WATER-LIFTING DEVICES IN ANCIENT INDIA: THEIR ORIGIN AND MECHANISMS

(From the earliest times to c. A.D. 1000)

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Agriculture was one of the main industries of ancient India, as it is in modern times; and from time immemorial irrigation has been one of the chief needs in developing agriculture. References to irrigation are numerous in the ancient literature, and the evidences scattered in them, particularly in Sanskrit and Tamil literature, shed much valuable light on the irrigational methods practised in ancient India. The modes of distribution of water were manifold. The various methods, intelligently invented and developed by the ancients, were the result of vast knowledge gained by experience handed down from generation to generation. The paper aims at a discussion of the methods employed for lifting water for irrigation in ancient India by making use of the available information collected from various sources.

The origin of the yantras or mechanical contrivances in ancient India is obscure, because of their great antiquity. R. J. Forbes believes that 'such machines existed in the later stages of antiquity and they were developed from the simple ladle gourd or vessel used to collect water from stream or pool. The machinery moved by beast or men was finally driven by force of the river alone, by water-wheels'. To make an enquiry into their evolution, it would be difficult, because different devices ranging from the simple basket to the water-wheel had been no doubt used in olden days side by side and remained in practice up to the present day. The first known mechanical aid practised in ancient India was the bucket-wheel or the water-wheel (Persian wheel). The oldest evidence of the existence of water-lifting devices is furnished by the antiquities unearthed from the Mohenjo-Daro and Harappa excavations. Sir John Marshall who studied the pottery evidences from Mohenjo-Daro expresses his opinion about the possible use of pottery for water-wheels. His argument runs thus: 'the jars that have been denominated “scored pottery” were made for attachment to an appliance for raising water very similar to the wheel that is used in most parts of Near and Middle East at the present day. This type of vessel is far more frequently found at Mohenjo-Daro than any other type and is variably very roughly made'.

This view amply finds corroboration in the remarks advanced by Ernest Mackay who says that, 'though there is no direct evidence that the water-wheel was
known to the people of Indus Valley the shape and make of these jars certainly suggest that why such a number were made and broken. It is thus quite discernible that some technically advanced devices were put into practical use during that period.

In the Vedas, mention is made of wells, canals and dams. That is to say, the Vedic Aryans did not entirely depend on rainfall alone for agriculture, but some definite artificial devices were used by them. In the areas where natural supply of water was scarce, people had to depend solely upon deep-sunk wells; and the Rgveda frequently mentions the term avata which signified a ‘well’. In the hymns of the same Veda the uses of mechanical contrivances for drawing water from deep and goodly wells are thus narrated:

5. ‘Prepare troughs for the drinking of the animals. Fasten the leather-string and let us take out water from this deep and goodly well which never dries up.

6. ‘The troughs have been prepared for the animals; the leather-string in the deep and goodly well which never dries up, and the water is easily got. Take out water from the well.

7. ‘Refresh the horses, take up the corn stacked in the field; and make a cart which conveys it easily. This well full of water for the drinking of animals, is one droña in extent, and there is a stone wheel to it. And the reservoir for the drinking of men is one skanda. Fill it with water’.

The contrivance with stone wheel as mentioned above is known as the aśma chakrā. In other places we are informed of the use of a machine, ghaṭi-chakra or ghaṭi yantra, for lifting water. It is a highly efficient lift and popularly known as the Persian wheel. In the Atharva Veda also such references are not wanting.

The mechanical contrivances worked by animals, particularly bullocks, were also clearly known and made use of in ancient India as early as the fifth century B.C., as indicated by the term yugavaratras. For Pāṇini, the celebrated grammarian, has mentioned in his Aṣṭadhyāyī the yugavaratras to mean the yoke and the rope or strap by which the bullocks were driven for raising water. He has also described two types of wells, the karkandhu and the shakandhu. It is possible that the latter type of well was used by the Śaka tribe and it denotes a form of the water-wheel. The word udam-chana denotes a large earthen bucket which must have been used to lift water from wells for irrigation.

During the days of Chandra Gupta Maurya there was an elaborate system of irrigation which is wholly attested by Kautilya’s Arthasastra and the Indica of Megasthenes. Though Megasthenes has described at length about the facilities provided for irrigation, he has not made any attempt to mention the mechanical water-lifters that were in practical application in that period. In the Arthasastra, certain more details are added, about which we find no
reference in Megasthenes. The water-rates, according to the Arthashastra, varied with the modes of irrigation, which were four in number, viz. (1) Hastaprayaritima—i.e. drawing with the hands and carrying it to the fields in pitchers, etc., (2) Skanda—the shoulders or the necks of bullocks, (3) Śrotovyantra—a mechanism for lifting water in channels flowing into the fields, (4) Udghātam—the water-wheel for raising water from river, etc.11 The above-mentioned account establishes that there were not only means of raising water by bullocks, but also mechanized devices worked by men or animals. The four types of irrigation as mentioned in the Arthashastra must have been classified for the convenience of taxation and a close study of them would prove how methodically Kautilya had arranged on the basis of their merit, efficiency and the extent of the area of irrigation.

Bhoja’s Samarāṅgaṇa Sūtradhāra describes a few types of water machines (vāri-yantras), but the text does not give a systematic classification of all the yantras.12

In the southern part of the Sub-Continent there were also water-lifting mechanisms prevalent from the very early centuries of the Christian era. But the Śaṅgam literary works, from which we derive materials for our study on the subject, do not clearly mention the provenance of the use of such devices. The application of water-lifters and other simple devices in South India is unmistakably mentioned in the following Tamil works such as (1) Ahanāyuru, a Śaṅgam work, (2) Maduraikāṇchi, one of the ten Idylls of Pattupāṭṭu, (3) Śilappadikāram and Maṇimēkhali, the two Tamil epics, (4) the Periyapurāṇam and so on. Besides, a number of early Tamil epigraphs also make definite mention about picotahs and baskets.

In the Śilappadikāram, the poet Ilango Adigal, while giving a detailed account of the Kāvēri describes the modes or devices, particularly the bucket, the water-lifts and palm-leaf baskets. In the tenth canto it is thus detailed: ‘By finding her (Kāvēri) movement arrested by the barrier—the anicut with its doorway—she noisily leaps beyond it in the sportive mood natural to her first freshes. No sound other than this can be heard. We can hear there neither the sound of the bucket nor of the water-lift; neither the usually loud picotah nor the palm-leaf bucket used in irrigation’.13 A passage like the above-cited one would surely indicate the existence of water-lifting mechanisms for the purpose of irrigation and cultivation. In the Maduraikāṇchi it is said that the palm-leaf baskets were responsible for the continuous water-logging in the paddy fields.14 Tev15 and edā16 are the terms generally met with in the Tamil literary works to denote palm-leaf baskets; and pīḷa17 is also a basket made of metal. The Periyapurāṇam, a compendium of biographical sketches of the 63 Śaivamāyanārs (saints), also makes reference to edā-pēridā-k-kollamun-kavitu. Here the term pēridā stands for a ‘large basket’.18
Ättapuḷam\textsuperscript{19} and ēttapādam\textsuperscript{20} are the terms often used in the Tamil inscriptions to categorize lands irrigated by means of picotahs (water-levers). Generally speaking, ēttam and ēṛram are the two terms current even now in local usage in South India. Inscriptions refer to two types of ēttam like kurreṭtam and pēṛettam and literally they stand for ‘small picotah’ and ‘large picotah’ respectively. Probably, they must have been applied depending upon the extent of wet-fields under irrigation. An epigraph\textsuperscript{21} from Tiruvorriyūr (Madras) of Pallava Kampavarman tells of the lands watered by four picotahs: Tengēri in-nilattirkē nāḷēttameṇuppadāga, that is the cultivable lands on the banks of the tank, Tengēri, to be irrigated by four picotahs. Another record\textsuperscript{22} from the same place of the Pallava king Aparājīta mentions about ‘the land irrigated by two large picotahs’ which by their description must have irrigated large acres of land. The same record\textsuperscript{23} refers to two water-levers (jala-yantra) which appear to have been added as an additional means of irrigation in the village. It is learnt from the Rāyakoṭa plate\textsuperscript{24} of Skandaśishya (fourth year) that such water-levers were also known as ēṭta-p-pādam, while there are these and other distinct references to the principal types of water-lifting devices, there is absolutely no full account or description of them in any ancient literary works.

In the preceding pages we have seen the application of various types of water-lifting devices with different local names varying with the area of cultivable land in the light of literary and epigraphic evidences. We shall speak of them in detail further on. Only selected devices and techniques have been dealt with a view to focusing attention on the technological achievements of the ancient Indians in this obscure but important sphere of activity.

Technically speaking, there can be no doubt about the evolution of devices. On the basis of all available evidences and references, the methods of mechanisms can be arranged under three broad heads. They are as follows:

(1) Intermittent or discontinuous water-supply from streams and canals,

(2) Semi-mechanical devices, i.e. the balanced-bucket, and lastly

(3) Continuous water-supply by water-lifting machinery.

A systematic classification of all the devices used in ancient kingdoms has been done by R. J. Forbes very recently.\textsuperscript{25} The list covers all the devices applied at various periods in different countries. But the Arthaśāstra of Kaṭṭilya has made a scientific classification of all the devices into four broad categories as early as the fourth century B.C.\textsuperscript{26} Based on this classification, the Superintendent of agricultural produce levied from the lessees of the agricultural lands. His method of arrangement of devices is fairly in accordance with the methods adopted by modern authors and it still holds good.
(I) Intermittent or discontinuous water-supply from streams

(i) Canals and wells—The three types, the basket, the bag or bucket moved by pulley-wheels and the water from wells by animal power, come under this category. In ancient India irrigation by means of baskets was practised from very early days as by means of animal power from wells. We have a few definite instances as proof of the widespread use of baskets, particularly those made of palm-leaf, in ancient South India. But references regarding their use in North India are either wanting or totally absent in Sanskrit literary works.

Piḷā or edā, otherwise known as ixaikūḍai in Tamil, was a basket specially employed for baling out water from deep channels or streams to nearby fields. It was practically made or knitted out of palm-leaf to get the required shape of a basket (kūḍai). It had a thin rimmed wide mouth with a shallow bottom. Even now such baskets are used in South Indian villages. Two factors may be ascribed to the common utilization of palm-leaf baskets in South India; one must be the easy availability of palmyra trees and the second factor is that the baskets are fairly leak-proof and durable. In the Northern region its use was completely absent probably because of the non-availability of palmyra trees.

(ii) Pulley-wheels—The earliest reference to ancient Indian pulley-wheels of stone or wood, similar to those used in modern times, found in the Rgveda was known as aśma chakra; here the word aśma stands for stone. That is, the water was raised by a wheel (cakra) of stone (aśma) with a pail (kōśa) attached to it. When raised it was poured into troughs (āhūva) of wood. In the Tamil country, the wells fitted with such pulley-wheels for drawing water from them were known as kilār. Among the devices invented by the ancients, the pulley-wheel was the simplest one for practical purposes. It was a one-man job to draw water from the well for increasing the flow of water. It is thus obvious that the pulley and rope gave rise to the ‘mhōte’ of Northern India, which was in use for irrigating fields, the rope being drawn by bullocks.

(iii) From wells by animal power—Irrigation from wells by means of animal on draught-plane came to be known and practised in ancient India at least as early as the fifth century B.C., as indicated by the word yugavarastra, meaning the yoke and the rope or strap by which the bullocks were harnessed for raising water from wells. The classified modes of irrigation in the Arthasastra of Kautilya brings to light the word skanda which stands for the shoulders or the backs of bullocks. It is thus evident that harnessing animals to the task of drawing water from wells had been conceived early, but no ancient representations are traceable of a beast pulling up the bucket. It is also curious to note that water from wells worked by bullocks, now popularly known as kapilai-ētam in South India, does not find place either in
early Tamil works or in the numerous inscriptions of South India. Probably this important mode or practice with full improvements may have been introduced into or adopted in South India at a later stage as an additional means of distributing water for irrigation.

Let us examine the actual working of the bullock mhōle. In this type, a pair of bullocks move down from the slope, specially constructed to the wall of the well, lifting behind them a bucket or a leather bag which is discharged into the connecting channel by means of a rope. After discharge the bullocks walk up the slope until they reach the top by which time the bucket will have again reached the surface of the water and got filled; and then the process is repeated. This method is not free from the application of human labour; for the man who sits on a seat in between the animals has to conduct the animals properly during the process. Two reasons may be ascribed for the low efficiency of this practice—(1) water flow is discontinuous and insufficient, (2) the time consumed by the animals during each operation is so much that the water-supply hardly covers the required portion of land. And this mode of practice, notwithstanding its handicaps and deficiencies, must have certainly given stimulus to the invention of the semi-mechanical and full-mechanical devices.

(II) Semi-mechanical Devices: The Balanced-bucket

(i) With counterweight—There were in practice in ancient India two types of balanced-bucket which by its operation and design was semi-mechanical; one was efficiently performed with counterweight, and the other one balanced by the weight of human body. It has been severally known in different countries to mean this semi-mechanical device, e.g. shadoof (Egypt), dāliya (Iraq), pícotah (South India), lāt (some parts of Northern India), and so on. It is generally known in South India as ēttam; while in the Kannada districts it is called the rājanams. Its application right from the days of the Vedic period is confirmed by the mention of the term tēra or the tiryaka yantra in the Rgveda. The device, shadoof or swape, though an offshoot from the evolution of bucket or pot, is only a semi-mechanized water-hoist worked not by any wheel but by a pair of vertical beams and a horizontal pole. Probably water was raised from wells by means of buckets tied by rope to one end of a long wooden pole, working about a fulcrum near the other end that carried a heavy weight.

Let us now go into the details of the actual working of this simple but efficient device. The shadoof or ēttam consists of a long tapering and nearly horizontal pole pivoted on a horizontal beam fixed across two vertical pillars about 8 to 10 feet high which are set up less than a yard apart above the ground. In some cases, granite stone pillars act as the vertical beams instead of the palmyra ones. A leather bag of considerable size or a bucket made
either of earthenware or metal is hung on a rope or thin bamboo pole from the larger and thinner end and a counterbalance placed on the shorter and thicker end. The counterbalance will always be a block of stone secured tightly at the end. In this context it may be worth while to quote the supposition of Earnest Mackay. The excavations of Mohenjo-Daro (DK. 8586) have brought to surface large-sized bricks (11-7" × 5-7" × 2-73") which have a cut-hole in the centre of about 2-5" in diameter. Ernest Mackay suggests that they 'may have been used as a weight for some form of apparatus. If the shadoof, or water-lifter, was in use in ancient Sindh, two or more such bricks might have been used to weigh it— one alone would have rather been too light. But we cannot reject this assumption as unwarranted and without proof, for irrigation and cultivation in the Punjab region were only possible by means of wells and we have already seen the direct evidences and allusions to wells and devices in the Rgveda; and it is, therefore, not surprising to find archaeological evidences on the water-lifting devices such as the counterbalance weights in the excavations of Mohenjo-Daro.

(ii) Balanced by the weight of human body—This is the same as the previous one in all respects; but one conspicuous difference is that it is operated with the application of human labour. This type of application is very common in Madras and some parts of South India. The tapering horizontal pole is worked by trampling along the pole instead of the counterweight placed at the other end. The man who stands and tramples the pole must have sure balance and adequate previous experience to operate the device and therefore it requires considerable practice.

The principle of the well-known picotah is the same as that of the balance and certainly goes back to early historic times. The change from the system of animal power to mechanical was doubtless an achievement; but the output was limited by the depth of the well. The shadoof, with its rhythm of rise and fall, dip and empty, to which the ancient labourer must have sung as does his modern descendant, can prove to be much more quicker and efficient than any non-mechanical type of water-lift.

(III) Continuous water-supply by water-lifting machinery

Wheels of pots or water-wheel—The next and the last stage, technologically speaking, was the fully mechanized water-hoist moved by a water-wheel or wheel of pots. As has been mentioned above that the wheel of pots was put into practical application as early as the second millennium B.C. A particular type of pottery found at Mohenjo-Daro shows the use of wheel for lifting water. Sir John Marshall opines that 'some arrangement for drawing water for irrigation, by means of an endless rope working over a wheel, with pottery vessels attached to it at intervals was in use in Sind and other parts of Western India from early times, though it may not have taken
the form of modern wheel'. But the excavation finds at other Chalcolithic sites unmistakably show that 'only one type of jar has been found broken in large numbers. Jars of this kind average about six inches in height have a pronounced, pointed and deeply scored belly, and are certainly too large to be grasped comfortably in one hand'. And, according to E. J. Mackay, 'they are frequently coated with a thin cream wash, they all have deep spiral grooves round the middle, which would have served to give greater security if they were attached to some kind of water-wheel'. Though the water-wheel 'may not have taken the form of modern wheel' but yet it must have had a definite form and shape which by the passage of time had got fully developed into the water-wheel of modern times. At this stage we are at a loss to reconstruct the actual model of the water-wheel used in the Protohistoric period; for the spade of the Archaeologist has not exhumed other relevant material evidences, other than the pottery, to throw light on the water-wheel and its essential parts. Sir John Marshall views that if the water-wheel 'had been in use in India from a very early date, it would have had some other name'. His opinion is quite contradictory; for in early literary works specific names are mentioned to mean the wheel of pots. It has been known as ghaṭi chakra in the Rgveda and udghaṭam in the Arthaśāstra. It has also been mentioned as jala-yantra-chakra (water-machine-wheel). There was also a contrivance by name araghatta for lifting water from wells and shallow canals by working at ara (spokes). All these documentary references indubitably prove that there was an indigenous method of raising water by using wheel of pots and having specific names from very early time.

Another point of controversy is that the wheel of pots or the one usually referred to in Anglicized jargon as the Persian wheel had spread from Persia to India and to other countries. Sir John Marshall says that the modern Persian wheel, which is almost exclusively confined to Balūchistān, Sind and the Punjab, and some parts of the Bombay presidency, may have been an improvement introduced into India from Persia. If this particular device had really come from Persia to India, it would have retained its original name, of dauwaryah or charki dauwar. Since the contrivance still bears the same Sanskrit name ghaṭi chakra to the present day, the current notion that the device was introduced into India from Persia is not tenable. Moreover the local names that are in currency presently in the villages of Northern India have very little to do with any of Persian origin. It is, therefore, reasonable to infer that the wheel of pots had its own independent origin in India in the ancient period.

The contrivance consisted of a row of earthen pots tied to the rim of a drum-shaped revolving wheel turning in a vertical plane over water. The wheel had spokes or ara and was worked like a capstan. It was moved by