this warming the physical state of water changed from liquid to gaseous form i.e. vapor form. These vapors enter in to atmosphere and this is the transfer of water from bodies of surface water into the atmosphere. It is estimated that approximately 90% of moisture in the atmosphere is contributed by the

process of evaporation from oceans, seas, bays and other open fresh water bodies i.e. rivers, lakes, ponds, streams etc.

SUBLIMATION: -

It is estimated that small amount of water enters to atmosphere by the process of sublimation. Actually it is conversion between solid and gaseous phases of matter, with no in-between liquid phase. Moreover, certain weather conditions are responsible for the process of sublimation e.g. low relative humidity and dry winds play an important role in the process. Besides this due to less air pressure at higher altitudes compare to lower altitudes also contributes to the process of sublimation.

TRANSPIRATION: -

The remaining 10% moisture in the atmosphere is contributed by the process of transpiration from plants (Chang and Okimoto, 1970). The plants get water along with nutrients from soil with the help of root system and transport to their leaves. The water from leaves is released by tiny pores known as 'stomates' present on the undersides of leaves through the process of transpiration. Transpiration is the evaporation of water from the stem and surface of leaves of plants in to the atmosphere.

The process of evaporation from oceans, other water bodies, soil and transpiration from plants contributes water to hydrological cycle. Hence, evapotranspiration is the term used to describe the return of water from earth's surface to the atmosphere by evaporation and transpiration collectively.

PRECIPITATION: -

It is the main source of fresh water supply to the entire world and it may occur in liquid or solid form. The water vapors get condense around fine particles which act as nuclei in the atmosphere. These fine water droplets increased in size while descending from upper atmosphere to lower atmosphere by the process of collision and coalescence. Ultimately under the influence of gravity these water droplets in the form rain fall on the earth's surface. Some vapor freezes into tiny ice crystals which attract cooled water drops and may fall as hail and snowfall known as freezing rain. Thus most of the water is returned to the oceans and on land in the form of rain, snow, hail etc.

INFILTRATION AND PERCOLATION: -

The water falling on earth's surface add water to rivers, streams and lakes etc. The water from these water bodies and land seeps to ground known as infiltration or infiltration may be defined as entry of water in to soil surface. The amount of water infiltrate depends upon various factors e.g. intensity of

rain fall, soil physical and chemical properties and vegetation cover on the soil etc. This infiltrated water slowly-slowly percolates down and form groundwater. Percolation is the downward movement of water from soil and rocks to groundwater. The ground water containing zone under earth's surface is known as aquifer. The terms infiltration and percolation are often used interchangeably.

RUNOFF AND SUBSURFACE FLOW: -

The water that does not infiltrate down to ground and flow under the influence of gravity on earth's surface is known as runoff. This free flowing water becomes the part of streams, rivers, lakes, ponds and ultimately falls in to the oceans. The amount of runoff water depends upon various factors namely rain fall intensity and duration, type of soil, slope of land and ground cover. Generally, runoff occurs when rainfall exceeds the infiltration or soil saturate with water.

The groundwater moves within the earth and may seep in to rivers, lakes and oceans but this is a very slow process.

IMPACTS OF HUMAN BEINGS ON WATER CYCLE: -

Due to population explosion, change in life style, industrial growth and modern agricultural practices have put a tremendous pressure on fresh water resources. The per capita demand of water is increasing while availability is decreasing day by day. The excessive withdrawal of groundwater for agricultural use is creating a lot of environmental issues in arid and semi-arid parts of the earth. There are various types of anthropogenic activities which affect water cycle. Global warming and climate change influence the evaporation and precipitation pattern of a region due to increase in temperature. Modern agricultural practices use excessive amount of fresh water and generally relay on groundwater. The excessive withdrawal of groundwater lowers the water table and may increase the rate of water percolation into deep aquifer. This water may not be available for subsurface flow. Deforestation affects the transpiration rate which lowers the moisture content of the atmosphere at a particular place. Due to global warming moisture content of soil may decrease.

SUMMARY: -

Safe drinking water is utmost requirement and fundamental right of any citizen. However, it is estimated that more than one billion people on earth have lack access to safe drinking water. The major sources of water on earth are rainfall, surface water and groundwater however; water cycle recycles the earth's precious fresh water supply. The radiant energy of the sun is driver to run water

cycle and atmosphere is the main source of water as water after evapotranspiration gets stored in the atmosphere (Punmia et. al, 2009). Water returns to the surface of the earth in the form of either liquid or solid precipitation. About 75 percent of the precipitation is returned to the atmosphere as vapor through direct evaporation and transpiration from plants during photosynthesis. The remaining 25 percent of the precipitation is stored in ice caps, drains directly off the land into lakes, streams, wetlands, rivers, and oceans, or infiltrates the soil and underlying rock layers and enters the groundwater system. Groundwater enters lakes and streams through underwater seeps, springs, or surface channels naturally under the influence of gravity. It is estimated that out of total precipitation on earth nearly 85% falls on oceans and remaining 15% falls on land surface. From the land surface, some water is evaporating, some enter in to surface water bodies and indirectly reached back to oceans through surface run off (Kuchment, 2004). The rest of the water is percolates to groundwater from where it may seep into open water bodies or in to oceans. Some amount of water present on land surface is utilized by plants with the help of roots and consumed by animals. The water utilized by plants and consumed by animals is returned back to atmosphere through the process of respiration and evapotranspiration.

WATER BUDGET: -

Water budgeting is a principal activity for proper management of water resources. Actually 'water budget' is an accounting of water inputs, outputs and storage of water e.g. in lithosphere, atmosphere and oceans. Hence, Water Budget means – the balance between the available water in the country and the water under use. Hence, it is balance between the accessible water and the water underutilization. The solar radiations evaporate water from oceans and land and transpiration of water from plants introduce moisture into the atmosphere which returns to earth as precipitation. It is estimated that about 525100 cubic kms water introduce into the atmosphere and from this about 21.6% water vapors comes to earth as precipitation over land surface. The water budget calculation includes the different mechanism used in water cycle e.g. precipitation, evaporation, evapotranspiration, surface and subsurface flow. The table 2 presents the Annual water budget of planet earth.

Table: 2 Annual water budget of planet earth

Sr. No.	Particulars	Water in cubic kms
1	Total evaporation from sea surface	4,52,600
2	Total evaporation from land surface	72,500
3	Total precipitation on ocean surface	4,11,600
4	Total precipitation on land surface	1,13,500
5	Total surface and ground water flow	41,000
6	Total evaporation from land and sea surface	5,25,100
7	Total precipitation on land and sea surface	5,25,100

It is evident from Table: 2 that world's oceans impart about 4,52,600 cubic kms water annually to atmosphere while get only 4,11,600 cubic kms as precipitation. However, this deficit is balanced by 41,000 cubic kms of surface and subsurface runoff, which they receive. This excess water ultimately flows back to oceans under the influence of gravity (Roggers, 1991). Moreover, the amount of water presents in oceans, on land, groundwater and water present in atmosphere in vapors form etc. are in a state of dynamic equilibrium.

WATER BUDGET OF INDIA: -

India has 18% population of the world and having only 4% fresh water resources of the earth. Moreover, the reserves of our surface and underground water are approximately 23840 billion cubic metres and only 10860 billion cubic metres are required for utilization (Bhattacharyya et al., 2015). 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 metres (Biswas, 1970).

There is a great variation in the distribution of water resources in space and time e.g. water is available in adequate amount during monsoon season in India. As the dry season sets in, there is a scarcity of water. Even though India is one of the wettest countries in the world, the accessibility of water to the people with time and space is extremely bumpy. On an average, it receives about 1150 mm of rainfall annually, which is highest in the world for a country having only 2.5% geographical area of the world. Yet, its distribution is highly uneven e.g. average number of rainy days in a year is only 40. Consequently, there is a lengthy curse of dry period in a year. Also, the rainfall is as high as 13 m in some areas of North-East regions and as a low as 20 cm in certain parts of Rajasthan. This irregular circulation of rainfall results in water shortage in several parts of our nation. India receives on an average about 4000 billion cubic metres (bcm) of rainfall every year. According to an estimate more than half of this quantity is lost to the atmosphere through evapotranspiration or through deep percolation in to groundwater and only about 1869 bcm flow in the rivers as surface flow. This is estimated to be the water resources potential of the country. Approximately 690 bcm of surface water and 432 bcm of groundwater are available for use per year. According to National Commission on Integrated Water Resource Development (NCIWRD), it is expected that the population of India would be 1581 million by the year 2050 (Van der Leeden, 1990). Keeping in view the increased demand for domestic use, industrial purpose, energy production etc. and above all for agricultural production there will be more demand of fresh water. The Central Water Commission has enumerated water demand scenarios up to the year AD 2050 for different sectors as depicted in Table 3.

Table 3 Sector-wise Demand Scenarios of Water in India (billion cubic metres).

Sr. No.	Sector	2010	2025	2050
1	Irrigation	688	910	1072
2	Drinking (including Livestock)	56	73	102
3	Industrial	12	23	63
4	Energy	05	15	130
5	Others (Forestry, Pisciculture, Tourism, Navigation etc.)	52	72	80
Total		813	1093	1447

Moreover, fresh water resources of country are already under pressure e.g. in year 1951, the per capita availability of fresh water was nearly 3000 m^3, has been declined to 1100 m^3 in 1998 and is projected to be 687 $m^3$by the year 2050 as given in 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	1283	938	814	687

The various researchers have estimated that the water resources of India are 1880 bcm and Central Water Commission (CWC) has reported that total utilizable water resources of the country is 1110 bcm. The water resources of India are depicted in Table: 5

Table: 5 Water resources of India

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

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CONCLUSION: -

Water, a marvelous liquid and universal solvent is basis of life on earth. Due to human activities surface and groundwater quality is deteriorating day by day. Beside these anthropogenic activities,

some natural contaminants e.g. arsenic, fluoride, iron and salinity are also affecting the groundwater quality. Due to increase in demand in water for domestic use, industrial as well as agricultural expansion there is urgent need to think about water resources seriously. For safe and sound drinking water it is necessary to generate reliable and precise information about water quality. The control of surface as well as ground water pollution and treatment of waste water before discharging are most important component for management of water resources. Above all, reuse and recycle of waste water, rain water harvesting, and creating awareness about importance of water resources are very important issues.