

WATER QUALITY AND WASTE WATER MANAGEMENT

Throughout the history, the use of water has reflected various experiences and interpretations of and values about health, illness and well being. The idea that water reflects a harmony between the physical, social and ecological environment can already be found in ancient medicine. As long as 4,000 years ago, the Indians were having the knowledge of purifying the water through boiling. Later, Hippocrates was known to use both water filters and boiling to improve water quality (UNESCO, IHP, 2011). The modern scientists at one time, used to consider rainwater as pure like distilled water. But later studies 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 may also dissolve particles of dust or other air borne materials. Thus, 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 milligram per litre to several tens of milligrams per litre of chloride but the observed concentration generally decreases rapidly in a landward direction.

In Vedas, we get some references to water quality, especially in Atharv Veda. Charaka Samhita, Susruta Samhita (both of pre or early Buddhist era), and Ashtanga Hridaya Samhita (9th century AD) are the repositories of knowledge accumulated on Ayurveda (Science of Life), during the earlier period. In all these ancient standard texts, discourses 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 the Rig Veda, the verse V,83.4 speaks about the tree plantation, forest conservation and yajna (यज्ञ) so as to create pure and healthy environment and good quality of water for well being of mankind as:

प्र वाता वन्ति पतयन्ति विद्युत् उदोषधीर्जिहते पिन्वते स्वः ।
इरा विश्वम्भै भुवनाय जायते यत्पर्जन्यः पृथ्वीं रेतसावति ॥ R.V.,V,83.4 ॥

Likewise, verse VII, 50.4 of the Rig Veda also reveals the importance of Yajna (यज्ञ) in relation to purification of water. In Yajur Veda (I,12), we read about the contamination due to combination of substances and about fire as the prime source of purification, by breaking the substances into minute particles, i.e. yanja, heat and sun rays are the agents to purify the water. viz.

पवित्रे स्थो वैष्णव्यौ सवितुर्वः प्रसव उत्पुनाम्याच्छिण पवित्रेण सूर्यस्य रश्मिभिः ।
देवीरापो अग्नेगुवो अग्नेषवो ग्र इममघ यज्ञं नयताग्ने यज्ञपतिं सुधातुं यज्ञपतिं देवयुवम् ॥ Y.V.I.12 ॥

In Sam Veda (Previous II.187), we read that the Sun rays cause the rain to come in purest form like white curd as:

इस्मास्त इन्द्र पृश्नयो घृतं दुहत आशिरम् ।
एनामृतस्य पिप्युषी ॥ S.V.P,II.187 ॥

A verse of Atharv Veda (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.

ओकों अस्य मूजवन्त ओकों अस्य महावृषाः ।
यावज्जातस्तक्मं स्तावानसि बल्हिकेषु न्योचरः ॥ A.V.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 during those days efforts were made to specify the water quality according to its taste.

रसो बहुविधः प्रोक्त ऋषिभिः प्राथियात्मभिः ।
मधुरो लवणस्तिक्तः कषायोम्लः कटृस्तथा ॥ M.B.XII.184.3 ॥

In the Vrhat Samhita, we find many references to water quality in the 54th chapter named “Dakargala”. Verse 54.2 states that ground water should be investigated in relation to its environment.

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

सशर्करा ताम्रमही कषायं क्षारं धारित्री कपिला करोति ।
आपाण्डुरायां लवणं प्रदिष्टं मृष्टं प्यो नीलवसुन्धरायाम् ॥ Vr.S.54.104 ॥

Soil colour has been described as an indicator of water quality in the Vrhat Samhita (54.104). It says that “pebbly and sandy soil containing copper makes water astringent (कसैला). Brown-coloured soil gives rise to alkaline water, pale white soil to salt water and blue coloured soil makes water pure and sweet”. A water treatment method was also suggested to improve the quality of drinking water as:

अज्जनमुस्तोशीरेः शराजकोशातकामलकचूर्णैः ।
कतकफलसमायुक्तैर्योगः कूपे प्रदातव्यः ॥ Vr.S.54.121 ॥

कलुषं कटुकं लवणं विरसं सलिलं यदि वाशुभगन्धि भवेत् ।
तदनेन भवत्यमलं सुरसं सुसुगन्धि गणैरपरैश्च युतम् ॥ Vr.S.54.122 ॥

The above verses say that 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, it 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 materials have medicinal value and are commonly available in almost all parts of India. In ancient medical texts such as Charaka Samhita, Susruta Samhita and Astangahradaya Samhita (by Vagbhata), collectively known as Brahatrayi (Great triad), and three other ayurvedic texts Madhavanidanam, Sarangadhara Samhita and Bhavaprakasha, collectively known as Laghutrayi (small triad), some references to water quality are available. In Bhava Prakash many parts have been incorporated from the medical texts of Charaka, Susruta, Vagbhata and the Tantrik texts. The tenth chapter of

Bhava Prakash with 86 verses 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 analyzed by Prasad (1979). The shloka 2 states the important properties of water and its usefulness for the living beings, as:

पानीयं श्रमनाशनं क्लमहरं मूर्छापिपासाहरं तन्द्राच्छर्दिबन्धहृदलकरं निद्राहरं तर्पणम् ॥ X.2 ॥

Meaning: “the water eliminates the fatigue of the body and mind, destroys weakness. It is good for heart, gives satisfaction, soft, clear, origin of rasas, and destroyer of vomiting, sleeping tendency and constipation”.

In shloka 3 and 4, the classification and nomenclature of different forms of water have been given as:

पानीयं मुनिभिः प्रोक्तं दित्यं भौममित द्विधा ॥ X.3 ॥

दित्यं चतुर्विधं प्रोक्तं धाराजं करकाभवम् ।

तौषारं च तथा हैमं तेषु धारं गुणाधिकम् ॥ 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 continuous shower from sky, ‘Karakabhavam’ when it falls like the pieces 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, shloka 25 gives classification of Terrestrial water (Bhauma Jalam).

भौमयभयौ निगदित्वं प्रथमं त्रिविधं बुधैः ।

जाग्दलं परमानूपं ततः साधरणं क्रमात् ॥ X.25 ॥

It means, “the 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, as:

अल्पोद कोल्पवृक्षश्च पित्तरक्तामयान्वितः ।
ज्ञातव्यो जाग्दलो देशस्त्रत्यं जांगलं जलम् ॥ X.26 ॥

बहम्बुर्वहुवक्षश्च वातश्लेष्मामयान्वितः ।
देशोनूप इति ख्यात आनूपं तदभवं जलम् ॥ X.27 ॥

मिश्रचिन्हस्तु यो देशः सहि साधारणः स्मतः ।
तस्मिन्देशे यदुदकं तन्तु साधरणं स्मृतम् ॥ X.28 ॥

जाग्दलं सलिलं रक्षं लवणं लघु पित्तनुत ।
वह्निकत्कफहृत्पथ्यं विकारन हरते वहून् ॥ X.29 ॥

आनूपं वार्यभिष्यन्दि स्वादु स्निग्धं धनं गुर ।
साधरणं तु मधुरं दीपनं शीतलं लघु ।
तर्पणं रोचनं तृष्णादाहदोषत्रयप्रणुत ॥ X.31 ॥

According to the above verses, the country having sparse trees and less water and having bad effect of causing pitta and vata disorders are the Jangala region and water originated in this region is termed as Jangala water. The region having plenty of water and abundant trees and able to cause Vata and Kapha diseases is called Anupam and its water as Anupam water. The regions having mixed characteristics of above two types is called Sadharanam 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 is a creator of other disorders. Sadharana Jalam is sweet, promotes digestion, soft, cool, pleasant and eliminates tridosha (three diseases). Thus, we see here that in the study of water, a large number of factors of ecology have also been considered.

Water Quality Standards

In the various reference quoted above, at various places, we come across the words such as विशदं (clear, clean, pure, pellucid, etc.), स्वच्छम् (clear), निर्दोष (blemishless), कलुषं (polluted) and निर्मलत्वं (unpolluted).

Shlokas 78-81 describe the characteristics of the contaminated water as:

पिच्छिलं कृमिलं क्लिन्नं पर्णशैवालदकर्मैः ।
विवर्णं विरसं सान्द्रं दुर्गन्धं न हितं जलम् ॥ X.78 ॥

कलुषं छन्नमम्भोजपर्णनीलीतृणादिभिः ।
दुः स्पर्शनमसंस्पृष्ट सौरचान्द्रमरीचिभिः ॥ X.79 ॥

अनार्त्तवं वार्षिकं तु प्रथम तच्च भूमिगम ।
व्यापन् परिहृत्तव्यं सर्वदोषप्रकोपणम् ॥ X.80 ॥

तत्कुर्यात्स्नानपानाभयां तृष्णाध्मानचिरज्वरान ।
कासाग्निमांघाभिष्यन्दकण्डूगण्डादिकं तथा ॥ X.81 ॥

According to these verses “waters which are of sticky nature, containing worms and spoilt by leaves and mud, of bad colour, thick, of bad smell, are not good for health. Muddy water and water covered by lotus leaves, grass etc., un-illuminated 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, आध्यामान, जीर्णज्वर, अग्नमान्द, कण्डु, गण्डा and so on. A critical study of other shlokas also clearly reveals 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 shlokas 59-67.

हेमन्ते सारसं तोयं ताडागं वा हितं स्मृतम् ।
हेमन्ते विहितं तोयं शिशिरेपि प्रशस्यते ॥ X.59 ॥

वसन्तग्रीष्मयोः कौप वाप्यं वा निर्झरं जलम् ।
नादेयं वारि नादेयं वसन्तग्रीष्मयोर्बुधैः विषवद्वनवृक्षाणां पत्राघैर्दूषितं यतः ॥ X.60 ॥

औदभिन्द चान्तरिक्षं वा कौपं वा प्रावषि स्मतम् ।
शस्तं शररि नादेयं नीरमंशूदकं परम् ॥ X.61 ॥

दिवा रविकरैर्जुष्ट निशि शीतकरांशुभिः ।
ज्ञेयमंशूदकं नाम सिग्धं दोषत्रयापहम् ॥ X.62 ॥

अनभिष्यन्दि निर्दोषमान्तरिक्षजलोपमम् ।

बलयं रसायनं मेध्यं शीतं लघु सुधासमम् ॥ X.63 ॥

शरदि स्वच्छमुदयादगस्त्याखिलं हितम् ॥ X.64 ॥

पौषे वारि सरोजातं माघे तन्तु तडागजम् ।

फाल्गुने कूपसंभूतं चैत्रे चौज्यं हितं मतम् ॥ X.65 ॥

भाद्रे कौपं पयः शस्तमाश्विने चौज्यमेव च ।

कार्तिके मार्गशीर्षे च जलमात्रं प्रशस्यते ॥ X.67 ॥

Meaning: “water belonging to ponds and tanks during the season हेमन्त (winter, i.e. November–January) are good; during शिशिर (the cool season, i.e. January–March) also the same waters are superior. During बसन्त (Spring, i.e., March–May) and ग्रीष्म (summer, i.e. May–July) the water belonging to wells, stepped deep wells and rocky springs are good. During बसन्त and ग्रीष्म seasons waters of rivers should not be used for drinking because during these seasons the river water becomes 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 the rivers and waters, illuminated by the sun during day time and by the moon during nights, called amsudakam, are good. Ansudak water is destroyer of the Tridosha, 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 (valley stream 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 shlokas of Bhava Prakash, we can identify some factors affecting the quality of water. हेम जलम् i.e. glacial water भौम जलम् i.e. ground water, नाढेय जलम् (river water), औदभिद जलम् (ground water flowing with artesian character), निर्झर (water fall water), तडाग जल pond Water), कौप जल (wells water), चौज्य जल (i.e. valley stream water, Shloka 65) and their qualities have been described in Bhava Prakash in details, 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 shlokas 26-27-28. The effect of agricultural soil on water quality (केदार जल, Shloka 57) is also described. viz.

केदारः क्षेत्रमुदिदष्टं कैदारं तज्जलं स्मृतम् ।
कैदारं वायुर्यभिष्यन्दि मधुरं गुरुं दोषकृतम् ॥ X.57 ॥

It also describes the effect of decaying vegetation on water quality. Also the effect of stagnation and lack of the penetration of sun light in water, on the water quality have been discussed (Shlokas 78 to 81). These verses show that the modern water quality related concepts were well known during ancient times in India.

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

धारनीरं त्रिदोषघ्नमनिर्देश्यकरं लघुम् ।
सौम्यं रसायनं बल्यं तर्पणं हलादि जीवनम् ॥ X.7 ॥

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

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

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

Water Treatment

Shlokas 5 and 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 रजते ताम्रे स्फटिके काचनिर्मिते ।
भाजने मृण्मये वापि स्थापितं धारगमूच्यते ॥ X.6 ॥

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

निदितं चापि पानीयं क्वथितं सूर्यतापितम् ।
सुवर्णं रजतं लोहं पाषाणं सिकतामपि ॥ X.82 ॥

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

शुचि सान्द्रपटस्त्रवि क्षुत्रजन्तुविवर्जितम् ।
स्वच्छं कनकमुक्ताघैः शुद्धं स्याददोषवर्जितम् ॥ X.84 ॥

पर्णमूल विसग्रंथिमुक्ताकनकशैवलैः ।
गोमेदेन च वस्त्रेण कुर्यादबुप्रसादनम् ॥ X.85 ॥

Meaning: “contaminated water can be purified by boiling, by exposure to the sun’s ray 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 are clearly revealed in the 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 drawback of the modern chemical methods of water treatment.

Wastewater Management Techniques

Lack of sanitation affects human development to the same or even greater extent as the lack of clean water. While there may be an added stigma to discussing waste treatment, sanitation is widely perceived as meriting a significant claim on financial and political resources as well on

the evolution of mankind. According to Victor Hugo (1892), 'The history of men is reflected in the history of sewers'. This proverb adequately indicates about the importance of sanitation and wastewater management.

The term sanitation is primarily used to characterize the safe/sound handling and disposal of human excreta as well as other waste products (Avvannavar and Mani, 2008). It is well known that the relationship between humans, water and sanitation has seen substantial changes, due to the influence of cultural, social and religious factors throughout the ages (Sorcinelli, 1998; Wolfe, 1999; De Feo and Napoli, 2007; Avvannavar and Mani, 2008; Lofrano and Brown, 2010). However, all through the ages, wastewater has been considered filthy (Maneglier, 1994; Lofrano and Brown, 2010). The process of evolution of wastewater management through the ages has been discussed by several authors worldwide such as Tarr (1985), Maneglier (1994), Sorcinelli (1998), Viale (2000), Sori (2001), and Neri Seneri (2007). More recently, Lofrano and Brown (2010) have presented an in-depth review of wastewater management in the history of mankind. In this review work they have categorically discussed about the evolution of sanitation through different civilizations of the world, including the ancient Indus civilization.

It would be appropriate to mention Kenoyer (1997) about the new heights of the Indus civilization, *'that many of the technologies first developed in the Indus cities provided the foundation for later technologies used in South Asia and other regions of the Old World'*. Wastewater management and sanitation were the major characteristics of the first urban sites of the Harappan civilisation (Kenoyer, 1991). Adding to this, Lofrano and Brown (2010) found on records that 'the Indus civilization was the first to have proper wastewater treatment systems' in the ancient times. Sewage and drainage were composed of complex networks, especially in Mohenjo-Daro and Harappa. Latrines, soak-pits, cesspools, pipes and channels were the main elements of wastewater disposal. Figure 7.1 shows drainage and sanitation systems of Mohenjo-Daro and Lothal cities of Indus valley civilization.



Figure 7.1: Drainage and sanitation systems of Mohenjo-Daro and Lothal cities of Indus valley civilization (after Khan, 2011; Kenoyer, 1998)

The houses were connected to drainage channels and wastewater was not permitted to flow directly to the street sewers without first undergoing some treatment. First, wastewater was passed through tapered terra-cotta pipes into a small sump. Solids settled and accumulated in the sump, while the liquids overflowed into drainage channels in the street when the sump was about 75% full (Lofrano and Brown, 2010). The drainage channels could be covered by bricks and cut stones, which probably were removed during maintenance and cleaning activities (Wolfe, 1999). Further, cesspits were fitted at the junction of the several drains or where a drain was extended for a long distance in order to avoid the clogging of the drainage systems (Wright, 2010). Fardin et al. (2013) found that almost all the settlements of Mohenjo-Daro were connected to the drain network.

In Jorwe, in present day Maharashtra, it has been demonstrated that the drainage system was implemented from 1375–1050 BC (Kirk, 1975; Fardin et al., 2013). Later (around 500 BC),

Ujjain's 'drainage system included soak-pits built of pottery-ring or pierced pots' (Kirk, 1975), and it has been supposed that ring-wells were used for the disposal of wastewater (Mate, 1969). In the 3rd century BC at Taxila, domestic wastewater was canalized out from the houses through earthenware drain-pipes into soak-pits (Singh, 2008). During 1st century BC, drains were being used for sewage disposal in Arikamedu, the southern part of India (Casal, 1949). Further, the wastewater systems were improved around 150AD with the use of corbelled drains (Begley, 1983). Bhardwaj (1997) found that this system was draining water from basins supposed to be a part of a textile and dye industry. This was the unique feature associated with this system as compared to the rest of ancient India, where the wastewater disposal was implemented for domestic effluents only.

Epilogue

From the above discussions it can be concluded that during the ancient times, modern concepts of water quality, sanitation and waste water management technology were very well known to the Indians and were in their advanced stages during the Indus valley civilization and later periods. Water classification and viewing its quality in relation to environment satisfies the modern concept of ecology. Water quality standards, factors affecting water quality, effect of decaying materials on quality of water, lack of aeration in stagnating 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 aromatic compounds etc. were adopted. These methods are frequently used even now-a-days and are better than the chemical disinfectants as there is no change in the desirable qualities and odours of water. Modern methods of wastewater disposal systems based on centralized and decentralized concept as well as methods for wastewater treatments during Indus valley civilization were even better than those used in the contemporary world.