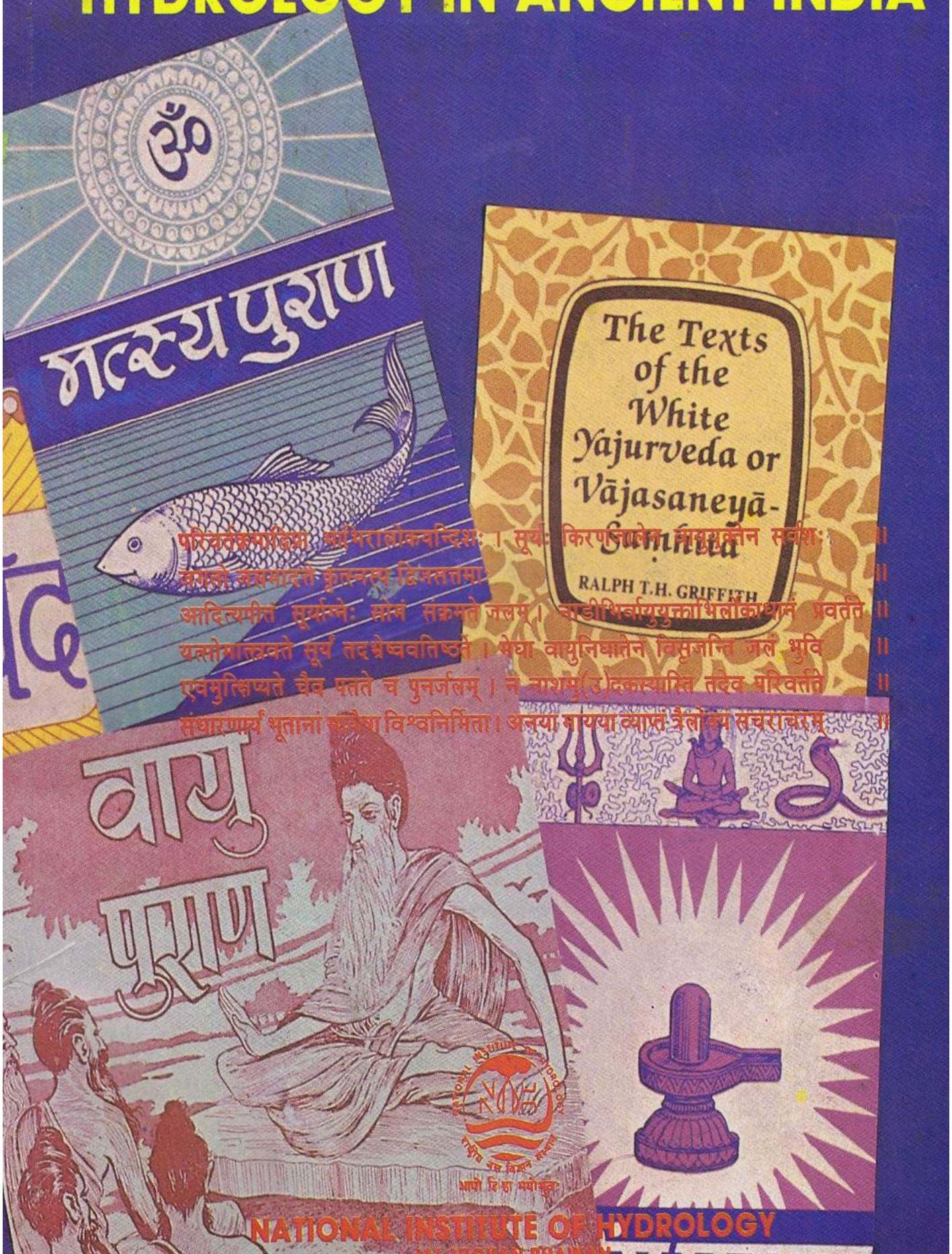
HYDROLOGY IN ANCIENT INDIA



NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
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ndia's Contribution to International Hydrology Programme (IHP)

National Institute of Hydrology
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PREFACE

While making a reconnaissance of ancient Indian literature it was found that it contains a gold mine of knowledge in hydrology. This encouraged the Institute to attempt a thorough study of various available ancient literature to arrive at a document compiling the wealth of hydrological treasures hidden in Indian literature. The report attempts at compiling information on various component processes of hydrology and their interaction.

While carrying out the studies on hydrological information in ancient Indian literature, it was heartening and revealing to note that the hydrological concepts which are coming to be discovered & invented in last 3 centuries were known and well documented in ancient Indian literature even as early as 3000 B.C.

Like other sciences, the science of water also was well developed in ancient India. It is regrettable that at present sufficient attention and respect is not being paid to our ancient Indian sciences. This is because some how, we have developed a notion that ancient Indian sciences have lost all their utility in the face of modern sciences, which have developed so much to their present position. But this concept of ours will prove false if one tries to realize the real merits of the ancient Indian sciences. It is expected that present report will be able to porove this thing in the area of hydrology.

The attempted study reveals that the field of hydrologic-cum-indological investigation remained totally unearthed and unexplored. This sort of report exploring the knowledge of hydrology as contained in the ancient Indian literature had become a crying need of the day, specially when hydrology has come to occupy its rightful place in India in the modern era. I am sure that if the ancient Indian hydrology is revived and brought to practical use it will prove of much benefit to the India in particular and to mankind as a whole.

This valuable document has been prepared by Shri T.M. Tripathi, Scientist 'B' and other scientists and staff of the Institute. A number of libraries of the country were consulted however special mention needs to be made of libraries of Gurukul Kangari University, Haridwar and Sampurnanand Sanskrit University, Varanasi.

Satish Chandra

Dated: Sept.7, 1990

(SATISH CHANDRA)
DIRECTOR

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LIST OF ABBREVIATIONS

(with approximate date of works)

Atharva Veda (Latest Veda, before 800 B.C.)	AV
Bhava Prakash (16th century A.D.)	BP
Brahmanda Purana (3rd - 4th century A.D.)	Brahmanda
Garuna Purana (6th century B.C.-7th century A.D.)	Garuna
Gopatha Brahmana (around 1000 B.C.)	GB
Kurma Purana (600 B.C. to 700 A.D.)	Kurma
Linga Purana (600 B.C. to 700 A.D.)	Linga
Mahabharata (400 B.C. to 400 A.D.)	M.B.
Markandeya Purana (6th century B.C. to 4th century A.D.)	Markandeya
Matsya Purana (6th century B.C. to 4th century A.D.)	Matsya
Narada Purana (600 B.C. to 275 A.D.)	Narada

Padma Purana (600 B.C.-400 A.D.)	Padma
Ramayana (800 B.C.-200 B.C.)	Ramayana
Rig Veda (3000 B.C. or before)	RV
Sam Veda (3000 B.C.)	SV
Satpatha Brahmana (2000 B.C.)	SB
Skanda Purana (7th century A.D.)	Skanda
Taithiriya Aranyaka	Tai.Ara.
Taithiriya Sanhita (later than Rig Veda, 1500 B.C.-800 B.C.)	TS
Vaisesika Sutra (600B.C.-700 B.C.)	Vais.Sutr.
Vayu Purana (200 B.C.-400 A.D.)	Vayu
Vishnu Purana (600 B.C.-275 A.D.)	Vishnu
Yajurveda (later than Rig Veda, 1500 B.C. - 800 B.C.)	YV

SUMMARY

If one studies the ancient Sanskrit literature he observes that it contains valuable references to hydrology. The important concepts of modern hydrology are scattered in various verses of Vedas, Puranas, Meghmala, Mayurchitraka, Vrhat Sanhita and various other ancient Indian works. In this document an attempt has been made to compile information pertaining to hydrology in ancient Indian literature.

In Vedic age Indians had developed the concept that water gets divided into minute particles due to the effect of sun rays and wind. In various places in Puranas it is alluded that water can not be created or destroyed, only its state is changed through various phases of hydrological cycle. Evaporation, condensation, cloud formation, precipitation and its measurement were well understood in India in Vedic and Puranic times. Effects of Yajna (यज्ञ), forests, reservoirs etc. on the causation of rainfall, classification of clouds, their colour, rainfall capacity etc. forecasting of rainfall on the basis of natural phenomena like colour of sky, clouds, wind direction, lightening, and the activities of animals was well developed in ancient India well before 10th century B.C. Contrivance to measure rainfall was developed during the time of Kautilya (4th cent. B.C.) which had the same principle as that of modern hydrology except weight measure of Drona, Pala etc. were adopted instead of modern linear measurement of rainfall. Scientific facts like arid region of Tibetan rain shadow area and no rainfall by polar winds are fully advocated in Puranas. The knowledge of monsoon winds and height of clouds alongwith the division of atmosphere was well developed in Vedic age. The technique of knowing the slope of an area by means of a flowing river and dimensions of meandering rivers alongwith velocity of flow were usefully developed. Mountaneous rivers are generally perennial, deposition of fertile soil periodically on flood plains, different types of topography alongwith the

classifications of land and soil as black, yellow, red, gravelly, boulders etc. were well known.

In ancient times when the western knowledge about the occurence of ground water was based on the wild theories, as they were believing that rainfall being inadequate in quantity, can not be the source of ground water, the Indians had the well developed concepts of ground water occurence, distribution and utilization. Literature also reveals that hydrologic indicators such as physiographic features, termite mounds, soils, flora, fauna, rocks and minerals were used to detect the presence of ground water. Variation in the height of water table with place, hot and cold springs, ground water utilization by means of wells, well construction methods and equipment are fully described in 54th chapter of Vrhat Sanhita named as 'Dakargala'. Sun rays, wind, humidity, vegetation etc. are the measure causes of evapotranspiration was well realized.

It is very interesting to learn that Varahamihira in as early as 550 A.D. presented a simple method for obtaining potable water from a contaminated source of water. Various plant materials alongwith the sun heating, aeration, quenching of water with fire heated stones, gold, silver, iron or sand were used. The change in the quality of water with the months of year and suitability of water from different sources for various uses were described.

Efficient water use, lining of canals, construction of dams, tanks, essential requirments for the construction of good tanks, bank protection methods, spillways and other minor aspects were given due consideration in ancient times in India. Well organized water pricing system was prevalent during the time of Kautilya. Various references are available in Vedas even, alluding the importance of efficient water use so as to reduce the intensity of water scarcity and drought etc.

In present study the knowledge of various aspects of water resources and hydrology as contained in ancient Indian literature and summarized above have been analysed. The report

has been divided into nine chapters dealing with different aspects of hydrology.

CHAPTER 1

INTRODUCTION

The origin and evolution of agriculture and feeling need of irrigation are not separate processes. They are closely connected with the general course of history of Plant growing, with the invention of tools and irrigation techniques. In ancient days when advanced methodologies or principles of hydrology were unknown man had realized that water is essential for survival , and therefore the earliest civilizations were distinctly and Predominantly hydraulic in character as they owe their origin to reliable sources of water to meet their various needs. Rivers Played such a pivotal role in the life and living of those people that their civilizations came to be known as river valley civilizations, such as the Nile in Egypt, the Tigris Valley Civilizations in Mesopotamia, the Howang-Ho in China and the Indus in India. All these civilizations existed from 3000-2000 B.C. and their are historical evidences to show that certain engineering measures were adopted during that period in order to sustain as well as enhance benefits from rivers and also to Protect against damaging phenomeno of floods. Fall of these civilizations and gradual decay of some of them were partly prompted by mankind's creeping inability to cope up with adverse and damaging consequences of his interference with hydrology and hydraulics of the respective rivers in his attempts to derive benefits.

Ancient Indian literature show the development of Sciences (as also hydrological Science) which go back to the age of Vedas. It is a good fortune that the ancient Sanskrit works have been preserved and not lost through centuries of domination by alien races and alien cultures in India. The elite in the society cherished an abiding love and respect for Sanskrit learning and Sanskrit culture which enabled the learning and culture to survive inspite of being subjected to the "winds of

changes" of alien cultures.

It is true that, in the realm of spiritual values, the Indian heritage was great and sublime and perhaps unparalleled as testified by some of the great personalities of the west who underwent the toil of learning Sanskrit and presenting the world with translations in English and German of the renowned texts of Vedas and Upanishads.

Sciences in Ancient India:

Very few workers in the scientific world are aware of how much science, as understood and accepted by scientists is contained in the ancient Sanskrit literature. It is a moot question whether the ancient sages had adopted the methods of modern science of laboriously collecting observational data and integrating them through apparopriate concepts into useful and acceptable truths. Observation as a medium of realising the underlying truths could not have been ignored.

Science is defined as ordered knowledge of natural phenomena and the rational study of the relations between the concepts in which these phenomena are expressed. It is in its widest sense, a systematic method of describing and controlling the material world. It can be seen, as it stands at any moment, as a logical and coherent account of that order which the scientists of the time finds in nature. It progressively affects man's life. In India, at the beginning of the third milennium B.C., an advanced state of Indus Valley Civilization existed at Mohenja-daro, Harrappa and elsewhere, and a scale had been discovered indicating the use of decimals. Preparation of the Vedic Calendar for various ceremonies and of rituals necessitated the study of heavenly bodies and of their movements, and this led to the advancement of the astronomical Science, (Prasad, 1980).

The sun light constitute seven colour rays was known to Vedic Aryans as it is clear from following mantra (RV.II,12.12)

यः सप्तरश्मिर्वृषभस्तुविष्मानवासृजत्सर्तवे सप्त सिन्धून ।
यो रौहिणमस्फुरद्वजवाहुर्द्यामारोह्स्तं स जनास इन्द्रः । (RV.II,12.12)

Which means that the sun containing red etc. seven colour rays is the cause of water flow in the rivers (because of rain). After rain it again attracts water from earth and this cycle goes on.

Indian arithmetic is remarkable in that there is evidence to show that as early as third century B.C. a system of notation was evolved from which the scheme of numerals that is in vogue even today has been copied. The Aryabhatta studied the summation of arithmetic series and attempted to solve quadratic indeterminate equations. Brahmagupta developed the application of explicitly general algebraic methods to astronomical problems. The beginning of the medical sciences go back to the age of the Vedas. The early beginnings of the art of healing and of the knowledge of healing herbs are found in the 'Kausikasutra' of the 'Atharvaveda'. Susruta and Charaka were well known surgens & physicians. The medical work of Vagbhata of the seventh century contains the first mention of mercury, (Prasad, 1980).

The most remarkable feature of the Buddhist Philosophy of India is the formulation of the atomic theory of Kanada (600 B.C.), (Prakash, 1965).

Biswas (1969) has rightly remarked that the growth of modern science in Europe would have been hardly possible without the background of poineering contributions from India, China and Arabian countries, well upto the 12th century A.D.

Domination of the foreign rulers for long time did not help in bringing the Scientific content of the Sanskrit literature to come to the fore. Even after independence, the situation did not improve for the obvious reason that there is no interaction between the modern scientists and the Sanskrit scholars. The scientist never bothered to know about the scientific content in the ancient Sanskrit literature while the

Sanskrit scholars never cared to bring to focuss the problems of scientific nature available in the Sanskrit works; they got entangled in such problems as 'Vyakarana','Mimansa' etc. Hence even to date the scientific content of the ancient works remained almost wholly unknown and unanalysed.

Hydrology in Ancient India:

In contrast to the ancient western science containing wild theories on the origin of water, the ancient Sanskrit literature contains the most valuable and highly advanced scientific discources on hydroscience.

The Vedic texts which are more than 3000 yrs. old, contain valuable refeerences on 'hydrological cycle'. The most important concept on which the modern science of hydrology is founded, are scattered in Vedas in various verses which are in the form of hymns and prayers addressed to various dieties. Likewise other Sanskrit literature have valuable discources regarding hydrology.

The historical development of hydroscience have been dealt by many writers (Baker and Horton, 1936; Chow,1964; Biswas,1970); but in all these works references to the contributions made in ancient India is conspicuously absent (Prasad,1980). Chow (1964) dividing the history of hydrology mentioned following western scholars leaving Indian scholars and their great contribution.

He has given the references of Homer (about 1000 B.C.), Thales, Plato, Aristotle in Greece, Pliny in Rome and many Bible scholars of that time. All above western scholars were believing in the wild theories regarding origin of water as quoted below. Thales an Ionion philospher stated that the sea water is driven into rocks by wind is the cause of ground water. Plato (427-347 B.C.) the great Athenian philospher stated that the water of seas, rivers, springs etc. come from a large underground reservoir and go back to the same. Aristotle

(384-322 B.C.) said that water of the springs etc. is derived from the underground water through system of underground openings. Famous stoic philospher Lucius Annacus Sencca (4 B.C. - 65 A.D.) declared that rainfall can not be the source of springs and underground water, because it penetrates only a few feet into the earth (Prasad, 1980). Marcus vitruvious who lived about the time of Christ conceived a theory saying that ground water is the part of rainfall originated through infiltration. From all above references of western scholars we gather the low level of development of hydroscience in western world. But the contemporary India had highly advanced knowledge of all aspects of water science.

The origin and evoluation of agriculture and experience in irrigation on the territory of India or anywhere in the world are not seperate processes, as evidenced from following hymns.

कृषिश्च मे यज्ञेन कल्पंताम ।
वृष्टिश्च मे यज्ञेन कल्पंताम ॥ यजुर्वेद, 18-9 ॥
मारुतश्च मे यज्ञेन कल्पंताम ॥ यजुर्वेद, 18-17 ॥

These hymns illustrate the importance of Yajna's (यज्ञ;Sacrifice) for rain, agriculture, and air or environment and their interelationship.

In ancient India the well developed concepts of different facets of hydrology were available. Water is not lost in the various processes of hydrological cycle namely evaporation, condensation, rainfall, streamflow etc. but gets converted from one form to other was known during Vedic and Puranic times. Water uptake by plants, division of water into minute particles by sun rays and wind, different types of clouds, their heights, their rainfall capacities etc. alongwith the prediction of rainfall quantity in advance by means of observing the natural phenomena of previous years are also available in Puranas, Vrhat Sanhita (550 A.D.), Meghamala (900 A.D.) and in other literature. The references of raingauges are available in Arthasastra of Kautilya (400 B.C.), and Astadhyayi of Panini (700 B.C.). The quantity of rainfall in various parts

of India was also predicted by Kautilya. Indians were acquainted with cyclonic, orographic effects on rainfall and radiation, and convectional heating of earth and evapotranspiration. Various other references of infiltration, interception, stream flow and geomorphology [in Ramayana (200 B.C.) the reference of artesian wells is available], erosive action of rainfall, etc. were also known. Ground Water development and water quality consideration were getting sufficient attention as evidenced by Vrhat Sanhita (550 A.D.). Water management and conservation, well organized water pricing system in 400 B.C., construction methods and materials of dam, tanks etc., bank protection, spillways and other minor considerations reflect the high stage of development of water resources and hydrology in ancient India.

Numerous references exist in Vedic literature, Arthasastra, Puranic sources, Vrhatsanhita, Mayuracitraka, Meghmala, Jain, Buddist and other ancient Indian literature which enumerate the status of hydrology and water resources in ancient India.

The following elements of hydrology and water resources as they are inferred in above ancient Indian literature and also discussed by some of the authors such as Tripathi (1969), Prasad (1980), Prasad (1987), and others have been reviewed, and analysed in present study.

1. Hydrologic Cycle
2. Precipitation, Cloud formation, measurement etc.
3. Interception and Infiltration
4. Stream flow and Geomorphology
5. Ground Water
6. Evapotranspiration
7. Water Quality
8. Water use and conservation.

CHAPTER 2

HYDROLOGICAL CYCLE

The Hydrological Cycle is an important concept in hydroscience. It is the chain of events describing the history of water. The cycle involves the total earth system comprising the atmosphere (the gaseous envelop), the hydrosphere (surface and subsurface water), lithosphere (soils & rocks), and the biosphere (plants & animals). In one of the three phases (solid, liquid, and vapour) the water passes through these four parts of the earth system.

The Vedic texts which are more than 3000 years old contain valuable references on water; the details of the 'hydrologic cycle' the most important concept on which the modern science of Hydrology is founded, are scattered in Rig Veda in various verses which are in the form of hymns and prayers addressed to various dieties and divinities such as Indra (firmament), Agni (fire), Maruts (wind) and so on. A Verse states like this

आवह स्वाधामनु पुनर्गर्भित्वमेरिरे ।
वधानानाम: यशियम ॥ Rigveda,I,6.4 ॥

that the water which get 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 (RV,I,7.3) states that the God has created sun and placed it so as whole the universe get illuminated, likewise this is the rule of universe to extracts up water continiously and then convert it to cloud and ultimately discharge as rain

इन्द्रो दीर्घाय चक्षस आ सूर्यं रोहयाद्दिवि ।
वि गोभिरादिभैरयत ॥ RV.I,7.3 ॥

Similarly 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 cloud is formed due to the water evaporated from the mother earth and then it wants to come back to its mother in the form of rain (I,32.9), verse I,32.10 says that the water is never stationery, but it continously get evaporated and comes down and due to smallness we can't see the upgoing water particles

य ईङ्खयन्त पर्वतान् तिरः समुद्रमर्णवम् ।
मरुद्भिरग्न आ गहि ।। RV,I,19.7 ।।

अमूर्या उप सूर्ये याभिर्वा सूर्यः सह ।
ता नो हिन्वन्त्वध्वरम् ।। RV,I,23.17 ।।

नीचावयां अभवद्वृत्रपुत्रेन्द्रो अस्या अव वधर्जभार ।
उत्तराः सूरधरः पुत्र आसीदानुः शये सहवत्सासधेनुः ।। RV,I,32.9 ।।

अतिष्ठन्तीनाम विवेदनानां काष्ठानां मध्ये निहितं शरीरम् ।
वृत्रस्य निण्यं वि चरन्त्यापो दीर्घतम् आशयदिन्द्रशत्रुः ।। RV,I,32.10 ।।

ऋतं देवाय कृण्वते सवित्र इन्द्रायाहिघ्ने न रमन्त आपः ।
अहरहर्यात्यक्तुरपां किमात्मा पक्षः सर्ग आसाम् ।। RV,II,30.1 ।।

यो वृत्राय सिनमत्राभरिष्यत्प तं जनित्री विदुष उवाच ।
पथो रक्षन्तीरनु जोषमस्मै दिवेदिवे धनुयो रक्षयम् ।। RV,II,30.2 ।।

These verses 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 continously engaged in extraction and discharge of water. A verse of Rig Veda states as follows:

या आपो दिव्या उत वा स्रवन्ति खनित्रिमा उत वा याः स्वयंजाः ।
समुद्रार्था याः शुचयः पावकास्ता आपो देवीरिह मामवन्तु ।।
RV,VII,42.2 ।।

"It says that 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 (RV.VIII,6.19; VIII,6.20; and VIII, 12.3) states the cousation of water evaporation, formation of cloud, rain, flow of water and its storage in oceans etc. The verse (RV.X,27.23) reads as follows:

देवानां माने प्रथमा अतिष्ठान्तूतवादेषामुपरा उदायन् ।
वयस्तपन्ति पृथिवीमनूषा दा बुबूकं वस्तः पुरिषम ।। RV,X,27.23 ।।

This indicates that at the start of creation, sun, etc, are created, rainfall causes 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. In Sam Veda (VI-607), the knowledge of hydrologic cycle is the next step after Rig Veda. A verse of Sam Veda reads as follows:

समन्या यन्त्युपयन्त्यन्याः समानमूर्व नद्यस्पृणान्ति ।
तम् शुचिं शुचयो दीदिवांसमपान्नपातमुप यन्त्यापः ।। SV.पूर्वाचिक,VI,607 ।।

It states that 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. Likewise Yajur Veda explains the process of water movement from clouds to earth and its flow through channels and storage into oceans and further evaporation (YV.,X-19).

प्र पर्वतस्य वृषभस्य पृष्णन्नावश्चरान्ति स्वसिचश्चयानाः ।
ता आववृत्रन्नधरा गुदक्ता अहिं बुध्न्यमनु रीयमाणाः
विष्णोर्विक्रमणमसि विष्णोर्विक्रान्तमसि विष्णोः क्रान्तमसि ।। YV,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, rinfall, river flow and storage and again repetiton of cycle was explained as in the earlier Vedas. The Sun rays are the main cause of rain & evaporation is mentioned as below:

अमूर्या उप सूर्ये याभिर्वा सूर्यः सह ।
ता नो हिन्वन्त्वध्वरम् ।। AV.I,5.2 ।।

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

विश्वमन्यामभीवार तदन्यस्यामधि श्रितम् ।
दिवे च विश्ववेदसे पृथिव्यै चाकरं नमः ।। AV.I,32.4 ।।

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

मित्रावरुणौ वृष्ट्याधिपत्यौ तौ मावताम् ।
अस्मिन् ब्रह्मंण्वसिमन् कर्मण्यस्यां पुरोधायामस्यां प्रतिष्ठायामस्यां
चित्त्यामस्यामाकूत्यामस्यांमाशिष्यस्यां देवहूत्यां स्वाहा ।। AV.V,24.5 ।।

The hydrologic cycle reaches into the atmosphere and traverses, impart, the domain of hydrometeorology. It may be seen in the Varahamihira's Vraht Samhita (550 A.D.) in which three Chapters are devoted to hydrometeorology comprising Pregnancy of coulds (Chapter 21), Pregananacy of air (Chapter 22) and quantity of rainfall (Chapter 23). Slokas 1 and 2 of Dakargelam (Chapter 54 of Vraht Samhita) which states the importance of science of ground water exploration which helps man to ascertain the existence of water are as follows:

धार्म्यं यशस्यं च यदाम्भसोऽहं वक्ष्यामि येन जलोपलब्धिः ।
पुंसां यथाङ्गेषु शिरास्नयोऽत्र क्षितावपि प्रोन्नतनिम्नसंस्था

एकेन वर्णेन रसेन चाम्भश्चक्षुं नभस्तो वसुधाविशेषात् ।
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 heigher and some lower. The water falling from sky assumes various colours and tastes from differences in the nature of the earth. These slokas 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 accends to sky with the help of अग्नि (fire) and air and then its humidity get condensed and subsequent rainfall.

अग्निः पवनसंयुक्तः खं समाक्षिपते जलम् ।
सोग्निमारुतसंयोगाद् घनत्वमुपपद्यते ।। MB,XII,183.15 ।।

तस्याकाशे निपतितः स्नेहस्तष्ठति यो परः ।
स संघातत्वमापन्नो भूमित्वमनुगच्छति ।। MB,XII,183.16 ।।

Verses (184.15-17) 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 सलिलपानाच्च् व्याधीनां चापि दर्शनात् ।
व्याधिप्रतिक्रियत्वाच्च् विद्यते रसनं द्रुमे ।। MB,XII,184.15 ।।

वक्त्रेणोत्पलनालेन यथोर्ध्वं जलमावहेत् ।
तथा पवनसंयुक्तः पादैः पिबति पाद्पः ।। MB,XII,184.16 ।।

In Verse (MB,XII,362.4 and 8) it is explained that the air and the sun rays get dispersed and fill whole universe together. The Verse 8 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

ततो वायुर्विनिः सृत्य सूर्यरश्म्याश्रितो महान् ।। M.B.,XII,362.4 ।।
योष्मासांस्तु शुचिना किरणेनोद्धितं पयः ।
पत्यावर्त्ते पुनः काले किमारचर्यमतः परम्ः ।। M.B.,XII,362.8 ।।

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

वायुवाधारा वस्न्ते वै सामृताः कल्पसाधकाः ।। Matsya I,54.15 ।।

In Verses (Matsya I,54.29-34 and Vayu 51.23-24-25-26) we come across the knowledge of evaporation, burning of water and conversion to smoke is caused by sun rays which ascends to atmosphere with the help of air, which again rains in next 6 months for the goodness of the living beings.

धुवेणाधिष्टाश्चापः सूर्यो वै गृह्य तिष्ठति
सर्वभूतशरीरिषु त्वापो ह्यानुश्चतारिश्चयाः ।। Matsya I,54.29 ।।

दह्यमानेषु तेष्वेह जाड्यमस्थावरेषु च ।
धूमभूतास्तु ता ह्यापो निष्क्रामन्तीह सर्वशः ।। Matsya I,54.30 ।।

तेन वास्त्राणि जायन्ते स्थानमभ्रमयं स्मृतम् ।
तेजोभिः सर्वलोकेभ्य आवत्ते रश्मभिर्जलम् ।। I,54.31 ।।

समुद्राद्वायुसंयोगात् वल्न्त्यापो गभस्तयः ।
ततस्त्वृतुवशात्कालेपरिवर्तन् दिवाकरः ।। I,54.32 ।।

नियच्छत्यापो मेघेभ्यः शुक्लाः शुक्लैस्तुरश्मभिः ।
अभस्थाः प्रपतन्त्यापोवायुनासमुदीरिताः ।। I,54.33 ।।

ततो वर्षति षण्मासान् सर्वभूतविवृद्धये ।
वायुभिस्तनितंचैव विधुतस्त्वग्निजाः स्मृता ।। Matsya I,54.34 ।।

In Linga Purana a fullfleshed chapter (I,36) has been devoted to the science of hydrology. It explains the

evaporation, condensation, rainfall with suitable examples very scientifically and says that the water can't be destroyed, only its state is changed.

दह्यमानेषु चराचरेषु गोधूमभूतास्त्वभ निष्क्रमन्ति ।
या या ऊर्ध्वं मारुतेनेरिता वै तास्तास्त्वभांयग्निनावायु व ।।
Linga I,36.38 ।।

अतो धूमाग्निवातानां संयोगस्त्वमुच्यते ।
वारीणि वर्षतीत्यभ्रमभस्त्वेशः सहस्त्रदृक् ।। Linga I,36.39 ।।

i.e. "After getting by sun, the water contained in the most of the materials on earth get converted to smoke (vapour) and ascends to sky with the air and subsequently get 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) say that the water is never destroyed or lost, but only converted from one form to other i.e. water to vapour by sunheat, then cloud and subsequent rainfall and loss of rainfall by wind etc. viz.

अस्यैवेह प्रसादात्तु वृष्टर्नाताभवद्विद्वजाः ।
सहस्त्र गुणमुत्स्त्रष्टुं मादत्ते किरणैर्जलम् ।। Linga I,36.66 ।।

जलस्य नाशो वृद्धिर्वा नातत्येवास्य विवारतः ।
धृवेणाभ्रिष्छतो वायुवृष्टि संस्रते पुनः ।। Linga I,36.67 ।।

Thus it is evident that the Linga Purana contains clear concept of rainfall, evaporation, condensation, cloud formation etc., alongwith the knowledge that water can not be created or destroyed.

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

वसंते चैव ग्रीष्मे च शतैः स तपते त्रिभिः ।
वर्षास्वथो शरदि च चतुर्भिस्त्वं प्रवर्षति ।। Linga I,41.30 ।।

चैत्रे मासि भवेदंशुर्धाता वैशाखतापन ।
जेष्ठे मासि भवेदिन्द्र आषाढ़े वार्यमा रविः ।। Linga I,41.33 ।।

Likewise Vayu and Brchmanda Purana also contain valuable references on hydrologic cycle. Vayu (51.14-15-16) state like this.

आदित्यपीतं सूर्याग्नेः सोमं संक्रमते जलम् ।
नाडीभिर्वायुयुक्ताभिर्लोकाधानं प्रवर्तते ।। Vayu,51.14 ।।

यत्सोमात्स्त्रवते सूर्य तदभ्रेष्ववतिष्ठते ।
मेघा वायुनिघातेन विसृजन्त जलं भुवि ।। Vayu 51.15 ।।

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

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

Brahmanda Purana (II,Chapt.9) gives some information on 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 sun is controlled. The very object of the chapter is the concept of hydrologic cycle explaining different parts one by one.

नावृष्ट्या परिविश्येत वारिणा दीप्यते रविः ।
तस्माद्यः पिबन्यो वै दीप्यते रविरंबरे ।। II,9.138 ।।

तस्य ते रश्मयः सप्त पिबंत्यंभो महार्णवात् ।
तेनाहारेण संदीप्ताः सूर्याः सप्त भवंत्युत ।।
Brahmanda II,9.1391 ।।

सप्तधा संवृतात्मानस्तमाग्निं शमयंत्युत ।
ततस्ते जलदा वर्षं मुंचंति च महौघवत् ॥ II,9.167 ॥

सुघोरमशिवं सर्वं नाशयंति च पावकम् ।
प्रवृष्टैश्च तथात्यर्थं वारिणा पूर्यते जगत् ॥ Brahmanda II,9.168 ॥

From the study of this chapter we can conclude that the knowledge of hydrologic science during the vedic age and afterward in the age of epics and puranas was highly advanced. Without sophisticated instruments of today people of that time were dependent upon their experience of nature.

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. There it gets condensed and subsequent rainfalls. Monthwise change in the facets of hydrological cycle was also known. Water uptake by plants which gets facilitated by the conjunction of air alongwith the knowledge of infiltration is revealed in ancient literature. At various places in Puranas it has been alluded that the water can not be created or destroyed, only its from (solid, liquid or gases) can be changed. From all above discourses we come to the well developed concept of hydrological cycle known by ancient Indians in those remote times while the contemporary world was believing on the wild theories of origin and distribution of water. Thus this level of knowledge of hydrology can be regarded as the great achievement of ancient Indians.

CHAPTER 3

PRECIPITATION, CLOUD FORMATION, MEASUREMENT etc.

The Rigvedic Aryans had keenly and carefully demarcated the variation in seasons and divided the whole year into six such divisions, viz.

उतो स मह्यमिन्दुभिः षड्युक्ताँ अनुसेषिधत् ।
गोभिर्यवं न चर्कृषत् ॥ RV,I,23.15 ॥

The sun was clearly known as determinant of seasons and the seasons were formed for the benefit of the earthly creatures, viz.

त्रीणि जाना परि भूषन्त्यस्य समुद्र एकं दिव्येकमप्सु ।
पूर्वामनु प्र दिशं पार्थिवानामृतूत्पाशासद्धि दधावनुष्ठु ॥ RV.I,95.3 ॥

Radiation, convection currents and rainfall as their effect are described in the RigVeda (I,164.47, VII, 70.2 and I,161.11-12).

उद्वत्स्वस्मा अकृणोतना तृणं निवत्स्वपः स्वपस्यया नरः ।
अगोस्यस्य यत्सस्तना गृहे तद्धेदमृभवो नानु गच्छथ ॥ RV I,161.11 ॥

संमील्यं यद्भुवना पर्यसर्पत क्व स्वत्तात्या पितरा व आसतुः ।
अशपत यः करस्नं व आददे यः प्राब्रवीत्प्रो तस्मा अब्रवीतन ॥
RV I,161.12 ॥

कृष्णं नियानं हरयः सुपर्णा अपो वसाना दिवमुत्पतन्ति ।
त आववृत्रन्त्सदनादृतस्यादिद्धृतेन पृथिवी व्युद्यते ॥ RV I,164.47 ॥

These Verses also says that the rays of the sun are the cause of the rains, and that the clouds are constituted of various elements.

Verses of Rigveda (I,27.6; I,32.8; I,32.14; I,37.11;

II,24.4; V,55.3) describe the formation of cloud by evaporation of water by sun & wind and then rainfall, and there is no other cause of rainfall other than sun viz.

विभक्तासि चित्रभानो सिन्धोरूर्मा उपाक आ ।
सद्यो दाशुषे क्षरसि ॥ RV.I,27.6 ॥

नदं न भिन्नममुया शयानं मनो रुहाणा अति यन्त्यापः ।
याश्चिद्वृत्रो महिना पर्यतिष्ठत्तासामहिः पत्सुतः शीर्बभूव ॥ RV.I,32.8 ॥

Above Verse explains that all that water goes to the Sky with wind by the heat of Sun rays get converted to clouds and then again after the penetration by Sun rays it rains and get stored into rivers, ponds, ocean etc. Verse (V 55.3) explains the simultaneous formation of mighty coulds which are co-dispensers of moisture. Clouds are said to be leaders for replenishment of water.

साकं जाताः सुभ्वः साकमुक्षिताः श्रिये चिदा प्रतरं वावृधुर्नरः
विरोकिणः सूर्यस्येव रश्मयः शुभं यातामनु रथा अवृत्सत ॥
RV.V,55.3 ॥

During Rigveda the seasonal variation of rainfall or the onset of monsoon was known, which is depicted through following verses (RV.VI,20.2 and VI,30.3) saying that the sun extracts water from earth during eight months and then this water rains during rainy season of four months.

दिवो न तुभ्यमिन्द्र सत्रासुर्यं देवेभिर्धायि विश्वम् ।
अहिं यदृत्रमयो वविवांसं हन्नृजीषिन्विष्णुना सचानः ॥ RV.VI,20.2 ॥

Verse (I 79.2) states that the Sun rays strike against moving clouds thus the black Shedders of rain roar, after that the Shower comes with delightful and smiling flashes of lighting, the rains then descend and finally the clouds thunder.

आ ते सुपर्णा अमिनन्त एवैः कृष्णो नोनाव वृषभो यदीदम् ।
शिवाभिर्न स्मयमानाभिरागात्पतन्ति मिहः स्तनयन्त्यभ्रा ॥ RV.I,79.2 ॥

Two verses (V.54.2 & V.55.5) explain the cloud-bearing winds as the cause of rainfall viz.

प्र वो मरुतस्तविषा उदन्यवो वयोवृधो अश्वयुजः परिज्रयः ।
सं विद्युता दधति वाशति त्रितः स्वरन्त्यापोऽवना परिज्रयः ॥
RV.V,54.2 ॥

"O cloud-bearing winds, your troops are rich in water, they are strengthners of life, and are your strong bonds, they shed water and augment food, and are harnessed with steads (waves) that wander far and spread every-where. Combined with lighting, the triple-group (of wind, cloud and lightning) roars aloud, and the circum ambient waters fall upon the earth"

उदीरयथा मरुतः समुद्रतो यूयं वृष्टिं वर्षयथा पुरीषिणः ।
न वो दस्रा उप दस्यन्ति धेनवः शुभं यातामनु रथा अवृत्सत ॥
RV.V,55.5 ॥

This explains that the cloud-bearing winds uplift water from ocean and charged with water shower down the rain.

Similarly instrumentality of winds in the causation of rainfall (I,19.3-4; I,165.1),and their relationship with clouds can be easily read in I, 19.8 as follows:

ये महो रजसो विदुर्विश्वे देवासो अद्रुहः । मरुद्भिरग्न आ गहि ॥
या ऊर्ध्वा अर्कमानृचुरनाधृष्टास ओजसा मरुद्भिरग्न आ गहि ॥
RV.I,19.3-4 ॥

Both of above mantras wants to reveal the cause of rain, who commands the rain to come down and execution of eternal laws.

आ ते तन्वन्त रश्मिभिस्तिरः समुद्रमोजसा ।
मरुद्भिरग्न आ गहि ॥ RV.I,19.8 ॥

The mantra I,38.7 reveals how the moisture leaden winds bring some scanty rainfall in desert region also.

सत्यं त्वेषा अमवन्तो धन्वञ्चिदा रुद्रियासः ।

मिहं कृण्वन्त्यवाताम् ।। RV.I,38.7 ।।

From mantras V,53.6-7 we come across the knowledge of Rigvedic Aryan's about the positive effect of yajna's (यज्ञ), forests and large reservoirs causing rainfall.

आ यं नरः सुदानवो ददाशुर्षे दिवः कोशमचुच्यवुः ।
वि पर्जन्यं सृजन्ति रोदसी अनु धन्वना यन्ति वृष्टयः ।।

ततृदानाः सिन्धवः क्षोदसा रजः प सस्रुर्धेनवो यथा ।
स्यन्ना अश्वा इवाध्वनो विमोचने वि यद्वर्तन्त एन्यः ।। RV.V,53.6-7 ।।

In two mantras (RV. VIII, 85.8 and V 52.17) there are references to sixty-three and forty-nine types of winds respectively. Their climatological and meteorological implications are still unravelled and they are mostly treated as merely mythologies.

सप्त मे सप्त शाकिन एकमेका शता ददुः ।
यमुनायामधि श्रुतमुद्राधो गव्यं मृजे नि राधो अश्वयं मृजे ।। RV.V,53.17 ।।

No clear cut mention of the monsoon is to be found in Rig Veda but the Marut hymns give its quite good and satisfactory descriptions; of course, monsoon is clearly referred to in the later period in the Yajurveda sanhita as सलिलवात (Taithriya IV.4.12.3).

वर्ष इदं क्षत्र सलिलवातमुग्रम् ।।
धर्त्री दिशां क्षत्रमिदं दाधारोपस्थाशानां मित्रवदस्त्वोजः ।। Ts,4.4.12.3 ।।

It will however not be unreasonable, if the south-east and south-west monsoon are traced in the Rigveda where there is also a better reference to rain bearing winds (RV X.137.2 and I,19.7)

द्वाविमौ वातौ वात आ सिन्धोरा परावतः ।
दक्षं ते अन्य आ वातु परान्यो वातु यद्रपः ।। RV.X,137.2 ।।

In versa,VIII,7.4 word मिहं is explained to mean mist, with which one cannot differ easily, if the content is taken into account, though at other places मिहं signifies rainfall.

वपन्त मरुतो मिहं प्र वेपयन्ति पर्वतान । यधामं यन्त वायुभिः ।।
RV.VIII,7.4 ।।

The importance of yojna to purify environment and causation of rainfall was well understood during Rigvedic time verses (RV.X,98.4; X,98.6/12; X.98.7 and X,98.11) clearly reveal above fact.

आ नो द्राप्सा मधुमन्तो विशान्त्विन्द्र देह्याधिरथं सहस्त्रम् ।
निषीद होत्रमृतुथा यजस्व देवान्द्रे दाये हविषा सपर्य ।। RV.X.98.4 ।।

अस्मिन्त्समुद्रे अध्युत्तरस्मन्पो देवोभिर्निवृता अतिष्ठन् ।
ता अद्रवन्नाष्टिंषेन सृष्टा देवापिना प्रेषिता मृक्षिणीषु ।।
RV.X.98.6/12 ।।

These mantras clearly indicates that the water collected by Sun rays kept in sky safely, and to create rain, one should take help of knowledgefull preists, who will do appropriate yajna (sacrifice) for rain.

The three other Vedas, namely Sama, Yajur and Atharva Veda furnish some additional information on climatology and meterology which we do not come across 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.

The rain is the Phenomena of Ocean, wind and moisture is proved to be clearly known by later Vedic time: from the Ocean, O Maruts Ye make (the rain) to fall, O Ye that are rich in moisture (Ts. II.4.8.2)

वृष्टयः उदीरयथा मरुतः समुद्रतो यूयं वृष्टिं वर्षयथा पुरीषिणः ।
सृजा वृष्टिं दिव अद्भिः समुद्रं पृण ।। Ts.II,4.8.2 ।।

Air circulation plays a definite role in the causation of rainfall is stated thus "Verily becoming of like hue he (wind) causes Parjanya to rain (Ts, II 4.9.1).

मारुतमसि मरुतामोज इति कृष्णं वासः कृष्णंतूषं परि धत्त् एतद्वै
वृष्टेः रूपं सरूप एव भूत्वा पर्जन्यं वर्षयति रमयत मरुतः श्येनमाशिमिति पश्चाद्धातं
प्रति सीवति पुरोवातमेव जनयति वर्षस्यावरुद्धयै वातमामानि जुहोति वायुर्वै वृष्ट्या ईशे
वायुमेव स्वेन भागधेयेनोप धावति स एवास्मै पर्जन्यं वर्षयस्य ष्टौ ।।
Ts,II,4.9.1 ।।

West wind and the rain bearing monsoon or east wind are spoken of in above lines - "Stay O maruts the speeding falcon (with these words) he pushes back the west wind: verily he produces the east wind, to win the rains. He makes offering to the names of the wind, the winds rule the rain (Ts,II,4.9.1).

As during Rigvedic time also Aryans & definitely knew that plants (or forests) had some influence on the causation of rainfall "Verily if rain from the water and the Plants (TS,II,4.9.3).

सौम्यायैवाहुत्या दिवो वृष्टिमव रुन्धे मधुषा सं योत्यपां वा एष ओषधीनां रसो
यन्मध्वाभ्य एवौषधीभ्यो वर्षत्यथो अद्भ्य एवौषधीभ्यो वृष्टिं नि नयति ।।
Ts,II,4.9.3 ।।

Like Rigveda, Yajurveda also tells about the influence of yajna (sacrifice) in purifying air, water and environment as a whole and help in causation of rainfall. Mantra (I,12) reads as follows:

पावत्रे स्थो वैष्णव्यौ सवितुर्वः प्रसव उत्पुनाम्यच्छिद्रेण पवित्रेण सूर्यस्य रश्मिभिः ।
देवीरापो अग्रेगुवो अग्रेपुवो व इममद्य यज्ञं नयताग्रे यज्ञपतिं सुधातु यज्ञपतिं देवयुवम्
।। YV,I,12 ।।

This mantra states that the substances like water, air etc. get polluted and if they will be broken into minute particles by fire (with the help of yajna) they will get purified and pure rainfall will occure. Mantra (VI,10) states that the materials

used in yajna get devided into minute atomic form due to attraction of sun and ascend to sky. This causes Plenty of rainfal. Likewise mantra (VI-16 and XIII-12) also reveals the same fact.

अपां पेरूरस्यापो देवीः स्वदन्तु स्वात्तं चित्सद्देवहविः ।
सं ते प्राणो वातेन गच्छतां समङ्गानि यजत्रैः सं यज्ञपतिराशिषा ॥
YV.VI,10 ॥

In the vedas at several Places mist has been given the appellation of नीहार (Vajasaneyi Sanhita 17,31),viz.

न तं विदाथ य इमा जजानान्यद्युष्माकमन्तरं बभूव ।
नीहारेण प्रावृता जल्प्या चासुतृप उक्थशासश्चरन्ति ॥ Vs.XVII,31 ॥

Yajurveda knew about the immense concentration of mist or fog on water bodies and oceans "thou are ocean full of mist". Pure waters purify all things through rain "May waters, like mother purify our bodies (YV.IV.2-3).

आपो अस्मान्मातरः शुधयन्तु घृतेन घृतप्वः पुनन्तु ।
विश्व हि रिपं प्रवहन्ति देवीः ।

उद्दिदाभ्यः शुचिरा पूत एमि दीक्षातपसोस्तनूरसि
तां त्वा शिवा शग्मा परि दधे भद्रं वर्ण पुष्यन् ॥ YV.IV.2 ॥

The Sun was known to be the disperser of clouds and cause of rain "O Sun, thou bringing rain on different parts of the earth"

महीनां पयोसि वचोदा असि वर्चो मे देहि ।
वृत्रस्यासि कनीनिकश्चक्षुर्दा असि चक्षुर्मे देहि ॥ YV.IV,3 ॥

Samveda gives more emphasis on wooing raingod. It clearly says that the eternal power sun penetrates the clouds and thus causes rain (SV.Previos II,179). It also reveals that the sun Pours rain water on moving earth with the help of wind (SV.Previous II,148).

यदिन्द्रो अनयाद्रितो महीरयो वृष्नतपः ।

तत्र पूषा भुवत्सचा || SV.Previous II.148 ||

इन्द्रो दधीचो अस्थभिर्वृ त्राण्यप्रतिष्कुतः ।
जघान नवतीर्नव || SV.Previous II.179 ||

Other verses of Samveda (V.562; final V.906; and final X.1317) discuss the kindness and greatness and power of god alongwith the process of rain. Verse (SV.Final, XX.1802) clearly mention the creation of oceans, rivers etc.due to the heavy rain by god.

असावि सोमो अरुषो वृषा हरी राजेव दस्मो अभि गा अचिक्रदत् ।
पुनानो वारमत्येष्यव्ययं श्येनो न योनिं घृतवन्तमासदत् ॥
SV.Previous,V.562 ॥

आ पवमान सुष्टुति वृष्टि देवेभ्यो दुवः ।
इषे पवस्व संयतम् ॥ SV.Final,V.906 ॥

त्व सिन्धू रासृजोधरावो अल्नसि ।
अशत्रुरिन्द्र जज्ञिसे विश्वं पुष्यसि वार्यम् ।
तन्त्वा परि ष्वजामहे नभन्तामन्यकेषां ज्यांका अधिधन्वसु ॥
SV.Final,XX.1802 ॥

In Atharvaveda we come across the similar concepts and hydrologic knowledge continued in other Vedas. Verse (I,4.3) states as follows:

अपो देवी रुपं ह्वये यत्र गावः पिबन्त नः ।
सिन्धुभ्यः कर्त्वं हविः ॥ AV.I,4.3 ॥

Above verse reveals the conept of evaporation by heating of sun rays and subsequently life giving rainfall. The Prithvi Sukta of the Atharvaveda (XII,1.51) speaks of a violent dusty storm which uprooted trees and calls it as मातरिश्वा, viz.

यां द्विपादः पक्षिणः संपतन्त हंसाः सुपर्णाः शकुना वयांसि ।
यस्यां वातो मातरिश्वेयते रजांसि कृण्वंश्च्यावयंश्च वृक्षान् ।
वातस्य प्रवामुपवामनु वात्यर्चिः ॥ AV.XII,1.5 ॥

It has been purported through the various commentaries

on vedic literature that the vedic literature mythically describes the Indian atmospheric phenomena, specially those of the monsoons and rainy season, and the violent thunderstorms by which they are usually accompanied. Following the Rig Veda the Satpatha Brahmana also recognises sixty three winds (SB Part I, 2,5,1,13). The same text calls hoar frost as पूरवा .

त्रिः पृष्ट्वा मरुतो वावृधाना अत्रा ह्व राशयो वशियासः ।
उप त्वेमः कृधि नो भागधेयं शुष्मं त एना सविषा विधेम ।।
RV,VIII,96,8 ।।

The Taithiriya Aranyaka (I,9,8) says that there are seven types of air currents or winds in the atmosphere which produces seven types of clouds of the same appellation. These are (1) वराह्व (2) स्वतपस (3) विद्युन्मस्स (4) धूपय (5) श्वापय (6) गृह्मेघ and (7) आशिमिविद्धिष. The वराह्व creates circumstances which are responsible for condensation and good rainfall. The स्वतपस is that whose temperature condition is little affected by the insolation or sun and perhaps occurs at a higher altitude and is responsible for precipitation. The actual text of the mantra is follows:

तातनुकामिष्यायः वरावस्स्वतपसः । विद्युन्मय सो धूपयः ।।
श्वापयो गृह्मेघारवेत्येते । पे चेमेशिमिविद्धिषः ।
पर्जन्यास्सप्त पृथिवीमिमि वरषन्ति । वृष्टिभिरति ।। Tai.Ara.,I,9,8 ।।

The विद्युन्मस्स gives rise to thunderstorm; the धूपय possesses some latent property or aroma which it impart to the objects with which it comes in contact, expanding quickly and the गृह्मेघ affects the humidity or moisture content of the atmosphere. These six belong to a single genus and have a single or similar regions of activity. The आशिमिविद्धिष belongs to another genus and its geographical realm or region is different from the preceding six; however it is highly favourable for agricultural purposes. These seven classes of clouds bring rainfall with seven type of winds. In (I,10,9) of Taithiriya Aranyaka, as given below two more types of clouds are mentioned.

भवितारं वितन्वन्तम् । अनुवध्नाति शाम्बरः । आपपूरषम्भरश्चैव ।
सवितारेपसोभक्त ।। I,10,8 ।। त्यं सुतपृं विदित्वैव ।

बह्वसोममरिं वशी || अन्वेति तुग्रोवाक्रियां तम् । आ यस्मुवान्त्सोमतृप्सुषु ||
Tai,Ara,I,10.9 ||

These are (1) शम्बर or शाम्बर and (2) बह्वसोममरी. The former is responsible for profuse rainfall, and the later is identified to be "the moving nimbus fall of water". The total nine types of clouds with their properties have been identified in the Taithiriya Aranyaka.

In the same line during the age of epics we get information regarding clouds, rainfall, evaporation, snow, storms etc. Verse VII.4.3 of Ramayana (8th to 3rd century B.C.) speaks of three kinds of clouds - ब्राह्म (Produced from Brahma), आग्नेय (produced from fire and पर्वज (produced on a mountain flank).

White, red, blue and grey clouds are also referred to in the epic (V.1.81) as below.

पाण्डुरारुणवर्णानि नीलमाञ्जिष्ठकानि च ।
कपिना कथ्यमाणानि महाभाणि चकाशिरे || Ramayana V, 1.81 ||
हरितारुणवर्णानि महाभाणि चकाशिरे || Ramayana V, 57.7 ||

Clamatic Vaguery or absence of rainfall is referred to in (I.9.9 of Ramayana), viz.

अनावृष्टिः सुघोरा वै सर्वलोकभयावहा || Ramayana I,9.8 ||
अनावृष्ट्यां तु वृत्तायां समानीय प्रवद्यति || Ramayana I,9.9 ||

Here it speaks indirectly of atmosphere free from dust, fog, frost and mist. Similarly condition of nocturnal sky (the moon from नीहार or mist) is alluded to in Ramayana (I.29.25).

शशीव गतनीहारः पुनर्वसुसमन्वितः || Ramayana I,29.25 ||

Mist and its disappearance through diurnal rise of temperature is referred to in I,55.25, mist and severe cold in III, 16.12,cold western wind made still colder due to the effect of him (frost) in III, 16.15, very dense mist in the vicinity of

earth surface in III, 16,23, water vapour hanging on the surface of the river structure in III,16,24, dew formation on the sandy margins of the bank in III,16,24 and snowfall in III,16,25. All of these verses are given below:

वद्धौ वै वसिष्ठस्य या भेरिति मुहुर्मुहुः ।
नाशायाम्यघ गाधेयं नीहारमिव भास्करः ॥ Ramayana I,55,25 ॥

निवृत्ताकाशशयना: पृथ्वनीता हिमारुणा: ।
शीतवृद्धतरायामास्त्रियाना यान्ति साम्प्रतम् ॥ Ramayana III,16,12 ॥

प्रकृत्या शीतलस्पर्शो हिमविद्धश्च साम्प्रतम् ।
प्रवाति पश्चिमो वायु: काले द्विगुणशीतल: ॥ Ramayana III,16,15 ॥

अवश्यायतमोनद्धा नीहारतमसावृता: ।
प्रसुप्ता इव लक्ष्यन्ते विपुष्पा वनराजय: ॥ Ramayana III,16,23 ॥

वाष्पसंछन्नसलिला स्रवद्विशेयसारसा: ।
हिमद्रिवालुकैस्तीरै: सरितो भान्ति साम्प्रतम् ॥ Ramayana III,16,24 ॥

तुषारपतनाच्चैव मृदुत्वाद् भास्करस्य च ।
शैत्याद्व्याप्तस्थमपि प्रायेण रसवज्जलम् ॥ Ramayana III,16,25 ॥

Verse IV,1,15 states about the mountain wind or winds of mountain valley. In another Verse VI, 78,19 we read about dusty, dry and gusty wind. Later on violent storm or Tornado is also mentioned in Ramayana,VI,106,21 (वाता मण्डलिनस्तीवा:)

शैलकंदर निष्क्रान्त: प्रवाति इव वानिल: ॥ Ramayana IV,1,15 ॥

Like Ramayana the second epic Mahabharata also contains valuable material related to hydrosciences. In the twelfth skanda of epic the atmosphere is divided into seven regions (skandha, sphere,XII,328,31), and they are discussed in considerable detail "that wind which is the first in above number and which is known by the name of प्रवह drivers, along the first course, masses of clouds born of smoke and heat. Thus

during this time the constituents of cloud were also predicted. This wind passes through the sky and comes into contact with water in the clouds (MB,XII,328,36).

पृथिव्यायन्तरिक्षे च यत्र संवान्त वायवः ।
सप्तैते वायुमार्गा वै तान् निबोधानुपूर्वशः ॥ MB,XII,328,31 ॥

पेरक्त्यभ्रसंघातान धूमजांरचोष्मजांश्च यः ।
प्रथमः प्रथमे मार्गे प्रवहो नाम योनिलः ॥ MB,328,36 ॥

The second wind called प्रावह, blows with a loud noise (MB,XII 329,37) that wind which drinksup water from the four ocean and having sucked it up gives it to the clouds, presents them to the gods of rain is the third in number and known as उद्वह (MB,XII 328,38-39-40).

अम्बरे स्नेहमाश्रेत्य विद्युद्भयश्च महाद्युतिः ।
आवहो नाम संभवति द्वितीयः श्वसनो नदन् ॥ MB,XII,328,37 ॥

उद्वयं ज्योतिषां शश्वत सोमादीनां करोति यः ।
अन्तर्देशेषु चोदानं यं वदान्त मनीषिणः ॥ MB,XII,328,38 ॥

यश्चतुर्भ्यः समुद्रेभ्यो वायुर्धारयते जलम् ।
उद्धयावद्धो वापो जीमूतेभ्योम्बरे निल ॥ MB,XII,328,39 ॥

योद्भिः संयोज्य जीमूतान पर्जन्याय प्रयच्छति ।
उद्वहो नाम बंहिष्ठस्तृतीयः स सदागतिः ॥ MB,XII,328,40 ॥

That winds which support the clouds and divides them into various parts which melts them for pouring rain and once more solidifies them, which in perceived as the sound of roaring clouds, known by the name संवह. Fifth layer is called विवह, sixth परिवह, and seventh परावह (MB,XII,328,41-42-43-47-48) is perhaps some cosmic region.

समूह्यमाना बहुधा येन नीताः पृथक घनाः ।
वर्षमोक्षकृतारम्भास्ते भवन्ति घनाघनाः ॥ M,B,XII,328,41 ॥

संस्ता येन चाविद्धा भवन्ति नद्यां नदाः ।
रक्षणार्थाय सम्भूता मेघत्वमुपयान्ति च ॥ M.B.XII,328.42 ॥

यो सौ वहति भूतानां विमानानि विहायसा ।
चतुर्थः संवहो नाम वायुः स गिरिमर्दिनः ॥ M.B.XII,328.43 ॥

दारुणोत्पातसंचारो नभसः स्तनयित्नुमान ।
पञ्चमः स महावेगो विवहो नाम मारुतः ॥ M.B.XII,328.45 ॥

षष्ठः परिवहो नाम स वायुर्जयतां वरः ॥ M.B.XII,328.48 ॥

येन स्पृष्टःपराभूतो शात्येव न निवर्तते ।
परावहो नाम परो वायुः स दुरतिक्रमः ॥ M.B.XII,328.52 ॥

Here at five places the term wind used actually implies a sphere or layer. These five names also occures in Puranas and other later literature. The epic gives another classification of clouds also. These four types of clouds संवर्तक, बलाहक (MB,VIII,34.28), कुण्डधार (XII 271.6) and ऊंक (MB XIV 55.35-36-37).

This ऊंक cloud rains in desert areas.

सोथ सौम्येन मनसा वेद्यानुनरवन्तिके ।
पर्यपश्यज्जलधरं कुण्डधारमवस्थितम् ॥ MB,XII,271.6 ॥

तदा मरौ भविष्यन्ति जलपूर्णाः पयोधराः ।
रसवच्च प्रदास्यन्ति तोयं ते भगुनन्दन,
ऊलवड्रोधा इत्युक्ताः ख्याति यास्यन्ति चापि ते ॥ MB,XIV, 55.36 ॥

The बलाहक clouds are formed in the विवह layer of atmosphere (described before) clouds bringing rainfall in desert area are called ऊंक. These classifications of clouds are different from those enumerated in Ramayana and Puranas.

Around 600-700 BC, Kanada in his Vaisesika sutra referred to the process of condensation and dissalution of water (Vais.Sutr.V,2.8).

अपां सङ्घातो विलयनञ्च तेजः संयोगात् ॥ Vais.Sutr.V,2.8 ॥

He remarks "condensation and dissolution of water is due to the conjunctive with fire or heat". He answered the question that what proof there is that snow, hail etc. are water with the help of action production in atoms by comjunction of light. About the Phenomena of thunder he observes that the rolling of thunder is a mark of the ingress of the light of the sky (Vais.Sutr.V,2.9), i.e. it is the pealing of thunder which warraants the inference. He again says (Vais.Sutr.V,2.11) that the rolling of thunder results from conjunction with water and disjunction from a cloud. Here it is fully evident that the great sage knew that thunder is caused due to impact of positively and negatively charged clouds.

तत्र विस्फूर्ज थुर्लिङ्गम् || Vais.Sutr.V,2.9 ||
अपां संयोगाद्विभागाच्च स्तनयित्नोः || Vais.Sutr.V,2.11 ||

Discussing the falling of raindrops and flowing of streams he presents causes as the falling of water results from gravity in the absence of conjunction (Vais.Sutr.V,2.3) i.e. falling of water in the form of rain, has gravity for its non-coinherent cause.

अपां संयोगाभावे गुरुत्वात् पतनम् || Vais.Sutr.V,2.3 ||

In the sloke V,2.4 the following or distant progression of the stream or great aqueous whole composed by mutual conjunction of the fallen waters or raindrops, is produced by fluidity as its non-coinherent cause and by gravity as its efficient cause.

द्रवत्वात स्यन्दनम् || Vais.Sutr.V,2.4 ||

By the time of Kautilya (4th century B.C.) Indians had developed the method and instrumental devices for measuring rainfall. This raingauge was known as वर्षामान. Kautilya describes its construction in these words "In front of the store house, a bowel (Kunda) with its mouth as wide as an aratni (24 angulas = 18" nearly) shall be set up as raingague (वर्षामान)" (Arthasastra, Book II, Chapt.V, P.56 Shamasastry). Kautilya was aquainted with the distribution of rainfall in various areas. He

furnishes a very accurate scientific description of the same with statistics. "The quantity of rain that falls in the country of Jangala (desert countries) is 16 dronas (4 आढक = 1 द्रोण = 200 पल and one आढक equals nearly 7 lbs, 11 ozs. avoirdupois, Tripathi 1969), half as much is moist countries (अनूपानाम्) as to the countries which are fit for agriculture (देशवायानाम्). 13.5 dronas in the countries of Asmakas (Maharastra); 23 dronas in Avanti, and an immense quantity in Western countries (अपरान्तानाम्), the border of the Himalayas and the countries where water channels are made use of in agriculture. From this it is evident that the spirit of the methodology of the measurement of rainfall given by Kautilya is the same as we have today, the only difference is that he expresses it in weight measures while we use linear measure nowadays (Arth.Chapt.XXIV, Book II, P.130).

Discussing the further geographical details of rainfall he observes "when one third of the requisite quantity of rainfalls both during the commencement and closing months of the rainy season, and two third in the middle, then the rainfall is considered very even (सुषुमात्वम्).

As can be easily expected out of the agricultural necessity, the science of forecasting the rains had also come into existence and must have been developing empirically. Regarding it Kautilya says "A forecast of such rainfall can be made by observing the position, motion and Pregnancy (garbhadhan) of Jupitar, the rising and setting and motion of Venus, and the natural or unnatural aspects of the sun from the movement of Venus, rainfall can be inferred.

Discussing the classification of clouds and interrelationship of rainfall and agriculture, the celebrated author adds "there are the clouds which continiously rain for seven days; eighty are they that pour minute drops; and sixty are they that appear with the sun shine". When rain, free from wind and unmingled with sunshine falls so as to render three turns of ploughing possible, then the reaping of good harvest is

certain.

The celebrated author of Astadhyayi, Panini (700 B.C.) refers to the rainy season as प्रावृष (IV, 3.26; VI, 3.14) and वर्षा (IV 3.18). The farmer was the first part of the season. These two parts were known as पूर्व वर्षा and अपरवर्षा (अववर्षापरवर्षाभ्यां VII 3.11). He also refers to वर्षप्रमाण (III, 4.32), viz.

वर्ष प्रमाण अलोपश्चास्यान्यतरस्याम् || Astadhyai,III, 4.32 ||

Citing examples for measurement of rainfall he writes गोष्पदमं वृष्टो देव: (rain equivalent to depression created by hoof of cow), सीतापं वृष्टो देव: (rain equivalent to fill the furrow created by indagineous plough). It is evident that the गोष्पद was the measure of the lowest rainfall.

The Phenomena of evaporation, cloud formation, classification of clouds and their relationship with winds or regions of atmosphere (वातस्कन्ध) are quite satisfactorily discussed in several puranas (Vayu Chapter 51, Liga Vol.I,Chapt.36, Matsya Vol.I,Chapt.54). Describing the general genesis of clouds the Vayu Purana (51.22-25) says that there is moisture content in all the movable or immovable objects of the world and due to insolation or Sun's rays evaporation of that humidity takes place, and this process produces clouds, viz.

आर्कं तेजोस्भिूतेभ्योस्यादत्ते रश्मिमर्जलम् || Vayu,51.23 ||

The later details in Vayu and Brahmanda are similar (Vayu,51.26-40).

मेघानां पुनरुत्पत्तिस्त्रिविधा योनिरुच्यते ।
आग्नेया ब्रह्मजाश्चैव वक्ष्यामि पृथाविधा: ।
त्रिधा घना: समाख्यातास्तेषां वक्ष्यामि संभवम् || VAYU 51.28 ||

आग्नेयास्त्वर्णजा: प्रोक्तास्तेषां तस्मात्प्रवर्तनम ।
शीत दुर्दिनवाता ये स्वगुणास्ते व्यवस्थिता: || VAYU 51.29 ||

जीमूता नाम ते मेघा येभ्यो जीवस्य संभवाः ।
द्वितीयं प्रवहं वायुं मेघास्ते तु समाश्रिताः || VAYU 51.36 ||

They say that those clouds which give or sprinkle water are called मेघ and which do not bring any rainfall are known as अभ्र. There are three types of clouds (1) आग्नेय (2) ब्रह्मज (3) पक्षज. These are connected with cyclonic (thermal & insolational), convectional (occuring in northern continents, siberia and equatorial regions) and orographic (occuring and proceeding from mountain flanks) types of rainfall respectively.

According to above mentioned Puranas आग्नेय occurs in the winter season and it is devoid of lightening and thunder and is of immense expanse and found in mountain foots also. It brings rainfall within a radius of a mile or two. This description approximates most to the Nimbus of modern days. The Brahmaja (ब्रह्मज) clouds are produced du' to convection currents. In precipitation they cover an area of radius of nearly a Yojana (five or eight miles). Most probably these are cumulonimbus. The Puskara - Vartaka (पुष्करावर्त) clouds originate from or in the wings of mountains (पक्षसंभवा). They assume various forms and produce deep rumbling sound. They are full of profuse water and bring excessive rainfall which is extremely destructive. This description conforms to a large extent to the modern class of altostratus.

The Matsya Purana (Vol.I, Chap.54) furnishes still more elaborate and scientific information regarding clouds. It says that the clouds जीमूत is the cause of life.

विषुवद्ग्रहस्वर्णश्च सर्वमेतद ध्रुवेरितम् ।
जीमूता नाम ते मेघा यदेभ्यो जीव सम्भवः || Matsya,I,54.9

Those clouds remain suspended on the air called Avaha. They change shape and goes up a Yojana, from there form into rain hence they are called the source of rain (Verse 10). If the Slokas (17,18 and 19) are interpreted symbolically, they give other four classes of clouds expressed by the nomenclature गज, पर्वत, मेघ and भोगी. Then in the Verse 17 can be recognized further

four classes of गज clouds, viz.

द्विविधा आवह्न वायुर्मेघास्ते त्वभिसंश्रिताः ।
द्वियोजनमात्राच्च अध्यर्द्धविकृताअपि || Matsya,I,54.10 ||

तेषामप्यायनं धूमः सर्वेषामविशेषतः ।
तेषां श्रेष्ठश्च पर्जन्यश्चत्वारश्चैव द्विपगजाः || Matsya,I,54.17 ||

गजानां पर्वतानाञ्च मेघानां भोगिभिः सह ।
कुलमेकं द्विधाभूतं योनिरेका जलं स्मृतम् || Matsya,I,54.18 ||

Parjanys (पर्जन्य) and द्विपगज rain in the season of हेमन्त and are very useful for agricultural growth is spoken in the verse below:

पर्जन्यो द्विपगजाश्चैव हेमन्ते शीतसम्भवम् ।
तुषारवर्षं वर्षन्ति वृद्धां ह्यन्नविवृद्धये || Matsya,I,54.19 ||

To the north and south of the snow-clad mountains (हिमवत) occurs the पुण्ड्र cloud which greatly increases the stock of rain. All the rain formed there converts itself into the snow. The wind on the हिमवत draws by its own force those snow flakes and pours them on the great mountains. Beyond the हिमवत there occurs little rain (Matsya,I,54.22-25).

शकीरान सम्प्रभुञ्जन्ति नीहार इति स मृतः ।
दक्षिणेन गिरिर्योसौ हेमकूट इति स्मृतः || Matsya,I,54.22 ||

उदग्हिमवतः शैलस्योत्तरे चैव दक्षिणे ।
पुण्ड्रं नाम समाख्यात सम्यगवृष्टि विवृद्धये || Matsya,I,54.23 ||

तस्मिन प्रवर्तते वर्षं तन्तु पारसमुद्भवम् ।
ततो हिमवतो वायुर्हिमं तत्र समुद्भवम् || Matsya,I,54.24 ||

आनयत्यात्मवेगेन सिञ्चियानो महागिरिम् ।
हिमवन्तमतिक्रम्य वृष्टिरोधं ततः परम् || Matsya,I,54.25 ||

Thus there is a reference to a very important geographic fact of scanty rainfall or arid condition of the Tibetan plateau. The study and knowledge of this fact is realy creditable on the part

of those ancient Indians.

The Linga Purana (Vol.I,36,38,39 and 49) says "it is the प्रवह wind or air current which makes the clouds produced by smoke and thermal activity full of water, so that the clouds Puskara (पुष्कर) and पद्मज give copious rainfall" viz.

दन्दह्यमानेषु चराचरेषु गोधूमभूतास्त्वथ निष्क्रमान्ति ।
या या ऊर्ध्वं मारुतेनेरिता वै तास्तास्त्वभ्रांयाग्निनावायुना च ॥
Linga,I,36,38 ॥

अतो धूमाग्निवातांनां संयोगस्त्वमुच्यते ।
वारीणि वर्षतीत्यग्रमभस्येशः सहस्रवृक् ॥ Linga,I,36,39 ॥

विरिचोच्छ वासताः सर्वे प्रवस्त्कंधजास्ततः ।
पद्मजाः पुष्कराधश्च वर्षांति च यदा जलम् ॥ Linga,I,36,49 ॥

Process of condensation and Precipitation on hygroscopic nuclei are very carefully described in nut-shell (Matsya,I,54,33)

नियच्छत्यापो मेघेभ्यः शुक्ला: शुक्लैस्तुरश्मिभिः ।
अभस्थाः प्रयतन्त्यापोवायुनासमुदीरिताः ॥ Matsya,I,54,33 ॥

Thus "the waters from the (vapours) of the clouds when brought into contact with the wind (namely hygroscopic content of the air) fall in the shape of rain".

The Vishun Purana (II,9,11-12) very scientifically enumerates the four sources of atmospheric moisture, "the glorious sun, O Maitreya, exhales moisture from four sources, namely - seas, rivers, the earth and living creatures", viz

अभस्था प्रपतन्त्यापो वायुना समुदीरिताः ।
संस्कारं कालजनितं मैत्रेयासाद्य निर्मलाः ॥ Vishnu,II,9,11 ॥

सरत्ससमुद्रभौमास्तु तथापः प्राणिसम्भवाः ।
चतुष्प्रकाश भगवानादत्ते सविता मुने ॥ Vishnu,II,9,12 ॥

Modern meteorology tells us that Polar winds actually never

bring any rainfall in the year in the region under their influence - flanking poles or Tundra, and only scanty summer rain occurs in those areas due to the sweeping of strong westerlies. The same fact is stated in the Puranic line,

ध्रुवेणाधिष्ठितो वायुर्विष्टिं संहरते पुनः || Matsya,Vol.I,54.36 ||

i.e. the air from the Pole drives away the rain.

The celebrated poet Kalidasa (100 BC) also knew a lot about clouds and the allied phenomena. He defines cloud thus "it is an assemblage of smoke, electricity, water and air" (Purvamegha Verse 5)

धूमज्योतिः सलिलमरुतां सन्निपातः क्व मेघः ।
सन्देशार्थाः क्व पटुकरणैः प्राणिभिः प्रापणीयाः ||
Meghadutam,Purvamegha.5 ||

At other places (Purvamegha, Verse 6) the poet names two types of clouds पुष्कर and आवर्तक

जातं वंशे भुवनविदिते पुष्करावर्तकानां जानामि त्वां प्रकृतिपुरुषं कामरूपं मघोनः ||
Purvamegha Verse 6 ||

The Mricchakatike (600 AD) refers to a kind of cloud द्रोण (x.26) from which the rain streams forth as from a bucket. In another context the famous drama refers to a special type of rain द्रोणवृष्टि streaming forth as from a trough (x.39) viz.

कोयमेवंविधे काले कालपाशास्थिते मयि ।
अनावृष्टिस्ते सस्ये द्रोणमेघं ह्वयोद्यतः || Mricchakatika,X.26 ||

केयमभ्युद्यते शस्त्रे मत्युवक्त्रगते मयि ।
अनावृष्टिस्ते सस्ये द्रोणवृष्टिरिवागता || Mricchakatika,X.39 ||

In above classifications four types of clouds in all have been spoken of they are आवर्त, संवर्त, पुष्कर and द्रोण. The Avarta brings no rainfall, the Samvarta gives abundance of rain, the Puskara causes flood of rain and the Drona is most congenial to

agriculture and mankind. This is stated in nut shell in the following lines -

आवर्तो निर्जलो मेघः संवर्तश्च वलाहकः ।
पुष्करो दुष्करजलो द्रोणः शस्यप्रपूरकः ॥
Kalidas Granthavali,Abhidhan Kosh,P.154 ॥

The Vrhat Sanhita and Mayuracitraka by Varahamihira are two very important treatises which are replete with climatological and meteorological informations though they abound in astrological guesses, they contain sufficient scientific facts also.

In the Vrhat Sanhita there are three chapters (21st, 22nd, and 23rd) on climatology and meterology and they treat the subject in their own ancient conventional style. Here only the salient features of the chapters are being surveyed.

Verses 23 and 24 of the chapter 21 state that extremely white or dark clouds resembling aquatic animals like huse fish, shark or tortoise and seen before the rainy season are a source of abundant rainfall viz.

मुक्ताराजतनिकाशास्तमालनीलोत्पलज्जनाभासः ।
जलचरसत्वाकारा गर्भेषु घनाः प्रभूतजलाः ॥ Vr.S.21.23 ॥

तीव्रदिवाकरकिरणाभितापिता मन्दमारुता जलदाः ।
रुधिता इव धाराभिर्विसृजन्त्यम्भः प्रसवकाले ॥ Vr.S.21.24 ॥

Verse 31 descusses the conditions or meterological ingradients which determine the sptial expanses of ranfall, though it appears to be of little value from modern meterological point of view.

पञ्चनिमित्तैः शतयोजनं तदर्द्धार्द्धमेकहान्यातः ।
वर्षति पञ्जनिमित्ताद्रूपेणैकेन यो गर्भः ॥ Vr.S.21.31 ॥

From chapter 22 it is gathered that fleecy and thick clouds give abudant rainfall which is very congenial to agriculture. Again if clouds situated in the east, south and north sail towards south, west and north respectively, they cause fine and copious

rainfall.

रविचन्द्रपरीवेषाः स्निग्धा नात्यन्तदूषिताः ।
वृष्टिस्तदापि विज्ञेया सर्वसस्यार्थसाधिका ॥ Vr.S.22.7 ॥

मेघाः स्निग्धाः संहताश्च प्रदाक्षिणगतिक्रियाः ।
तदा स्यान्महती वृष्टिः सर्वसस्याभिवृद्धये ॥ Vr.S.22.8 ॥

Like Kautilya, Kanad and other Precursor authorities, Varahamihira also describes the device of the father of the raingauge and tell us how to measure rainfall from it. In Verse 2 of chapter 23, he states that constructing a circular bowl (कुण्डकम्) measuring one cubit, one should tell the amount of rainfall, viz.

हस्तविशालं कुण्डकमाधिकृत्याम्बुप्रमाणनिर्देशः ।
पञ्चाशत्पलमाढकमानेन मिनुयाज्जलं पतितम् ॥ Vr.S.23.2 ॥

For calculating rainfall he adopts weight measures of pala, drona and adhaka (4 आढक = 1 द्रोण = 200 पल, and 1 आढक = 7 lbs. nearly). For measurement, rain water received in the bowl during the actual falling should be measured. The distribution of the rainfall according to time is discussed in the verses 6,7,8 and 9. These Verses specify amount of rainfall in various lunar mansions, viz.

हस्ताप्यसौम्याचित्रापोष्णधनिष्ठासु षोडश द्रोणाः ।
शतभिषगैन्द्रस्वातिषु चत्वारः कृत्तकासु दशः ॥ Vr.S.23.6 ॥

श्रवणे मघानुराधाभरणीमूलेषु दश चतुर्युक्ताः ।
फल्गुन्या पञ्चकृतिः पुनर्वसौ विंशतिद्रोणाः ॥ Vr.S.23.7 ॥

ऐन्द्राग्न्याख्ये वैश्वे च विंशति सार्पभे दश त्र्यधिकाः ।
आहिर्बुध्न्यार्यमणप्राजापत्येषु पञ्चकृतिः ॥ Vr.S.23.8 ॥

पञ्चदशाजे पुष्ये च कीर्तिता वाजिभे दश द्वौ च ।
रौद्रेष्टादश कथिता द्रोणा निरुपद्रावेष्वेते ॥ Vr.S.23.9 ॥

In chapter XXXV, he says that phenomenon of rainbow is the

result of spectro analysis of sun's rays through clouds in the atmosphere. (XXXV.1)

सूर्यस्य विविधवर्णाः पवनेन विघाट्टिताः कराः साभे ।
वियति धनुः संस्थाना ये दश्यन्ते तद्दिन्द्रधनुः || Vr.S.35.2 ||

In the Mayura citraka it is stated that scattered clouds devoid of lightning are harmful to people and those of red and white silken or golden or kraunca bird's hue, embedded in the atmosphere and fleecy in texture are always beneficial to the people. Causation of fog or mist in Pausa (December - January) is conductive to good rainfall. (Sampurnanand Sanskrit University, Library, Manuscript No.34332, Page 36-37).

पौषस्य कृष्णसप्तम्यां नभो विमलतारकम् ।
स्वात्यां तुषारपातः स्यात श्रावणे तत्र वर्षणम् ||

Discussing the conditions determining rainfall, it says that if there is no frost in Magha (January - February), no vigorous wind in Phalguna (February - March), no clouds in Caitra (March - April), no hailstrom in Vaisakha (April - May) and no scorching heat in Jyestha (May - June), there is insufficient rain in the rainy season (Above manuscript, Page 17-18). viz.

माघे हिमं न पतति वाता वान्ति न च फाल्गुने ।
न च धूमायितं चैत्रे घनैर्नभस्ततं न तु ||

कारका मोच न वैशाखे शुक्रे चण्डातपो न हि ।
तदातितुच्छा वृष्टिः स्यात् प्रावृष्टकाले न संशयः ||

If sun is hot in the morning, its light during the day is of yellowish hue and clouds are fleecy and dark-coloured, the conditions result in good rain. Similarly if the sun is hot in the morning or at the time of rising and scorching at noon and clouds have a pigment of molten gold, rain occurs during the very day (Above manuscript, Page 18).

प्रावृटकाले यदा सूर्यो मध्यान्हे दुः सहो भवेत् ।
तद्दिने वृष्टिदः प्रोक्तो भृशं स्वर्णसमप्रभः ||

If water appears to be dull, clouds are of the shape of mountain, quarters are clear, the sky is of the hue of crow's egg, there is lull or calm in the atmosphere and aquatic animals like high and others disappear in the bottom and grogs make loud noise, very fine and copious rainfall comes soon (Manuscript No.34332, Page 18). Further if the texture of the clouds rasemble the wings of a Partvidge, rainfall occurs positively (Above manuscript, Page 18).

यदा जलं च विरसं.....गोनेत्र सन्निभः ।
दिशश्च विमलाः सर्वाः काकाण्डाभं यदा नभः ।।

न यदा वाति तपनः पवनः स्थलं यदा ।
शब्दं कुर्वन्ति मण्डूकास्तदा स्याद् वृष्टिकत्तमा ।।

Thus it is evident that Mayuracitraka has attempted to formulate principles for forecasting rainfall through the observation of natural phenomena and the synchronisation and corelationship of the two. The symptomatic synchronisation in the realm of nature is often governed by laws having mathematical accuracy in which intuition of the animate (birds and the animals) and scientific cause and effect relationship of events form the accurate base provided the observation has been made very carefully. In those ancient days, when advanced meteorology and its complecated computations, computers and other cybernatics and servomechanic contivances were unknown this was of special significance and most probably the only method.

Parasara knew the contrivance of primitive rainguage and method of measuring the quantity of rain received (Vraht Sanhita, Chapt.21, Garbhlakhsnadhyaya).viz.

आढकाज्श्चतुरो द्रोणानयां विद्यात् प्रमाणतः ।
धनुः प्रमाणं मेदिन्यां विद्याद द्रोणाभिवर्षणम् ।।

चतुर्विंशाङ्. गुलानाहे द्वित्तुष्काङ्. गुलोच्छिते ।
भाण्डे वर्षाम्बुसंपूर्णे, ज्ञेयमाढकवर्षणम् ।।
Vr.S.between 21.32 and 21.33 ।।

In the Saraswati Bhavan Pustakalaya of Sampurnand Sanskrit University, Varanasi a manuscript treatise entitled as मेघमाला is available. As the very name suggests, it is a work on climatology and more specifically science of clouds. On the basis of content and style of dialogue Tripathi (1969) tried to establish that Meghamala is a part of रुद्रायमालतंत्रम् (900 AD around). The Meghamala actually anticipated Ghagha and Bhaddari in U.P., M.P. or northern India and Khana in Bengal. Following is the content of मेघमाला (with 11 chpters) as surveyed by me during my visit of Sampurnanand Sanskrit University, Varanasi in connection to collect literature to write present report.

The first chapter of मेघमाला opens with the enquiry

मेघस्तु कीदृशादेव कथं विद्युत्प्रजायते ।
कीदृशं वर्णरूपं तु शरीरं तस्य कीदृशम् ।। (Meghamala, Manuscript No.37202, kept at Saraswati Bhawan Pustkalaya of above University) ।।

What are clouds, how is lightning produced, what are nature, texture, ingradients and colours of clouds.

Later in the Verse 20,21,22 is expressed, in ther conventinal Indian style, that the mountains control clouds. From Verses 32 to 68 we gather that there is a larger division of clouds comprising twelve species and designated as 1. सुबुध 2. नन्दशाला 3. कन्यद 4. पयुश्रवा 5. वासुदी 6. तक्षक 7. विकर्त 8. सारवत 9. क्षेमकाली 10. जलेन्द्र 11. वज्रदंष्ट and 12. विष्णुप्रभ. But no scientific detail of these is furnished.

The Chapter II enumerates various types of years, refers to their rainfall, and discusses the economic characteristics or conditions of each of them. The IIIrd chapter dwells on astrological influence on rainfall, climatology and economic condition of people, state of plenty and scarcity and production of various crops.

The eighth chapter aspires to discuss the nature of rainfall and

other meteorological conditions in the twelve months of the year. About the Kartika (October - November) the author says that during this month scattered clouds of varied colours occure. In Pausa (December - January) if sky is over cast with clouds, it is a very good symptom. If the month of Magha (January - Febraury) is not normally cold (or has no frost) there occurs scanty rainfall in Phalaguna (Febraury - March) northeast wind brings good downpour.

मासि मासि कथं देवि लोकृतं गर्भलक्षणम् ।
किं वातं किं घनं वृक्तं कस्य कालेन वर्षति ।।

कार्तिके शुक्ल नन्दायां पञ्चरूपाणि यो भवेत् ।
अभ्राणि श्वेतवर्णानि रक्तवर्णानि यो भवेत ।।

पीतवर्णानि यो मेघा हि कृष्णवर्णरच भवेत् ।
कांस्यवर्णो भवेद्यस्तु ताम्रवर्णस्तथा भवेत् ।।

न माघे पतितं शीतं ज्येष्ठे मूलं न वृष्टिकृत् ।
नार्दायां पतितं तोयं दुष्टकालस्तदा भवेत् ।।

तदा देवि भविष्यन्ति सुभिक्षं क्षेममेव च ।
पूर्वोत्तरजवातेन रात्रयन्ते जलमुत्तमम् ।। Meghmala, Page 14-38 ।।

In the following chapter there is a dilation on clouds, winds and lightning. Firstly it discusses the correlationship of rainfall with different shapes and directions of lightning. Then we are told that north-east wind is conductive to prosperity, southerly does good to people, south-west wind causes misery, westerly is much beneficial for the higher production of rice, northerly is also favourable to the good of people, and it produces a condition of plenty.

पूर्वे विद्युत्करामेघा अग्निरूपां जलशोषिणी ।
दक्षिणे रौरवं घोरं नैऋत्यां तापमादिशेत् ।।

सुभिक्षं पूर्ववातेन जायते नात्र संशयः ।
दक्षिणे तु क्षेमकरो नैऋत्यां दुः खदो भवेत ।।

वारुण्यां क्विंधान्यानि वायव्यां वायुजे भवेत् ।
उत्तरे शुभदो देवि ऐशान्यां सर्वसम्पदः ।।
Meghamala,Page 47-48 ।।

The chapter 10 deals with the propitiation of clouds and apart from repeating the twelve species of clouds, already mentioned, adds another classification of the same comprising seven species designated as अम्बुद, गोलक, गिरि, आरोपक, सपर्वत, विखिन्द and कोटिवार.

The encyclopaedic Tantrik literature does not lag behind in suplying various information on hydrology. From the Tantraloka of Abhinavagupta, we can find out some important climatological and meteorological facts.

In its Ahnika designated as देशाध्वप्रकाशन are described winds, clouds, track of winds and the allied phenomena (Vol.V of the Tantraloka)(Tripathi,1969). It refers to ten air channels (वायुपथ) which are perhaps peculiar to only this text. Those ten air channels are 1. वितत 2. ऋतार्द्धि 3. वज्राङ्क, 4. वैद्युत 5. रैवत 6. विषावर्त (दुर्जय) 7. परावह 8. आवह 9. महावह and 10. महापरिवह (Vol.V,121,138). These are arranged in space according to increasing height. The outstanding Tantrik work recognised ten types of clouds 1. मूलमेघ 2. प्राणिवर्षी 3. विषवारिवर्षी 4. स्कान्द 5. संवर्त 6. ब्राह्म 7. पुष्कर 8. जीमूत 9. ईशकृत, and 10. महेशिकृत (कपालोत्थ). These types occur according to the increasing height. It is perhaps for the first time in Indian literature that we find in this work special, cogent and logical allusion to the height of clouds. It is Praise-worthy even if it be merely an attempt, right or wrong, to represent a scientific fact. It reveals at least a knowledge of the notion that different clouds occur at different levels in the atmosphere.

The other important notable point is that a few of the above mentioned names of clouds are common to Brahmanic technical terminology for example, संवर्त, ब्राह्म, पुष्कर and जीमूत which have already been discussed at their proper places in the present report.

Jain Contribution:

The Jainas have made considerable contribution in the field of meteorology. The 'Prajnapana' and 'Avasyaka Curnis' provide outstanding studies of the various types of winds (Tripathi, 1969). This tradition must have been far older than these treatises. Avasyaka Curnis furnish a list of sixteen winds (9-7/913) as 1. प्राचीनवात (easterly) 2. उदीचीन (northerly) 3. दक्षिणवात (southerly) 4. उत्तर पौरस्त्य (northerly blowing from the front) 5. सवात्सुक (undefined) 6. दक्षिण पूर्वतुंगर (southerly strong wind) 7. अपरदक्षिणबीजाय (blowing from the south-west) 8. अपरबीजाय (westerlies) 9. अपरोत्तरगर्जन (north-westerly hurricane) 10. उत्तरसवात्सुक (unknown) 11. दक्षिण सवात्सुक 12. पूर्वतुंगर 13. दक्षिण and पश्चिम बीजाय 14. पश्चिमगगर्जभ (western storm) 15. उत्तरीगर्जभ (northern strom). Later in the same continuation tornadoes are referred to as कालिकावात. This vocabulary had influenced the Arabian geographers and navingators and they readily absorbed several of these indian technical terms in their own language (Motichandra, 'Sarthavaha' (Hindi), P.202).

The 'Prajnapana' refers to snowfall (हिम) and hailstorm (करक) (I.16). The 'Trilokasara' (Passage 679, P.280) of Nemichandra says that there are seven types of कालमेघ (periodic clouds). They rain for seven days each in the rainy season. Then there are twelve species of white clouds designated as द्रोण, they also bring rain for seven days each. Thus the season of rainfall extends over 133 days in all.

Buddhist Contribution:

In the narrative of the first Jataka, named 'Apannaka', we come across a few climatological facts which are expressed thus "we have been just told ..... that it is raining just ahead in the belt of forest, now how far does a rain wind carry, and how for off can you see the crest of a storm cloud ?

In 'Migalopajataka (cowel, eng. trans. vol.III, P.164, Tripathi, 1969), two violent storms are mentioned as कालवात (black

wind) and वेरम्बरात. The latter is said to belong to the upper air (Samyutta Nikaya, Eng. Trans. XVII.1-9, P.157). The Sumeru mountains was frequently visited by a violent hurricane (उत्पातवात or रूपवात) (Mahamorajataka No.491, P.333; Harit Jataka No.431, P.497). It resembled whirlwind in movemnt. In 'Milinda Panho' hot wind or Loo is spoken of as वातातप (Eng.Trans.Vol.II,IV,6.35, P.86). 'Aryasura' names four types of winds नियतानिल (monsoon), वण्डानिल (tempest), उत्पातवात (hurricane) and परचात्यवायु (westorlies)(Jatakamala, ed. by H.Kern, 10.29, P.90, 127, 133).

The 'Vinaya Pitaka' (III,V.9.4,P.85), whirlwind is called वातमण्डलीका. The Divyavadana' speaks of some kinds of hurricane as कालिकावात (Vol.II,P.41), and of storm accompanied by rain as वातवर्षम (Vol.II,P.163).

The 'Milindapanho' (IV.1.36) says that there are four types of rainfall: 1. of rainy season 2. of winter season, 3. of the two months आषाढ़ and श्रावन (July and August), and 4. rain out of season. At a glance it can be seen that the classification is fully scientific.

The Buddhist refer to two general classes of clouds, कालमेघ (monsoon cloud) and अकालमेघ (storm clouds or accidental ones) (Mahavastu vol.II, P.34, Tripathi,1969). The 'Samyutta Nikaye' classifies clouds into five categories (Vol.III, Book XI, 32.1.1, P.200), 1. शीतवलाहका (cool clouds), 2. उष्णवलाहका (hot clouds) 3. अभवलाहका (thunder clouds, it can be identified with cumulus), 4. वातवलाहका (wind clouds - perhaps clouds formed due to the activity of convection current in the atmosphere) and 5. वर्षवलाहका (rain clouds - most probably cumulonimbus which brings copious downpour of rain).

Thus we see that Buddhist at least before 400 BC have attempted at a very scientific classification of clouds and four species mentioned by them and discussed above can be compared with the most important four species enumerated in modern meteorology. So much of subtle observation at such an early date is an achievement of no less order.

From the foregoing discussion on this chapter we see that the development of this facet of hydrological cycle relating to the cloud formation, precipitation and its measurement was of outstanding order in ancient India. Condensation of evaporated water which is facilitated by the presence of dust particles etc. (which acts as nuclii as per modern meteorology), effect of yajna (यज्ञ), forests, reservoirs etc. on the consation of rainfall and the classification of clouds alongwith their colour, rainfall capacity etc. are thouroughly described in ancient literature like Vedas, Puranas, Vaisesika sutra, Astadhyayi, Arthasastra and Puranas. The forecasting of rainfall on the basis of natural phenomena like colour of sky, clouds, lightening, rainbow etc. and the activities of animals was done and full references are available in Meghmala, Mayurchitraka, and Vrhat Sanhita. Contrivances to measure rainfall were developed and the principles were same as that of modern hydrology except weight measure of Drona, Pala etc. were used instead of modern linear measurement. Kautilye successfully described the distribution of rainfall in different areas of India. Modern meteorological facts like arid region of Tibetan rain shadow area and no rainfall due to polar winds are fully advocated in Puranas. The Jaina and Buddhist works guessed the actual height of clouds. Knowledge of monsoon winds and their effects as conceived by ancient Indians is in accordance to modern hydroscience.

CHAPTER 4

INTERCEPTION AND INFILTRATION

In the hydrology cycle, water from the oceans and various surface bodies on the land evaporates and becomes part of the atmosphere. The evaporated moisture is lifted and dispersed in the atmosphere until it precipitates on the land or in the ocean. The precipitated water may be intercepted and used in transpiration of the plants or may run over the ground.

Some references of interception are found intermixed with other topics in ancient literature, such as explaning the effect of forests and vegetation on rainfall, cloud formation and environmental purification, Taithiriya Sanhita mentions the effect of forests on causation of rainfall (TS.II,4.9.3)

सौभ्ययैवाहुत्या दिवो वृष्टिमव रून्धे मधुषा सं यौत्यपां
वा एष ओषधीनां रसो यन्मध्वाभ्य एवौषधीभ्यो वर्षयथो
अद्भ्य एवौषधीभ्यो वृष्टिं नि नयति ।। TS.II,4.9.3 ।।

Verses (184.15-17) of 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. This clearly reveals the knowledge of capillary action of soil in movement of water up and down. viz.

पादैः सलिलपानाच्च् व्याधीनां चापि दर्शनात् ।
व्याधिप्रतिक्रियत्वाच्च विद्यते रसनं द्रुमे ।। MB.XII,184.15 ।।

वक्त्रेणोत्पलनालेन यथोर्ध्वं जलमाददेत् ।
तथा पवनसंयुक्तः पादैः पिवति पादपः ।। MB.XII,184.16 ।।

As far as infiltration is concerned varahamihira clearly reveals in opening shloka of the Vrahatsanhita Verse I tells us

that at some places water table is higher and at others it is lower, viz.

पुंसां यथा देन शिरास्तथैव क्षितावपि प्रोन्ननिम्नसंस्थाः (Vr.S,54.1)

It implies that the water veins beneath the earth are like veins in the human body, some higher and some lower. Verse 2 reads like this.

एकेन वर्णेन रसेन चाम्भःच्युतं नभस्तो वसुधाविशेषात् ।
नानारसत्वं बहुवर्णतां च गतं परीक्ष्यं क्षितितुल्यमेव ।। Vr.S.,54.2 ।।

It says that the water falling from sky assumes various colours and tastes from differences in the nature of earth. Thus it directly imply that the infiltration of rainwater is the source of groundwater, the ground water is a complex function of rainwater. Rainwater originally has the same colour etc., but assumes different colour & taste after coming down on the surface of the earth and after percolation.

Three verses quoted by Bapudeva Sastri (in Sindhanta Siromani by Bhaskaracharya, Part II, Goladhayaya, Tripathi, 1969) belonging to an era prior to 1200 A.D., provide scientific details of the phenomena of fog or mist (for which the term रजः संहति has been used). The verses purport to say that at the end of rainy season dissipated clouds (moisture) hang near to the surface of the earth and eclipse mountains, trees, vegetation cover or gardens and disappear through the activity of air and heat from these surfaces. This clearly reveals the fact of interception by earthy materials, vegetation etc. and its disappearance with time by the activity of air and heat.

Thus it can be said that the concepts of interception and infiltration were well conceived in ancient India. The interception of water by vegetation and hanging of water particles near the surface of earth on other materials was also observed, which disappear through the activities of wind and heat. The modern soil science tells us that the soil is composed of interconnected pore spaces. This was clearly

realised by ancient Indians and was compared with the veins in the human body, through which infiltration takes place which is the source of ground water. Plants drink up water through roots which is facilitated by the conjunction of air is alluded to in Mahabharata which fully corroborates the modern concept of capillarity in soil, water and plant relationship.

CHAPTER 5

STREAMFLOW - GEOMORPHOLOGY

The two mantras X.82.1 and X.121.1 of Rig Veda represent the creation to have started with the origin of water and the cosmic golden egg (embryo) (हिरण्यगर्भ) which very well fits in the geological and biological evalution of the earth with the water age, origin of zoophytes, primeaval fishes, reptiles, invertebrats, vertebatess and mammals.

विश्वकर्मा विमना आद्विहाया धाता विधात परमोत संदृक् ।
तेषामिष्टानि समिषा मदन्ति यत्रा सप्तऋषीन पर एकमाहुः ॥ RV.X.82.1 ॥

हिरण्यगर्भः समवर्तताग्रे भूतस्य जातः पतिरेक आसीत् ।
स दाधार पृथिवीं द्यामुतेमां कस्मै देवाय हविषा विधेम ॥ RV.X.121.1 ॥

According to the Rig Veda the earth abounds in heights bears the burden of mountains, and supports the trees of the forests in the ground (द्यावा). She quickens for she scatters rain, and the showers of heaven are shed from the lightning of her clouds. She is great (महीं), firm (दृढ़) and shining (अर्जुनी).

Perhaps the Rigveda Aryans had the concept of knowing slopes also of a region by the help of rivers as indicated (RV.IX.88.6) below:

एते सोमा अति वाराण्यव्या दिव्या न कोशासो अभ्रवर्षाः ।
वृथा समुद्रं सिन्धवो न नीचीः सुतासो अभि कलशां असृग्रन ॥
RV.IV.88.6 ॥

Talking about the river flow whose turbulence is lost after meeting the oceans, the Rigveda says

समन्या यन्त्युप यन्त्यन्याः समानमूर्वं नद्यः पृणन्ति ॥ RV.II.35.3 ॥

In the verses (IV,18.6 and IV,19.3) say that rivers are the daughters of sun & cloud. They run towards oceans breaking the soil, rocks etc, coming on their way. They flow in thrugh zig-zap paths

एता अर्षन्त्यलालाभवन्तीऋतावरीरिव संक्रोशमानाः ।
एता वि पृच्छ किमिदं भतन्ति कमापो अद्रिंपरिधिं रुजान्ति ॥
RV.IV,18.6 ॥

During Rigveda the Aryan were clearly aquanted with the river stages and its velocity at different stages. One verse (VI 24.6) mentions the high spead of mountaneous rivers flowing down the slope. Similarly verse VI 36.3 reveals the same fact.

वि त्वदापो पर्वतस्य पृष्ठादुक्थेभिरिन्द्रानयन्त यज्ञैः ॥ RV.VI,24.6 ॥

By the time of Samveda, Yajurveda and Atharveveda the Indians had come to acquire sufficient knowledge of physiography and geomorphology. This is established by the following geographical technical terms - उपह्वर (mountain slopes, SV.II, 5.9), इरिण (cleft or ऊपर), शिला (stony place), द्रवण (habitable place), काट (forest having a difficult communication), ह्रद (lake), लोप (rugged lands or bad lands)(Ts,IV,5.9.1). In the Samveda we come across a brief but fine description of a river mouth and as a wave of the sea opposit to the mouth of a river sends into it a portion of its water (SV XIV,4). The Prithvi Sukta (XII) of the Atharveveda, furnishes a concise account of physiography - mountains, snowcapped mountains, forest lands, plain areas (सम) and perennial stream or slopes (प्रवत). Following two Mantras of Atharvaveda say that if the water source is on mountains, then the river formed will be Perrenial and will flow with high speed (AV.I.,15.3) viz.

ये नदीनां संस्रवन्त्युत्सासः सदमक्षिताः । A.V.I.,15.3 ॥

Similarly Verse (II,3.1) reveals the same fact saying that the rivers originating from snowclad mountains will keep on flowing in summer also.

उदो यद्वधावत्यवत्कमाधि पर्वतात् ।। AV.II,3.1 ।।

In the Gopathabrahmane the nomencleture for a meandering river is विपाट (II.8). It was also aquainted with two types of springs or falls, namely hot and cold,.... शीतोष्णाविस्रोतसौ (G.B.II,8).

The celebrated epic Ramyana reveals very rich and accurate knowledge of various types of geomorpholigical patterns. Some of the geomorphological patterns in the Ramayana related to water are quoted below:

Rivers and rills and Plateous, caverns and fountains (II,54.42), the plain tracts (II,56.11), sandy banks of rivers (II,55.31).

सरित्प्रस्त्रवणस्थान् दरीकन्दरनिर्झरान् ।। Ramayana II, 54.42 ।।
समभूमितले रम्ये द्रुमैर्बहुभिरावृते । पुण्ये रंस्यामहे तात चित्रकूटस्य कानने ।।
Ramayana.II,56.11 ।।

विचित्रवालुकजलां हंससारसनादिनाम् ।
रेमेजनकराजस्य सुता प्रेक्ष्य तदा नदीम् ।। Ramayana II, 55.31 ।।

Those lands watered by the Ganga are dense and hard to track (II,85.4)

कत्तरेण गमिष्यामि भरद्वाजाश्रमं यथा ।
गहनोयं भृशं देशो गङ्गानूपो दुरत्ययः ।। Ramayana II, 85.4 ।।

Knowledge of water falls (II,94.13) and descent of a river (II,103.25) is described as below:

जलप्रपातैरुच्चभेदैर्निष्पन्दैरच क्वचित् क्वचित् ।
स्त्रवद्धिर्भात्ययं शैलः स्त्रवन्मद इव द्विपः ।। Rama.II,94.13 ।।

नदीं मन्दाकिनी रम्यां सदा पुष्पितकाननाम् ।। II,103.24 ।।

शीघ्र स्त्रोतसमासाद्य तीर्थं शिवमकर्दमम् ।
सिषिचुस्तूदकं राजे तत एतद् भवत्विति ।। Rama.II,103.25 ।।

How after melting of snow, a mountaneous topography becomes charming is spoken of thus - हिमात्यये नगमिव वास्कन्धरम् (Ramayana II, 7,15). The author of epic has also marked "river erosion on non-resistant or soft steep river bank (II,63,46; V,34,19; VII,14,18).

स्यन्दि मृदु सोत्सेधं तीरमम्बुरयो यथा || Rama,II, 63,46 ||
वितं ह्रसि मे सौम्य नदीकूलं यथा रयः || Rama,V, 34,19 ||
सीदन्ति व तथा यज्ञाः कूला इव जलेन ह || Rama,VII,14,18 ||

In VII,23,42 we read about the erosive action of the downpour of rain on mountains, viz.

सायकैश्चापवलभ्रष्टैर्वज्रकल्पैः सुदारुणैः ।
दारयन्ति स्म संक्रुद्धामेघा इव महागिरिम् || Rama,VII, 23,42 ||

The Mahabharata devides the Himalayan mountains into three regions. It mentions large tracts of desert several times (I,70,2). In certain context the word नदीकच्छ is used. Most probably it indicates the land form which nowadays called Delta.

एक एवोत्तमबलः क्षुत्पिपासाश्रमान्वितः ।
स वनस्यान्तमासाद्य महत्कूपं समासदत् || M.B.,I,70,2 ||

नदीकच्छोद्भवं कान्तमुच्छ्रितध्वज संनिभम || M.B.,I,70,17 ||

In Paninis Astadhyayi (600-700 BC), we come across several important geomorphological patterns. The grammarian calls a river moving and breaking its banks as भिन्द्य and are whose water overflow the banks as उद्धय (III,1,15).

Glacier is named as हिमानी (IV,1,49) viz.

इन्द्रवरुणभवशर्वरुद्रमृडहिमारण्ययवयवनमातुलाचार्याणामानुक ||
Astadhya,IV,1,49 ||

Topography and Geomorphology have not been left out of the campus of the versatile genius of Kautilya (4th century BC). At

certain context he talks of such varities of land as "forests, villages, waterfalls, levlel plains and uneven ground", stretching between the Himalayas and Ocean (Arthasastra, Trans. by Shamshastri P.404). At various places be speaks of fertile, infertile, cultivable, uncultivable and waste land, which reveals that he must have possessed good knowledge of the science of soil also.

The Vayu Purana refers to various types of topography namely lakes, dales, barren tracks (Chapter 38), rocky throughs between mountains (अन्तद्रोणी)(38.36).

पश्चिमायां दिशि तथा येन्तरद्रोणिविस्तराः ।
तान्वर्ण्यमानांस्तत्त्वेन शृणुतेमान्द्विजोत्तमाः || Vayu,38.36 ||

The chapter also speaks a large number of hot springs in a mountainous region (38.78).

तथा ह्यनलतप्तानि सरांसि द्विजसत्तमाः ।
शैलकुक्ष्यन्तरस्थानि सहस्त्राणि शतानि च || Vayu,38.78 ||

In the Markandeya Purana we come across a peculiar type of topography found "in the Kimpurusaversa and seven other countries" where water bubles up from the ground (53.21-22).

नवस्वपि च वर्षेषु सप्त सप्तकुलाचलाः ।
एकैकास्त्रिस्त था देशे नद्यश्चाद्रि विनिः सृताः || Markandeya P.53.21 ||

यानि किं पुरुषाद्यानि वर्षाण्यष्टौ द्विजोत्तमः ।
तेषूदभिज्जानि तोयानि नैवं वार्यत्र भारते || Markandeya P.53.22 ||

The Vishnu Purana (II,5.3) classified the soils of subterranean region in seven categories, (1) Black (2) White or Yellowish (3) Blue or Red (4) Yellow (5) Gravelly (6) Hilly or boulder and (7) Golden hued, viz.

शुक्लकृष्णाः पीताः शर्करा: शैलकाञ्चनाः ।
भूमयो यत्र मैत्रेय वरप्रासाद्माण्डिता || Vishnu, II, 5.3 ||

The Jain work Vrhatsetrasamsa (6-7 century AD, Tripathi, 1969) appears to be quite scientific and mathematical enumerations conforming to some hydrographical or hydrological law, but actually they contain a small grain of truth. For example "the dimension of a river at its mouth when it enters ocean is ten times that is possesses at its source in a lake or the like (I.227). But the knowledge contained is appreciable atleast qualitatively. A Buddhist literature Anguttaranikaya (before 400 BC), classifies lakes into four categories (Part II, Page 105, Tripathi, 1969).

In the celebrated law work Manusmriti, a lake has been termed as गर्त (IV.203).

नदीषु देवखातेषु तडागेषु सरः सु च ।
स्नान समाचरेन्नित्यं गर्तप्रस्त्रवणेषु च ॥ Manusmriti,VI,203 ॥

From the above discussion we gather that in ancient India the knowledge of streamflow and geomorphology was well developed on scientific lines. The techniques of knowing slope of an area by means of a flowing river and dimension of river at various stages alongwith velocity were developed. Mountaneous rivers are generally perennial and deposition of fertile soil periodically on flood plains was understood which is in accordance to the modern experiences. Various types of topographies such as springs, water falls, mountaineous, plateaue, eroded land etc. alongwith many geographical terms such as शिला, इरिण, क्षयण, लोप were used. Land classification such as fertile, infertile, cultivable, waste land etc. and soil classifications such as black, yellow, red, gravelly, boulders etc. well before 4th century B.C. which are in vogue even at present can be regarded as the important achievement of the ancient Indians in this field.

CHAPTER 6

GROUNDWATER

Groundwater development and utilization have been of great interest from ancient times in arid and semi arid regions of Asia where the activities of man were controlled by the occurrence of water. From the dawn of history until comparatively recent times the source of water of the springs and streams had constituted a puzling problem and had been the subject of much speculation and controversy.

The old testament of Bible contains numerous references to ground water, spring, and wells (Prasad, 1980). The most extraordinary work of ancient man for collecting groundwater are the 'Kanats' (also called Kariz, Kahriz, canaut, ghanat etc.). In the persions they are the infiltration galleries which are the structures inteded to collect groundwater from alluvial deposits and soft sedimentary rocks. Such Kanats were believed to be used first more then 2500 years ago in Iran.

The ancient western science of groundwater which generally assumed that the water discharged by the springs could not be derived from the rain, firstly because the rainfall was believed to be inadequate in quantity, and secondly because the earth was believed to be too impervious to permit penetration of the rain water far below the surface. In contrast to above wild theories the ancient Indian literature contains the most valuable and highly advanced scientific discource on groundwater.

In Rigveda, Samveda, Yajurvada we get concepts of hydrological cycle and water use through wells etc., which clearly imply the use of groundwater.

In the area of groundwater renowened astronomer,

astrologer and mathematician, Varahanihira (AD.505-587), author of Vrhat Sanhita which is esteemed for its learning of many important branches of knowledge, in this the 54th chapter, entitled 'Dakargalam' deals with ground water exploration and exploitation with various surface features, which are most obvious,as hydrological indicators to locate sources of ground water at depths varying from 2.29 m to as much as 171.45 m.(Prasad, 1980)

The hydrologic indicators, described in this ancient Sanskrit work, include various plant species, their morphologic and physiographic features, termite mounds, geophysical characteristics, soils, and rocks. All these indicators are nothing but the conspicuous responses in biologic and geologic materials in a microenvironment, consequential to high relative humidity in a ground water ecosystem, developed in an arid or semi arid region.

The treatise on Dakargala (science of underground water) by Manu is referred to in the Vrhat Sanhita. By the latest his time must be (400BC-200BC). Varahnihire alludes that मनुना विरचितं दकार्गलम, clearly indicates 'Manu's contribution to this science thus it is established that this science of geohydrology studied and cultivated in India several centuries before christ and that it was developed by indigeneous people altogether independently.

Varahmihira has utilized to a greater extent another treatise on the science of underground water and water table, written by 'Saraswat'. Rather the farmer (Manu) appears to give a preference to the latter over the Manava dakargala (Vrhat Sanhita, 54.99).

सारस्वतेन मुनिना दकार्गलं यत् कृतं तलवलोक्य ।
आर्याभिः कृतमेतद्वृत्तैरपि मानवं वक्ष्ये ॥ Vr.S.54.99 ॥

So far absolutely nothing is known about Saraswata and his work, though Varahmihira mentioned him. From this atleast one thing is certain that Sarasweta's work existed in that time.

Now so far as subject proper, the science of underground water and water table is concerned, a brief survey of chapter 54 of the Vrhat Sanhita designated as 'Dakargalam' is furnished below.

Apart from the wider term "Dakargala" there are two other technical terms शिरा and शिरादिज्ञान used in this chapter (Verse 54.1, 54.61-62) viz.

धार्यं यशंस्यं च वदाम्यतोहं दकार्गलं येन जलोपलब्धिः ।
पुंसां क्वाप्यूर्ध्वं शिरास्तथैव क्षितावपि प्रोन्ननिम्न संस्थाः ।। Vr.S.54.1 ।।

मरुदेशे भवति शिरा यथा तथातः परं प्रवक्ष्यामि ।
द्यौरिव तोयभाणामिव भूतलसंस्थाः शिरा यान्ति ।। Vr.S.54.62 ।।

The term शिरा implies arteries of water or streams and the शिरादिज्ञान exactly conveys the meaning of water table. Verse (54.1 as above) tells us that at some places water table is higher and at others it is lower, resembling the veins in the human body. From Verse 2 we learn that water table is a complex function of rainwater, viz.

एकेन वर्णेन रसेन चाम्भश्च्युतं नभस्तो वसुधाविशेषात् ।
नानारसत्वं बहुवर्णतां च प्राप्तं परीक्ष्यं क्षितितुल्यमेव ।। Vr.S.54.2 ।।

i.e. water which falls from the sky originally has the same colour and same taste, but assumes different colour and taste after coming down on the surface of the earth and after percolation. Then in the latter verses are given the modes of occurrence of sub-terranean water and its depth, at different places. Verse 3,4 and 5 inform us that the sub-terraneon streams are rainfied in all the quarters, and also apart from nine arteries, thousands more are present flowing to various directions.

पुरुहूतानलयमनिऋतिवरुणपवनेन्दुशंकरा देवाः ।
विज्ञातव्याः क्रमशः प्राच्याद्यानां दिशां पतयः ।। VR.S.54.3 ।।

दिक्पतिराज्ञा च शिरा नवमी मध्ये महाशिरानाम्नी ।
एताभ्योन्याः शतशो विनिः सृता नामभिः पृथिताः ।। Vr.S.54.4 ।।

पातालाद्ध्वंशिरा शुभा चतुर्दिक्षु संस्थितता याश्च ।
कोणद्विगुत्था न शुभाः शिरानिमित्तान्यतो वक्ष्ये ।। Vr.S.54.5 ।।

Rock or soil cture and depth of water table from the surface of the earth is described correctly in various verses. Verse 7 describes the various symptoms of occurrence of water along with pervious and impervious strata.

चिन्हमपि वार्धपुरुषे मण्डूकः पाण्डुरोश मृत पीता ।
पृथ्भेदकश्च तस्मन् पाषाणो भवति तोयमधः ।। Vr.S.54.7 ।।

which means that on digging we will get yellow frog at a depth of half purusha (1 Purusha = height of man with erected hand = 7.5 feet) then yellow soil, then rock and then ample amount of water. Similarly many other verses describes some 70 odd field situations or ecological spectra from which it should be possible to deduce the presence of underground springs.

Actually the technique of under ground water exploration as described by Varahmihira depends upon a close observation of naturally occurring specific signs in the terrain, comprising the flora, fauna, rocks, soils and minerals, whose state and variation can be logically or empirically linked up with the presence of under ground springs in the vicinity.

One startling factor emphasized in detail by Varahamihira is the role of termite knolls as indicator of underground water.

Apart from the underground water exploration some of the verses of the chapter deal with topics such as digging of wells, their alignment with reference to the prevailing winds, dealing with hard refractory stony strata, sharpening and tempering of stone-breaking chisels and their heat treatment, treating with harbs of water with objectionable taste, smell, protection of banks with timbering and stoning and planting with trees, and

such other related matters. Some thirty-three verses deal with termite standing alone by themselves, or associated with vegetation, thirty with vegetational factors alone, and the remaining using other factors to help in exploration.

जम्बूवृक्षस्य प्राग्वल्मीको यदि भवेत समीपस्थः ।
तस्माद्दक्षिणपार्श्वे सलिलं पुरुषद्वये स्वादु ।। Vr.S.54.9 ।।

उत्तार्जुनस्य वृश्चो वल्मीको यदि ततोर्जुनाद्धस्तैः ।
त्रिभिरम्बु भवति पुरुषैस्त्रिभिरर्धसमन्वितैः पश्चात ।। Vr.S.54.12 ।।

"If there is a termite mound nearby to the east of a Jambu tree, plenty of sweet water, yielding for a longtime occures at a depth of two Purushas, at a distance of three hastas (cubit) to the south of the tree (54.9). Similarly an Arjuna tree with a termite mound to the north shows water at a depth of 3.5 Purushas at a distance of 3 hastas to the west".

The mound builder variety of the termites are responsible for the impressive soil structure called the 'Ant-hills' in lay terms, but termite - knolls - mounds - spires, or - prominences by the scientists, which are familiar features of most tropical and subtropical landscape, and the once that are of interest to us in the technique of exploration of underground springs. Without exception the water requirements of the insects are generally very high, and they need to protect themselves against fatal dessication by living and working within the climatically sealed environment of their nest or within earth-covered galleries. According to present level of research (Rao, etal.1971) the atmosphere within the nest has to be maintained practically saturation moisture level (99-100% relative humidity). It is a matter of common observation that whenever a termite nest or runway, is damaged, the insects immediately rush to the breach and repair it with wet soil brought up from within the nest. From an over-all consideration of the evidence it seems to be safe to conclude that, while normally the insects use every readily available source of water close to the ground surface, under conditions of severe climatic stress, they can and they probably do descend to

the water table, no matter how deep it may be. Hence a well-developed, active, persistent colony of mould-building termites can be taken as an indication of underground springs in the proximity.

In the dry regions of Katanga province (Congo-Krishasa), the great termitaries of the macrotermes are seen clearly aligned on the slopes right down to the ooze level. (Kumara-Krishna etal. "Biology of Termites" Vol.II, P.190). E.G.K. Rao (1979) observed the alignment of the termite knolls in the dry-jungle uplands of coastal Mysore as well as the Deccan Plateau area, and testified the verses of Vrhat Sanhita relating the same. Following verse of Vrahat Sanhita suggests that the Ancient Hindus were aware of this tendency of mould builders.

वल्मीकानां पङ्क्त्यां यद्येकोन्नमुच्छ्रितः शिरा तदधः ।। Vr.S.54.95 ।।

"If in a line of termite-moulds one is found to be raised up (Taller), water vein is to be found within it". Similarly, Verse 82 says that if a group of five termites are found in a place (desert region), and the middle one among them is found white, water should be declared in it at a depth of fifty five Purushas (i.e. 7.5' x 55 = 412.5 feet).

It is a matter of common observation that many times termitaries are met with in close association with trees; and it is quite common sight to see termite mounds inhabited by these insects completely covered over with grass or vegetation and very close observation is often necessary to detect the termitary. The ancient Hindus have exploited this association quite extensively in the exploration of underground springs, viz.

जम्बूस्त्रिवृता मौर्वी शिशुमारी सारिवा शिवा श्यामा ।
वीरुधयो वाराही ज्योतिष्मती गरुत्पवेगा च ।। Vr.S.54.87 ।।

सुकरिकमाषपर्णीव्याघपदारवेति यद्यहेर्निलये ।
वल्मीकादुत्तरतात्स्त्रीभिः करैस्त्रपुरुषे तोयम ।। Vr.S.54.88 ।।

"If Jambu, Trivrt, Maurva, Sisumari, Sariva, Siva, Syama, Varahi, Jyotismati, Garudavega, Sukarika, Masaparni, Vyaghra Pada trees and creepers are seen by a termite mound there is water 3 hastas to its north at a depth of 3 Purushas. The names of the flora mentioned are given below with their botanical names:

Jambu (Eugenia Jambos, Engenia Jamboiana), Trivrta (Ipomea turpethum), Maurvi (Sanservieraroxburgiana), Sisumari (?), Sariva (Hemidesmus indicus), Siva (Several Plants: Cucumis Utilissimus, Terminalia Chebula, Emblica officinalis, Cynodon dactylon), Syama (Ichnocarpus fructens - black creeper, Krsna Sariva, Datura metal, Agalaia rox-burgiana, Panicum coloncum etc.), Sukarika (Lyccopodium imbricatum, I.Clovatum), Masaparni (Glycine debitis, G.Labialis).

Likewise various other verses of the chapter are related to the underground water exploration with relation to combination of different symptoms.

अतृणे सतृणा यस्मिन सतृणे तृणवर्जिस्मिता महीयत्र ।
तस्मिन् शिरा प्रविष्टा वक्तव्यं वा धनं वास्यिन ।। VrS.54.52 ।।

i.e. if in a grass less place, there is a patch of grass or in a grassy place, there is a grassless place, water or treasure is indicated.

कण्टवयकण्टकानां व्यत्यासेम्भास्त्रिभिः करैः पश्चात् ।
खात्वा पुरुषत्रितयं त्रिभागयुक्तं धनं वा स्यात् ।। Vr.S.54.53 ।।

i.e. a flourishing thorny tree in the midst of non-thorny trees or vice-versa indicates water or treasure at a depth of 3 3/4 Purushas at a distance of 3 hastas to the west.

यस्यामूष्मा धात्र्यां धूमो वा तत्र वारि नरयुगले ।
निर्देष्टव्या च शिरा महता तोयप्रवाहेण ।। Vr.S.54.60 ।।

Where there is stream or smoke issuing from the ground, an

abundant water vein will be struck at a depth of 2 Purushes (54.60).

From the point of view of occurrence of sub-terranean water, Varahamihira has discussed the occurrence of underground water in the desert region. He says that sub-terreneon streams or water table in the desert region takes the shape of the neck of a camal and is at a great depth from the surface of the earth viz.

मरुदेशे भवति शिरा यथा तथातः परं प्रवक्ष्यामि ।
ग्रीवा करभापामिव भूतलसंस्थाः शिरा यान्ति ।। Vr.S.54.62 ।।

Geological strata scheme of the modern artesian well fully corroborates this. In the Verse 102 is described how water occurs in a mountaneous region.

विभीतको वा मध्यान्तिका वा यत्रास्ति तस्मिन पुरुषत्रयेभः ।
स्यात्पवर्तस्योपरि पर्वतोन्यस्तत्रापि मूले पुरुषत्रयेभः ।। Vr.S.54.102 ।।

सशर्करा ताम्रमही पयायं क्षारं धरित्री कपिला करोति ।
आपाण्डुरायां लवणं प्रविष्टं मृष्टं पयो नीलवसुन्धरायाम् ।। Vr.S.54.104 ।।

Above Verse (104) explains the relation of soil and water. It says that Pebbly and sandy soil of copper colour makes water astringent. Brown-coloured soil gives rise to alkaline water, yellowish soil makes water briny and in blue soil under ground water become pure and fresh.

In Ramayana (VI,22.37-38) we come across the knowledge of artesian wells. Verses say that the water from deep earth comes out by force continiously through the hole created by arrow of Lord Rama, viz.

निपातितः शरो यत्र वज्राशनिसमप्रभः ।। Ramayana,VI,22.36 ।।
तस्माद व्रणमुखात तोयमुत्पपात रसातलात ।। Ramayana,VI,22.37 ।।

स बभूत तदा कूपो व्रण इत्येव विश्रुतः ।
सततं वोत्थितं तोयं समुद्रस्येव दुरक्षं ।। Ramayana,VI,22.38 ।।

It clearly and very scientifically explains the artesian well flowing continiously with force.

The Vayu Purana also refers to the various underground structures and topography such as lakes, barren tracts, dales, rocky rift valley between mountains अन्तद्रोणी (38.36). The chapter 38 also speaks of a large number of hot springs in a mountaineous region.

तथा स्फुटत्व तप्तानि सरांसि द्विज सत्तमाः ।
शैलगुह्यन्तरस्थानि सप्तत्रापि शतानि च ।। Vayu.38.78 ।।

In Markandeya Purana we come across - Peculiar type of topography found "in the Kimpurusavarsa and seven other countries" when water bubbles up from the ground (55.21-22).

नवस्वपि च वर्षेषु सप्त सप्तकुलावताः ।
स्वैकस्मिन्मस्तथा देशे नद्यश्चाद्रि-विनिः सृताः ।। Markandeya.53.21 ।।

यानि किंपुरुषाद्यानि वर्षाण्यष्टौ द्विजोत्तम ।
तेषुस्विज्जानि तोयानि नैवं वार्षत्र भारते ।। Markandeya.53.22 ।।

the Gopathbrahmana was also acquainted with two types of springs or falls, namely hot and cold (II,8). शीतोष्णाविहोत्सौ .....

All above literature reveal some knowledge about groundwater, but as discussed above, chapter 54 of the Vrahat sanhita is the most important treatise on ground water exploration.

In Ancient days when the western knowledge about the occurence of ground water was based on the wild theories as they were believing that rainfall being inadequate in quantity can not be the source of ground water, the Indians had the scientific concepts of its occurence, distribution, prospecting and utilization. By means of hydrologic indicators such as physiographic features, termite mounds, geophysical characteristics, soils, flora, fauna, rocks and minerals etc. the presence of ground water was being detected, which is fully scientific and presence and variation of these indicators have

been linked up with the availability of underground springs in modern era. Termite mounds were used as an important indicator of ground water. Modern scientists have also established that the moisture within the mounds is kept practically at saturation level (99-100%) and presence of underground spring in proximity is indicated. Well before many centuries of christ Indians were aware of underground water bearing structures, change in the direction of flow of ground water, high and low water tables at different places, hot and cold springs, ground water utilization by means of wells, well construction methods and equipment, underground water quality and even the artesian well schemes. This high level of knowledge of ground water in those remote days was developed by indigeneous people of India altogether independently.

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 सातिमीमहे दिवो वा पार्थिवादधि ।
इन्द्र महोवार जसः ॥ RV.I,6.10 ॥

नव्यं तदुक्थ्यं 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.

समुद्रादूर्मिर्मधुमां उदारदुपांशुना सममृतत्वमानट् ।
घृतस्य नाम गुह्यं यदस्ति जिव्हा 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 अस्स्द्धनम् ।
छर्दे जिह्वायावधात् ।। R.V.VIII,72.4 ।।

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

देवो वनस्पतिर्देवमिन्द्रं वयाधसं देवो देवमवर्धयत ।। YV.,28.43 ।।
देवो देवैर्वनस्पति हिरण्ययर्णो मधुशाख: सुपिप्पलो देवमिन्द्रमवर्धयत् ।।
YV.,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 याभ्यां रजों युपितयन्तरिक्षे ।
ययोः प्रायं नान्वानशे कश्चन तौ नों मुञ्चतमंहसः ।। A.V.IV,25.2 ।।

अपः समुद्राद दिवमुद्वहन्ति दिवस्पृथिवीमभि ये सृजन्ति ।
ये अभिद्ईशानां मरुतश्चरान्ति ते नो मुञ्चन्तंहसः ।। AV.,IV,27.74 ।।

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

प्र यद्दित्था महिना नृभ्यो अस्त्यरं रोदसी कक्ष्ये नास्मै ।
सं विव्य इन्द्रो वृजनं न भूमा भर्ति स्वधावां ओपशमिव द्याम् ।।
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 परमस्यां पृथिव्यां मध्यमस्यामवमस्यामुत स्थः ।
अतः परि वृषणावा हि यातंमथा सोमस्य पिवतं सुतस्य ।।
RV.I,108.9-10 ।।

षड् भारों एको अचरन्विभर्त्यूर्तं पक्षिष्ठमुप गाव आगुः ।
तिस्रो महीरुपरास्तस्थुरत्यामुहा द्वे निर्हते दशैका ।। RV.III, 56.2 ।।

त्री षधस्था सिन्धवास्त्रिः कवीनामुत त्रिमाता विदथेषु सम्राट ।
ऋतावरीर्योषणास्तिस्त्रो अप्वास्त्रिरा दिवो विदथे पत्यमानाः ।।
RV,III,56.5 ।।

त्रिरन्तरिक्षं सविता महित्वना त्री रंजांसि परिभूस्त्रीणि रोचना ।
तिस्रो दिवः पृथिवीस्तिस्र इन्वति त्रिभिव्रतैरभि 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 firmanent 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 दिवो वृष्टमव रुन्धे मधुषा सं यौत्यापां वा एष ओषधीनां
रसो यन्मध्वभ्यस्य एवौषधीभ्यो वर्ष्मतयो उद्भय 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 धामच्छदे पुरोडाशमष्टाकपालं निर्वपेन्मारुतं सप्तकपालसौर्यमेककपालमग्निर्वा इतो वृष्ट मुदीरयति मरुतः सृष्टां नयन्ति यदा खलु वा असावादित्यो न्यड. रश्मिभिः पर्यावर्ततेथ वर्षति धामच्छदिवि खलु वै भूत्वा वर्षत्येता वै देवता वृष्ट्या ईशते ता एवं स्वेन भागधेयेनोप 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 strech 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 ।
मारुता इति विख्याता दित्यरूपा 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 करैर्मेघमिवांशुमान् || 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 insolational heating of the ocean water is also referred to in the Verse VII.25.30 of Ramayana.

दीप्तास्येनात्मनोद्भूतस्तप्ताम्भा इव सागरः ।
ततो ववौद 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 उद्वह (MB.XII,328.38-39).viz.

अम्बरे स्नेहमभ्येत्य विधुदभ्रयश्च महाद्युतिः ।
आवहो नाम संवाति तृतीयः श्वसनो नदन् ।। MB.XII,328.37 ।।

उद्यं ज्योतिषां शश्वत सोमादीनां करोति यः ।
अन्तर्देहेषु चोदानां यं वदन्ति मनीषिणः ।। MB.XII,328.38 ।।

यश्चतुर्थं समुद्रेभ्यो वायुर्धारयते जलम् ।
उद्धयावद्धो वापो जीभूतेभ्योम्बरे सितः ।। 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 सर्वदेहिनाम ।
सर्वौषाधिरसानां च पुनर्वर्षासु मुञ्चसि ।। MB.III.3.49 ।।

संदह्स्यैकार्णवं 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 aquinted 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 philospher 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 सप्तैवाऽर्ध्वतलाः क्षितौ ।
सप्त स्कन्धास्तथा वायोः सब्रह्मसदना 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 (Brahamand Vol.II, Chapt.9., Vayu.Chapt.51, Linga,I,41, Matsya,I,54) and a full-fledged seperate 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:

नावष्टभ्या परिविशमेत वारिणा दीप्यते रविः ।
तस्माद्यः पिबन्यो वै दीप्यते रविरंबरे || Brahmand,Vol.II,9.138 ||

तस्य ते रश्मयः सप्त पिबंत्यंभो महार्णवात ।
तेनाहारेण संदीप्ताः सूर्याः सप्त भवंत्युत ।।
Brahmand,Vol.II,9.139 ||

वर्षाधर्मो ह्यिं रात्रिः संध्या चैव दिनं तथा ।
शुभाशुभं प्रजानां च ध्रुवात्सर्व प्रवर्तते || Vayu 51.11 ||

ध्रुवेणाधिकृताश्चैव 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.

वैद्युतो जाठरः सौरावारिगर्भास्त्रियोनियः || (Linga I,41.11) ||

याश्चासौ तपने सूर्यः पिवन्नभो गभस्थिभिः ।
पार्थिवाग्निविभिश्रोसौ 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 गुह्य तिष्ठति ।
सर्वभूतशरीरिषु त्वापो ह्यानुश्चतारिचयाः || Matsya I, 54.29 ||

तेजोभिः सर्वलोकेभ्य आदत्ते रश्मिभिर्जलम || Matsya I, 54.31 ||

समुद्राद्धायुसंयोगात वहन्त्यापो गभस्तयः ।
ततस्त्वृतुवशात्कालेपरिवर्तन दिवाकरः || Matsya I, 54.321 ||

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 milleenium B.C.

In Prabhrta 4, Sutra 25 are d cussed 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 लेश्या 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 (परतीर्थिकानाम). Then it refers to another important fact, that unseen (invisible) objects also posses 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 verticle 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, lightening, 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.

CHAPTER 8

WATER QUALITY

The modern scientists at one time, used to consider rainwater as pure like distilled water. But later studies have revealed that it is not so. The water of precipitation is characteristically the purest water in the hydrological cycle, but even so it may collect from less than 1 to several hundred milligrams of dissolved material per litre of water during its fall through the atmosphere. Rainwater as it falls to the earth has ample opportunity to dissolve gases from the air and also may dissolve particles of dust or other air borne materials. Rain water becomes a mixed electrolyte containing varying amounts of major and minor cations and anions. Sodium, Potassium, Magnesium, Calcium, Chloride, Bicarbonate and Sulphate are the major constituents. Ammonia and various nitrogen compounds are generally present. Dust particles are added locally in industrial areas, large population centres and desert areas. Among the land based factors which may be significant in altering the composition of rainwater are the sulphur emitted by Volcanoes, Fumaroles, Springs, and Dust particles.

Rainwater close to the ocean commonly contains from 1.0 milligran per litre to several tens of milligrams per litre of chloride but the observed concentration generally decrease rapidly in a landward direction.

In Vedas we get some references to water quality, especially in Atharvaveda. Charaka Sanhita, Susruta Sanhita (both of pre or early Buddistic era), and Ashtanga Hrdaya Sanhita (9th century AD) are the repositories of knowledge accumulated on Ayurveda (Science of Life), during the earlier period dating back to the Vedic age. In all these ancient standard texts discources on water quality constitute an

important aspect of Ayurveda. Bhavamisra's Bhava Prakash (16th century AD), which is more or less a compilation of all the Ayurvedic texts of earlier antiquity, also elaborately deals with water quality.

In Rigveda the verse (V,83,4) says about the tree plantation, forest conservation and Yajna's so as to create pure & healthy environment and good quality of water for well being of mankind viz.

प्र वाता वन्ति पतयन्ति विद्युत उद्ओषधीर्जिहते पिन्वते स्वः ।
इरा विश्वस्मै भुवनाय जायते यत्पर्जन्यः पृथ्वीं रेतसावति ॥ RV,V,83,4 ॥

Likewise verse (VII,50,4) of Rigveda also reveals the importance of Yajna (यज्ञ) in relation to purification of water. In Yajurveda (I,12) we read the contamination of substances by combination and fire as the prime source of purification by breaking the substances into minute particles i.e. yanja, heat and sunrays are the agents to purify the water. viz.

पवित्रे स्थो वैष्णव्यौ सवितुर्वः प्रसव उत्पुनाम्यच्छिद्रेण पवित्रेण सूर्यस्य रश्मिभिः ।
देवीरापो अग्रेगुवो अग्रेपुवो व इममद्य यज्ञं नयताग्रे यज्ञपतिं सुधातुं यज्ञपतिं देवयुवम ॥
YV,I,12 ॥

In Samveda (Previous II,187) we read that the sun rays cause the rain to come in purest form like white curd viz.

इन्नमास्त इन्द्र पूरवो घृतं दुक्षत आशिरम ।
एनामृतस्य पिप्युषीं ॥ SV,P,II,187 ॥

A verse of Atharvaveda (V,22,5) directs to take preventive measures against the diseases caused by the areas with much grass, high rainfall and bad water quality viz.

ओकौ अस्य मूजवन्त ओकौ अस्य महावृषाः ।
यावज्जातस्तवमं स्तावानसि वनस्पितेषु न्योवरः ॥ AV,V,22,5 ॥

In the celebrated epic Mahabharata (XII,184,31 and 224,42) we read about the various qualities of water according to its taste

thus it is clear that atleast they were trying to specify the water quality according to its taste.

रसो बहुविधः प्रोक्त ऋषिभिः प्राधितात्मभिः ।
मधुरो लवणस्तिक्तः कषायोम्लः कटुस्तथा ॥ M.B.XII, 184.3 ॥

In the Vraht Sanhita we find many references to water quality in the 54th chapter named "Dakargala". Sloka 2 states that ground water should be investigated in relation to its environment: viz.

एकेन वर्णेन रसेन चाम्भश्च्युतं नभस्तो वसुधाविशेषात ।
नानारसत्वं बहुवर्णतां च गतं परीक्ष्यं क्षितितुल्यमेव ॥ Vr.s.54.2 ॥

Soil colour was described as an indicator of water quality viz.

सशर्करा ताम्रमही कषायं क्षारं धारित्री कपिला करोति ।
आपाण्डुरावां लवणं प्रदिष्टं मृष्टं पयो नीलवसुन्धरायाम ॥ Vr.s.54.104 ॥

"that Pebbly and sandy soil containing copper makes water astringent (कसैला). Brown-coloured soil gives rise to alkaline water, pale white soil salt water and blue coloured soil makes water pure & sweet".

A water treatment method was also suggested to improve the quality of drinking water. viz.

अञ्जनमुस्तोशीरैः शरराजकोशातकामलकचूर्णैः ।
कतकफलसमायुक्तैर्योगः कूपे प्रदातव्यः ॥ Vr.s.54.121 ॥

कलुषं कटुकं लवणं विरसं सलिलं यदि वाशुभगन्धि भवेत ।
तदनेन भवत्यमलं सुरसं सुसुगन्धि गुणैरपरैश्च युतम ॥ Vr.s.54.122 ॥

i.e. a mixture of Anjanam (collyrium, autimony or extract of ammonium), Musta tubers (Nagarmodha), Usira (Khas), Powder of Rajkosataka (Torayi), and Amalaka (आवला), combined with Kataka nuts should be put into a well. If the water is turbid, pungent, saltish, of bad taste and not of good odour will be

rendered clear, tasty, aromatic, and with other good qualities.

Thus Varahamihira at that time presented a simple method for obtaining potable water from a contaminated source of water. All above plant materils have medicinal value and are commonly available in almost all parts of India.

In ancient medical texts are such as Charaka sanhita, Susruta sanhita and Astangahrdaya sanhita (by Vagbhata) collectively known as Brahattrayi (Great triad), and three other ayurvedic texts Madhavanidanam, Sarangadhara Sanhita and Bhavaprakasha are collectively known as Laghutrayi (small triad) some references of water quality are available.

In Bhava Prakash many parts had been incorporated from the medical texts of Charaka, Susruta, Vagbhata, and the Tantrik texts. The tenth chapter of Bhava Prakash with 86 slokas named as Vari Vargah deals with different aspects of water. Here some aspects of water quality are presented as given in above text (10th chapter, Vari Vargah part) and also analysed by Prasad (1979).

Sloka 2 states the important properties of water and its usefulness for the living beings.

पानीयं श्रमनाशनं बलमरं मूर्छापिपासाहरं तन्द्राच्छर्दिविबन्धहृद्धनकरं निद्राहरं तर्पणम ॥ X.2 ॥

"Water eliminates the fatigue of the body and mind, destroyes weakness. It is good for heart, gives satisfaction, soft, clear, origin of rasas, and destroyer of vomiting, sleeping tendency, and constipation.

In Sloka 3 and 4 the classification and nomenclature of different forms of water have been given.

पानीयं मुनिभिः प्रोक्तं दिव्यं भौममिति द्विधा ॥ X.3 ॥

दिव्यं चतुर्विधं प्रोक्तं धाराजं करकाभवम ।
तौषारं च तथा हैमं तेषु धारं गुणाधिकम ॥ X.4 ॥

Water which rains from sky is called 'Divyam' and when it gets collected on the earth or as ground water it is termed as 'Bhaumam' by sages. 'Divyan' water is divided in four categories: 'Dharajalam' falls as continious shower from sky, 'Karakabhavam' when it falls like the pices of stones, 'Tausaram' is free from the smoke etc. and 'Haimam' is caused from the snow of Himalayas. Among these 'Dhavajalam' is better having full of qualities.

Similarly sloka 25 gives classification of Terrestrial water (Bhauma Jalam).

भौमयम्भौ निगदित्तं प्रथमं त्रिविधं बुधैः ।
जाङ्गलं परमानूपं ततः साधारणं क्रमात ।। X.25 ।।

"Bhaum Jalam is of three varieties viz. Jangalam, anupam, and Sudharanam. Above water divisions are based on the characteristics of the regions which are differentiated according to their environmental conditions.

अल्पोद कोल्पवृक्षश्च पित्तरक्तामयान्वितः ।
ज्ञातव्यो जाङ्गलो देशस्तत्रत्यं जांगलं जलम ।। X.26 ।।

बहम्बुर्बहुवृक्षश्च वातश्लेष्मामयान्वितः ।
देशोनूप इति ख्यात आनूपं तद्भवं जलम् ।। X.27 ।।

मिश्रचिन्हस्तु यो देशः सहि साधारणः स्मतः ।
तस्मिन्देशे यदुदकं तन्तु साधारणं स्मृतम ।। X.28 ।।

जाङ्गलं सलिलं रुक्षं लवणं लघु पित्तनुत ।
वन्हिकृत्कफहृत्पथ्यं विकारान हरते बहून् ।। X.29 ।।

आनूपं वार्वभिष्यन्दि स्वादु स्निग्धं घनं गुरु ।
साधारणं तु मधुरं दीपनं शीतलं लघु ।
तर्पणं रोचनं तृष्णादाह्दोषत्रयप्रणुत ।। X.31 ।।

The country having sparse trees and less water and having the bad effect of causing Pitta and Vata disorders are the Jangla region and water originated in this region is termed as Jangala

water. The region having plenty of water and abundent trees and able to cause Vata and Kapha diseases is called Anupam and its water as Anupam water. The regions having the mixed characteristics of above two types is called Sedharanam region, and its water is called Sadharana Jalam. Jangala water is saltish, soft, eliminates Pitta and Kapha, Promotes digestion, and a good diet in diseases. Anupa water is tasty, oily, viscus, hard, retards digestion, promotes Kapha and creator of other disorders. Sadharana Jalam is sweet, promotes digestion, soft, cool, pleasant and elimates Tridosa. Thus we see here that in study of water a large number of factors of ecology have been considered in line to the modern hydrology.

Standards for Water Quality:

In the chapter at various places we get the words such as विशदं (clear, clean, pure, pellucid, etc.), स्वच्छम् (clear), निर्दोष (blemishless), कलुषं (polluted), and निर्मलत्वं (unpolluted), frequently.

Slokas 78-81 describe the characteristics of thw contaminated waters, viz.

पिच्छिलं कृमिलं विलग्नं पर्णशैवालवल्कधीः ।
विवर्णं विरसं सान्द्रं दुर्गन्धं न हितं जलम ॥ X.78 ॥

कलुषं छन्नमम्भोजपर्णनीलितृणादिभिः ।
दुः स्पर्शनमसंस्पृष्टं सौरवान्ध्मरीचिभिः ॥ X.79 ॥

अनार्त्तवं वार्षिकं तु प्रथमं तच्च् भूमिगम ।
व्यापन्न् परिहर्त्तव्यं सर्वदोषप्रकोपणम ॥ X.80 ॥

तत्कुर्यात्स्नानपानाभ्यां तृष्णाध्मानविरज्वरान ।
कासामिनमांद्याभिष्यन्दकण्ड्वाण्डादिकं तथा ॥ X.81 ॥

"Waters which are of stiky nature, containing worms and spoilt by leaves and mud, of bad colour thick of bad smell, such waters are not good for health. Muddy and covered by lotus leaves,

grass etc. unillumined by sunlight or moonlight, lacking movement, caused by untimely rain or the first rain water which gets collected in the ground, such waters are the source of many disorders; thus they should be prohibited. Because the use of such waters for drinking and bathing purposes, cause तृषा, आध्मान, जीर्णज्वर, अगमान्द, कण्डु, गण्डा and so on. A critical study of other slokas also clearly reveal the approach of ancient Indians for water quality standard for different uses.

Variation in the quality of water with seasons as also from different sources has been explained in slokas 59-67.

हेमन्ते सारसं तोयं ताड़ागं वा स्तितं स्मृतम ।
हेमन्ते विस्तितं तोयं शिशिरेपि प्रशस्यते ।। X.59 ।।

वसन्तग्रीष्मयोः कौप वाप्यं वा निर्झरं जलम ।
नादेयं वारि नादेयं वसन्तग्रीष्मयोर्बुधैः विषवद्धनवृक्षाणां पत्राद्यैर्दूषितं यतः ।।
X.60 ।।

औदभिद वान्तरिक्षं वा कौपं वा प्रावषि स्मतम् ।
शस्तं शरदि नादेयं नीरमंशूद्भवं परम् ।। X.61 ।।

दिवा रविकरैर्जुष्टं निशि शीतकरांशुभिः ।
शेयमंशूद्भवं नाम स्निग्धं दोषत्रयापहम् ।। X.62 ।।

अनभिष्यन्दि निर्दोषमान्तरिक्षजलोपमम् ।
बल्यं रसायनं मेध्यं शीतं लघु सुधासमम् ।। X.63 ।।

शरदि स्वच्छमुदयाद्यास्त्यासितं स्तितम् ।। X.64 ।।

पौषे वारि सरोजातं माघे तन्तु तडागजम् ।
फाल्गुने कूपसंभूतं चैत्रे चौज्ज्यं स्तितं मतम् ।। X.65 ।।

भाद्रे कौपं पयः शस्तमाश्विने चौज्ज्यमेव च ।
कार्तिके मार्गशीर्षे च जलमात्रं प्रशस्यते ।। X.67 ।।

"Water belonging to ponds and tanks during the season हेमन्त (winter November - January) are good; during शिशिर (the coal season, January - March) also the same waters are superior. During वसन्त (Spring: March - May) and ग्रीष्म season (summer: May-July) the water

belonging to wells, stepped deep wells, and rocky springs are good. During वसन्त and ग्रीष्म seasons waters of rivers should not be used for drinking get during these seasons the river waters become contaminated with the leaves of poisonous trees etc. During rainy season aubhida water (ground water of artesian character) or Antariksha water (the atmospheric precipitation) are good. During शरद season waters of to rivers and waters, illuminated by the sun during day time and by the moon during nights are called amsudakam are good. Ansudak water is destroyer of the Tridosa, not causing abhisyanda and is free from bad qualities. It is equal to akasodakam, good for brain, soft and cool. During शरद season after the rise of star Agastya in the sky all waters become pure. Vriddha Susruta said that during the month of Pusya waters from lakes or ponds, during Magha waters from tanks, during Phalguna waters from wells, during Chaitra Chaunjya (velley stream water) water, during Vaisakha Nairjhara water etc. during the months of Jyestha the water of artesian character, Asadha the well water, and in Kartika and Margasira all kinds of waters are good".

Factors affecting water quality:

As seen from above slokas of Bhave Prakash we can identify some factors affecting the quality of water.

हेम जलम् i.e. glacial water भौम जलम् i.e. Ground Water, नाद्येय जलम् (River water), औदभिद जलम् (Ground water flowing with artesian character), निर्झर (Water falls water), तडाग जल (Pond Water), कौप जल (Wells Water), चौज्ज्य जल (i.e. Valley Stream Water, Sloka 65) and their qualities have been described in Bhave Prakasha with detail, indicating the knowledge of the effect of geographic condition on the quality of water. These conditions are related to the differences in the earth as अनूप, जांगल and साधारण regions as described before in slokas 26-27-28. The effect of agricultural soil on water quality (केदार जल, Sloka 57) is also described, viz.

केदार: क्षेत्रमुद्दिष्टं कैदारं तज्जलं स्मृतम् ।
कैदारं वायर्यभिष्यन्दि मधुरं गुरु दोषकृत ।। X.57 ।।

It also describes the effect of decaying vegetation on water quality. Also the effect of stagnation, lack of the penetration of sun light (due to depth) on water quality have been described (Slokas 78 to 81). Thus the modern hydrologic concepts related to water quality are fully satisfied in this Sanskrit work.

The knowledge of the hardness of water has been described in many slokas (7,19,21,24,29 and 43) quoting the properties of various waters according to origin.

धारनीरं त्रिदोषघ्नमनिर्देश्यकरं लघु ।
सौम्यं रसाक्तं बल्यं तर्पणं ह्लादि जीवनम ॥ X.7 ॥

करकाजं जलं रूक्षं विशदं गुरु च स्थिरम् ।
दारुणं शीतलं सान्द्रं पित्तहृत्कफवातकृत् ॥ X.19 ॥

Here सौम्यम् (Saumayam) means soft and रूक्षं (ruksam) or दारुणं (darunam) means hard water.

Diseases in relation to water have been described which is clear from the verses X.27-31, X.78-81 and some others. This discourse on water quality and related subjects is quite scientific and shows broad outlook of ancient Indians.

Water Treatment:

Sloka 5,6 suggest collection of water in golden, silver, copper and glass vessels or earthen pots, after filtrating from cloth. It reveals the attention paid to get clear water.

सौवर्णे राजते ताम्रे स्फटिके कावनिर्मिते ।
भाजने मृण्मये वापि स्थापितं धारणमुच्यते ॥ X.6 ॥

In sloka 82 we get that water treatment for drinking purpose should be done by heating or boiling and filtration, sloka 83 reveals the treatment by the aid of heated sand, stones etc.and use of aromatic materials viz.

निक्षिप्तं वापि पानीयं क्वथितं सूर्यतापितम् ।
सुवर्ण रजतं लोहं पाषाण सिकतामपि ॥ X.82 ॥

भृशं सन्ताप्य निर्वाप्य सप्तधा सार्धितं तथा ।
कर्पूरजाति पुन्नागपाटलादिसुवासितम् ॥ X.83 ॥

शुचि सांन्द्रपटस्त्रवि क्षुत्रजन्तुविवर्जितम् ।
स्वच्छं कनकमुक्ताद्यैः शुद्धं स्याद्दोषवर्जितम ॥ x.84 ॥

पर्णमूल विसग्रंथिमुक्ताकनकशैवलैः ।
गोमेदेन च वस्त्रेण कुर्याद्विशुप्रसादनम् ॥ x.85 ॥

"Contaminated water can be purified by boiling, by exposure to the sun's rays or by quenching with fire heated gold, silver, iron, stone or sand and flavouring it with the smell of Camphor, Jati (chameli; Jasminum grandiflorum), Punnaga (Nogkesar; Calophyllum inophyllum), Patala (Padhar; Cocsalpinia banducella) etc, and then filtration through clean cloth makes water free from small germs. Purifying it with gold, pearl, etc, also makes it free from pollution. Water should be made free from leaves, roots, stalks of lotus leaves, gold, pearls, cloth etc".

From above treatment procedure we gather that the positive effects of intense sunlight, heating, filtration, aeration, and addition of aromatic components is clearly revealed in above treatise. The bad effects of stagnation of water, contamination of water by leaves, algae etc, are also described. The treatment methods given need no costly inputs and no desirable qualities of water will be changed, which is a measure draw back of the modern chemical methods of water treatment.

From this chapter it can be concluded that the water quality in relation to taste, soil, rock, season, source etc, was known to ancient Indians. Water classification and viewing its quality in relation to environment satisfies the modern concept of ecology. Yajna as the medium of water purification by means of breaking it into small particles and the hydrological cycle as the main source of water purification by

evaporation, were realized. Water quality stadards, factors affecting water quality, effect of decaying materials on quality of water, lack of aeration in staynating and deep water bodies etc. were known which are in accordance to modern science. Water treatment methods using filtration, pots of different materials like earthen, silver, gold etc., quenching with hot stones, sun heating, aeration, addition of aeromatic compounds etc. were adopted. These methods are frequently used even now a days and are better than the chemical disinfectants as there will be no change in the desirable qualities and odours of the water.

CHAPTER 9

WATER USE AND CONSERVATION

No agriculture can proceed without assured timely supply of water required for the growth and survival of plantation. Water unifortunately cannot be produced by man, and one has to depend on the blessings of mother nature for the rains. However, what man can achieve is to effectively and efficiently make fullest use of this naturally and periodically available primary commodity for growth and well being of agriculture and life as well on the planet earth. The importance of effective and efficient use of this precious resource was realised in very ancient time. As we have seen that almost all ancient civilizations were confined to the areas of reliable water resources and thus came to be known as River Valley civilizations, revealing the importance of water for development from very ancient days.

Even during the time of Rigveda we get many references of water use by means of rivers, wells, ponds etc. for agriculture, domestic and other purposes. Verse I, 121.8 of Rigveda reveals the same fact viz.

अष्टा महोदिव आदो हरी इह धुम्नासाह्यभि योधान ऊतम् ।
हरिं यत्ते मन्दिनं दुक्षन्वृधे गोरभसमद्रिभिर्वाताप्यम् ।। RV.I,121.8 ।।

Similarly verses (I,23.18 and V,32.2) state that the agriculture can be progressed by use of water from wells, ponds etc. wisely and efficiently. The verse (VIII,3.10) of Rigveda says about the construction of artificial canals to irrigate desert areas also, which is possible only by efforts of skilled persons (engineer) viz.

येना समुद्रमसृजो महीरयस्तदिन्द्र वृष्णि ते शवः ।
सद्यः सो अस्य महिमा न सन्नशे यं क्षोणीरनुचक्रदे ।। RV.VIII,3.10 ।।

उतनों दिव्या इष उत सिन्धूरसर्विदा ।
अप द्वारे व वर्षथः ॥ RV.VIII,5.21 ॥

Verses (VIII,49.6;X,64.9) speak about the importance of water for irrigation. The water from wells, rivers, rain and from any other source on the earth should be wisely used as it is gift of nature for well being of all.

उद्रीव वज्रिन्नवतो न सिञ्चते ह्रदन्तिन्द्र धीतयः ॥ VIII,49.6 ॥

सरस्वती सरयुः सिन्धुरूर्मिभिर्म हो महीरवसा यन्तु वक्षणीः ।
देवीरापो मातरः सूदयित्नवो घृतवत्पयो मधुमन्नो अर्चत ॥ X,64.9 ॥

In the same line of Rigveda, Yajurveda also contains references directing the man to use rain and river water by means of wells, ponds, dams and distribute it to various places having need of water for agriculture and other purposes, viz.

नमः स्रुत्याय च पथ्याय च नमः काट्याय च नीप्याय च ।
नमः कुल्याय च सरस्याय च नमो नद्येाय च वैशन्ताय च ॥ YV,16.37 ॥

In Atharvaveda we have references of drough management through efficient use of available water resources and water conservation. It clearly says that the water of river, well etc. if used efficiently will reduce the intensity of drought viz.

आपो यद् वस्तपस्तेन तं प्रति तपत यो स्मान् द्वेष्टि यं वयं द्विष्मः ॥
AV,II,23.1 ॥

Verses (VI,100.2 and VII,11.1) explain that the learned men bring water to desert areas by means of well, pond, canals etc. (VI,100.2). It also stresses that the man should think about the drought, flood and like natural calamities in advance and take preventive measures accordingly, viz.

यद् वो देवा उपजीका आसिञ्चन धन्वन्युदकम् ।
तेन देव प्रसूतेनदं दूषयता विषम् ॥ VI,100.2 ॥

Verse (XII,1,3) explains that those who use rainwater wisely by means of river, well, canals etc. for the purposes of navigation, recreation, agriculture etc. prosper all the time. viz.

यस्था समुद्र उत सिन्धुरापो यस्यामन्न कृष्टयः संवभुवुः
यस्यामिदं जिन्वति प्राणदेजत सा नो भूमिः पूर्व पेयें दधातु ||
AV.XII,1.31 ||

शंत आपो हेमवतीः शमु ते सन्तु वर्ष्याः ।
शं ते सनिष्पद्य आपः शमु ते सन्तु वर्ष्याः || AV. 19,2.1 ||

"that one should take proper managerial action to use and conserve the water from mountains, wells, rivers and also rainwater for use in drinking, agriculture, industries etc." Similarly one verse (XX,77.8) directs the king to construct suitable canals across mountains to provide water for his subject for agriculture, industry etc. and to facilitate navigation between two areas. viz.

आपो यददि पुरुहूत दर्दराविर्भुवत सरमा पूर्व्यं ते ।
स ना नेता वाजमा दर्षि भूरिं गोमा रुजन्नङ्गिरोभिर्गृणान || AV.XX,77.8 ||

As can be easily expected, out of the agricultural necessity, the science of water management was given considerable importance during ancient india. During the time of Kautilya the agricultural planning was common so as to manage the rainfall excess or deficit. The celebrated author says in Arthasastra that "According to the rainfall (more or less) the superintendent of agriculture shall sow the seeds which require either more or less water". Kautilya also says (Arthasastra, Tras. by Samsastry, Book II, Chapt.1, Page.46) that "king should construct dams, reservoir etc. filled with water either perennial or drawn from some other source or he may provide with sites, roads, timber and other necessary things those who construct reservoir of their own accords. Kautilya further says that the king shall exercise his right ownership (स्वाम्यम्) with regard to fishing, ferrying and trading in vegetables in

reservoirs or lakes (सेतुषू). Thus it can be concluded that the versatile author touched almost all aspects of water management, including water pricing also as described below.

An organised water pricing system which is an important part of water management was developed during the time of Chanakya (3rd-4th century BC.) as evidenced by following lines of Arthasastra "those who cultivate irrigating by manual labour (स्तापवर्तिमाम्) shall pay 1/5 th of the produce as water rate (उदकाभागम); by carrying water on shoulders (स्कन्धापावर्तिमाम्) = (water lift worked by bullocks), 1/4th of the produce; by water lifts (स्त्रोतोयंत्रापवर्तिमाम्) 1/3rd of the produce; and by raising water from rivers, lakes, tanks and wells (नदिसरासततकाकुपदाहाटम्) 1/3rd or 1/4th of the produce (Arthasastra, Tras. by Samasastry, Book II, Chapt.XXIV, Page 131).

In Vrahat Sanhita we get few references regarding the orientation of ponds so as to store and conserve water efficiently, plantation types for bank protection and proper slucing to protect reservoir from any possible damage viz.

पाली प्रागपारायताम्बु सुचिरं धत्ते न याम्योत्तरा
कल्लोलैखदारमेति मस्ता सा प्रायशः प्रेरितैः ।
तां चेदिच्छति सारदारुभिरपां सम्पातमावारयेत
पाषाणदिभिरेव वा प्रतिचयं क्षुण्णं द्विपाश्वादिभिः ॥ Vr.s.54.118 ॥

i.e A pond laid east to west retains water for a long time while one from north to south is spoilt invariably by the waves raised by the winds. To render it stable the walls have to be lined with timber or with stone or the like and the adjoining soil strengthened by stamping and trampling of elephants, horses etc.

ककुभवटाम्रप्लक्षकदम्बैः सनिचुलजम्बूवेतसनीपैः ।
कुरबकतालाशोकमधूकैर्बकुलविमिश्रैश्चावृततीरम ॥ Vr.s.54.119 ॥

't the banks must be shaded by Kakubha, Vata, Amra,
'. Nicula, Jambu, Vetasa, Nipa, Kuravaka, Tala,
Bakula trees.

In next sloka it directs the construction of spillway viz.

द्वारं च नैर्वाह्यिकमेकदेशे कार्यं शिलासिञ्चतवारिमार्गम् ।
कोशास्थितं निर्विवरं कपाटं कृत्वा ततः पांशुभिरावपेत्तम् ॥
Vr.S.54.120 ॥

i.e. "An outlet for the water has to be made on a side with the passage being laid with stones. A panel without apertures has to be fixed in a frame and which is fastened to the earth with mud and clay". From this discourse we can realise that the water management was getting due importance in ancient India and even bank protection, spillway etc. and other minor aspects were given due consideration.

In ancient India much attention was paid to the proper location of artificial tanks. Various techniques were applied and equally different materials utilized for the construction of works. It appears that special works or treatise on science of hydrology must have existed in south India. The Porumamilla tank inscription of Bhaskara Bhavadura dated A.D. 1369 throws on abundant light on the elaborate system carried out in the method of construction of tanks and dams in the south India.

Characteristics of good tanks and reservoirs are described in ancient literature. According to the Sastra (Epigraphia Indica, Vol.XIV, PP.108, Quotes from Hemadri, Verses 37-38, Srinivasan T.M., 1970) the following are the 12 essentials of a good tank.

(i) A king endowed with righteousness, rich, happy and desirous of the permanent wealth & fame.

(ii) Brahmana learned in hydrology (Pathas-Sastra).

(iii) Ground adorned with hard clay.

(iv) A river conveying sweet water and three Yojanas distance from its source.

(v) The hill, parts of which are in contact with tank.

(vi) Between (these portions of the hill) a dam (built) of a compact-stone wall, not too long but firm.

(vii) Two extremes (Srimga) pointing away from fruit giving land (Phala-Sthira) outside.

(viii) The bed extensive and deep.

(ix) A quarry containing straight and long stones.

(x) The neighbouring fields, rich in fruit and level.

(xi) A water course (i.e. the sluice) having strong eddies on account of the portion of the mountain (adri-sthana).

(xii) A gang of men (skilled in the art of its construction).

With these 12 essentials an excellent tank is easily attainable on this earth. From these points on comparison with the modern, science of water management regarding construction of dams and reservoirs we will find that the technique in those days was just comparable to the modern sophisticated engineering, as far as general requirements are concerned.

Along with the 12 essentials six faults were also recognised which will reduce the usefullness of the reservoir and water conservation will become difficult. These faults (Dosas) are as follows:

(i) Water oozing from the dam.

(ii) Saline soil.

(iii) Situation at the boundary of two kingdoms.

(iv) Elevation (Kurma) in middle (of the tank) bed.

(v) Scanty supply of water and extensive stretch of land (to be irrigated), and

(vi) Scanty ground and excess of water. (Source: Epigraphia Indica, Vol.XIV, PP.108, Quotes from Hemadri, Verse 39, through Srinivasan T.M. (1970))

Water use by means of wells, ponds, tanks and canals was prevelent alongwith the efforts to supply water in deserts also. Organized water pricing system was prevelent and preventive measures against natural calamities such as floods, drought etc. was common. Construction methods and materials of dam and ponds, essential site and other requirements of good tanks, bank protection spillways etc. were paid sufficient attention. High level of development was achieved in the areas of proper location and orientation of tanks, lining of banks, evapotranspiration control, drought management etc.

The foregoing detailed account shows that ancient India was at a high plane of development in the field of engineering in irrigation and water conservation. This shows the keen interest the Hindu kings of India had taken in affording irrigational facilities for the increase of agricultural produce apart from the drinking water provided for the people. The ancient India was highly progressive in the area of water management. The absence of scientific instruments of those remote times compel the astonishment and admiration of the beholder.

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GLOSSARY OF TERMS

1. Albedo: The portion of the total incoming radiatin that is reflected back to space expressed as a ratio of the reflected to incoming radiation.

2. Alkalinity: A term used to represent the content of carbonates, biocarbonates, hydroxides and occasionally borates, silicates and phosphates in water expressed in ppm (part per million) or mg/lit of equivalent calcium carbonate.

3. Arid Zone: Region or climate lacking sufficient moisture for crop production without irrigation; upper annual limit of precipitation for cool region is 25 cm and for tropical region is 40-50 cm.

4. Artesian Well: A well penetrating an artesian aquifer. An artesian aquifer is overlain and underlain by a confining layer so that water in these aquifers occurs under pressure. Boring in this aquifer causes the water to rise due to its own pressure.

5. Atmosphere: The word atmosphere is taken to refer to the gaseous envelop of any heavenly body, and especially that of the earth.

6. Boulder: Largest unit in sedimentary rocks. soils etc. usually bigger than 10 cm in size.

7. Canal: Artificial water course used for irrigation or inland navigation.

8. Capillarity: The rise of soil water by adhesion and surface Tension forces as a continous film around soil particles and in the capillary spaces.

9. Caverns: Synonymous with cave, though sometimes it implise a cave of large dimensions. A cave is the under ground hollow space in the earth's crust which may be entered from the surface.

10. Climatology: It is a subdivision of meteorology which deals with the average or normal or collective state of the atmosphere over a given area within a specified period of time i.e. it studies the some total of all atmospheric influences, principally temperature, moisture, wind, pressure and evaporation.

11. Cloud: A mass of small water drops or ice crystals formed in the atmosphere due to condensation of water vapour at great height above the land.

12. Condensation: The physical process of transformation from the vapour to the liquid state.

13. Convection: A process of heat transfer within the atmosphere (or within a gas or fluid), which involves the movement of the medium itself.

14. Dales: Open river valleys.

15. Delta: Roughly triangular area of river - transported sediment at the river mouth deposited by decreasing velocity of water. The sediment is constituted mainly of sand, clay, remains of brackish water organisms, debris of plants and animals washed from land. Delta is formed on low lying coastlines.

16. Desert: Almost barren land having arid hot or cool climate, resulting in sparse vegetation. A desert may have a poor grass-land or scrub.

17. Drought: Lack of rainfall so great and long continued as to affect injuriously the plant and animal life of a place and to deplete water supplies both for domestic purposes and for the operation of power plants, especially in those regions where rainfall is generally sufficient for such purposes. The term has different cannotations in various parts of world e.g. In Bali a period of 6 days without rain is drought. In USA a drought is defined as a period of 21 days or more when the rainfall is 30% or less of the average for the time and place. In parts of Libya, droughts are recognised only after two years without rain.

18. Ecology: Science which deals with interrelations of organisms and their environment.

19. Environment: Sum total of all external conditions influencing the existence or development of an organism or a community.

20. Erosion: Wearing away of land surfaces or detachment and movement of soil, rock etc. by flowing water, wind, ice, gravity etc.

21. Evaporation: The process by which the water is changed from the liquid state to a gaseous state below the boiling point through the transfer of heat energy.

22. Evapotranspiration: Combined loss of moisture from soil by evaporation and from vegetation by transpiration from a given area in a specified time period.

23. Flood: The flow of water which causes submergence of land not usually covered with water, or an increase in the depth of water on land already partially submerged, through a temporary rise in river lake or sea levels.

24. Flood Plain: The low-lying land that borders a river and is subjected to periodic flooding. It is camposed of deposits of sediment (alluvium) of variable thickness laid down by the flood waters above the rock floor and is bounded by low bluffs.

25. Fog: Droplets of water suspended in the lower layers of the atmosphere resulting from the condensation of water vapour around nuclei of floating dust or smoke particles. A visibility of less than 1 Km is the internationally recognised definition of fog.

26. Frigid Zone: A general term for Arctic - Antarctic type climates or for areas where the surface is snow covered for a large part of the year and where the sub soil is permanently frozen.

27. Frost: A weather condition that occurs when the air temperature is at or below 0°C. Moisture on the surface of the ground and objects freezes to form an icy deposit.

28. Geomorphology: The study and interpretation of the origins and development of land forms on the earth's surface.

29. Glacier: A mass of ice that moves under the influence of gravity along a confined course away from its source area. It is formed by the accumulation and compaction of snow, which is transformed to firn and ultimately to glacier ice.

30. Gravel: A deposit of unconsolidated material ranging in size from 2 to 60 mm. The particles are usually water worn and hence rounded, and are derived from more than one type of rock.

31. Ground Water: Water that is contained in the soil and underlying rock. Ground Water may be derived from rain water that has percolated down or from water that was trapped within the rock during its formation.

32. Humidity: The amount of water vapour present in the atmosphere.

33. Hurricane: A wind that has a velocity in excess of 32.7 m per second. It is tropical cyclone occuring around the Caribbean Sea and Gulf of Mexico.

34. Hydrologic Cycle: The cyclic movement of water between the atmosphere, the land and the sea. Water is released into the atmosphere as water vapour through evapotranspiration. After condensation within the atmosphere to form clouds it returnes to the land and to its water bodies as precipitation. This water may runoff the land in rivers and streams into lakes and the oceans or move under ground as ground water. Water keeps on moving continously among above facets of hydrological cycle.

35. Hydrology: The studv of water on the earth, including its chemical and physical properties, occurrence, distribution, and circulation on the surface and below the ground surface.

36. Infiltration: The seepage of water into the soil. The maximum rate at which rainfall can be absorbed by a soil in a given condition is known as infiltration capacity.

37. Insolation: The radiant energy that reaches the surface of the earth from the sun.

38. Interception: The capture of drops of rain by the leaves, branches, and stems of plants. The interception of the rainfall by the vegetation cover prevents some of its from reaching the ground.

39. Ionosphere: The part of earth's atmosphere extending upwards above the stratopause from an altitude of about 60 km.

40. Meander: A pronounced curve or loop in the course of a river channel.

41. Meteorology: The scientific study of the atmosphere and the physical processes at work within it including presure wind, temperature, clouds, pressure etc.

42. Mist: A reduction of visibility within the lower atmosphere to 1-12 km caused by condensation producing water droplets within the lower layers of the atmosphere.

43. Monsoon: A large - scale seasonal reversal of winds presure and rainfall in the tropics. The largest and best developed monsoonal area in the world is South East-Asia.

44. Perennial river: Rivers flowing throughout the year are called perennial rivers.

45. Pervious Strata: A rock system through which water can pass freely as a result of joints, bedding planes, cracks and fissures in the rock.

46. Physiography: The study of the surface forms of a region. The word has changed its meaning over the years from covering the whole of physical geography including geomorphology.

47. Plateous: An extensive elevated area of relatively flat land. Widespread movements of the earth's crust may result in vertical warping, which produces plateous and rift valleys divided by faults.

48. Pore space: The amount of space between the mineral grains of rock, soil or sediment.

49. Precipitation: The particles of water or ice that form within clouds and fall towards the earth's surface.

50. Rain gauge: An instrument designed to measure rainfall . In its simplest form it consists of a funnel fitted into a collecting vessel. Any rain collected in the vessel over a set period of time is measured in a specially graduated measuring cylinder, an exercise that occurs twice daily at most meteorological stations.

51. Rain Shadow: An area of low rainfall in the lee of hills or mountain ranges.

52. Reservoir: A storage area for water usually a river valley that has been dammed to retain water for one or more purposes, such as irrigation, industrial use, water supply , hydro-electric power or recreation.

53. Rills: Erosion of the soil surface by shallow short lived channels .These small channels are called rills.

54. Saline soil: A group of intrazonal soils that contain high concentrations of salts such as common salt. They often occur in semiarid and arid areas where there is strong evaporation.

55. Semi Arid: The climate of the areas between desert and tropical grassland. The mean annual rainfall ranges between 100 mm to 300 mm.

56. Sluice: Channel or conduit to drain off surplus water at high velocity or for passing debris. Also to allow a water flow at high velocity for ejecting debris.

57. Snow: A form of precipitation consisting of crystals of ice. It is produced when condenstation takes place at a temperature below freezing point.

58. Spillway: An open or closed passage cut in soil or rock. When a dam is full, any further incoming water flows over or through the spillway without any damage to the structure.

59. Stratosphere: The layer of the atmosphere that lies between the tropopause, at an average altitude of about 8 km, and the stratopause, at about 50 km.

60. Temperate Region: The division of the world based on temperature lying between the Torrid and frigid zones, and meaning an area where there are no extremes of temperature.

61. Termite mound: The nest made from mud or plant debris, that houses a colony of termites (Tropical type of ant).

62. Topography: The surface features (i.e. land forms) of an area of land or sea bed.

63. Tornado: A violently rotating storm in which winds whirl around a small area of extremely low pressure.

64. Torrid: One of the three divisions of the world based on temperature . It is the zone lying between the tropics.

65. Troposphere: The lowest layer of the earth's atmosphere.

66. Turbudity: The muddiness of water resulting from suspended sediment.

67. Turbulence: An irregular disturbed flow of fluid (e.g. water, air).

68. Water falls: A steep cliff like section of a river channel down which water falls vertically.

69. Water lift : Any mechanism (generally lever principle) to raise the water from a source of lower datum, to obtain water for useful purposes.

70. Water oozing: Water seeping out of the ground and wetting it without perceptible flow.

71. Water Table: The upper surface of the zone of saturated rocks i.e. rocks in which all voids are filled with water.

72. Water Treatment: Any method used to obtain potable water from a contaminated source of water.

73. Water uptake: Water ascend upward through the capillarity of soil and root system of plants. The utilisation of water by plants is termed as water uptake.

74. Water Veins: The underground structures through which the water moves through the soil. These are passages formed by the interconnections of pore spaces of soil. In ancient Indian literature these have been said to be resembling the veins in the human body.

ERRATA

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8	18	5	Bottom	आ ते तन्वन्त	आ ते तन्वन्ति
9	20	4	Top	वपन्त, यन्त	वपन्ति, यान्ति
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11	21	18	Top	वृष्टमव	वृष्टिमव
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24	34	7	Bottom	scas	seas
25	35	11	Top	सन्नपात:	सन्निपात:
26	46	12	Bottom	state	states

Sr.No.	Page	Line No.	From	Existing	To be read as
27	49	6	Top	vertebratess	vertebrates
28	50	4	Top	Zig-Zap	Zig-Zag
29	53	2	Top	leveiel	level
30	53	9	Top	throughs	troughs
31	58	2	Bottom	harbs	herbs
32	65	3	Top	get	gets
33	65	3	Bottom	get	gets
34	68	13	Bottom	पुवक	पुत्रक
35	69	11	Top	संवा, तीय:	संवाति, द्वितीय:
36	70	2	Bottom	नावष्ट्या	नावृष्ट्या
37	71	6	Top	ध्रुवेणा	ध्रुवेणाधिकृतांश्चैव
38	72	11	Top	d cussed	discussed
39	76	5	Bottom	autimony	antimony
40	78	7	Top	Dhavajalam	Dharajalam
41	78	14	Top	Sudharanam	Sadharanam
42	78	10	Bottom	स्मत:	स्मृत:
43	81	3	Top	get	because
44	81	7	Top	to	-
45	85	3	Top	unifortunately	unfortunately
46	92	7	Top	Pub-lished	Published
47	93	8	Top	thnan	than
48	93	11	Bottom	Bhasye	Bhasya
49	93	3	Bottom	3rd, 4th	3rd-4th
50	94	8	Bottom	24th above	20th above

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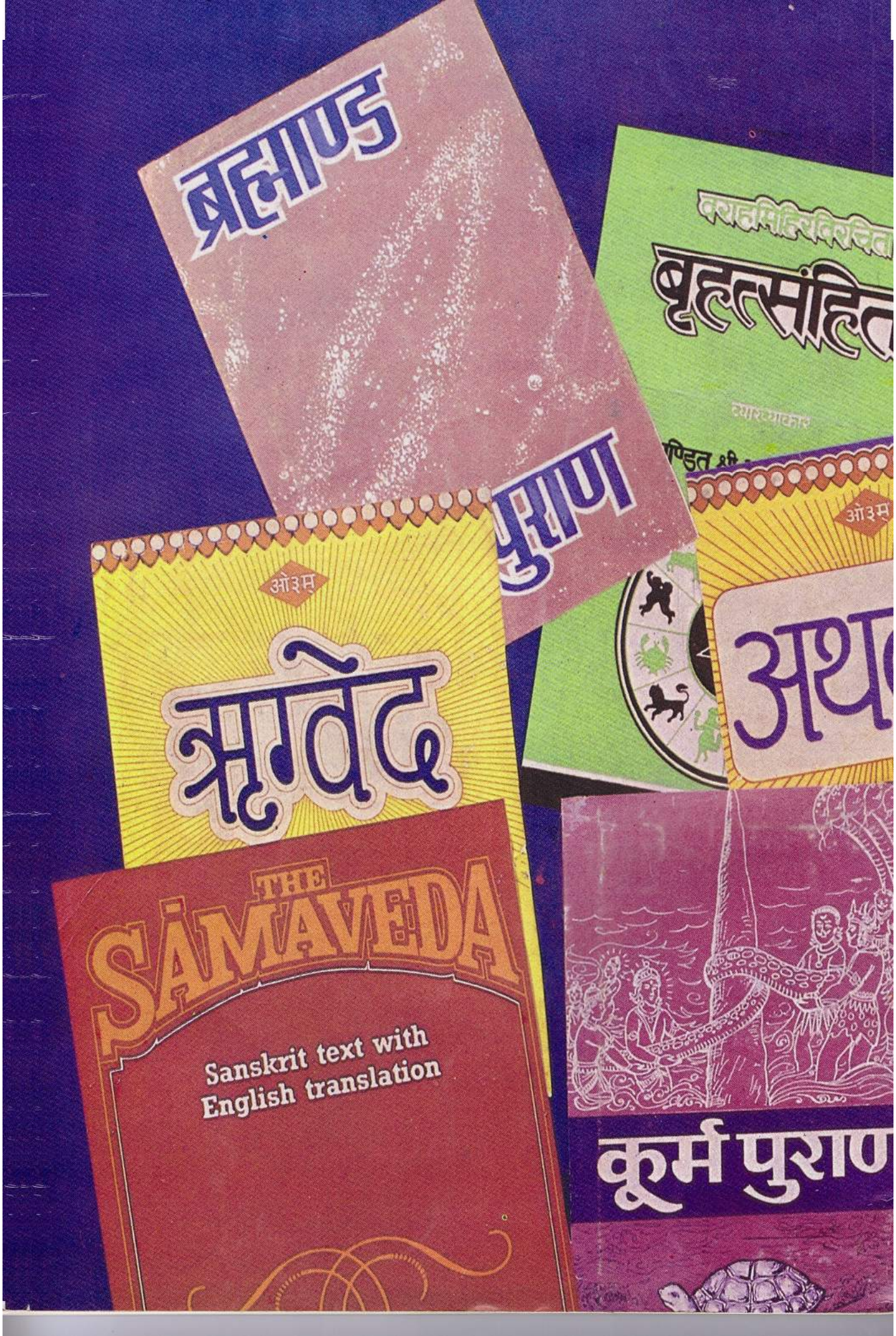
ब्रह्माण्ड
बृहत्संहित
ओ३म्
ऋग्वेद
अथ
THE SAMAVEDA
Sanskrit text with
English translation
कूर्म पुराण