Water for Human Consumption through the History

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Abstract: The evolution of urban water management in ancient Greece begins in Crete during the early Minoan period of the island and takes full control of the Greek territory originally and then to the European continent. A great variety of remarkable developments have been marked in several stages of the Minoan civilization, such as the practices used to supply the cities with clean water even from distant sources. Water for human consumption has had a long and interesting history. It is closely related to the development of human civilizations and thus a great deal of related events occurred in all over the world. All great civilizations had a large chapter written for water transportation, treatment and management of the urban water. In this paper some of the important steps of water history relevant to the water treatment technologies and hygiene of potable water chronologically, since the Minoan era, are presented and discussed.

Keywords Hippocrates sleeve; Minoan era; Phaestos palace; Tylissos house; water hygiene; water filters.

Prolegomena

Historically, drinking water has been cindered the clear water. Considering the scientific knowledge of that era, this simplification was totally justified. Without the tools of chemistry and microbiology, even today, clarity (and probably taste) is the main criterion for classifying water as fit for human consumption. Therefore, the first treatment attempts were aiming at the improvement of the aesthetic conditions of water. An ancient Hindu source presents, probably, the first water standard, dating 4000 years ago. It dictates that the dirty water should be exposed to sun and then a hot cupper bar to be inserted 7 times in it. Then filtration, cooling and storage in clay jar.

The availability of drinking water was always an prerequisite and necessary circumstance throughout the development of human civilization. For thousands of years this factor has been critical for the choice of location for the development of the cities. The first great civilizations were developed close to rivers both for the availability of water suitable for human needs as well as transportation purposes. Initially the water purification was very limited. It is only the last 200 years that water processing has been developed aiming at the improvement of the hygiene and aesthetic conditions.

The scope of this article is not the exhaustive presentation of what is known today about water treatment, related technologies and their uses in water supply since the Minoan era. It presents he main achievements in selected fields of potable water management chronologically extend from early Minoan to the present. Emphasis is given to the periods of great achievements.

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Period before 500 B.C.

Archaeological and other evidence indicate that during the Middle Bronze Age a “cultural explosion”, unparalleled in the history of other ancient civilizations, occurred on the island of Crete. A striking indication of this is manifested, inter alia, in the advanced urban water management techniques practised in Crete at that time. One of the salient characteristics of the Minoan civilization (ca. 3,300-1,200 B.C.) was the treatment devices used for water supply in palaces, cities, and villages from the beginning of the Bronze Age. Two examples of water management findings are the Tylissos houses and the Phaestos Palace.

Tylissos houses

In the Tylissos houses the water was transported through the aqueduct to the three Minoan houses from the Agios Mama Spring to a distance of about 3km. Terracotta infiltration devices were discovered in the place of the Agios Mamas, where is located the spring, from where water was transported to the Tylissos village (Fig. 1). These devices were filled with charcoal, thus playing the role of activated carbon treatment processes of removing both organic and inorganic constituents. In addition to that devices, a terracotta pipe of 42m length, similar of those used in Knossos was discovered in the northwestern site of House B. Other remains of the aqueduct are shown in Figures 2. A small cistern of stone was used for removal of suspended solids of water before its storage to the main cistern (Fig. 1a). This cylindrical-chapped cistern (Fig. 2b) was located in the northern site of the House C and was considered as a party of the aqueduct (Hatzidakis, 1934).

Figure 1 Terracotta infiltration device discovered in the spring of Agios Mamas, Tylissos (Photo courtesy of M. Nikiforakis, 2006).

Phaestos palace

In palace of Phaestos as in other cities and villages in Minoan Crete the water supply system was dependent directly on precipitation: here, the rainwater was collected from the roofs and yards of buildings in cisterns. In Phaestos the water supply system was dependent directly on surface runoff; there, rainfall water was collected in spatial cisterns from the roofs and yards of buildings. Special care was taken to hygienic of collecting water by (Angelakis and Spyridakis, 1996): (a) cleaning the surfaces used for collecting the runoff water (Fig. 3a) and
(b) filtering in coarse sandy filters the water before it flew into the cisterns in order to maintain the purity of water (Fig. 3b). It was estimated that about 8 Mm³ of rainwater were collected in an average year. That water was mainly used for washing clothes and for other cleaning tasks.

Figure 2 Small cistern of stone (a) used for removal of suspended solids of water before its storage to the main cylindrical-chapped cistern (b) used for water supply of the house.

Figure 3 Open yard (a) and special cistern (b) with sandy filter in the Phaestos palace.

Period 500 B.C. - 1000 A.D.

Since the prehistoric era the availability of water source was the primary criterion for the selection of small site settlements. All other criteria such as the natural protection of the site, the good soil and the ease of approach, were considered as secondary.

Gradually, as the small settlements grew to cities, during the archaic and classic period, the sources of fresh water within the boundaries of the city were not sufficient for the needs of the larger population. So they had to be enhanced with water quantities brought from sources outside the boundaries of the city. These sources had to be as close as possible in
order to make the transportation of water easy and safe. The Mycenaean cities had constructed under the walls tunnels that provided safe underground passages to water sources, in order to secure adequate supply of water during seizures. The same period important water projects are realized such as the draining of Lake Kopaes and the dam near Myticas in W. Greece.

During the historic years, after 8th century B.C., the settlements and cities obtain drinking water from springs, wells, rivers and precipitating water collected from roofs to reservoirs. The use of remote sources required water transportation. The Hellenes (Greeks is a name imposed later by the Romans) used mostly the clay pipes. Since every City-State had limited ruling domain the water sources had to be as close as possible to the walls so the protection of the water system could be effective. The most impressive remote water transportation system was constructed in the island of Samos by the Tyrant Polycrates who constructed a 1000m underground tunnel through the mountain based on the design of the famous engineer Eupalenos. The particular tunnel is an engineering marvel, since the construction started simultaneously from the two opposite ends and at the meeting point the deviation of the two axis was just 1.8 meters. Later the King of Pergamos, Eumenes the 2nd (197-159 B.C.) constructed the first complete Hellenic water transportation and storage system based on branching pipes.

Despite the fact that during the classic era Hellenes had both the financial and technical capacity (the technology of arch construction was known since Mycenae years) for large scale constructions, they did not build long, above ground, open water transportation systems for a number of reasons. First of all are political reasons. The organization of relatively small City-States resulted in frequent conflict. Open and long water transportation systems were vulnerable. Underground pipe systems are not visible and not easy to reach and inflict damage. City-States are relatively small. They did not need huge amounts of water, therefore, relatively small clay pipes of manageable size for that level of technology, would suffice. Closed pipe systems are also known to offer the best protection against natural pollution. Hippocrates probably influenced the choice towards closed systems. He had identified the significance of good water quality for good health. He indicated that it is preferable to use water from a good source than attempting to treat water from an inferior source. Moreover, he is credited with the development of the “Hippocrates sleeve” made of clothe and used to filter rain water.

The small diameter closed water transportation systems had two particular problems, besides the usual structural and leakage problems. Calcium carbonate deposits in the pipes used. The predominance of limestone formations in the Balkan Peninsula as well in many places across Europe, result in high concentrations of calcium carbonate in surface and underground water as well as relatively alkaline pH values. These conditions cause high rate of calcium salts depositions on the surface of pipes, which in practice can not be removed. So, the pipes gradually had the diameter reduced and the amount of water flow considerably diminished. This problem has been noticed in many excavations of ancient water pipes. Lead was also used as a sealing medium in clay pipes of larger diameters as well as to form pipes of small diameters. As far as we know, ancient civilizations ignored the epidemiology of lead, but the problems arising from lead use would be the same as they are today. For the construction of lead pipes were set up specialized workshops. Their remains have been uncovered in a number of excavations.

As the cities and states grew bigger and more confident, shifted their technology to longer and bigger water transportation systems, namely the open aqueducts. The Carthage water transportation system was 132 km long above ground. The first Roman aqueduct supported on consecutive arches, known as Aqua Marcia, was constructed in 144 B.C. by Marcius Rex.
It was 90 km long and the last 9 km was supported on arches. When the Romans concluded the occupation of the Hellenic states, after the era of emperor August, a great deal of long aqueducts was constructed in the Hellenic region as well as all over Europe. However, the vulnerability of these open systems never ceased to be a problem. In 537 A.D. the aqueduct of Rome was destroyed by the Goths and was used as a weak point to enter the city.

Figure 4 Remains sections of the aqueduct of Patras in western Greece.

The extensive use of open aqueducts was aided by the technology of brick which and the strong bonding mixture called *pozzolana* which made the constructions of these type inexpensive and fast to execute. The distribution of water inside the cities was made through pipes, clay and lead for smaller diameters, brickwork sealed with specialized hydraulic plaster for larger diameters. These distribution systems were operating under pressure which allowed the construction of recreational jet fountains. It is known that the water system in ancient Pergamos, 45 km long, reached inside the city the pressure of 20 atm.

Figure 5 Lead water pipe of the Roman period.  
Figure 6 Ceramic water pipes from an excavation in Aigio in western Greece.

Despite the availability of public water supply, individual houses maintained their own water sources. Where there was available underground water, a well was constructed. The internal surface of the wall was covered with built stones or clay rings, which at regular interval had holes to facilitate the access to the bottom of the well for maintenance. They also utilized the rain water which was collected from the roofs of the houses and stored in built tanks, usually underground. This water was mostly used for cleaning the house if running water was available for human consumption.

During the Classic and mostly during the Roman period, water was extensively used for human personal hygiene. Baths were both private and public. Public baths were more than
places for hygiene. They were places for social conduct and recreation. The “complete” Roman bath included a first cold bath called frigidarium, followed by a stage of mild warm bath called tepidarium and finished with a hot stage called caldarium. The space was heated by hot air passing in clay pipes inside the walls and in the empty space under the false floor.

During 8th century A.D. the Arab alchemist Gever distilled water to render it free from evil spirits and 11th century A.D. the Persian physician Avicenna advised travelers to boil the water or at least filter it through a cloth.

Figure 7 Cylindrical terracotta rings, for coating the walls of a Roman well. Figure 8 Tank to catch rain water in the atrium of a roman house in Patras, west Greece.

Figure 9 Hypocaust columns of a roman bath. Figure 10 An early Christian bath in Patras, Western Greece.

Period 1000 A.D. to Today

As in every other field of art and science middle age has to present no progress on the area of water treatment.

17th century

The British philosopher and scientist Francis Bacon who managed to transform nature probing to scientific conclusions devoted considerable effort in studying water purification techniques. In 1627 he published experimental results on percolation, filtration, distillation
and coagulation. In 1680 Dutch naturalist Antony van Leeuwenhoek discovers the microscope and in 1984 gives a first account of bacteria observed in water which he named as “animacules”. These findings were dismissed by the scientific community as unimportant curiosities. It would take another 200 years in order to be understood the importance of the van Leeuwenhoek’s findings for the public health. In 1685 the Italian Lu Antonio Porzio designed the first multi-pass filter containing a straining section and two sand filtration passes.

18th century

France is taking the lead. In 1703 the scientist Phillippe La Hire presented a home filter suitable for treating rain water consisting of a sand filter and a storage tank. He also noticed that the water coming from underground aquifers is rarely polluted. In 1746 Joseph Amy received the first patent for a water filter that in 1750 he put on the market. The filter was made of sponge, wool and sand. However, it is the British architect James Peacock that he manages to claim a patent for a sand filter with backwashing.

19th century

In 1804, Paisley, Scotland, became the site of the first filter facility to deliver water to an entire town. In 1806, a large water treatment plant opened in Paris, using the River Seine as a source. Water was settled for 12 hours prior to filtration then run through sponge prefilters that were renewed every hour. The main filters consisted of coarse river sand, clean sand, pounded charcoal, and clean Fountainebleau sand. The filters were renewed every six hours. A simple form of aeration was also part of the process, and pumps were driven by horses working in three shifts (steam power was too expensive). This plant operated for 50 years. In 1807 in Glasgow, Scotland, filtered water was piped directly to customers.

The first slow sand filtration plant in the USA was built in 1832 in Richmond. In 1833, the plant had 295 water subscribers. The next USA plant to open was in Elizabeth, N.J., in 1855. Slow sand filters were introduced in Massachusetts in the mid-1870s. Sand filters and other treatments were primarily designed to improve the aesthetic quality of water. By the end of the century the rapid sand technology has been practiced. At that time it becomes evident that in addition to the suspended solids removal, extensive bacteria removal is achieved. Also, at the same time the first attempts to use chlorine and ozone for water disinfection has been made.

20th century

In 1906 ozone is used for the first time for disinfection in Nice (France) and becomes very popular in Europe. In USA, chlorine is mostly used for disinfection due to the complexity and the cost of the ozone equipment. The Europeans were particularly negative against chlorine due to its use in the chemical warfare during World War I. In 1908 sodium hypochloride is used in Jersey (USA) for disinfection and in 1917 chloramines are used first time for disinfection in Ottawa (Canada) and Denver (USA). The first serious efforts on water desalination technology were made during World War II for the supply of units which encountered difficulties in securing drinking water.
**Epilogue**

Relationships based on exchange are known between the Minoans and continental Greece, Egypt, and the Levant. There is no doubt that some hydraulic practices and water management has been transferred from Mesopotamia and Syria to Crete by that time since such several works concerning the management of water have been already applied in these areas. However, the Minoans applied this skill and developed it, especially in urban hydraulics, in the palaces, cities and villages, up to a degree, which had never been reached before (Angelakis and Koutsoyiannis, 2003). Thus, the first indication for development practices relevant to the treatment of urban water and hygienic of water supply lies in Minoan civilization. At that time the first aqueduct were constructed to transport clean water to the urban areas. Also, the first sedimentation tanks and the first sand filters appear to be developed at that period. It seems likely that these technologies have been transferred to the Mycenaeans in continental Greece (Angelakis and Spyridakis, 1996).

Later, during the Hellenistic and Roman periods, significant developments were done by water engineers, in the construction and operation of aqueducts, cisterns, sedimentation tanks, water filters and disinfection technologies. Greeks and Romans capitalized on this knowledge and made great advances in potable water management (Petropoulos, 2006). The unfortunate middle Ages period of stagnation is followed by the revival of letters and technology. Slow in the beginning, faster and faster as time was passing, progress in drinking water transportation, treatment and management was made. The fast progress has created huge problems and the ease of communication has made the problems global. As usually the problems are emerging from politics in the broad sense. Looking to the future we wander: What is going to grow faster, the problems or the technology than can solve them?

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**References**


