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Water Management, Purification and Testing Techniques in Indo-Pak Landscapes in the Early Modern Period

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ABSTRACT

This article reviews water transportation, testing and purification techniques in a regional context - the Indo-Pak subcontinent, a southern region of Asia - during the early modern period. A brief history of comparative methodologies based on surveys and historical texts has been explored as evidence of the evolving types of water testing parameters between the sixteenth and the nineteenth centuries. This analysis also took under consideration the role of culture, beliefs as well as religious rituals in the selection of drinking water and how it has influenced the population living conditions, dominating the process of decision-making within a specific community

Keywords: Water transportation, Water purification techniques, Water testing, Shalamar Garden, Pakistani rivers

ARTICLE

Introduction

The history of water management and purification goes back to prehistoric times and attempts to respond to seasonal changes in water availability. Water management and purification was crucial during the transition from hunting-gathering to farming societies, and it became even more important with the emergence of cities, industrial towns, and administrative centers. Water management has never solely been a matter of technical intervention. It is embedded in a web of great diversity of cultural, social and political arrangements. Water management was essential to ensure water supply to the places where it was needed, as well as getting rid of excess or polluted water. Water management was also involved in protecting fields, cities and sacred places, as much as in catering to domestic (drinking), agricultural, industrial and cultural needs (DUTT and WASSON 2008: 40). There has always been a strong connection between humans and water (WEGERICH and WARNER 2010: 3-18). Early on, humans stayed close to water sources as he learnt that animals and humans could both survive almost anything except without water (BAKER 1981: 1-24; RUGGLES 2008: 23). Similarly, different territories have used different types of water collection devices to abstract water from various sources like lakes, rivers, streams and groundwater. It has all depended on water availability according to the area's situation and geography.

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People have chosen to live near rivers and lakes because water could be easily obtained and then be used in everyday house chores, in creating farmland, in producing crops, and in providing sea foods and other goods (JUUTI et al. 2007: 4-12). Many of the earliest civilizations succeeded due to the presence of rivers. Such were the cases of the Mesopotamian cultures and the Euphrates River and Tigris River, the Egyptians and the Nile River, the Indians and the Indus River, and the Chinese and the Huang and Yangtze River (CAVENDISH 2006: 181-294; GARCIA 2011: 97).

Concept of purification in the early ages

The treatment processes of drinking water have been gradually developed over centuries of both experimentation and accidental discovery. The main concerns regarding the purification of drinking water were its taste, temperature, and color. Hindus in India, for example, used to boil foul water to improve its taste and clarity. Water has always been an essential part of the development of human communities around the globe; the study of water trespasses the areas of politics, social studies, environment, science, medicine, geography and technology that still stand in present time (CECH 2010: 374; YOUNOS and GRADY 2014: 8).

This article focuses on a historical insight into water testing, purification and transportation techniques in the Indo-Pak subcontinent territories, which primarily include the regions that now belong to the countries of India and Pakistan.

Natural Herb/Flower/Fruits	Application/Description
Tulsi (*Ocimum sanctum*)	Used as water purifier for anti-bacterial and insecticide purpose
Seeds of Honge (*Pongamiaglabra*)	Used as water clarifier
Amla (*Phyllanthus emblica*)	It is also called the clarifier tree. It produces seeds that were used for water purification. The wood of Amla (*Phyllanthus emblica)* was considered to have the ability to adsorb pollutants and kill the germs in the water
Drumstick trees (*Moringa Oleifera*)	It is also called the clarifier tree. It produces seeds, which were used for water purification
Neem *(Azadirachta indica)*	Neem were added into water to inhibit the production of microorganisms and prevent other contaminations
Nuts of Nirmali tree (*Strychnospotatorium*)	Used as water clarifier

Table 1: Herbal Technique for water purification (SADUL et al. 2009: 1-9; KUMAR 2002: 60-95; MISHRA et al. 2013: 4)

In these territories, people used to collect water from streams, rivers, lakes and ground water but this water was not always clean and hence different ways and methods had to be adopted to kill the microbes that caused diseases such as Diarrhea, Cholera, Typhoid, and Dysentery etc. Even in ancient civilizations there was already an awareness regarding the need to develop strategies to test and purify water. Many of the existing methods at that time were not efficient enough though when it came to remove microbes; still, they have helped lay the foundations for many of the modern water purifying techniques.

Old civilizations that dwelled in this region of the Asian subcontinent discovered and used various herbal treatments for water purification. Many of the Indian scriptures stress the importance of clean water and referred to the use of natural techniques to purify water by using herbs, and various kinds of flowers and fruits (KUMAR 2002: 70-80). Varahamihira (505-587 AD), for instance, suggested the use of plants, metals and heating for the purification of potable water (SKANDHAN et al. 2011: 448; MISHRA et al. 2013: 4). Another scientist, called Ayurveda (1998) described water purification methods for drinking purposes that included the use of lotus bulbs, nuts, moss, clearing nuts, pearls and thick cloths for the removal of suspended particles from water (KUMAR 2002: 77-78; SMITH 2017: 421-468, SADUL et al. 2009: 1-9). These techniques have actually provided the foundations for the development of current days methods for purifying water. The brief description of these techniques can be found in table 1.

Techniques for water purification and testing

India and Central Asian countries started testing out water and purification techniques by resorting to methods such as boiling, straining and gravel filtration. Some of the traditional methods used by different communities included sedimentation, decantation, boiling by means on fire, filtration via winnowing sieves, via cloth (common practice in India), and filtration and clarification by means of plant material (common in Tamil Nadu and Kerala, India) (VIGNESWARAN 2009: 43-44; VIGNESWARAN and SUNDARAVADIVEL 2009: 84-85; SALZMAN 2012: 1-11). Boiling water is one of the oldest and traditional methods of water purification process. This process has been used to remove temporary hardness of the water and kill the bacteria and other microbes that may be present as well as to remove other sources of contamination (SPELLMAN 2000: 20; TOLBA 2001: 1403-1404). One of the most ancient famous techniques involved are the *sedimentation* and *decantation*. These methods were efficient enough to remove large suspended particles from water especially muddy water. Muddy water was left undisturbed for some time in order to let the heavier soil particles settle down and the upper liquid be decanted (VIGNESWARAN and VISVANATHAN 1995: 79). These methods were mostly followed when access to other water resources was not possible. All these methods had long been used in Indo-Pak subcontinent and they are still under practice in many rural areas (ZUANE 1997: 441-444;YOUNOS 2014: 8-9).The analysis of water following specific parameters such as color, odor, turbidity and temperature was also among the main criterion used in water testing. Turbidity and taste were probably considered to be the main driving force for earliest water treatment process-

Sr. No:	Techniques
1	Boiling by heating on fire
2	Exposing to the sun light
3	Dipping a piece of hot copper, iron
4	Filtration through cloths and charcoal
5	Filtration via winnowing sieve
6	Filtration via clay vessels
7	Filtration through gravel
8	Hot sand in conjunction with boiling
9	Straining
10	Sedimentation
11	Decantation

Table 2: Techniques/Traditional methods for water purification (VIGNESWARAN 2009: 43-44; VIGNESWARAN and SUNDARAVADIVEL 2009: 84-85; SALZMAN 2012: 1-11, TOLBA 2001: 1404,1578)

es. Change in color of drinking water may occur due to the presence of organic matter like human feces or contaminated industrial wastes and plant material like heavy metals, algae and weeds respectively. So, colorless water was considered as safe to drink. Similarly, the absence of odor and pungent taste were also analyzed (BOYD 2000: 111-112). Turbidity, which is the presence of suspended particles in the water, was also linked with the water quality.

Distribution, management and uses

During the thirteenth to the fifteenth centuries, when Islamic teachings were being spread under the rule of Muslim emperors (QUATAERT 2005: 95-96; KHAN 2009: 416-418) these fountains were used as an alternative source for ritual ablution (CHAMBERLAIN 2008: 169). One of the principle uses of fountains was in mosques, which provided facilities for washing before prayer (ASSON2001: 160; RASHID 2005: 107). Fountains were often associated with places of worship (for ablution in mosques), as for example Pond of Jalal, situated in the center of Sylhet, and part of Dargah-e-Shah Jalal (a holy place) in Bangladesh. It is a sacred pond whose water was used for religious rituals before prayers, such as ablution (KUBAN 1974: 9; SUVOROVA 2004: 165; RASHID 2005: 107). The ablution fountain covered by a dome in the center of the courtyard was added to the mosque in the late thirteenth century (ABOUSEIF-BEHRENS 1989: 54; MICHON 2008: 150).

The Indo-Pak subcontinent has been under the rule of various government systems. The time period of Mughal emperors who ruled this region from the fifteenth to the eighteenth century, paid special attention to architecture based on gardening and landscaping that included well-developed waterworks (PETERSEN 2002: 159; HUDMAN and JACKSON 2003: 450; DUTT and WASSON 2008: 20). Of all the artificial water sources, fountains received singular attention in architecture, since they were known as miraculous in garden landscaping (STEFOFF 2007: 44). Fountains, considered as both artificial spring or aqueducts, were designed by experienced engineers of that era as a part of the architecture; they splashed water from pots or jets into the air and were used to provide water for decorative purposes as well as for bathing and washing by residents of cities, villages and towns (CONAN and OAKS 2007: 226-230).

In the territory which is now India, in the tomb, palace and garden Taj Mahal located in Agra, water was a prominent source of ornament and public use. This historical place was built by the Mughal emperor Shah Jahan in the years 1610-1626 (GADUGESH 2016). A very charming and attractive place named as Mehtab Garden or Mehtab Bagh, also called Moonlight garden was located at its Northern side (SCHREUDER 2014: 378-380). An efficient water transport system was developed to supply water to the whole complex. The Yumna River was

Figure 1 and 2. Views of Taj Mahal. Photographs by Vera Nobre da Costa.

the main source of water for the garden whereas ground water was extracted in the complex for palaces and other temples. The water from the river was transported through oxen and ropes into the huge storage tanks from where it was distributed to the fountains and channels of the garden located in front of Taj Mahal. Each fountain had a copper pot beneath it to ensure the steady supply and release of water (TEMPLE 2003: 56-58).

Following the same model, lakes and fountains such as this can also be found in the Shalimar Gardens, Lahore, built by Emperor Shah Jahan during Mughal Empire. The construction of the gardens began in 1637 A.D. and it was completed in 1641. There were approximately 410 fountains at the time of the construction of the palace and they were built to increase the beauty of those areas. They were originally designed for ornamental purposes (CONAN AND OAKS 2007: 228). The water of the fountains was so clean and transparent that water drops resembled pearls reflecting the sunlight and the beautiful colors of rainbow. Many of them still exist today (SCHIMMEL and WAGHMAR 2004: 295).

The end of Monarchy in the Indo-Pak Subcontinent was followed by the 1857 conquering of the land by the

Figures 3 to 6. Views of Shalamar Garden. Photographs by Farhan Alam

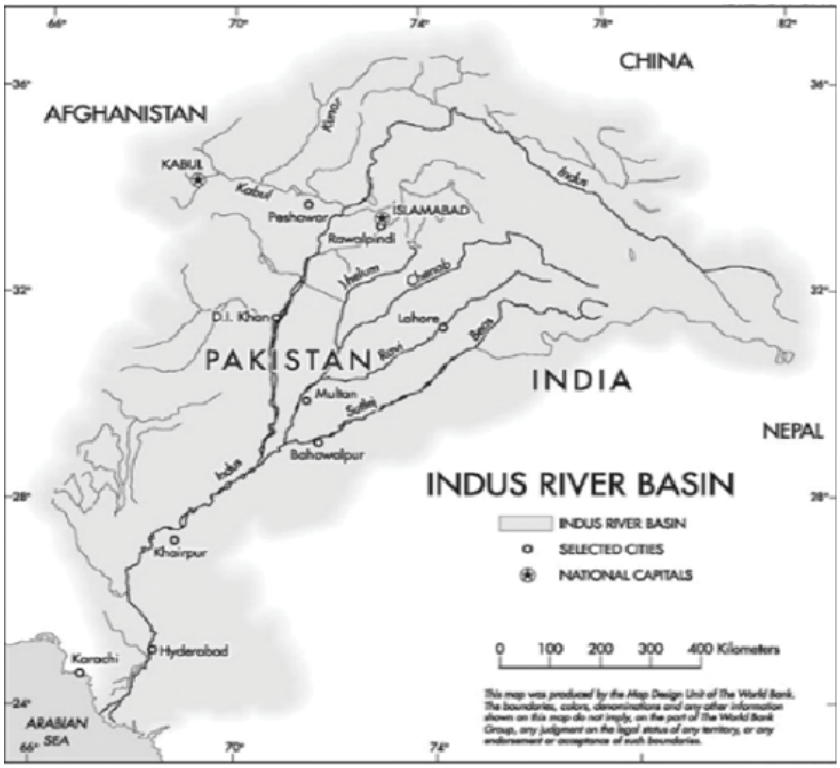
British, who defeated the last emperor, Bahadur Shah Zafar. This was a time when various innovations in the field of water purification were being implemented in Europe (ORTS and DEKETELAERE 2001: 1-39; SILVA and BUCEK 2016: 82). The British rule in this region is not acknowledged as being associated with any precise detail of reforms in the context of water management and there is little evidence of any introduction of new methodologies in these areas. However, there were some renovations in the existing water irrigation systems and some new canal systems were introduced for the distribution of water (LAWRENCE 1895: 24; JAIN and AGARWAL et al. 2007: 370; SINGH 2009: 275). In 1850, weirs were built in the Tungabhadra and Krishna rivers in order to store and direct water to the canals (MOLLINGA 2003: 123). The British policy towards water management was somewhat based on political convenience and on individual interests too. A case-study is the Ganga Canal. In 1841, governor general Lord Auckland was able to get the project approved from the government for the Ganga Canal but, upon Auckland's replacement as governor general, the construction work was nearly stopped as funding was

reduced (STONE 2002: 16-17; SINGH 2005: 70-91). However, the construction of some dams in specific places was a considerable step taken during this time period. In the District of Rawalpindi, province of Punjab, there are still some places to be found that had been converted into water reservoirs. These reservoirs were artificially built to fulfill the needs of the region's inhabitants. One of the dams, Misriot Dam, was constructed in 1931 and it is located in the southwest of Rawalpindi. This small dam was built on an artificially created lake (NADIEM 2006: 49).

In 1947, the British Empire in India formed Pakistan as a homeland for the Muslims in South Asia. As an intersecting territory between Southern Asia, Central Asia and Southwestern Asia, it became the land of many people from different linguistic and cultural backgrounds, but where Islamism and Urdu language were dominant.

The Pakistani river system and water management

The Pakistani river system has its major natural source originating from the snow-covered Himalayan and the Karakoram Range. The system comprises mainly five rivers that mostly flow through the Punjab province, hence the name "Punjab" – "Panj" meaning five and "abb" meaning water. There are five main rivers in Pakistan: the Indus Jhelum, Chenab, Ravi, Sutlej rivers, and Indus rivers (CHATURVEDI 2013: 122). The Indus River is the main river of Pakistan and also the major south-flowing river in Southern Asia. It begins in Tibet, in the Himalaya Mountains, and empties into the Arabian Sea. The Indus River system is divided into the Western Rivers (Indus, Jhelum, and Chenab) and the Eastern Rivers (Ravi, Beas, and Sutlej) (SALMAN and UPRETY 2002: 37-44; MOHIUDDIN 2007: 11-12).



Map 1. Map showing Indo-Pak subcontinent territories. Courtesy of World Scientific.

in DINAR, Ariel (2013), *Bridges Over Water: Understanding Transboundary Water Conflict, Negotiation and cooperation,* Singapore: World scientific publshing Co, Pte. Ltd, p. 324

The Indus River system reinforces the largest irrigation networks in the world, after its drainage it is called Indus River Valley. The Indus River yields about 170.9 Bm3 of water annually (TVEDT and JAKOBSSON 2006: 40) and the huge volume of 80,000 cubic feet of water empties into a second one that is over four times the size of the Ganges. The Ganges river discharges at Sicri about 21,500 cubic feet of water in a second (BURNES 1835: 137).

In 1960, under the Indus Basin treaty, Pakistan and India shared the river waters of the Indus Basin. The treaty adjudicated the three western rivers, Indus, Jhelum and Chenab to Pakistan (YU and YANG et al. 2013:44-80; RICHARDSON 2005: 4-8; CHATURVEDI 2013: 109-122). The largest contiguous irrigation system in the world entrusted to Pakistan is known as the Indus Basin Irrigation System (IBIS).

The Indus Basin Irrigation System com-

prises the main stem of the Indus River and its major tributaries - the Jhelum, Kabul, Chenab, Sutlej, and Ravi rivers. The IBIS is the backbone of Pakistan's agricultural economy. The Indus Basin has an ancient and resourceful record of irrigation development and localized irrigation methods such as shallow depressions, hand-dug, masonry-lined wells and canals that provided water for local irrigation of agriculture and livestock husbandry (WAINES 2010: 36). There is evidence of the existence of canal systems even in the eighth century A.D. when the Arabs conquered this region. Still, as time went by, many of them became dysfunctional or suffered a shortage of water supply. During the eighteenth century, the restoration work of some of the canals was planned. The Begari canal from the Indus River, which is 77 km long, was remodeled in 1853 by the British government with the ability to carry 107 m3/s of water. The western Nara canal, an inundation canal taken off from the Indus River, which covered some of the areas of Sindh (the west of what is now called Pakistan) and irrigated an area of 84,000 ha, carried approximately 220 m3/s of water through its further extensions. In 1856, the western Nara canal system was further expanded as they built a link canal to connect it to the Ghar canal system (REHMAN 2006: 1-2).

Groundwater wells - being another natural water source - are still in use in areas where there is no river nearby. Before the invention of pumps and motors, water buckets lifted by ropes, pulleys and Persian wheels (geared mechanisms that lifted chains of terracotta water pots) were used to take water out of wells, and they were powered by human and draft animals. Such examples were found in Baluchistan, where deeper wells tapped into hillside groundwater supplies, and tunnels known as "Qanats" conveyed water to irrigated fields and their settlements, to balance the crops production.

When the human population started growing extensively, water supply was no longer adequate and the system of pipes and taps was introduced to distribute water to far away locations from water sources. These taps had sieves to retain the different types of waste and contaminations and allow for the extraction of clean water.

Based on the type of topography, the variations in systems of water management can be clearly observed (BARTRAM and REES 2002). Pakistan landscape features some rocky, dry and sandy plateaus where water is a scarce resource. Therefore, people must use water carefully, as can be observed in Cholistan and Thar Desert (HEIDEN 2011).

In Cholistan, the only sources of freshwater for about 110,000 inhabitants and their livestock used to be the rainfall and underground wells. Various storage units such as "tobas" and "kunds" were used to store and collect water. They usually supplied water for only three to four months since the groundwater has always been either very deep or highly saline (QURESHI and AKHTAR 2004). In deserts, water was not easily accessible to the population of the areas such as Cholistan and Thar Desert. People travel long distances to get potable drinking water from wells (AHMED 2014). Animals such as camels and donkeys have been usually used to lift groundwater from depths of up to 30 to 150 meters (ALSHEH 2015: 107). Desert people have also used nets to obtain water. They set up huge nets to catch mist and fog. Fog/mist collected on the nets changed into water droplets. Then wate dripped into pipes carrying it to tanks which was then utilized for different purposes (BUFFY 2016: 28).

In the Cholistan desert, rainwater has long been collected in man-made ponds or wells, dug at different places for drinking purposes; they are locally known as "tobas" (Water Reservoir or artificial lake in the Seraiki language) (SMITH and HUQ et al. 2003: 306). There were approximately 1,500 small "tobas" in the Cholistan desert at that time. "Tobas" have remained the only source of water for humans and animals in Cholistan.

Another storage unit used locally in the desert was known as "kunds". In general, it was an underground covered rectangular tank that was basically developed for the storage of drinking water (ROBERTSON 2007). "Kunds"

were made up of local material built to store rainwater for human consumption during dry periods (Programme, UN-Water et al. 2009). There were approximately 200 "kunds" in the Cholistan Desert (BEHRENS-ABOUSEIF 1989).

There were still other primitive methods developed to store water (MOUNTJOY and MCNEESE 2004: 88-89). The most successful one was a system of underground irrigation tunnels, named "Karez", which was used in Baluchistan to prevent water from evaporating (KHAN 1991). "Karez" (Qanat)" was a water tunnel and it ran for one or two km underground (sometimes 5-10Km long), before it came out into the surface. It linked together a system of wells, and after surfacing, the "Karez" irrigated the orchards and agricultural fields. The selection of the site to dig a "Karez" was made by elderly experienced people of those areas and by a group of traditional laborers (KHAWAR and MITHA et al. 2003; JAIN and AGARWAL et al. 2007). The inhabitants used that water for drinking, bathing and other needs like washing etc. "Karez" constituted a major factor to support 15% of the irrigated acreage of Baluchistan (KHAN 1991).

In order to compare various water testing and purification methods during the eighteenth century, as well as their reliability in current times, we carried out a survey in certain areas of Pakistan. Those areas were selected according to the places where water was considered as pure (based on certain beliefs that have been passed down from generations to generations).

Results have shown that many water purification techniques used in ancient times are still put into practice. People within the age of 40 to 85 years old were interviewed[1] and questioned concerning the water purification methods followed by their forefathers. The common techniques followed throughout the eighteenth century involved the filtration process through cloth, clay vessels, gravel etc. Moreover, the techniques of sedimentation and decantation were used extensively and are still successfully applied in many rural areas where the population lives near the poverty line and is unable to afford modern technology. In certain areas, people practice the use of clove in water and it is believed that it helps in combating the diseases. Moreover, the use of brass vessels has also been applied for many years and is still part of their routine in current times. In the early modern time period, the methods of tasting the water and analyzing its color, among others, were used to detect the water's purity and it was through the trial-error method that they found out how to formulate water for drinking. If the water had a pleasing taste, then it was considered as appropriate for drinking purposes.

It was also believed that natural water resources, such as glaciers, springs, lakes, rivers, oceans, rainwater etc., were also suitable for drinking, because people thought that natural sources were clean and overall safe for life. Water was divided into different types: salty water, sweet water, hard water, etc. On the basis of these types, some perceptions were formed.

In one of the case studies, the water came from "Dargah Sharif" which is a holy place located in Shahrah-e-Firdousi Karachi, Sindh, Pakistan (adjacent to the Arabian sea). The sea water and water of other wells in this area is salty. But the water of this Dargah is considered to be sweet water according to the local language. This is small well associated to a sufi saint person "Baba Shah Ghazi". The water of this well is famous amidst local population as they believe it can cure various diseases.

1 Survey Duration: September to November 2016,
Man = 125 , Females= 106
Profession of Females = House wives, Lecturers, Social Worker Welfare,
Profession of Male = Self-employed, Labors, Small Scale Industrialist, farmers, Government employees.

In another study, the water from "Peer Kand," which is a holy place located in Chakwal, Punjab, Pakistan, was investigated for its properties. It is considered as salty water or 'kharapani" in the local language. There is a small well of water situated at an inflated hillside, higher than ground level. The water of this well is famous among local population as they believe it can cure various kidney and stomach diseases.

Many other drinking water resources are based on such kind of beliefs and are still under use due to the reliance on the concepts that have been transferred from generations to generations. For example, the water well of the Mosque "Syed Abdul Qadir Shah Hamdani," located at Tehsil Gujar Khan District Rawalpindi, is associated with the beatitude of this saint. Water is supplied through pipes and taps, and it is used for drinking purposes due to the beliefs of the local community that the water has the power to cure diabetes.

Another example of fresh water sources with historical importance is the Ilyasi Mosque located in Abbottabad District, Khyber Pakthunkhwa of Pakistan, built over a stream of water that flows from the mountain. The mosque still stands to this day and still has water flowing underneath it.

It is the oldest and largest Mosque in Abbottabad and it was built in 1932 on a mountain spring that still turns out fresh mineral water year-round. The water of this mosque is cold, clear and clean like glass. The water source is considered reliable for drinking purposes by the local community basically due to the traditional beliefs and mystic stories about the area and the water. "Karamat" is the ability to perform supernatural wonders by saints and that is why peoples call it "Aab-e-shifa" (water with the ability to cure).

The present study has shown that cultural beliefs values and mores have been playing a key role in the selection of water utilized for drinking purpose and it has affected the living habits of population, as it deeply influences the ability to take decisions with in a community.

Final Remarks

Though Indo-Pak subcontinent underwent major political transformations from Monarchy of Mughals to British rule during 19th century, yet the historical study of this period conveys that water purification and distribution remained a major topic.

Mughal emperors famous for their unique taste in architecture and gardening paid attention on the use of water as an ornamental source by creating small lakes and installing fountains. Similarly, when British annexed this region, the government worked for the improvement of water distribution systems by constructing new canals and renovating the older ones. These resources contributed to some extent in facilitating the community to get access to water.

Throughout this period major scientific developments that were being taken place in Europe. However, they were not significantly introduced in Indo-Pak subcontinent. Hence, traditional water purification and management techniques were predominant among the common people which involved filtration, use of herbs, boiling, among others. Many of those techniques became part of customs and have been carried on throughout generations until current time. Similarly, karez system that had been in use in some dry regions of Pakistan, like Balochistan, for centuries, is still practiced for water distribution.

Thus, focusing on water analysis through the lens of history, one may gain knowledge of historical development processes based on various factors like religion, culture and science. Water is a natural element, and its purification and management techniques remained a primary focus in early modern time period too. It exhibits unique features as compared to other natural resources since its qualities get affected by socialization which has been the

major reason of development of its purification methods throughout the timeline.

The approach through which societies have conceived the understanding about water has defined the attitude regarding the water transport, testing and purification methods. From a cultural and religious perspective, the understanding and conceptualization of water is as wide and varied as the water itself and provides a rich foundation which metaphors, metonymies and reveries social matters or aspects of life. Cultural values and people's costumes play a key role along with scientific knowledge within a community in the selection of water, and affect the living habits of population. Hence, approaching the history of the purification and utilization of water from different traditions based on culture, society and development, science and philosophy, contributes with new knowledge in both natural and social beneficial aspects.

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