

Science improves our knowledge of the nature and living beings. It helps the humans to investigate the several unknowns of the universe and generates solutions for practical problems. In fact, science has several functions, including the attempt to improve the quality of the human life. In ancient days, although science was unknown as such, yet man had realized the importance of water for survival, and therefore, the earliest civilizations were distinctly and predominantly hydraulic in character as they owed 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. Prominent among these were the Nile valley civilization in Egypt, the Tigris valley civilizations in Mesopotamia, the Howang-Ho valley civilization in China and the Indus valley civilization in India. Most of these civilizations existed from 3500 to 300 BC and there are historical evidences to show that certain engineering measures were adopted by them to sustain as well as enhance benefits from rivers and also to protect against damages due to floods and droughts.

Humankind established permanent settlements about 10,000 years ago when people adopted an agrarian way of life. Due to settled and somewhat secured life, population began to expand faster than ever before. Settled agricultural life made it possible to construct villages, cities and eventually states, all of which were highly dependent on water (Vuorinen et al., 2007). This created a unique relationship between humans and water. Most of the ancient civilizations, i.e., Indus valley, Egyptian, Mesopotamian and Chinese were developed at places where water required for agricultural and human needs was readily available, i.e., close to springs, lakes, rivers and at low sea levels (Yannopoulos et al., 2015). Most ancient civilizations were highly developed and technologically equipped for societal sustainability as well as to enhance benefits from rivers and also to protect against damaging floods and other hydrological extremes. Water transport over long distances was based on gravity. Thus, long aqueduct systems (indeed, sometimes exceeding 100 km) were used to convey water over large distances, using gravity. Also, water cisterns for harvesting rainwater, canals and ground water wells were practiced since the Bronze Age (ca. 3200–1100 BC). However, 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. Scarborough et al. (2003) and Ortloff et al. (2009) have reviewed how water management affected ancient social structures and organization through typical examples in the Eastern and Western hemispheres, covering the whole ancient world.

It is well known that in the realm of spiritual values, the Indian heritage has been 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 translation of the renowned texts of Vedas and Upanishads in English and German. Besides the spiritual growth, ancient India also exhibited the growth of science. The Indus Valley civilization, one of the earliest and most developed civilizations of that time, was the world's largest in extent and epitomises the level of development of science and societies in proto-historic Indian sub-continent. Ancient Indian literature, dating back from the age of the Vedas, further witnesses this development of sciences (including the water science). It is a good fortune that the ancient Indian Sanskrit works have been preserved and not lost through centuries of domination by alien races and alien cultures in India.

### **Science 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 appropriate concepts into useful and acceptable truths. Observation as a medium of realizing 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 find in nature. It progressively affects man’s life.

In India, at the beginning of the third/fourth millennium B.C., a highly developed civilization, popularly known as the Indus Valley civilization or Harappan Civilization (a Bronze Age civilization) grew in parts of Pakistan and northwest India, on the fertile plains of the Indus River. The Harappan civilization was mainly located in present-day Indian states of Gujarat, Haryana,

Punjab, Rajasthan, Uttar Pradesh, Jammu and Kashmir; and present-day Pakistan provinces of Sindh, Punjab, and Balochistan. It was located mainly in the region of the Indus and Ghaggar-Hakra Rivers. The major urban centres were at Harappa, Mohenjo-daro, Dholavira, Ganeriwala and Rakhigarhi.

The people of the Indus Civilization made great scientific advancements. They achieved great accuracy in measuring length, mass, and time. These people were among the first to develop a system of uniform weights and measures. Preparation of the Vedic calendar for various ceremonies and of rituals necessitated the study of heavenly bodies and of their movements. This led to the advancement of the astronomical Science (Prasad, 1980). The fact that sun light constitutes seven colour rays was known to Vedic Aryans, as evident from the following shloka of the Rig Veda (RV.II,12.12),

यःसप्तरश्मिवृषभस्तुविष्मानवासृजत्सर्वेसप्तसिन्धून् ।

योरोहिणमस्फुरद्वज्रवाहुर्घामारोहन्तं स जनासइन्द्रः । (RV.II,12.12)

*Meaning:* the sun containing 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 (476–550 CE), a great mathematician and astronomer, studied the summation of arithmetic series and attempted to solve quadratic indeterminate equations. Brahmagupta, the great mathematician of 7<sup>th</sup> century, developed application of explicitly general algebraic methods to astronomical problems. The beginning of the medical sciences goes 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 surgeons and physicians. During the Buddhist period, renowned scholar Jivaka was famous for his amazing medical and surgical cures. Medicine was also an important and compulsory subject in the ancient universities of Taksasila, Nalanda and Vikramasila. 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 by 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 pioneering contributions from India, China and Arabian countries, well up to the 12<sup>th</sup> century A.D.

Domination of the foreign rulers for a long time did not help in bringing the scientific content of the Sanskrit and other 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 focus the problems of scientific nature available in the Sanskrit works. They got entangled themselves in problems such as 'Vyakarana', Mimansa' etc. Hence, even to date, the scientific contents of the ancient works have remained almost wholly unknown and unanalyzed.

### **Significance of Water in Indian Traditions**

Since ancient times India is known as the land of culture and spiritualism. Water has always had a pervasive influence on the cultural and the religious life of Indian people. The Great Bath of Mohenjo-Daro is a great testimony to this fact (Fig. 1.1). The bath is considered by scholars as the "earliest public water tank of the ancient world". Although, the exact significance of the structure is unknown, most scholars agree that this tank was used for special religious functions.



Fig. 1.1: The Great Bath of Mohenjo-Daro (Source: Wikipedia)

Drier climates and water scarcity in India led to numerous innovations in water management. Since Indus valley civilization. Irrigation systems, different types of wells, water storage systems and low cost and sustainable water harvesting techniques were developed throughout the region. The reservoir built in 3000 BC at Girnar and the ancient step-wells in Western India are examples of some of the skills. Technologies based on water were also prevalent in ancient India. Reference to the manually operated cooling device “Variyantra” (revolving water spray for cooling the air) is given in the centuries old writing “Arthashastra” of Kautilya (400 BC). The “Arthashastra” and “Astadhyayi” of Panini (700 BC) give reference to rain gauges (Nair, 2004).



Fig. 1.2: Sophisticated Water Reservoir at Dholavira, evidence for hydraulic sewage systems in the ancient Indus Valley Civilization (Source: Wikipedia).

In the Vedic and other Indian traditions, all natural forces including planets and rivers are personified as gods and goddess and worshipped. Early Indian culture originated near river regions. As a matter of fact, the very name of the country is derived from the name of river Indus. The seven rivers namely Ganga, Yamuna, Saraswati, Narmada, Godavari, Krishna and Kaveri are considered important on cultural basis. For example, the Holy River Ganges is mythologically linked to Lord Shiva and is considered by the Hindus as the symbol for purification of the soul and rejuvenation of the mind. All over India people throng for a dip in the holy river to wash away their sins. Divine water is consumed in the temple after puja worship rituals; idols of worship are sprinkled with water (abhishekam); and a plantain leaf kept for a meal is cleaned with water and a prayer. Table 1.1 presents some of the important shlokas in the Sanskrit which are invoked while offering prayers to water as God.

Table 1.1: Some selected shlokas (prayers) invoking water as God

SHLOKA	MEANING
<p>आपो हिष्ठा मयोभुवस्था न ऊर्जे दधातन । महे रणाथ चक्षसे ॥१॥</p>	<p>हे जल ! आपकी उपस्थिति से वायुमंडल बहुत तरोताज़ा है और हमें उत्साह और शक्ति प्रदान करता है। आपका शुद्ध सार हमें प्रसन्न करता है इसके लिए हम आपको आदर देते हैं ।</p> <p>O Water, because of your presence, the atmosphere is so refreshing, and imparts us with vigour and strength. We revere you who gladdens us by your pure essence.</p>
<p>यो वः शिवतमो रसस्तस्य भाजयतेह नः । उशतीरिव मातरः ॥२॥</p>	<p>हे जल ! आप अपना यह शुभ सार कृपया हमारे साथ साझा करें जिसप्रकार एक मां की इच्छा होती है की वह अपने बच्चों को सर्वश्रेष्ठतम प्रदान करे ।</p> <p>O Water, this auspicious sap of yours, please share with us, like a mother desiring (to share her best possession with her children).</p>
<p>तस्मा अरं गमाम वो यस्य क्षयाय जिन्वथ । आपो जनयथा च नः ॥३॥</p>	<p>हे जल ! जब आपका उत्साही सार किसी दुखी प्राणी को प्राप्त होता है तो वह उसे जीवंत कर देता है । हेजल ! इसलिएआपहमारेजीवनदाताहैं।</p> <p>O Water, when your invigorating essence goes to one affected by weakness, it enlivens him, O Water, you are the source of our lives.</p>
<p>शं नो देवीरभिष्टय आपो भवन्तु पीतये । शं योरभि स्रवन्तु नः ॥४॥</p>	<p>हे जल ! जब हम आपका सेवन करते है तो उसमे शुभ दिव्यता होने की कामना करते हैं । जो शुभकामनाएँ आपमें विद्यमान हैं , उसकाहमारे अंदर संचरण हो।</p> <p>O Water, may the auspicious divinity which is wished for, be present in you when we drink (water). May the auspiciousness which supports you, flow to us.</p>
<p>ईशाना वार्याणां क्षयन्तीश्वर्षणीनाम् । अपो याचामि भेषजम् ॥५॥</p>	<p>हे जल आपकी दिव्यता कृषि भूमियों में भी संचरित हो ! हे जल, मेरा आग्रह है कि आप फसलों का समुचित पोषण करें।</p> <p>O Water, may the divinity in Water dwell in the farm lands. O Water, I implore you to give nutrition (to the crops).</p>

<p>अप्सु मे सोमो अब्रवीदन्तर्विश्वानि भेषजा । अग्नि च विश्वशंभुवम् ॥६॥</p>	<p>हे जल , सोमा ने मुझे बताया कि जल में दुनिया की सभी औषधीय जड़ी बूटीयाँ और अग्नि जो दुनिया को सुख समृद्धिप्रदान करती है भी मौजूद है।</p> <p>O Water, soma told me that in water is present all medicinal herbs of the world, and also agni (fire) who brings auspiciousness to the world.</p>
<p>आपः पृणीत भेषजं वरूथं तन्वेऽ मम । ज्योक्च सूर्यं दृशे ॥७॥</p>	<p>हे जल, आपमें औषधीय जड़ी बूटीयाँ प्रचुर मात्रा में समायी हुई हैं; कृपया मेरे शरीर की रक्षा करें, ताकि मैं सूर्य को लंबे समय तक देख सकूँ (अर्थात् मैं लंबे समय तक जीवित रह सकूँ।</p> <p>O Water, you are abundantly filled with Medicinal Herbs; Please protect my body, so that I can see the sun for long (i.e. I live long).</p>
<p>इदमापः प्र वहत यत्किं च दुरितं मयि । यद्वाहमभिदुद्रोह यद्वा शेष उतानृतम् ॥८॥</p>	<p>हे जल, मुझमें जो भी दुष्ट प्रवृत्तियों हैं, कृपया उन्हें दूर करें और मेरे मस्तिष्क में विद्यमान समस्त विकारों को दूर करें और मेरे अंतर्मन में जो भी बुराइयाँ हैं उन्हें दूर करें।</p> <p>O water, please wash away whatever wicked tendencies are in me, and also wash away the treacheries burning me from within, and any falsehood present in my mind.</p>
<p>आपो अद्यान्वचारिषं रसेन समगस्महि । पयस्वानग्न आ गहि तं मा सं सृज वर्चसा ॥९॥</p>	<p>हे जल, आप जो उत्साही सार से भरे हुए हैं मैं आपकी शरण में आया हूँ   मैं आप में गहराई से सम्महित हूँ .अर्थात् स्नान कर. से घिरा हुआ है .अग्नि सिद्धांत. जो अग्नि. मुझमें चमक पैदा करे।</p> <p>O Water, today, to you who is pervaded by fine rasa (invigorating sap) I came, I deeply enter (i.e. bathe) in you who is pervaded by agni (fire principle); may that agni produce lustre in me.</p>

### Hydrologic Knowledge in Ancient India

The historical development of hydro-science has 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), for example, describing the history of hydrology, has referred to the works of Homer, Thales, Plato, Aristotle in Greece, Pliny in Rome and many Biblical scholars of that time but has not made any reference to any



Indian scholars and literature, and their great contributions. Most of these western scholars believed in the wild theories regarding origin of water. Thales, an Ionian philosopher, mathematician and astronomer for example, stated that the sea water driven into rocks by wind is the cause of ground water. Plato (427-347 B.C.), the great Athenian philosopher, stated that the water of seas, rivers, springs etc. come from a large underground reservoir and goes 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 philosopher Lucius Annacus Seneca (4 B.C.) declared that rainfall cannot be the source of springs and underground water, because it penetrates only a few feet into the earth (Prasad, 1980). Marcus Vitruvius who lived about the time of Christ conceived a theory saying that ground water is part of rainfall originated through infiltration. All these theories of the western scholars indicate a low level of development of hydroscience in the western world during ancient times. On the other hand, contemporary Indian scholars appear to have developed an advanced level of knowledge about the various aspects of water science, as reflected in the ancient Indian literature which contains very valuable and important scientific discourses on hydrology and their practical applications. There are adequate archaeological evidences to testify that the Harappans of the Indus Valley were well aware of the seasonal rainfall and flooding of the river Indus during the period between 2500 and 1700 B.C., which is corroborated by modern meteorological investigations (Srinivasan, 1975). The Vedic texts, which were composed probably between 1500 and 1200 BC (1700–1100 BC according to some scholars), contain valuable references to ‘hydrological cycle’. The important concepts of hydrology are scattered in the Vedas in various verses, in the form of hymns and prayers addressed to various deities. Likewise, other Sanskrit literature also contains valuable knowledge related to the science of hydrology.

The origin and evolution of agriculture and experience in irrigation on the territory of India or anywhere in the world are not separate processes, as evidenced from following hymns of the Yajur Veda:

कृषिश्चमे यज्ञेनकल्पंताम ।

वृष्टश्चमे यज्ञेनकल्पंताम ॥ यजुर्वेद, 18–9 ॥

मारुतश्चमे यज्ञेनकल्पंताम ॥ यजुर्वेद, 18–17 ॥

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

That water is not lost in the various processes of the hydrological cycle namely evaporation, condensation, rainfall, streamflow etc., but gets converted from one form to other was known during Vedic and later 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. along with the prediction of rainfall quantity in advance by means of observing the natural phenomena of previous years are also available in Puranas, Vrhat Samhita (550 A.D.), Meghamala (900 A.D.) and in other literature. The references to rain gauges 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 predicated by Kautilya. Indians were acquainted with cyclonic, orographic effects on rainfall and radiation, and convectional heating of earth and evapotranspiration. Various other aspects such as infiltration, interception, stream flow and geomorphology, erosive action of rainfall, etc. were also known. In Ramayana (200 B.C.) the reference to artesian wells is available. Ground water development and water quality consideration were also getting sufficient attention in ancient India is evident from the Vrhat Samhita (550 A.D.).

References to water management and conservation, well organized water pricing system around 400 B.C., construction methods and materials of dam, tanks etc., bank protection, spillways etc. in the ancient Sanskrit literature reflect the high stage of development of water resources and hydrology in ancient India. Numerous references exist in Vedic literature, Arthashastra, Puranic sources, VrhatSanhita, Mayuracitraka, Meghmala, Jain, Buddhist and other ancient Indian literature which illustrate the status of hydrology and water resources in ancient India. The various elements of hydrology and water resources as they are discussed in an inferred from the various ancient Indian literature and also discussed by some of the authors such a Tripathi (1969), Prasad (1980), Prasad (1987), and others have been reviewed, analyzed and presented in this volume.

The various aspects of knowledge hydrology and water resources in ancient India have been discussed and presented in this report under the following chapters:

1. Introduction
2. Hydrologic Cycle
3. Cloud Formation, Precipitation, and its Measurement
4. Interception, Infiltration and Evapotranspiration,
5. Geomorphology and Surface Water

6. Ground Water
7. Water Quality and Waste Water Management
8. Water Resources Utilization, Conservation and Management
9. Concluding Remarks

