Water Quality and Life Expectancy

Subjects: Water Resources
Contributor: Petri Juuti

Since ancient times, the need for healthy water has resulted in the development of various kinds of water supply systems. From early history, civilizations have developed water purification devices and treatment methods. The necessity for fresh water has influenced individual lives as well as communities and societies.

Keywords: contemporary times ; historical times ; life expectancy ; medieval times ; population growth ; water quality

1. Introduction

The total global population has been rather constant from ca 10,000 to 5000 BC, accounting for less than five million people [1]. It started growing in the Bronze Age, reaching 50 million at its end, while in the year 200 AD, it accounted for approximately 190 million [2][3]. In the following years, the increase was minimal, with 265 million in the year 1000 AD and 350 million in 1400 AD [1][4][5]. After 1500 AD, the global population grew steadily and reached one billion people 200 years ago. However, between 1900 and 2000, the increase was dramatic, from 1.5 to 6.1 billion in just 100 years, and most impressively, from 2.50 billion in 1950 to 7.55 today [6].

Since ancient times, the need for pure water has resulted in the development of water purification methods. These methods did not remove disease-causing microbes, but formed the basis of modern purification methods (e.g., filtration and decontamination). Ancient civilizations that used these methods include Minoans on the island of Crete, people in the Indus Valley, Mesopotamians, Egyptians, and Chinese [7][8].

During the last two hundred years, two major events have occurred: great efforts have succeeded in providing communities with adequate quantities of good quality water, while human life expectancy has increased all over the world. Historical trends in life expectancy for the entire world show an increased rate in life expectancy for the entire world over time, especially since the beginning of the last century (Figure 1a). Additionally, the percentage of the population aged 65 years and above seems to have followed a constant increase since 1960 (Figure 1b). In addition, research by demographers, epidemiologists, and others suggests that further progress is likely to be made in advancing the frontier of survival and healthy survival to even greater ages [6][9].

Figure 1. Life expectancy is constantly increasing. (**a**) Historical trends in life expectancy for the entire world [adapted from “Our World in Data”—Global Change Data Lab, University of Oxford (https://ourworldindata.org; accessed on 8 March 2021) and (**b**) proportion of population over 65 years old since 1960 adapted from “DataBank”—World Bank

(https://databank.worldbank.org; accessed on 8 March 2021).

Water can affect human morbidity and mortality by transmitting microbes and/or poisonous substances. On the other hand, life expectancy is a health indicator influenced by multiple factors at different points in time, and regarding various human communities. Hence, questions have arisen as to which factors have affected life expectancy at different time periods and different societies, and what the role of water was in achieving this milestone.

There has been a co-evolution of water purification and supply technology as well as other factors and sectors affecting human health [10]. Many of them, often distantly related, seem to have worked in accordance with one another, thus affecting human life expectancy. Water technology evolved together with sanitation, personal hygiene, medicine, pesticides, education, food production and safety, housing, transportation, and communication technology as well as a general rise in the standard of living, all contributing to diminish excess morbidity and mortality. However, the impact of these factors on life expectancy has constantly been counteracted by other factors such as overcrowding, unhealthy life (consumption of sugar, animal fat, alcohol, and tobacco, obesity, lack of exercise) and aging, especially in Western countries.

Several books and reviews have appeared discussing the rapid rise in life expectancy. However, the role of water has been in a minor focus in these, since they are mostly connected to the sanitation movement in Europe and their main focus has typically been the last two centuries [11][12].

2. Water Supply and Quality from Prehistoric to Medieval Times (ca 3200 BC–1400 AD)

2.1. Prehistoric Times

Fresh water has been of utmost importance since the development of very early human settlements, influencing both individual lives and the organization of communities. Most prehistoric civilizations developed and flourished near rivers and lakes where a water supply for drinking and agricultural use was readily available (e.g., Mesopotamians near the Tigris and Euphrates Rivers in Asia, Egyptians near the Nile in Africa, Indians near the Indus River, and Chinese civilizations near the Yellow River and Yangtze River in Asia) [13]. Remnants of human bones and hunting tools, one million years old, have been found near rivers, the oldest known from Ethiopia [1].

There is evidence of prehistoric water treatment and purification dating back to 4000 BC. These methods have improved the appearance (i.e., taste, clarity) of water. However, micro- and macro-parasites representing a major threat for human health were unknown and therefore not recognized. Between 4000 BC and 1000 AD, several devices for water treatment were developed and natural minerals were used for purification [7][8][14].

It has proven impossible to locate the first human-made well. However, it has become easier to locate some existing remains of wells from the Neolithic era. Two have been found in Israel and Cyprus. The one in northern Israel, roughly 10,000 years old, was found in the pre-pottery Neolithic B settlement of Atlit Yam, constructed by dry-stone walling, with a diameter of 1.5 m and depth of 5.5 m [15]. Another of the same era was found in western Cyprus at Kissonerga-Mylouthkia, and is approximately 7–8 m deep [16].

The discovery of agriculture and domestication of farm animals in early human history has had a great impact on life expectancy [17]. Paleo-anthropological records show evidence of infectious diseases (including many zoonoses) as major causes of morbidity and mortality at the dawn of human civilization [18]. Anthrax, smallpox, and brucellosis originated around this time, and it should be noted that tuberculosis originated earlier, but started to spread much wider during this period.

The abandonment of the nomadic lifestyle of hunter-gatherers and the establishment of agricultural settlements near bodies of water had initially increased food insecurity, brought about food shortages, and the lack of important micronutrients. Evidence of growth arrest (Harris lines), osteomyelitis, and shorter stature in Neolithic skeletons suggests deterioration in the health and life expectancy of early farmers [19].

There are many questions regarding the existing water supplies during this early era and their impact on societal and economic progress. For example, it would be interesting to know how much of the extensive urbanization of ancient Mesopotamia [20] was the result of the rudimentary water supply and sewerage systems. It has to be taken into account that some of these urban communities were very large, like that of Uruk, with a population of some 50,000 around 3000 BC. There is no indication of prehistoric civilizations being aware of the causes of human illness in the modern sense.

2.2. Historical Times (ca. 490 BC–330 AD)

In historical times, as in the prehistoric period, rivers and lakes were used not only for water supply, but also for providing food through fishing and hunting [1]. Hunting was more rewarding near rivers and lakes, and used as a source of drinking water by animals, hence making it easier for hunters to prey on them there [1]. According to the Ancient Greek historian Herodotus, fish were dried in the sun, ground in a mortar, reduced to flour, and then used to make buns or pies [21].

High mortality rates during the historical period were connected to specific agricultural practices, as reported by Herodotus quoting: *wheat is cultivated with manure and, therefore, the life of those who eat it is short* [22]. The increase in contagious diseases at that time was mainly due to population density and infectious diseases, due partly to the use of polluted water, which was a main factor in the spread of disease causing organisms [23].

However, in contrast to prehistoric people in Archaic and Classical Greece (ca. 776–323 BC), more than 400 Asclepieia were operating and offering their medical services including water quality. Ancient Greeks were among the first to gain an interest in water quality. At that time, Hippocrates, the father of medicine, and his successors wrote a large number of medical texts in which the crucial role of water and sanitation is documented. Since the early times (ca. 5th century BC), the possible influence of water quality on the health of people was stated (Aëtius, in Opinion of the philosophers V. 30.1). However, Hippocrates attributed the appearance of some diseases or even the weakness of some people to bad water quality. This might have meant one or more of the following water features such as salinity, bitterness, nitrites, sulfites, ferrous, acidic, or perishable rain water that may damage human cells or irritate the skin [24].

During the Classical period, philosophy and preliminary forms of science were more dominant than theocratic theory. A characteristic example was the Pythagorean philosopher and physician Alcmaeon of Croton in the ancient colony of Italy-Magna Graecia who lived around 470 BC, who originally stated the possibility of water quality influencing health (Aëtius, in Opinion of the philosophers V. 30.1) [25]. Perhaps he was a pioneer who had pondered the possibility of the causation.

In Antiquity, aeration basins were used for water purification [https://www.lenntech.com/water-purification-FAQ (accessing on 8 March 2021)]. One treatise, among the more than sixty of the so called "Hippocratic writings", devotes a substantial section on water and health. It is called "*Airs, Waters, Places*", and was written in the second half of the 5th century BC [26]. This treatise became a fundamental text about the effects of water on human health and remained unrivalled during Antiquity [27]. The author extensively discusses the qualities of various waters, being the first to establish a sensory criteria for water quality [28]. Hence, this first work determined the purification of potable water as the basis of human health. The Hippocratic purification process, using what was later called the "Hippocrates Sleeve", which was a conical cloth filter bag through which water was poured after it had been boiled to trap sediments causing bad taste and odor [24]. (I would leave these sentences out and if they are included there must be a reference to the exact place in Hippocratic Writings or some other ancient text were this method has been mentioned). This device was used for patients [7]. The rules introduced in "*Airs, Waters, Places*" described running, tasty, or tasteless, cool, odorless, and colorless water as healthy, and stagnant, marshy water or water originating in mining areas as unhealthy and to be avoided, and these were followed until the end of Antiquity. Hence, in the late 1st century BC, Vitruvius, following these rules in his manual "*De Architectura*", quoted: *"I should write about the discovery of water, the qualities of its special sources, the methods of water supply and testing before using it"* [29].

Following these recommendations, the source of water for an aqueduct in Roman times was carefully examined. It became evident that the safeguarding of ample amounts of clean water was crucial for the urbanization in the Mediterranean area, and that it was a major prerequisite for the development and growth of historical cities such as Rome, Alexandria, Antioch, Carthage, Constantinople, and others that in the peak of their prime had populations of hundreds of thousands.

Aqueducts were omnipresent in the Roman Empire. However, building an aqueduct was not enough, as its maintenance was of utmost importance. It had to be kept in good condition to deliver high-quality clean water to towns or private villas. Curator aquarium Sextus Julius Frontinus (ca 30–103 AD) expressed fears that Rome's water supply system could be damaged in many ways and that there was an urgent need for regulating statutes guaranteeing their constant maintenance for proper function [30].

However, due to deficient sources, it is not possible to evaluate the role of water in Roman life expectancy. It is, nevertheless, safe to conclude that guaranteeing high quality water was not enough to compensate for the high mortality in Roman urban areas due to several other reasons. Hence, Roman cities had to rely on migration from rural areas to maintain population stability and/or growth [31].

Additionally, there is limited evidence on the quality of the water consumed by most people in rural areas. They fetched daily water from wells, springs, rivers, or lakes or collected rain water in cisterns. Many ancient cities never built aqueducts and relied on wells and cisterns throughout antiquity. Roman towns of Italy were established and many of them prospered before aqueducts were introduced in the 1st century AD [32]. Pliny the Elder (23/24–79 AD) noticed that wells were widely used in towns as their water quality was highly appreciated by the commons [33].

Greeks and Romans used several methods to improve water quality. It can be assumed, though, that since knowledge on water-borne microbes was lacking, most of these methods were probably ineffective and quality requirements rarely sufficient.

However, boiling would have been an efficient method to diminish the waterborne biological risks. After the first suggestion of boiling by the author of *Airs, Waters, Places*, it had been recommended by several others (e.g., the Greek doctor Diocles of Carystus in the 4th century BC, Pliny the Elder in the 1st century AD, and Paulus Aeginata in the 7th century AD). Although boiling had been feasible for small quantities, it was not naturally, ecologically and economically feasible for big quantities and extensive use, since firewood and other combustibles were becoming gradually scarce around the heavily populated Mediterranean coasts [34].

The first recorded epidemic of “plague” from 430 to 426 BC during the Peloponnesian war occurred in Athens, Greece, and it is believed that water pollution played a major role in the spread of the epidemic. The Spartans had been accused of poisoning the cisterns of Piraeus, the source of most of Athens’ water supply. Thucydides wrote about it as a “pest”, but it was probably a disastrous epidemic with heavy lethality, referred to as the Athenian plague [1]. *Suddenly falling upon Athens, first attacked the population of Piaraeus, and it was said that the Peloponnesians had poisoned the water reservoirs there* [35]. Publications [36][37][38] refer to it as plague, while ancient DNA analyses suggest that it was typhoid fever [39]. Typhoid fever, caused by *Salmonella typhi*, spreads through drinking water or food contaminated by fecal flora, or through contact with flying insects feeding on feces [40]. However, the case of typhoid fever has been disputed [41], and it is suggested that the cause was drinking water pollution due to malfunctioning of the sewage system. Regardless of the source of the outbreak, it was lethal, claiming the lives of 30% of Athenians (estimated 100,000) including that of Pericles, who was the main political figure and the leader of the city. Many historians believe that this epidemic contributed to the beginning of the fall of Classical Greece.

Hence, the Greeks, based on experience, observations, and intellectual progress, were among the first to gain interest in water quality and to make efforts to improve it by using several methods, however elementary by modern standards [42].

2.3. Medieval Times (ca 330–1400 AD)

During the Middle Ages, lack of proper sanitation increased the number and effects of epidemics, especially in urban areas. The sewage system, previously improved by Greeks and Romans, gradually deteriorated dramatically, and it was not until the mid-19th century that scientific knowledge and civil engineering met the needs of public health.

During the 4th century AD, the population of Rome collapsed to just 30,000 people for reasons not fully understood. The situation concerning water quality was generally poor in other areas of Europe and remained so for centuries. Medieval towns had few and insufficient public latrines, inadequate for the size of the population. Quite often, they were built near bodies of water, projecting out over a river. London only had sixteen public latrines for a population of 25–30,000. In Helsingör, Denmark, it was the executioners who had the duty of emptying the cesspits and were apparently doing a poor job. Hence, a Dutchman living there annoyed the locals by emptying his own toilet when the city officials were unable to do it. Private toilets were dug in backyards, even under houses and apartments. The contents were dumped in local lakes or rivers or were used as manure in farming areas [43][44]. However, despite this extremely poor situation, it was at that time that distillation of potable water began to be used, though most likely for specific purposes only and not for wider community water services.

References

1. Iaccarino, M. Water, Population Growth and Contagious Diseases. Water 2019, 11, 386.
2. McEvedy, C.; Jones, R. Atlas of World Population History; Penguin Books Ltd.: Middlesex, UK, 1978.
3. Kremer, M. Population Growth and Technological Change: One Million B.C. to 1990. Q. J. Econ. 1993, 108, 681–716, doi:10.2307/2118405.
4. Manning, S. Year-by-Year World Population Estimates: 10,000 B.C. to 2007 A.D. Historian on the Warpath, 2008. Available online: https://scottmanning.com/content/year-by-year-world-population-estimates/ (accessed on 4 October 2019).

5. UN; Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. World Population Prospects: The 2006 Revision and World Urbanization Prospects. The 2005 Revision, 2007. Available online: https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/files/documents/2020/Jan/un_2006_world_population_prospects-2006_revision_volume-i.pdf (accessed on 8 March 2021).
6. UN. World Population Prospects: The 2017 Revision. 2017. Available online: https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf (accessed on 8/3/2021).
7. Mays, L.W. A brief history of water filtration/sedimentation. Water Supply 2013, 13, 735–742, doi:10.2166/ws.2013.102.
8. Angelakis, A.; Mays, L. Evolution of Water Supply through the Millennia; IWA Publishing: London, UK, 2014.
9. Vaupel, J.W. Biodemography of human ageing. Nature 2010, 464, 536–542.
10. Geels, F. Co-evolution of technology and society: The transition in water supply and personal hygiene in the Netherlands (1850–1930)—A case study in multi-level perspective. Technol. Soc. 2005, 27, 363–397, doi:10.1016/j.techsoc.2005.04.008.
11. Riley, J.C. Rising Life Expectancy: A Global History; Cambridge University Press: Cambridge, UK, 2001.
12. Mackenbach, J.P. A History of Population Health: Rise and Fall of Disease in Europe; Brill Rodopi: Amsterdam, the Netherlands, 2020.
13. Krasilnikoff, J.; Angelakis, A.N. Water management and its judicial contexts in ancient Greece: A review from the earliest times to the Roman period. Water Policy 2019, 21, 245–258, doi:10.2166/wp.2019.176.
14. Angelakis, A.N.; Voudouris, K.S.; Tchobanoglous, G. Evolution of water supplies in the Hellenic world focusing on water treatment and modern parallels. Water Supply 2020, 20, 773–786, doi:10.2166/ws.2020.032.
15. Marchant, J. Deep Secrets: Atlit-Yam, Israel. New Scientist.
16. Peltenburg, E. Kissonerga-Mosphilia: A major Chalcolithic site in Cyprus. Bull. Am. Sch. Orient. Res. 1991, 282, 17–35.
17. Diamond, J. Evolution, consequences and future of plant and animal domestication. Nature 2002, 418, 700–707, doi:10.1038/nature01019.
18. Wolfe, N.D.; Dunavan, C.P.; Diamond, J. Origins of major human infectious diseases. Nature 2007, 447, 279–283, doi:10.1038/nature05775.
19. Pearce-Duvet, J.M.C. The origin of human pathogens: Evaluating the role of agriculture and domestic animals in the evolution of human disease. Biol. Rev. 2006, 81, 369–382, doi:10.1017/S1464793106007020.
20. Algaze, G. Entropic Cities: The Paradox of Urbanism in Ancient Mesopotamia. Curr. Anthropol. 2018, 59, 23–54, doi:10.1086/695983.
21. Cartledge, P.; Holland, T. Herodotus, Histories, Book 1 (Clio), 200; SMK Books: Plano, TX, USA, 2014. ISBN-10 1617207691 (http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.01.0126%3Abook%3D1&force=y, accessed on 8 March 2021).
22. Waterfield, R.; Dewald, C. Herodotus, Histories, Book 8 (Thalia), 23; Cambridge University Press: Cambridge, UK, 2008. ISBN 9780521575713 (http://www.perseus.tufts.edu/hopper/text?doc=Perseus:abo:tlg,0016,001:8, accessed on 8 March 2021).
23. Percival, S. Preface. In Microbiology of Waterborne Diseases; Percival, S., Chalmers, R., Embrey, M., Hunter, P., Sellwood, J., Wyn-Jones, P., Eds.; Academic Press: London, UK, 2004; p. vii, doi:10.1016/B978-012551570-2/50000-8.
24. Angelakis, A.N.; Antoniou, G.P.; Yapijakis, C.; Tchobanoglous, G. History of Hygiene Focusing on the Crucial Role of Water in the Hellenic Asclepieia (i.e., Ancient Hospitals). Water 2020, 12, 754.
25. Lambert, T.A. Brief History of Medicine. 2020. Available online: http://www.localhistories.org/medicine.html (accessed on 25 February 2021).
26. Jouanna, J. Hippocrates; De Bevoise, M.B., Translator; The Johns Hopkins University Press. Baltimore/London, UK, 1999.
27. Jacques Jouanna, B.; Van der Eijk, P. Greek Medicine from Hippocrates to Galen: Selected Papers; Brill: Leiden, The Netherlands, 2012.
28. Hippocrates. Ancient Medicine. Airs, Waters, Places. Epidemics 1 and 3. The Oath. Precepts. Nutriment. Translated by W. H. S. Jones. Loeb Classical Library 147. Cambridge, MA: Harvard University Press, Volume I, 1923.
29. Vitruvius: On Architecture; Granger, F., Translator; In Two Volumes, Volume II; The Loeb Classical Library. First Printed 1931; Harvard University Press: Cambridge, MA, USA; London, UK, 1985.

30. Rodgers, R.H. Frontinus: De Aquaeductu Urbis Romae; Cambridge University Press: Cambridge, UK, 2004; Volume, 42.

31. Scheidel, W. Progress and problems in Roman demography. In Debating Roman Demography; Brill: Leiden, The Netherlands, 2001; pp. 1–81.

32. McClendon, C.B. From Classical Antiquity to the Middle Ages: Urban Public Building in Northern and Central Italy, AD 300–850 by Bryan Ward-Perkins; The Society of Architectural Historians: Chicago, IL, USA, 1990.

33. Pliny. Natural History; Rackham, H. Translator; In Ten Volumes; Volume VIII; The Loeb Classical Library (First Published in 1963); Harvard University Press—William Heinemann Ltd.: Cambridge, MA, USA; London, UK, 1975.

34. Vuorinen, H.S. Ancient Greek and Roman authors on health and sanitation. In Evolution of Sanitation and Wastewater Technologies through the Centuries; Angelakis, A.N., Rose, J., Eds.; IWA Publishing: London, UK, 2014; pp. 429–438.

35. Langmuir, A.D.; Worthen, T.D.; Solomon, J.; Ray, C.G.; Petersen, E. The Thucydides Syndrome. N. Engl. J. Med. 1985, 313, 1027–1030, doi:10.1056/nejm198510173131618.

36. Littman, R.J. The Plague of Athens: Epidemiology and Paleopathology. Mt. Sinai J. Med.: J. Transl. Pers. Med. 2009, 76, 456–467, doi:10.1002/msj.20137.

37. Morens, D.M.; Littman, R.J. Epidemiology of the plague of Athens. Trans. Am. Philol. Assoc. (1974-) 1992, 122, 271–304.

38. Baziotopoulou-Valavani, E. A mass burial from the cemetery of Kerameikos. In Excavating Classical Culture: Recent Archaeological Discoveries in Greece; Archaeopress: Oxford, UK, 2002; pp. 187–201.

39. Papagrigorakis, M.J.; Yapijakis, C.; Synodinos, P.N.; Baziotopoulou-Valavani, E. DNA examination of ancient dental pulp incriminates typhoid fever as a probable cause of the Plague of Athens. Int. J. Infect. Dis. 2006, 10, 206–214, doi:10.1016/j.ijid.2005.09.001.

40. Crump, J.A.; Mintz, E.D. Global trends in typhoid and paratyphoid Fever. Clin. Infect. Dis. 2010, 50, 241–246, doi:10.1086/649541.

41. Shapiro, B.; Rambaut, A.; Gilbert, M.T. No proof that typhoid caused the Plague of Athens (a reply to Papagrigorakis et al.). Int. J. Infect. Dis. IJID: Off. Publ. Int. Soc. Infect. Dis. 2006, 10, 334–335; author reply 335–336, doi:10.1016/j.ijid.2006.02.006.

42. Lenntech. History of drinking water treatment, (1998-2019). Available online: https://www.lenntech.com/processes/disinfection/history/history-drinking-water-treatment.htm#ixzz5UxrBJxRZ (accessed on 4 October 2019).

43. Foil, J.L.; Cerwick, J.A.; White, J.E. Collection systems past and present. Water Environment and Technology, December 1993.

44. Gray, H.F. Sewerage in Ancient and Mediaeval Times. Sew. Work. J. 1940, 12, 939–946.