

HYDROLOGIC CYCLE

Hydrologic Cycle is a fundamental and important concept in hydroscience. The cycle involves the total earth system comprising the atmosphere (the gaseous envelop), the hydrosphere (surface and subsurface water), lithosphere (soils and rocks), the biosphere (plants and animals), and the Oceans. Water passes through these five spheres of the earth system, in one or more of the three phases: solid (ice), liquid and vapour. Figure 2.1 represents the various processes of the hydrologic cycle.

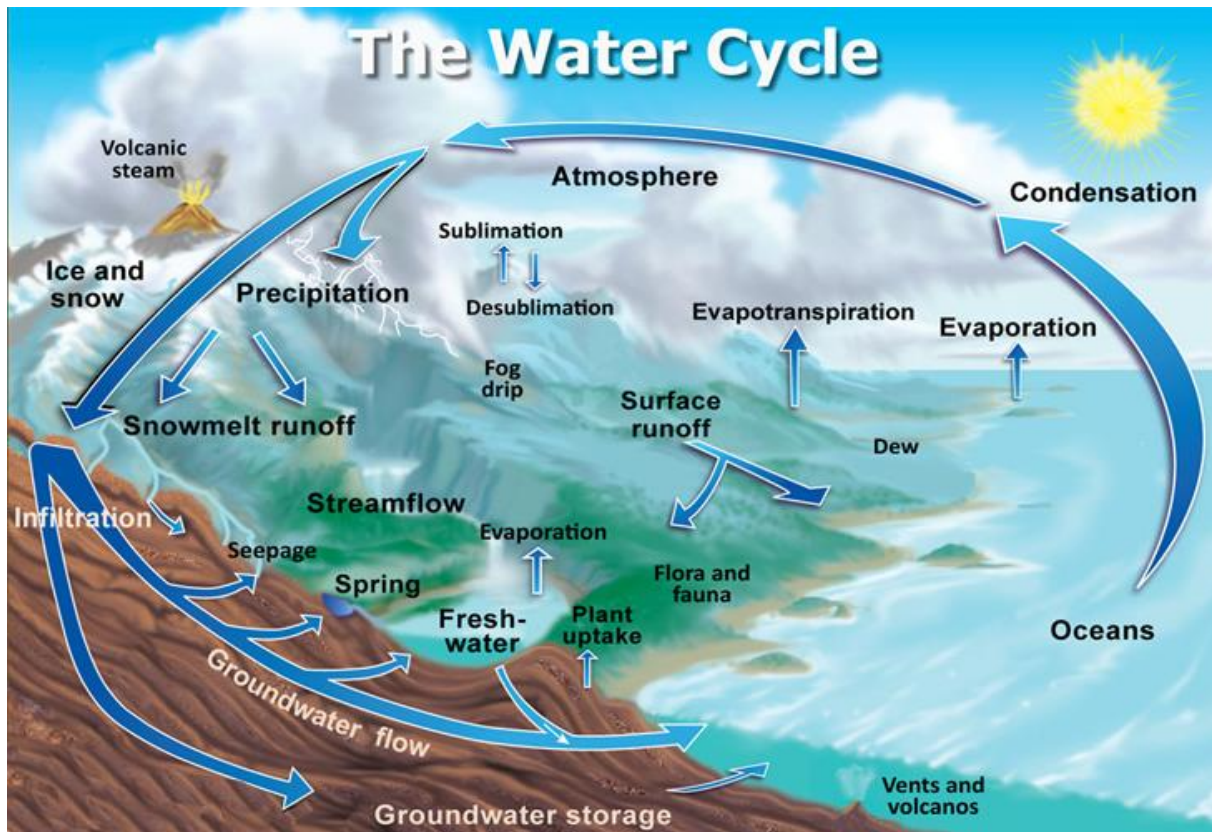


Figure 2.1: Representation of the various processes of the hydrologic cycle
(Source: John Evans and Howard Periman, USGS - <http://ga.water.usgs.gov/edu/watercycle.html>)

The Vedic texts which are more than 3000 years old contain valuable references to water and the ‘hydrologic cycle’. As mentioned earlier, the most important concepts, on which the modern science of Hydrology is founded, are mentioned in Rig Veda in various verses in the form of hymns and prayers addressed to various deities and divinities such as Indra (firmament), Agni (fire), Maruts (wind) and so on. For example, a verse from Rig Veda states like this:

आदह स्वाधामनु पुनर्गर्भत्वमेरिरे ।
दधानानामः यज्ञियम ॥ R.V., I,6.4 ॥

It means that the water which gets divided in minute particles due to the heat of sun is carried by wind and after the conversion into cloud it rains again and again. Another verse of the Rig Veda (R.V, I,7.3) states that the God has created sun and placed it so, that the whole universe gets illuminated, likewise this is the rule of universe to extracts up water continuously and then convert it to cloud and ultimately discharge as rain.

इन्द्रो दीर्घाय चक्षस आ सूर्य रोहयादिदति ।
वि गोभिराद्रिमैरयत ॥ R.V. I,7.3 II

Following verses of Rig Veda explain the transfer of water from earth to the atmosphere by the wind (I, 19.7), breaking up of water into small particles and evaporation due to sun rays and subsequent rain (I, 23.17), the formation of cloud due to the water evaporated from the mother earth and its come back to its mother in the form of rain (I,32.9).

The verse I,32.10 of the Rig Veda says that the water is never stationery. It continuously gets evaporated and comes down, but due to smallness, we can't see the rising water particles.

य ईखड्यन्त पर्वमतान् तिरः समुद्रमर्णवम् ।
मरुद्भिरग्न आ गहि ॥R.V., I,19.7 II

अमूर्या उप सूर्ये याभिर्वा सूर्यः सह ।
ता नो हिन्वन्त्वध्वरम् ॥R.V., I,23.17 ॥

नीवातयां अभवद्वृत्रपुत्तेन्द्रो अस्या अव अधर्जभार ।
उत्तराः सूरधरः पुत्र आसीददनुः शये सहवत्सानधेनुः ॥ R.V., I,32.9 ॥

The following verses of the Rig Veda say that the rays of the Sun are the cause of rains and that the sun extracts water from all parts of the world and the start of creation is through fire only, which is continuously engaged in extraction and discharge of water.

अतिष्ठन्तीनाम विवेशनानां काष्ठानां मध्ये निहितं शरीरम् ।
वृत्रस्य निष्यं वि चरन्त्यापो दीर्घतम् आशयदिन्द्रशत्रुः ॥R.V., I,32.10 ॥

ऋतं देवाय कृष्वते सवित्र इन्द्रायाहिघे न रमन्त आपः ।
अहरह्यात्यक्तुरपां कियत्त्या प्रथमः सर्ग आसाम् ॥R.V., II,30.1 ॥

यो वृत्राय सिनमत्राभरिष्यत्प्र तं ज नित्री विदुष उवाब ।
पथो रदन्तीरनु जोषमस्मै दिवेदिवे धनुयो यन्त्यर्थम् ॥R.V., II,30.2 ॥

A verse of Rig Veda further states as follows:

या आपो दित्या उत वा स्त्रवन्त खनित्रिमा उत वा याः स्व्यंजाः ।
समुद्रार्या याः शुचवः पावकास्ता आपो देवीरिह मामवन्तु ॥R.V., VII,42.2 II

Meaning: The waters which are from heaven, of those which spring up by themselves, the bright pure waters that tend to the sea, may those divine waters protect me here. Like these verses, various other verses of the Rig Veda (RV. VIII,6.19, VIII,6.20; and VIII, 12.3) states the causation of water evaporation, formation of cloud, rain, flow of water and its storage in oceans etc.

The verse RV. X,27.33 of Rig Veda reads as follows:

देवानां माने प्रथमा अतिष्ठान्कृन्तत्रादेशामुपरा उदायन् ।
त्रयस्तपन्ति पृथिवीमनूषा द्वा बृबूकं वहतः पुरीषम ॥R.V., X,27.23 ॥

Meaning: At the start of creation, sun, etc. are created, rainfall is caused from sky and the vegetation is created by the combination of cloud, air and sun. The sun extracts water in the form of vapour & air, causes it to form cloud and rain.

Further elaboration of the knowledge about hydrologic cycle is found in the Sam Veda (VI-607).

A verse of Sam Veda reads as follows:

समन्या यन्त्युपयन्त्यन्याः समानमूर्व नघस्पृणान्ति ।
तम् शुचिं शुचयो दीदिवांसमपान्पातमुय यन्त्यायः ॥S.V. पूर्वाचिक VI, 607 ॥

Meaning: One type of water goes up and other type of water comes down, both of these may go to the atmosphere after treatment of sun's heat. From up they flow into rivers after rain and get stored there.

Similarly, the Yajur Veda explains the process of water movement from clouds to earth and its flow through channels and storage into oceans and further evaporation (Y.V., X-19).

प्र पर्वतस्य वृषभष्य पृष्णन्नावश्चरान्ति स्वसिचज्ञयानाः ।
ता आववृत्रन्नधरा गुदक्ता अहिं बुहन्यमनु रीयमाणाः
विष्णोर्विक्रमणमसि विष्णोर्विक्रान्तमसि विष्णोः क्रान्तमसि ॥Y.V., X-19 ॥

In the Rig Veda, Sam Veda and Yajur Veda the concept of infiltration, water movement, storage and evaporation as the part of hydrologic cycle are revealed clearly. During the time of Atharva Veda the concept of water evaporation, condensation, rainfall, river flow and storage and again repetition of cycle was explained as in the earlier Vedas. According to the Atharva Veda, the sun rays are the main cause of rain and evaporation, as mentioned below:

अमूर्या उप सूर्ये याभिर्ग सूर्यः सह ।
ता नो हिन्वन्त्वध्वरम ॥ A.V., I,5.2 ॥

The verse I, 32.4 of the Atharva Veda states that the entry of rainwater into earth and its continuous movement in the cycle from earth to atmosphere is by sun rays. The Verse reads as below:

विश्वमन्यामभीवार तदन्यस्यामधि श्रितम् ।
दिवे च विश्ववेदसे पृथिव्यै चाकरं नमः ॥A.V.,I,32.4 ॥

Another Verse of the Atharva Veda (V,24.5) says that the water from earth goes to the atmosphere due to oxygen and then it comes down (rains) due to carbon dioxide.

मित्रावरुणौ वृष्टयाधिपती तौ माक्ताम् ।
अस्मन् ब्रह्मण्यसिमन् कर्मण्यस्यां पुरोधायामस्यां प्रतिष्ठायामस्यां
चित्यामस्यामाकूत्यामस्यांमाशिष्यस्यां देवहृत्यां स्वाहा ॥A.V., V,24.5 ॥

The hydrologic cycle reaches into the atmosphere and traverses, imparts, the domain of hydrometeorology. It may be seen in the Varahamihira's Vrhat Samhita (550 A.D.) in which three chapters are devoted to hydrometeorology comprising pregnancy of clouds (Chapter 21), pregnancy of air (Chapter 22), and quantity of rainfall (Chapter 23). Shlokas 1 and 2 of Dakargalam (Chapter 54 of Vrhat Samhita) which states the importance of science of ground water exploration, helps man to ascertain the existence of water are as follows:

धमर्यं यशस्यं च वदाभवतोहं दकार्गलं येन जलोपलब्धिः ।
 पुंसां यथाग्देषु शिरास्तथैव क्षितावपि प्रोन्नतनिनसंस्था
 एकेन वर्णेन रसेन चाम्भश्च्युतं नभस्तो वसुधाविशेषांतु ।
 नाना रसत्वं बहुवर्णतां च गतं परीक्ष्यं क्षितितुल्यमेव ॥ Vr.S., 54.1-2 ॥

The water veins beneath the earth are like vein's in the human body, some higher and some lower. The water falling from sky assumes various colours and tastes from differences in the nature of the earth. These shlokas imply that the infiltration of rainwater through the veins into earth surface is the source of ground water. The epic Mahabharata (XII, 183.15.16) explains that the water ascends to sky with the help of अग्नि (fire) and air and then its humidity get condensed and causes subsequent rainfall.

अग्निः पवनसंयुक्तः खं समाक्षिषते जलम् ।
 सोग्निमारुतसंयोगाद् घनत्वमुपपद्यते । MB,XII,183.15 ॥
 तस्याकाशे निपतितः स्नेहस्तष्टति यो परः ।
 स संघातत्वमापन्नो भूमित्वमनुगच्छति ॥ MB,XII,183.16 ॥

The verses 184.15-17 of the Mahabharata state that the plants drink water through their roots. The mechanism of water uptake by plants is explained by the example of water rise through a pipe. It is said that the water uptake process is facilitated by the conjunction of air.

पादैः सलिलपानाच्च व्याधीनां चापि दर्शनात् ।
 व्याधिप्रतिक्रियत्वाच्च विद्यते रसनं दुमे ॥ MB,XII,184.15 ॥
 वक्त्रेणोत्पलवालेन यथोर्ध्वं जलमाददेत् ।
 तथा पवनसंयुक्तः पादैः पिबति पादपः ॥ MB,XII,184.16 ॥

In verse XII,362.4 and B of the Mahabharata, it is explained that the air and the sun rays get dispersed and fall on whole universe together. The Verse further says that the sun rains in rainy season (four months) and in next eight months the same water is again extracted by the sun rays. Thus, it explains two faces of hydrological cycle clearly viz.

यतो वायुर्विनिः सृत्य सूर्यरश्म्याश्रितो महान् ॥ M.B.XII,362.4 ॥

योष्टमासांस्तु शुविना किरणेनोक्षित पयः ।

प्रत्यादत्ते पुनः काले मिश्चर्यमतः परम् ॥ M.B.,XII,362.B ॥

Like Vedas and Epics, in Puranas (which are dated between 6th century B.C. to 7th century A.D.) we get various references which show the development of knowledge of hydroscience during their periods. Matsya Purana (Vo. I, Chapter 54) reveals that the air saturated with moisture is the cause of creation (earth) viz.

वाय्वाधारा वहन्ते वै सामृताः कल्पसाधकाः ॥ Matsya I,54.15 ॥

In verses I,54.29-34 of the Matsya Purana and 51.23-24-25-26 of the Vayu Purana, we come across the knowledge of evaporation. According to these verses, burning of water and its conversion to smoke is caused by sun rays which ascend to the atmosphere with the help of air, which again rains in next 6 months for the goodness of the living beings. The various verses are given below:

ध्रुवेणाधिष्टताश्चापः सूर्यो वै गृह्य तिष्ठति

सर्वभूतशरीरेषु त्वापो ह्यानुश्चताश्चियाः ॥ Matsya I,54.29 ॥

दह्यमानेषु तेष्वेह जग्दमस्थावरेषु च ।

धूमभूतास्तु ता ह्यापो निष्क्रामन्तीह सर्वशः ॥ Matsya I,54.30 ॥

तेन चास्त्राणि जायन्ते स्थानमभ्रमयं स्मृतम् ।

तेजोभिः सर्वलोकेकेभ्य आदत्ते रश्मभिर्जलम् ॥ I,54.31 ॥

समुद्राद्वायुसंयोगात् वहन्त्यापो गभस्तयः ।

ततस्त्वृतुवशात्कालेपरिवर्तन् दिवाकरः ॥ I,54.32 ॥

नियच्छत्यापो मेघेभयः शुक्लाः शुक्लैस्तुरश्मभिः ।
अभ्रस्थाः प्रपतन्त्यापोवायुनासमुदीरिताः ॥ I,54.33 ॥

ततो वर्षति षण्मासान् सर्वभूतविवृद्धये ।
वायुभिस्तनितंचैव विधुतस्त्वग्निजाः स्मृताः ॥ Matsya I,54.34 ॥

In Linga Purana a full-fledged chapter (I,36) has been devoted to the science of hydrology. It explains evaporation, condensation and rainfall with suitable examples very scientifically and says that the water can't be destroyed, only its state is changed.

दन्दह्यमानेषु चराचरेषु गोधूमभूतास्त्वभ निष्क्रमन्ति ।
या या ऊर्ध्वं मारुतेनेरिता वे तास्तास्त्वभांयग्निनावायु च ॥ Linga I,36.38 ॥

अतो धूमाग्निवातानां संयोगस्त्वमुच्यते ।
वारीणि वर्षतीत्यभ्रमभ्रस्येशः सहस्त्रदृक् ॥ Linga I,36.39 ॥

Meaning: After getting by sun, the water contained in most of the materials on earth gets converted to smoke (vapour) and ascends to sky with the air and subsequently gets converted to cloud. Thus, the combination of smoke, fire and air is the cause of cloud formation. These clouds cause rainfall under the guidance of lord Indra, having thousand eyes.

Similarly verses I,36.66-67 of the Linga Purana say that the water is never destroyed or lost, but only converted from one form to other i.e. water to vapour by sun heat, then cloud and subsequent rainfall and loss of rainfall by wind etc. viz.

अस्यैवेह प्रसादात्तु वृष्टर्नाताभवदिदवजाः ।
सहस्त्र गुणमुत्त्रष्टूं मादत्ते किरणैर्जलम् ॥ Linga I,36.66 ॥

जलस्य नाशो वृद्धिर्वा नातत्येवास्य विचारतः ।
ध्रुवेणाश्रिष्टतो वायुवृष्टिं संहरते पुनः ॥ Linga I,36.67 ॥

Thus, it is evident that the Linga Purana contains clear concept of rainfall, evaporation, condensation, cloud formation etc., along with the knowledge that water cannot be created or

destroyed. Chapter 41, Vol. I of the Linga Purana furnishes some more knowledge about the change in the facets of hydrological cycle with months of the year. viz.

वसन्ते चैव ग्रीष्मे च शतैः स तपते त्रिभिः ।
वर्षास्वथो शरदि च चतुर्भिस्स्यं प्रवर्षति ॥ Linga I,41.30 ॥

चैत्रे मासि भवेदंशुर्धाता वैशाखतापन ।
जेष्ठे मासि भवेदिन्द्र आषाढे वार्यमा रविः ॥ Ling I,41.33 ॥

Likewise Vayu Purana also contains valuable references to hydrologic cycle. Vayu Purana (51.14-15-16) state like this:

आदित्यपीतं सूर्याग्नेः सोमं संक्रमते जलम् ।
नाडीभिर्वायुयुक्ताभिलोकाधानं प्रवर्तते ॥ Vayu,51.14 ॥

यत्सोमात्स्त्रवते सूर्यं तदभ्रेष्वतिष्ठते ।
मेघा वायुनिघातेन विसृजन्त जलं भुवि ॥ Vayu 51.15 ॥

एवमुत्क्षिप्यते चैव पतते चं पुनर्जलम् ।
न नाशमु उदकस्यास्ति तदेव परिवर्तते ॥ Vayu 51.16 ॥

Meaning: The water evaporated by sun ascends to atmosphere through the capillary of air, and there gets cooled and condensed. After formation of clouds, it rains by the force of air. Thus, water is not lost in all these processes but gets converted from one form to other continuously.

Brahmanda Purana (II, Chapt. 9) also gives some information on the hydrologic cycle. It says that seven colour rays of the sun extracts water from all sources, by heating them (II,9.138-139). Thereafter, the clouds of different shapes and colours are formed. Then they rain with high intensity and great noise. (II,9.167-168). In this way, the fire of the sun is controlled. The very object of the chapter is the concept of the hydrologic cycle explaining different parts one by one.

नावृष्ट्या परिविश्येत वारिणा दीप्यते रविः ।
तस्मादयः पिबन्धो वै दीप्यते रविरंबरे ॥ II,9.138 ॥

तस्य ते रश्मयः सप्त पिबंत्यंभो महार्णवात् ।

तेनाहारेण संदीप्ताःसूर्याः सप्त भवंत्युत ॥ Brahmanda II,9.1391 ॥

सप्तधा संवृतात्मानस्तमाग्निं शमयंत्युत ।

ततस्ते जलदा वर्ष मुंचंति च महौघवत् ॥ II,9.167 ॥

सुघोरमशिवं सर्व नाशयंति च पावकम् ।

प्रवृष्टश्च तथात्यर्थ वारिणापूर्यते जगत् ॥ Brahmanda II,9.168 ॥

The treasure of knowledge about hydrology and hydrologic cycle available in various ancient Indian literature has still not been explored fully. As observed by V. T. Chow (1974) in the Symposium organized by UNESCO in Paris in August, 1974 “*the history of hydrology in Asia is fragmentary at best and much insight could be obtained by further study*”. Although the efforts are on, they are not numerous. In a recent study, Malik (2016) has made efforts to extract and analyze the concept of hydrological cycle as understood from the Ramayana Epic, focusing on the conceptual aspects of hydrological cycle interpreted from the 28th sarga of 4th Kanda of Kishkindha Kanda of Ramayana by the great poet Valmiki. The Schematic representation of hydrological cycle extracted from Kishkindha Kanda of Ramayana of Valmiki by Malik (2016) is shown in Figure 2.2.

Malik (2016) has also compared the modern concept of the hydrologic cycle with the concept present during the Ramayana of Valmiki. The comparison is shown in Figure 2.3. From the comparative analysis of the two concepts, he observes that “in the modern concept sun throughout the year evaporates the oceanic water or water from others water bodies coupled with transpiration. But in the epic, there is no signature of transpiration. Also, contrasting difference occurs for run-off where present concept considering run-off, infiltration and sub-surface flow. In the epic concept of infiltration and sub-surface flow are found to be lacking”. However, if we ignore these limitations, the concept of Ramayana is outstanding and very close to the modern concept.

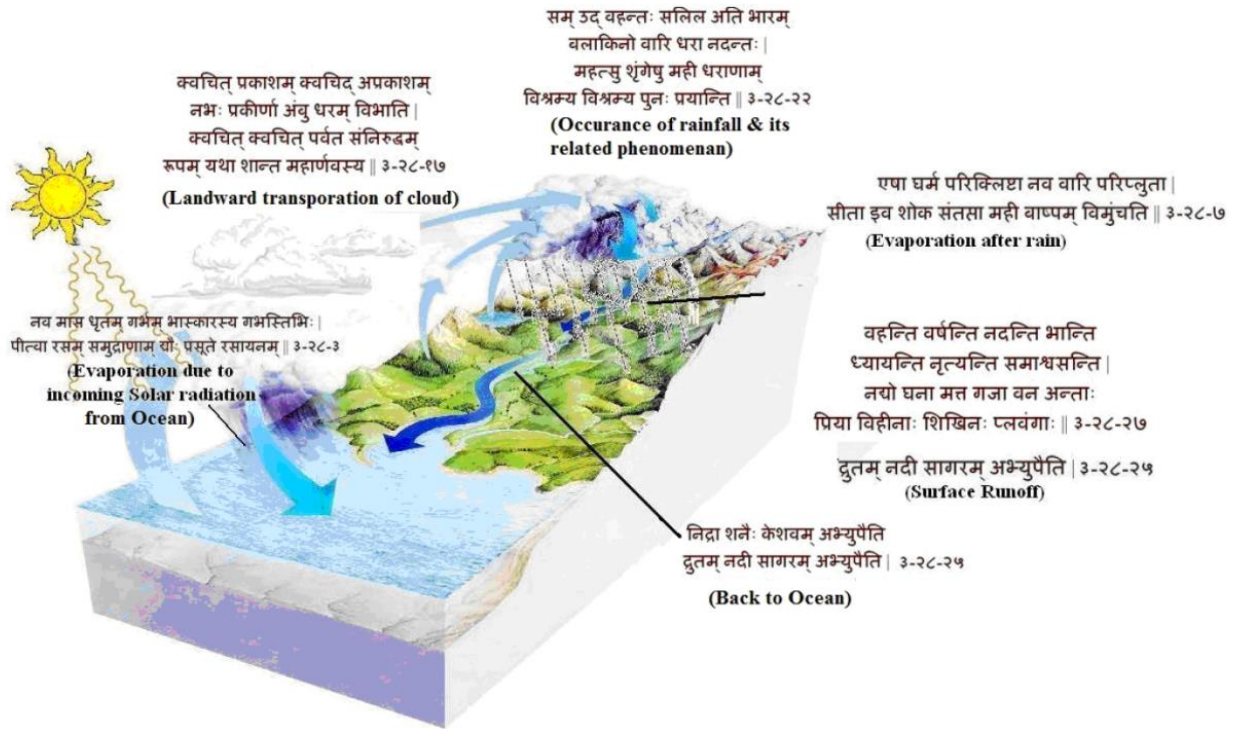


Figure 2.2: Schematic Representation of the Hydrological Cycle extracted from Kishkindha Kanda of Ramayana of Valmiki by Malik (2016)

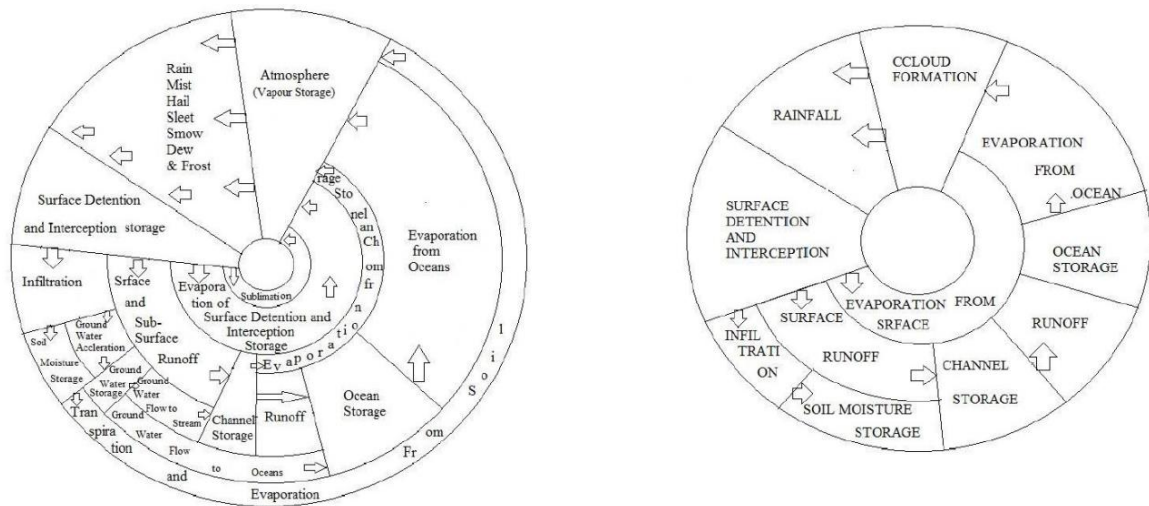


Figure 2.3: Schematic comparisons between Modern Hydrological cycle and hydrological cycle concept in Valmiki Ramayana by Malik (2016)

Epilogue

This chapter brings out that the knowledge of water science during the Vedic age and afterwards in the age of Epics and Puranas was highly advanced, although the people of those times were solely dependent upon their experience of nature, without sophisticated instruments of modern times. In the Vedic age, Indians had developed the concept that water gets divided into minute particles due to the effect of sun rays and wind, which ascends to the atmosphere by the capillary of air. It gets condensed there and subsequently falls as rainfall. Month-wise change in the facets of the hydrological cycle was also known. Water uptake by plants which gets facilitated by the conjunction of air along with the knowledge of infiltration is revealed in the ancient literature. From all above discourses, we can conclude that well developed concepts of the hydrological cycle were known to the ancient Indians in those ancient times while the contemporary world was relying on the wild theories of origin and distribution of water. Thus, the ancient Indian knowledge of water science can be regarded as the great achievement of that time.

