

CHAPTER 7

EVAPOTRANSPIRATION

In the hydrological cycle, the water which falls as rain reappears as infiltrated water, runoff, surface and underground water storage and simultaneously water in turn get condensed and subsequent rain falls. The surface and ground water reservoirs are constantly get replenished by recharge (precipitation) and depleted by evapotranspiration. The phenomena and its interrelation with other hydrological processes was well understood by Ancient Hindus as evidenced by Vedic literature.

In Rigveda (I,6,10) we see that the sun rays breaks the water contained in the earth and other materials into minute particles then these minute particles ascend by air and form cloud, viz.

इतो वा सातिमीमहेँ दिवो वा पार्थिवादधि ।
इन्द्र महोवार जसः ॥ RV.I,6,10 ॥

नद्यं तद्वत्थं हितं देवासः सुप्रवाचनम् ।
ऋतमर्षन्ति सिन्धवः सत्यं तातान सूर्यो वित्तं मे अस्य रोदसी ॥
RV.I,105,12 ॥

This verse of Rigveda (I,105,12) says that the water from the sea etc., evaporates due to the heat of sun rays, which is the primary cause of rain formation. The same fact is revealed in the verse (IV,58,1) of Rigveda viz.

समुद्राद्गर्मिर्मधुमां उदारदुपांशुना समृतत्वमानत् ।
घृतस्य नाम गुह्यं यदस्ति जित्वा देवनाममृतस्य नाभिः ॥ RV.IV,58,1 ॥

Verse (VIII,72,4) says that the atmospheric air get heated due to sun, then this heat reaches to the earth and converts the humidity into vapour and collects it as clouds, which is the

cause of the rain and food production, viz.

जाम्यतीतये धनुर्वयोधा अरुहद्वनम् ।
धषर्दे जिह्वायावधात् ॥ R.V.VIII,72.4 ॥

Like Rigveda, Yajurveda also contains some knowledge about evaporation alongwith transpiration, viz.

देवो वनस्पतिर्देवमिन्द्रं वयाधसं देवो देवमवर्धयत् ॥ YU.,28.43 ॥
देवो देवैर्वनस्पतिं हिस्त्रयणो मधुशाखः सुपिप्पलो देवमिन्द्रमवर्धयत् ॥
YU.,28.20 ॥

Both of the above verses say that the vegetation attracts water from earth and evaporates it to the atmosphere due to heat, wind etc. to form clouds. Similarly Atharvaveda (IV,25.2 and IV,27.14) says that due to universal sun and air the water goes to the sky and comes back as rain. The evapotranspiration is caused due to sun rays and wind, viz.

ययोः संख्याता वरिमा पार्थिवानि याम्भ्यां रजो युपितयन्तरिक्षे ।
ययोः प्रायं नान्वानशे कश्चन तौ नो मुञ्चतमंस्सः ॥ A.V.IV,25.2 ॥

अपः समुद्राद् दिवमुद्वहन्ति दिवस्पृथिवीमिमि ये सृजन्ति ।
ये अभिदरीशानां मस्तश्चरन्ति ते नो मुञ्चन्तंस्सः ॥ AV.,IV,27.74 ॥

The verse (RV.I,173.6) of Rigveda states that the atmosphere encompasses the earth

प्र यद्विधा महिना नृभ्यो अस्त्यरं रोदसी कश्ये नास्मै ।
सं वित्य इन्द्रो वृजनं न भूमा भर्ति स्वधावां ओपशमिव घाम् ॥
RV.I,173.6 ॥

The Solar Phenomena are associated with the vault of the sky or heaven, while lightning, rain and wind are referred to as occurring in the atmosphere but it is doubtful whether the Rigveda knew or guessed exactly the limit or the verticle height of the atmosphere. In Verses (RV.,IV,53.5, III.,56, I.,108.9-10)

यदिन्द्राग्नी परभस्यां पृथिव्यां मध्यमस्यामवमस्यामुत स्थः ।
अतः परि वृषणावा हि यातमथा सोमस्य पिवतं सुतस्य ॥
RV. I, 108.9-10 ॥

षड् भारो एको अचरन्विभर्त्युतं पर्षिष्ठमुप गाव आगुः ।
तिस्त्रो महीस्परस्तस्थुरत्यागुहा द्वे निस्तिरे दश्येका ॥ RV. III, 56.2 ॥

त्री षधस्था सिन्धवास्त्रिः कवीनामुत त्रिमाता विद्येषु सघाट ।
ऋतावरिरीषणास्तिस्त्रो अप्यास्त्रिरा द्विो विद्ये प्रत्यमानाः ॥
RV, III, 56.5 ॥

त्रिस्त्रिद्वं सविता महित्वना त्री रंजासि परिभूस्त्रीणि रोचना ।
तिस्त्रो द्विदः पथिवीस्तिस्त्र इन्वति त्रिभिर्बतैरभि नो रक्षति त्मना ॥
RV, IV, 53.5 ॥

We read "Savitr (the sun) encompassing them by magnitude pervades the three divisions of the firmament, the three world, the three brilliant spheres, the three heavens, the three fold earth ". In this connection a very significant question occurs to mind, whether the three divisions of firmament denote Troposphere, stratosphere, and ionosphere ? Again in the triple divisions of the earth are we entitled to identify frigid, temperate and torrid zones, for different schools regarding Aryan home do recognize the Rigvedic Aryans knowledge about frigid and temperate zones and just possible in course of their ocean voyages and advances for habitate they might have known torrid zone also.

The three other Vedas, namely Sama, Yajur and Atharvaveda furnish some additional information on climatology and meteorology, which we do not come across in the Rigveda. If the theory that these three Vedas chronologically belong to a later period be correct, it can be easily seen that during this age the two above mentioned practical sciences progressed empirically to a considerable extent.

Aryan definitely knew that plants (or forests) had some influence on the loss of water and causation of rainfall (TS., II, 4.9.3).

सौम्ययैवाहुत्या द्विवो वृष्टमव रुन्धे मधुषा सं यौत्यापां वा एष औषधीनां
रसो यन्मध्वभक्ष्य एवौषधीभ्यो वर्षत्यथो अद्भय एवौषधीभ्यो वृष्टिं नि नयति ।।

The concept and role of insolation is also referred to in the Taithiriya sanhita. Agni (Insolation) causes the rain to arise (TS., II, 4.10.2). viz.

अहोरात्राभ्यां पर्जन्यं वर्षयतो ग्नेये धामच्छ्वे पुरोडाशमष्टाकम्पालं निर्वयेन्मास्तं
सप्तकपालसौर्यमेककपालमग्निर्वा इतो वृष्ट मुदीरयति मस्तः सृष्टां नयन्ति यदा खलु
वा असावाद्वियो न्यड. रश्मिभिः पर्यावर्ततिथ वर्षति धामच्छदिवि खलु वै भूत्वा
वर्षयेता वै देवता वृष्ट्या ईशते ता एवं स्वेन भागधेयेनोष धावति ता ।।

TS.II,4.10.2 ।।

Ramayana (canto 4 of the book VII) furnishes a lot of information regarding the atmosphere, its conditions and cosmic regions, upto the distance of the moon from the earth. Here the entire atmospheric cosmic stretch has been divided into nine regions, where last one is the longest. Ramayana (I.46) describes mythically the origin of the atmospheric regions.

वातस्कन्धा इमे सप्त चरन्तु दिवि पुचक ।

मास्ता इति विख्याता दिव्यरूपा मामात्मजाः ।। Ramayana.I,47.4 ।।

Intensive insolation and high temperature as an agency of destruction or dispersion of the existing clouds is spoken of in VI.43.29 (Ramayana).viz.

निर्विभेद शरैस्तीक्ष्णैः करैर्मघमिवांशुमान् ।। Ramayana.VI,43-29 ।।

In the verse (II.105.20) we read about evaporation by the sun's rays in general, about the formation of clouds due to solar heating of the ocean (VII,32.68).

आयूषि क्षपयन्त्याशु ग्रीष्मे जलिमवांशवः ।। Ramayana,II,105.20 ।।

उद्भूत आतपापाये पयोदानामिवाम्बुधौ ।। Ramayana,VII,32.68 ।।

The insolation heating of the ocean water is also referred to in the Verse VII.25.30 of Ramayana.

दौदात्म्येनात्मनोद्धतस्ताप्ताम्भा इव सागरः ।

ततो ब्रवीद दशग्रीवः क्रुद्धः संरक्तलोचनः ॥ Ramayana.VII,25.30 ॥

In the twelfth skanda of epic Mahabharata the atmosphere is divided into seven regions (Skanda, Spheres) and they are discussed in considerable detail. The wind named as आवह (M.B.XII,328.37), blows with a loud noise. Another wind which drinks up water from the four ocean and having sucked it up gives it to the clouds in the sky and subsequently to rain god is called उद्धह (MB.XII,328.38-39).viz.

अम्बरे स्नेहमभ्येत्य विधुद्धमयश्च महाघृतिः ।

आवहो नाम सेवारि त्रितयः श्वसनो नदन ॥ MB.XII,328.37 ॥

उद्यं ज्योतिषां शश्वत सोमादीनां करोति यः ।

अन्तर्देहेषु चोदानां यं वदन्ति मनीषिणः ॥ MB.XII,328.38 ॥

यश्चतुर्भ्य समुद्रेभ्यो वायुर्धारयते जलम् ।

उद्धयाद्वदते चापो जीभूतेभ्योम्बरे निलः ॥ MB.XII,328.39 ॥

Apart from the wind the sun was realised as the main cause of evapotranspiration. The Vana Parva tells us that the sun evaporates moisture from all plants and water bodies and causes rainfall (MB.III.3.49).

त्वमादायांशुभिस्तेजो निदाघे सर्वदिह्लाम ।

सर्वौषाधिरसानां च पुनर्वर्षसु मुञ्चसि ॥ MB.III.3.49 ॥

सदहृत्यैकार्णवं सर्वं त्वं शोषयसि रश्मिभिः ॥ MB.III.3.59 ॥

The epic informs us of various types of clouds and atmospheric layers as well.

Kanada in his Vaissesikasutra explains the cause of evaporation of water thus, "the sun's rays cause the ascent of water, through conjunction with air". (Vais.Sutra.,5.2.5)

नाड्यो वायु संयोगादारोहणम् ॥ Vais.Sutr.5.2.5 ॥

Kanada was also acquainted with convection currents in the atmosphere which he refers to in very scientific terms viz.

नोदनापीडनात्संयुक्त संयोगाच्च ॥ Vai.Sutr.5.2.6 ॥

Sankara Mishra (1600 AD) has beautifully explained this and illustrated it with the example of a kettle of water heated from below, (Tripathi, 1969). It conclusively proves that the great philosopher Kanada knew that the earth is heated by sun's rays through radiation and convection currents in the atmosphere.

Various Puranas inform us that there are seven regions or layers (वातस्कन्ध) in the atmosphere or there are seven types of winds (Vayu 49.163). Narada Purana speaks of seven air channels (60.13) viz. सप्तैतेवायुमार्गाः, Kurma Chapt.41.6-7 also reveals same thing with little variations.

रसातलतलात्सप्त सप्तैवाध्वतलाः क्षितौ ।
सप्त स्कन्धास्तथा वायोः सप्तस्य सप्त द्विजाः ॥ Vayu. 49. 163 ॥

आवहः प्रवहश्चैत ततैवानुवहः पुनः ।
सम्बहो विवहश्चैव तदूर्ध्वं स्यात्परावहः ॥ Kurma 41.6 ॥

तथा परिवहश्चैव वायोर्वै सप्त नेमयः ॥ Kurma 41.7 ॥

The Phenomena of evaporation cloud formation and their relationship with winds or regions of atmosphere (वातस्कन्ध) are quite satisfactorily described in several Puranas (Brahmand Vol.II, Chapt.9., Vayu.Chapt.51, Linga,I,41, Matsya,I,54) and a full-fledged separate chapter has been devoted to them in these topics, which positively evinces that due importance of this branch of meteorology was realised. Some of the verses are quoted below:

नावष्टया परिविश्रमेत वारिणा दीप्यते रविः ।
तस्माद्यः पिबन्वो वै दीप्यते रविरंबरे ॥ Brahmand, Vol. II, 9. 138 ॥

तस्य ते रश्मयः सप्त पिबंत्यंभो महार्णवात् ।
तेनाहारेण संदीप्ताः सूर्याः सप्त भवंत्युत ॥

Brahmand, Vol. II, 9, 139 ॥

वर्षाघर्मो हिमं रात्रिः संध्या चैव दिवं तथा ।
शुभाशुभं प्रजानां च ध्रुवात्सर्वं प्रवर्तते ॥ Vayu 51.11 ॥

ध्रुवेणाऽकृतांश्चैव सूर्योपावृत्य तिष्ठतिः ।
तदेषदीप्त किरणः स कालाग्निर्दिवाकरः ॥ Vayu 51.12 ॥

सूर्यः किरणजालेन वायुमुक्तेन सर्वशः ।
जगतो जलमादत्ते कृत्स्नस्य द्विज सत्तमाः ॥ Vayu 51.13 ॥

Above lines of Vayu Purana explain that the sunrays alongwith the air extract water from earth. The Linga Purana (I, 41.11, 21, and 30), specifically recognizes the role of sun rays in evaporation of water, which get converted to clouds and subsequent rainfall.

वैष्टुतो जाठरः सौरावारिगभस्त्रयोनियः ॥ (Linga I, 41.11) ॥

याश्चासौ तपने सूर्यः पिवन्नभो गभस्थिभिः ।
पार्थिवाग्निविभिभ्रोसौ दिव्यः शुचिरिति स्मृतः ॥ (Linga I, 41.21) ॥

वसंते चैव ग्रीष्मे च शनैः स तपते त्रिभिः ।
वर्षास्वथो शरदि च चतुर्भिस्यं प्रवर्षति ॥ (Linga I, 41.30) ॥

ध्रुवेणाधिष्टताश्चापः सूर्यो वै गृह्य तिष्ठति ।
सर्वभूतशररिषु त्वापो ह्यानुश्चतारिचयाः ॥ Matsya I, 54.29 ॥

तेजोभिः सर्वलोकेभ्य आदत्ते रश्मिभिर्जलम ॥ Matsya I, 54.31 ॥

समुद्राद्वायुसंयोगात् वहन्त्यापो गभस्तयः ।
ततस्तवृत्वशात्कालेपरिवर्तनं दिवाकरः ॥ Matsya I, 54.32 ॥

From all above verses it is revealed that the ancient Indians had very scientific knowledge of evaporation and transpiration caused by sun rays, wind etc., its condensation and formation of clouds and subsequent rain. Thus it can be concluded that they

had developed the scientific concept of hydrological cycle, the most important aspect of modern hydrology.

Jain Contribution: (Tripathi, 1969)

The celebrated Jain treatise 'Surya Prajnapti' has dwelt at length on insolation, radiation and reflection of the sun's light and energy and heating of the earth and various surfaces, the subject so essential in hydrology. Its conception of an contribution to "albedo" appears to be something wonderful, when we take into account the fact that the work was composed at least nearly half a millennium B.C.

In Prabhrta 4, Sutra 25 are discussed the range of insolation or heat of the sun (तापक्षेत्र), but it is all incorrect due to the assumption of two suns. Prabhrta 5, Sutra 26 (designated as लेशया प्रतिहति, reflection of sun's light), enquires into the phenomena of scattering of the sun's light, radiation, insolation, reflection and albedo and gives accurate scientific details. First it mentions twenty theories on reflection of the sun's light held by the adherents of other sects (परतीर्थिकानाम्). Then it refers to another important fact, that unseen (invisible) objects also possess reflective capacity.

In aphorism 30 of the Prabhrta 9 are discussed the nature of convection and radiation heating through the sun's rays with reference to earth surface, water bodies and its objects and atmosphere and its continents. The author of the Surya Prajanapti also speaks that slanting rays of the sun give lesser heat and vertical ones greater heat. This is discussed with reference to the rising of the sun, noon and evening and different places (or latitudes).

From the study of this chapter we gather that the ancient Indians had realised the importance of the study of evapotranspiration as an important facet of water cycle. Solar phenomena, lightning, wind, cloud formation etc. take place in

lower layer of the atmosphere. Atmosphere was divided in troposphere, stratosphere and ionosphere and globe in torrid, temperate and frigid zones which is just comparable to modern meteorology. Plants and forests have some influence on water loss, differential rate of heating of the continents and water bodies, formation of convection currents and their effects was well understood. Sun rays, wind, humidity, vegetation etc. are the measure causes of evapotranspiration had known to them. Thus it can be said that ancient Indians had developed the scientific concepts of evapotranspiration and the factors affecting it of no less order.