

Water Storage and Supply System in Ancient India

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Abstract

Evidence from historical water history provides perception into the hydrological knowledge generated by means of Indians extra than 3000 years ago. This paper explores many aspects of ancient Indian information on hydrology and water assets with a focus on hydrological processes, dimension of precipitation, water control and generation, and wastewater management, which can be based on opinions of the Indian scriptures, including the Vedas, Arthashastra (Shamasastri, 1961), Astadhyayi (Jigyasu, 1979), Ramayana (Goswami, 1973), Mahabharata; Puranas, Brihat Samhita (Jha, 1988), Meghamala, Mayurchitraka; Jainist and Buddhist texts; and different historic texts. In this overview, we gift a glimpse of the expertise that existed in historical India in water sciences via exploring many disciplines which includes records, archeology, hydrology, hydraulic engineering, history of generation, and records of way of life.1-3.

Keywords: Ancient, Water, Management, Indus Valley, Vedic Period, Mauryan dynasty, Epic Era, Jainism and Buddhist Period.

INTRODUCTION

Water is one of the most critical components in nature and daily lifestyles, and the look at of this very commonplace substance is a subject of many one-of-a-kind disciplines. The majority of modern water studies are involved with troubles of water control, which includes water excellent and amount, the wide schedule of human organizations, and institutions of water distribution and sanitation. Most of the ancient civilizations, i.e, the Indus Valley, Egyptian, Mesopotamian, and Chinese, evolved at places in which water required for agricultural and human needs became with no trouble to be had, i.e., in the location of springs, lakes, rivers, and seas (Yannopoulos et al., 2015). As the water turned into the top mover of the historical civilizations, a clear expertise of the hydrologic cycle, nature, and patterns of its diverse additives at the side of water uses for unique functions led those civilizations to flourish for thousands of years⁴.

Indus Valley civilization

Indus Valley civilization (~3000–1500 BCE), one of the earliest and most superior civilizations of ancient instances, become additionally the sector's biggest in spatial extent and epitomizes the extent of improvement of technological know-how and society inside the protohistoric Indian subcontinent. The Harappan civilization did not have the “single kingdom” idea as become practiced with the aid of the opposite modern-day civilizations inclusive of the Mesopotamian civilization, pointing to evidence of centralized control of palaces and temples and differentiated burials (Kenoyer, 1994; Possehl, 1998, 2003)⁵. The Harappan society turned into based totally on shared standards of electricity; dominance and styles of army conquests have not been found in this society (Kenoyer, 2003). However, extra facts will be found out to the sector once the linguists decipher the Harappan script inscribed on the seals, amulets, and pottery vessels (Kenoyer, 2003)⁶. Jansen (1989) states that the citizens of the Harappan civilization have been recognised for his or her obsession with water; they prayed to the rivers each day and accorded the rivers a divine popularity. The urban facilities had been evolved with modern-day civil and architectural designs with provisions for sophisticated drainage and wastewater control structures. It is interesting to notice on this context that the water and wastewater control structures had been relatively amenable to the socio-cultural and socioeconomic situations and religious approaches of societies thru every age of civilizations (Sorcinelli, 1998; Wolfe, 1999; De Feo and Napoli, 2007; Lofrano and Brown, 2010)⁷.

Agriculture changed into the principal monetary hobby of the Harappan society and an extensive network of reservoirs, wells, and canals in addition to low-price water-harvesting techniques evolved in the course of the area at that point (Nair, 2004). Mohenjo-Daro and Dholavira, the two primary cities of the Indus Valley, are great examples of advanced water control and drainage systems. The Great Bath of Mohenjo-Daro of the Indus Valley is considered the “earliest public water tank of the

historic world” (Mujumdar and Jain, 2018). Adequate archeological proof exists to testify that the Harappans of the Indus Valley have been properly aware of the seasonal rainfall and flooding of the Indus River through the length between 2500 and 1700 BCE, that's corroborated by using present-day meteorological investigations (Srinivasan, 1976)8.

The development of socio-cultural societies, agricultural institutions, and everlasting settlements brought about the established order of a unique relationship between people and water (Vuorinen et al., 2007; Lofrano and Brown, 2010)9. Scarborough (2003) and Ortloff (2009) discussed the impacts of water control practices on historical social systems and organizations with examples from the jap and western hemispheres. The systems that Harappans of Dholavira town advanced for conservation, harvesting, and storage of water speak eloquently about their advanced hydraulic engineering capabilities, given the state of technology (Baba et al., 2018)10. The “Lothal” (which means “mound of the useless”), called the harbor city of the Harappan civilization (Bindra, 2003), is located on the doab of the Sabarmati and Bhogavo rivers. A roughly trapezoidal structure having dimensions of 212.40 m at the western embankment, 209.30 m on the Japanese one, 34.70 m at the southern one, and 36.70 m on the northern one (Rao, 1979) at Lothal is an example of advanced maritime activities in the one's vintage days; and it's miles claimed with the aid of the archeologists to be the first recognized dockyard of the world (Nigam et al., 2016)11.

The Harappan civilization epitomizes the extent of improvement in water sciences. Agriculture turned into the principle financial interest of Harappan society. Extensive networks of canals, water storage systems, one-of-a-kind styles of wells, and sustainable low-cost water-harvesting systems had been advanced for the duration of this period. Harappans had created sophisticated water and wastewater management structures, deliberate networks of sewerage structures thru underground drains, and additionally had the earliest recognized gadget of flush toilets within the international. The Harappan civilization is also credited with the primary-recognized dockyard in the whole global. The Harappans have been additionally aware of oceanic calamities which include tsunamis. There are portions of proof to reveal that the Harappans had developed one of the smartest urban centers in those historic times with an exemplary fusion of civil, architectural, and cloth sciences. The Indus Valley civilization is known to have developed the earliest-known gadget of flush toilets in the world. They additionally evolved state-of-the-art water control systems comprising a sequence of reservoirs, step wells, and channels.

Vedic Period

The Vedic Period within the Indian subcontinent can be bracketed between ~1500 and 500 BCE. The “Rigveda” (the earliest of the four Vedas) as well as many different Vedic texts have been composed in this era and in later periods (Kathayat et al., 2017; Witzel, 2014; Sen., 1999)12. The Vedic Period can be similarly categorized into two ranges the “Early Vedic Period” (~1500–1100 BCE) and the “Late Vedic Period” (~1100–500 BCE) (Kathayat et al., 2017; Witzel, 1987, 1999)11. During the Late Vedic Period, agriculture, metallurgy, commodity manufacturing, and change had been largely improved (Kathayat et al., 2017); after the Late Vedic Period the length of “Mahājanapadas” came into life, which ultimately converged into the “Mauryan Empire”. The Vedic texts comprise treasured references to the hydrological cycle. It became recognized at some point in Vedic and later instances (Rigveda, VIII, 6.19; VIII, 6.20; and VIII, 12.3) (Sarasvati, 2009)12 that water is not lost within the diverse approaches of the hydrological cycle, particularly, evaporation, condensation, rainfall, stream flow, and so forth., however, receives transformed from one form to every other. At that point, Indians had been acquainted with cyclonic and pornographic effects on rainfall (Vayu Purana) and radiation, in addition to traditional heating of the Earth and evapotranspiration. The Vedic texts and other Mauryan period texts consisting of Arthashastra mention different hydrologic methods together with infiltration, interception, flow waft, and geomorphology, along with the erosion manner. Reference to the hydrologic cycle and artesian wells are available in Ramayana (~200 BCE) (Goswami, 1973)13. Groundwater development and water great considerations additionally acquired sufficient attention in ancient India, as obvious from the Brihat Samhita (550 AD) (Jha, 1988). Topics such as water uptake by vegetation, evaporation, and clouds and their characteristics, in conjunction with rainfall prediction via gazing at the natural phenomena of preceding years, have been discussed in Brihat Samhita (550 AD), Meghamala (900 AD), and different literature from historical India.

The Rigveda, that's an ancient non-secular scripture, includes many references to the hydrologic cycle and related techniques (Sarasvati, 2009)14. The Rigveda mentions that “the God has created Sun and positioned it in this sort of role that it illuminates the entire universe and extracts water continuously (in the shape of vapor) after which converts it to cloud and ultimately discharges as rain” (verse I, 7.3). Many other verses of the Rigveda (I, 19.7; I, 23.17; I, 32.9) in addition explain the transfer of water from the Earth to the atmosphere through the Sun and wind; breaking apart of water into small debris, evaporation because of Sun rays, and subsequent rain; and formation of cloud due to evaporation of water from Mother Earth and returning in the form of rain. Verse I, 32.10, of the Rigveda, similarly mentions that the water is never stationary but it continuously receives evaporated, and due to the smallness of debris we cannot see the evaporated water debris. According to Atharvaveda also (~1200–one thousand BCE), the Sun's rays are the primary cause of rain and evaporation (verse I, 5.2, in Sanskrit language): amurya up surye yabhirg suryah sah|ta no hinvantvadhavaram||

The Yajurveda (~1200–1000 BCE) explains the system of water motion from clouds to Earth and its waft through

channels and storage into oceans and further evaporation (verse X, 19). During the time of Atharvaveda, the ideas of water evaporation, condensation, rainfall, river glide and garage, and once more repetition of the cycle had been also nicely called in the earlier Vedas. Therefore, it is able to be inferred that, all through the Vedic and in advanced periods in India, the ideas of infiltration, water motion, garage, and evaporation as part of the hydrologic cycle were widely known to the modern Indian pupils.

Yajurveda additionally incorporates references to water management. Verses VI, 100.2, and VII, eleven.1, of Yajurveda, point out “that the found out men carry water to desolate tract regions by way of well, pond, canals, and so on., and the person ought to consider the drought and flood like herbal calamities earlier and take preventive measures as a result”. Verse XII, 1.3, of Atharvaveda mentions that those who use rainwater through rivers, wells, and canals for navigation, exercise, agriculture, etc., prosper all of the time. Similarly, verse XX, 77.8, of the Atharvaveda, directs the king to assemble suitable canals throughout mountains to provide water for his “topics” for agriculture and other purposes. The Yajurveda also has references directing the person to use rain and river water through wells, ponds, and dams and to distribute it to numerous locations having want of water for agriculture and other purposes. The Atharvaveda talks about drought control via green use of to-be-had water sources and emphasizes that those waters are used correctly and could lessen the intensity of droughts. Verse 2.3.1 of the Atharvaveda instructs the reader on the correct control of numerous water bodies such as brooks, wells, and pools and the efficient use of their water resources for lowering the drought intensity and water shortage (Sharma and Shruthi, 2017)¹⁵. At this juncture, it might be suitable to say Kenoyer (2003) said “both Harappa and Mohenjo-Daro guide the settlements courting to the Vedic Period”. Therefore, greater research on paintings is wanted for the Vedic Period (1500–500 BCE) coupled with archeological investigations.

The Vedas, particularly the Rigveda, Atharvaveda, and Yajurveda, especially dwell upon the hydrologic cycle and diverse related techniques. The principles of evaporation, cloud formation, water movement, infiltration and river float, and repetition of the cycle are explicitly mentioned in these historical texts. Rigveda also mentions a water-lifting device which includes Asma-chakra and Ghatyanta (much like Noria), among others. Ramayana has also cited the hydrologic cycle and artesian wells. Mahabharata explains the monsoon seasons and the water uptake process by means of vegetation. Matsya Purana, Vayu Purana, Linga Purana, and Brahmanda Purana additionally point out the approaches of evaporation; formation of clouds because of cyclonic, conventional, and pornographic results; rainfall potential of clouds; and plenty of different associated hydrological processes.

The Rigveda, Atharvaveda, Brihat Samhita, Susruta Samhita, and Charaka Samhita have numerous references to water best and nature-primarily based answers (NBS) for obtaining potable water. The Dakargalam chapter of Brihat Samhita dwelt upon the prevalence and distribution of groundwater assets the usage of geographical recommendations and soil markers.

Mauryan dynasty

The Arthashastra, attributed to Kautilya “who reportedly was the leader minister to the emperor Chandragupta (300 BCE), the founder of the Mauryan dynasty” (Encyclopedia Britannica, <https://www.Britannica.Com/topic/Artha-shastra>, ultimate access: 27 April 2020), offers with several issues of governance, along with water governance. It mentions an operated by hand cooling tool known as “Variyantra” (revolving water spray for cooling the air). The Variyantra turned into much like the water cooler. According to Megasthenes (an ancient Greek historian, who visited the courtroom of king Chandragupta Maurya around three hundred BCE), the Variyantra changed into utilized by the wealthier sections of the society for cooling the air. The Arthashastra also offers an extensive account of hydraulic structures built for irrigation and different purposes throughout the duration of the Mauryan Empire (Shamasastri, 1961)¹⁶.

The Pynes and Ahars (blended irrigation and water management device), reservoir (Sudarshan lake) at Girnar and many other structures were also built during the Mauryan Empire (~322–185 BCE). McClellan III and Dorn (2015) referred to that “the Mauryan Empire became first and essential an extraordinary hydraulic civilization”. This indicates that the generation of the development of the dams, reservoirs, channels, measurement of rainfall, and knowledge of the various hydrological processes existed inside the ancient Indian society. Megasthenes mentions that “more than 1/2 of the arable land became irrigated and turned into agriculture and produced two harvests in a year”. Further, there was a separate branch for supervision, construction, and upkeep of a properly-evolved irrigation system with tremendous canals and sluices, wells, lakes, and tanks. The same bureau becomes liable for planning and agreement of the uncultivated land. A similar description of the extraordinary institutional arrangements for the duration of the Mauryan length can be seen in Arthashastra. The significance of the hydraulic systems within the Mauryan length may be judged on the idea of the punishments or fines imposed on the offenders. As mentioned inside the Arthashastra, “while a person breaks the dam of a tank full of water, he shall be drowned in the very tank; of a tank without water, he will be punished with the best amercement; and of a tank that is in ruins attributable to forget about, he shall be punished with the middle-most amercement”.

Water pricing turned into additionally a vital component of the water control machine in the Mauryan Empire. According to

Arthashastra, those who cultivate thru irrigation (i) by means of manual exertions (hastaprāvartimam) could must pay one-fifth of the produce as water charge (udakabhāgam); (ii) via sporting water on shoulders (skandhaprāvartimam), one-fourth of the produce; (iii) with the aid of water lifts (srotoyantprāvartimam), one-third of the produce; and (iv) by using elevating water from rivers, lakes, tanks, and wells (nadarastatākakūpodghātam), one-1/3 or one-fourth of the produce. The superintendent of agriculture became accountable for compiling the meteorological statistics by using a rain gauge and for staring at the sowing of the wet crops, winter vegetation or summer vegetation relying on the availability of the water.

The first observatory for measuring rainfall using Varshamaan (rain gauge) changed into hooked up during the Mauryan Empire in India. The reservoirs, dams, and canals prepared with spillways have been built for irrigation and domestic materials with good enough knowledge of water balance. A water pricing system become advanced. Some systems have been additionally constructed that consider 50-year return intervals. In water history, the Mauryan period is identified because of the first and predominant hydraulic civilization. They had additionally evolved a system to forecast rainfall.

Epic Era

The epic Mahabharata (verse XII, 184.15–16) explains the water uptake process via vegetation and mentions that rainfall happens in four months (the Indian summer time monsoon, ISM) (verse XII, 362.4–5); in the subsequent 8 months (non-monsoon months), the identical water is extracted by the Sun rays thru the process of evaporation. Likewise, in other Indian mythological scriptures consisting of Puranas (which might be dated probably between 600 BCE and seven hundred AD), several references to the hydrological cycle can be found (NIH, 2018). The Matsya Purana (verse I, 54.29–34) and Vayu Purana (verse 51.23–26) point out the evaporation technique which burns water by using Sun rays and that's transformed to vapor (i.e., the system of evaporation). These vapors ascend to the environment with the assistance of air and fall as rain in the subsequent wet season for the good of living beings (NIH, 2018). The Vayu Purana and the Matsya Purana additionally point out the rainfall ability of clouds and the formation of clouds via cyclonic, conventional, and pornographic results (Nair, 2004). Similarly, the Linga Purana (verse I, 36.67) absolutely explains the numerous procedures of the hydrologic cycle including evaporation, and condensation, and mentions that water cannot be destroyed; it gets changed from one shape to another (NIH, 2018; Sharma and Shruthi, 2017) as the following ghravenashrishthto vayuvrishti Stanhope punch.

The Brahmanda Purana (verse II, 9.138–139; 167–168) explains that the Sun has rays of 7 hues which extract water from all sources via heating (evaporation), and it gives to the formation of clouds of different hues and shapes and finally those clouds rain with excessive intensity and splendid noise (NIH, 2018). The Vayu Purana additionally refers back to the various underground systems and topography including lakes, barren tracts, dales, and rocky rift valleys between mountains (verse 38.36). The Kishkindha sarga (chap. 28; verses: 03, 07, 22, 27, 46) of the epic Ramayana discuss diverse aspects of the hydrological cycle. Verse 3 mentions the formation of clouds by the Sun and wind (thru the procedure of evaporation from the sea) and raining the elixir of lifestyle (water), and verse 46 mentions the overflowing of the rivers because of heavy rains within the rainy season. Verse 22 explains the process of cloud transportation laden with water and the elevational consequences of the mountains on the entire technique. Based on those verses (and lots of greater ones no longer referred to right here), an outline of the diverse tiers of the hydrologic cycle can also be installed much like Horton (1931). Malik (2016) additionally compared the numerous concepts of the contemporary hydrologic cycle with the ones offered within the Ramayana and located that a corollary may be installed between them.

The Brihat Samhita (literally meaning big collection) (550 AD) by Varahamihira contains many scientific discourses on the various aspects of meteorology, e.g., “pregnancy” of clouds, pregnancy of air, winds, cloud formations, earthquakes, rainbows, dust storms, and thunder bolts among other things such as colors of the sky, shapes of clouds, the growth of vegetation, behavior of animals, the nature of lightning and thunder, and associated rainfall patterns (Jha, 1988)17. The water falling from the sky assumes various colors and tastes from differences in the nature of Earth. Out of 33 chapters in the Brihat Samhita, 10 chapters are specifically devoted to meteorology. This highlights the depth of the meteorological knowledge prevalent during the period of Varahamihira and his predecessors in ancient India.

Verse f44.104 of Brihat Samhita explains the relation between soil and water. It is stated that pebbly and sandy soil of copper coloration makes water astringent. Brown-colored soil offers upward thrust to alkaline water, yellowish soil makes water briny, and in blue soil, underground water will become pure and clean. Brihat Samhita also discusses approximately the geographical recommendations which include plants, reptiles, and insects in addition to soil markers to gauge the groundwater assets (occurrence and distribution) (chap. 55, “Dakargalam”). It explains groundwater recharge as “the water veins under the earth are like vein's within the human body, a few higher and a few lower” as given in the following verses (NIH, 2018): Dharmyam yashashyam va vadabhaytoham dakargalam yen jaloplabdhiha Punsam yathagdeshu shirastathaiva chhitavapi pronnatnimnasanstha. Ekayna vardayna rasayna chambhyashchutam namaste vasudha vishayshanta Nana Eastham bahuvartanam cha ghatam pareekshyam chhititulyamayva.

The Dakargalam (Brihat Samhita, chap. 55) deals with groundwater exploration and exploitation with numerous floor

features, which might be used as bioindicators to locate sources of groundwater, at depths varying from 2.29 m to as a whole lot as 171.45 m (Prasad, 1980). The bioindicators, defined in these ancient Sanskrit paintings, encompass numerous plant species, their morphologic and physiographic features, termite mounds, geophysical traits, soils, and rocks (Prasad, 1986)18. All those signs are not anything but conspicuous responses to organic and geological materials in a microenvironment, consequential to the excessive relative humidity in groundwater surroundings, developed in an arid or semiarid location. Variations in the peak of the water table with area, hot and bloodless springs, and groundwater usage through wells, alongside proper creation techniques and gadgets, are completely described inside the Dakargalam (Jain et al., 2007). It additionally approaches that the water which falls from the sky, in the beginning, has an identical color and equal flavor but assumes specific color and taste after falling on the floor of the Earth and after percolation. There are also mentions of the plant species and/or stone pitching in details for bank protection of water channels in Brihat Samhita.

Glücklich (2008) opines approximately the Brihat Samhita: “because the name of the work itself suggests, its facts got here from several sources, a number of them in all likelihood pretty vintage. However, the prestige and systematic nature of the Brihat Samhita gave its cloth the authority of prescriptions”. Further, it is also appropriate to cite Varahamihira (chap. 1, verse II, Brihat Samhita) that “having correctly tested the substance of the voluminous works of the sages of the past, I try to write a clear treatise neither too long nor too short” (Iyer, 1884)18. Here, it'd be suitable to don't forget words of Murty (1987) that Varahamihira may be taken into consideration the “earliest hydrologist” of the modern-day world in the equal vein as Leonardo da Vinci is considered the “Master of Water”. An interesting reality included in the element by means of Varahamihira is the role of termite knolls as a hallmark of underground water. Apart from underground water exploration, some of the verses of the bankruptcy deal with subjects along with digging of wells; their alignment with regards to the winning winds; dealing with tough refractory stony strata; polishing and tempering of stone-breaking chisels, and their warmness remedy; treating water with herbs when having an objectionable taste or odor; safety of banks with timbering, stoning, and planting with trees; and such different associated topics.

Jainist and Buddhist Period

The Jainist literature also made great contributions within the area of meteorology. The “Prajnapana” and “Avasyaka Curnis” provide brilliant references to the diverse varieties of winds (Tripathi, 1969)19. The Avasyaka Curnis furnishes a listing of 15 styles of winds, and the Prajnapana also mentions blizzards and hailstorms as sorts of precipitation. The Buddhist literature also throws giant light on meteorology. In the narrative of the first Jataka, named “Apannaka”, numerous climatological facts are described therein. The Buddhist literature refers to 2 standard training of clouds: monsoon clouds and storm clouds or accidental ones (Tripathi, 1969). The Samyutta Nikaya classifies clouds into five classes (i) cool clouds, (ii) warm clouds, (iii) thunder clouds, (iv) wind clouds – formed due to the activity of convection current inside the ecosystem, and (v) rain clouds – maximum likely cumulonimbus, which brings copious downpours of rain.

Conclusion

Water is an inevitable one in the lifestyles of humans, animals, and flora on the earth. Rain is simplest equal to getting water. In India, October, November, and December months are rainy months where the earth receives excessive water. Lakes, ponds, and pools are places for water storage for human wishes including for Agriculture, Industry, and office purposes. Indians are very clean progressive and foresight thinkers, calculative predators to meet their fundamental wishes. In the ancient period, Indian turned to save the waste waters and provide the next nine months with no interceptions. This article significantly and elaborately mentioned the approximate function of the Indus Valley civilization, Vedic Period, Mauryan dynasty, Epic Era, Jainist and Buddhist Period our forefathers were the function model to all till now inside the manner of water garage and water supply. This article helps the People folks that are contained in the water storage and water deliver now our forefathers saved the water and deliver to all purposes.

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