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Review

Water Quality and Life Expectancy: Parallel Courses in Time

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Abstract: 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. During the last two hundred years, intensive and effective efforts have been made internationally for sufficient water quantity and quality. At the same time, human life expectancy has increased all over the globe at unprecedented rates. The present work represents an effort to sketch out how water purity and life expectancy have entangled, thus influencing one another. Water properties and characteristics have directly affected life quality and longevity. The dramatic increase in life expectancy has been, indisputably, affected by the improvement in water quality, but also in other concomitant factors, varying temporally and spatially in different parts of the world throughout the centuries. Water technologies and engineering have an unequivocal role on life expectancy. In some cases, they appear to have taken place earlier than the progress of modern medicine. Among these, improved sanitation, personal hygiene, progress in medicine, and better standards of economic living have played the greatest roles.

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

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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].

(a)

(b)

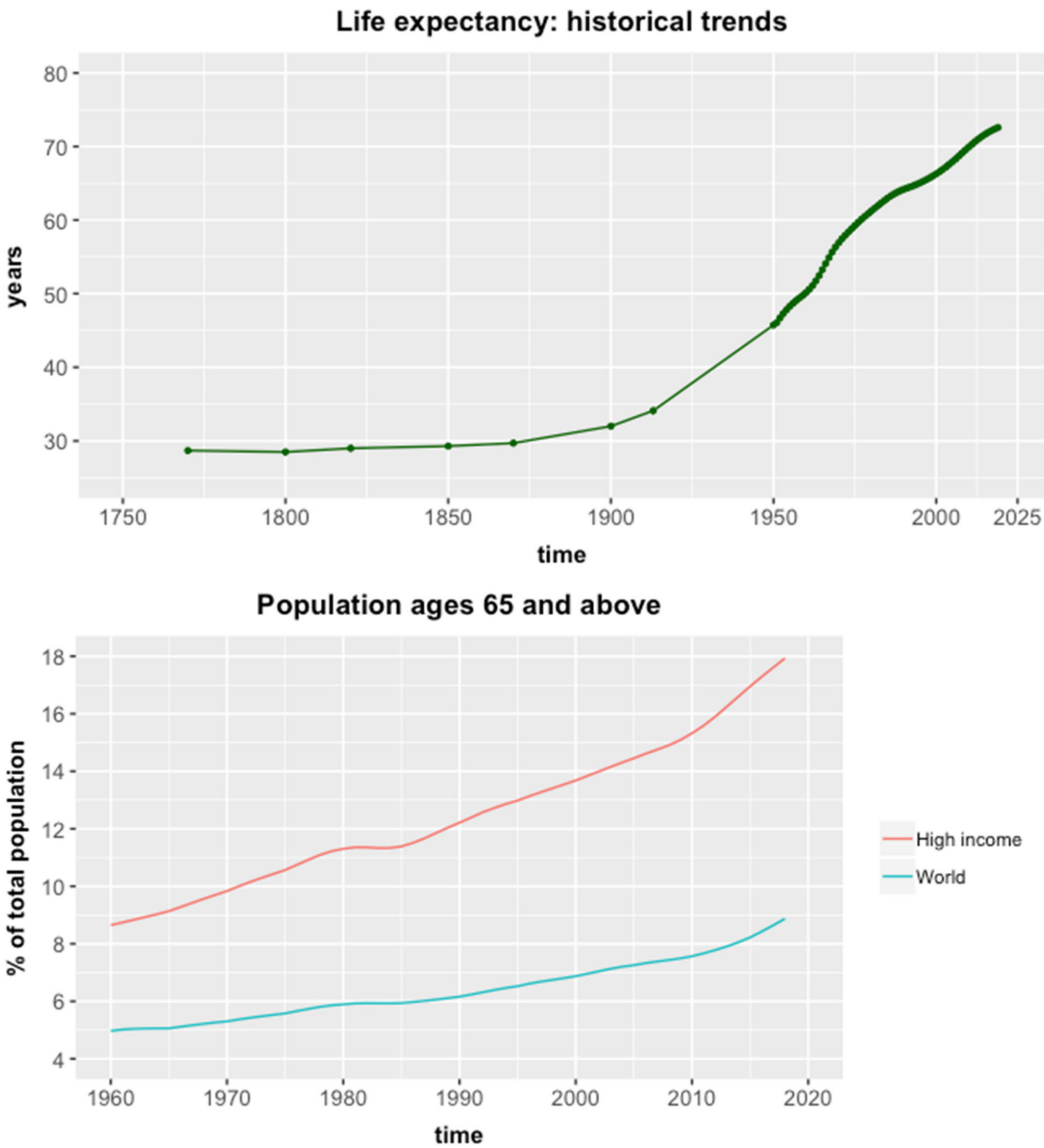

Figure 1. Life expectancy is constantly increasing. (**a**) Historical trends in life expectancy for the entire world [adapted from "Our World in Data"—Global Change Data Lab, University of Oxford (https://ourworldindata.org; accessed on 8 March 2021) and (**b**) proportion of population over 65 years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

The present work represents an effort to sketch out how water quality and life expectancy have entangled and influenced each other over time. Several examples from all over the world are reviewed with emphasis on water quality versus life expectancy. Water quality has been somewhat considered since the prehistoric times.

As a whole, this review paper is organized in four major sections as follows: the first section is the Introduction; the second describes the Methodology used; the third covers the Results and Discussion where the history is extensively considered and extended to the contemporary times; and the fourth provides our concluding remarks. The paper shows how water quality issues have been of great interest since early history up until now, and how this has impacted life expectancy.

2. Methods

The paper was based on its authors' long experience and studies in the field. The key method of this study was a literature review, more specifically, a narrative literature review and an overview. The big picture of the development of the complex nexus of water, sanitation, health, and life expectancy can be achieved by revealing historical path dependencies and highlighting historical development paths. This is done with a long series of health and mortality data. A trustworthy outline for the future must be based on historical analyses: we must learn how earlier choices affect future development paths. We can look back into history to explore factors of success and bifurcation points. Thus, the research determines which strategies, principles, and practices have resulted in historically significant changes in the overall development of life expectancy and health.

3. Results and Discussion

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

3.1.1. 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.

3.1.2. 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 [36–38] 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].

3.1.3. 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.

3.2. Early and Mid-Modern Times (ca. 1400–1900 AD)

It was only during the 19th century that new ideas about cleanliness, personal hygiene, sanitation, and water purification started to gain power and circulate.

Cholera was the disease that served as justification for the sanitation movement in Europe in the 19th century. The famous English doctor John Snow (1813–1858) held the well-justified view that a disease could be transmitted through contaminated water, a view he actively propagated with articles and letters in medical journals in the 1850s. In 1854, he was able to show that mortality along Broad Street in Soho, London was highest in the vicinity of one single handpump well. In the 1860s, his ideas started becoming popular, and by the 1870s, typhoid fever, cholera, dysentery, and diarrheal diseases were considered waterborne. Snow is considered one of the founders of modern epidemiology, and his findings and work inspired fundamental changes in the water supply and sanitation of

London. This led to similar changes in other cities, and a significant improvement in general public health around the world.

By the end of the 19th century, Sir Edwin Chadwick (1800–1890) was one of the most influential people in the field of public health. He was a pioneer in instituting major reforms in urban sanitation and demonstrated that unsanitary housing and poverty caused diseases [45]. He estimated that by establishing proper sanitation and providing clean water to communities, an extra thirteen years of life could be gained by the laboring class. He suggested that a system with a constant and abundant flow of good quality water and correctly constructed sewers, flushed away diseases and even moral deficiencies such as criminality, drunkenness, and other similar social problems of English cities. He also suggested that sludge, following certain rules and practices, could be potentially used to fertilize agricultural land.

Piped water supply systems, common in Europe during the late 19th century, were dangerous in the absence of purification, especially if surface water was used. This was proven in a ghastly way in Hamburg during the cholera epidemic of 1892 [46]. The "bacteriological revolution" brought an understanding of the benefits of water filtration and boiling. Hence, a new rationale of drinking water purification was developed, after the understanding of microbial transmission through water, while after the discovery of the causative agent of cholera, disinfection of drinking water gained impetus. Interestingly, although the disinfectant properties of chlorine compounds were already noticed in the middle of the 19th century, the chlorination of drinking water started in 1890s and rapidly spread around the world during the first decades of the 20th century.

James C. Riley, in his book *Rising Life Expectancy: A Global History* (2001), identified six factors contributing to the increase in life expectancy from the 18th century onwards: public health, medicine, income and wealth, nutrition, behavior, and education. Among the public health measures, a well-organized supply system of clean and healthy water resulting from sand filtration and chlorination has been proven to be the most important for the rise in life expectancy in industrialized European urban centers during the 19th and early 20th centuries. Morbidity and mortality from waterborne diseases rapidly diminished and cities became healthier places to live. However, building and maintaining systems delivering quality water and waste disposal required great financial input, consequently restricting their spread over the globe [11].

During the 19th century, other factors such as the smallpox vaccination introduced in 1798 by Edward Jenner (1749–1823), also increased life expectancy. In the 18th century, this disease represented a major cause of morbidity and mortality in Europe. The impact was of paramount importance for the health of European populations from the early 19th century onwards [47,48]. Vaccinations against other diseases followed, especially during the 20th century, significantly decreasing childhood mortality and contributing to gains in life expectancy.

Improvement in the water supply in the 19th century was intimately connected to the improvement in personal hygiene, which diminished morbidity and mortality and consequently increased life expectancy [10,11,49]. Improvement of personal hygiene was also connected to a rise in the standard of living and increased literacy, all of which helped spread new ideas of hygiene.

The so-called *epidemiological and demographic transition* is a well-studied phenomenon that is consistently observed when countries go through the developmental stages of industrialization, technological innovation, and modernization. It is characterized by an initial increase in population growth, followed by an enduring plateau (re-leveling of population) due to subsequent decline in births. Life expectancy rises, mainly due to a decrease in childhood mortality and infectious diseases, which are replaced by chronic diseases such as cardiovascular and neoplastic diseases, which gradually become dominant [50].

Thomas McKeown (1912–1988) was a British physician and demographic historian who studied population growth in the industrialized world from the late 1700s to the 20th century. He claimed that the rise in population numbers, especially in the 19th and early

20th century, was not the result of increased fertility, but was largely due to a decline in mortality, particularly among children under the age of five. This was brought about by improved standards of living such as better diet and nutrition, and improved economic conditions, and, controversially, less attributed to public health interventions (e.g., sanitary reforms, vaccination, and quarantine). This was the most disputed part of his theory, which was generally viewed as a social and political critique. However, McKeown was right in that gains in life expectancy prior to the Second World War, that is, before the advent of antibiotics and modern medicine, were brought about by technological innovations. The sanitation of water and better supply systems, organization of sewage systems, and the establishment of hygiene legislation has played a prominent role in this transition [51].

Historical data from England and Wales have shown an increase in life expectancy of approximately 20 years between 1850 and 1930 (from 40 years for males and 42 for females in 1851, to 59 and 63, respectively, in 1930). These impressive gains were recorded before the discovery of antibiotics and should be attributed to other factors [52]. During these times, infectious diseases (e.g., pneumonia, tuberculosis, meningitis, etc.) contributed to most of the years of life lost, thus shortening life expectancy at birth.

In a prominent example of this type, Kramek and Loh (2007) reported that in Philadelphia, USA, due to water pollution, typhoid deaths reached several hundred in 1900 [53]. A filtration construction was completed in 1912 and chlorination of the city water supply started immediately after in 1913. Consequently, typhoid deaths were dramatically reduced, demonstrating a direct connection between sanitation measures and human health as well as the paramount benefits of technology (Figure 2).

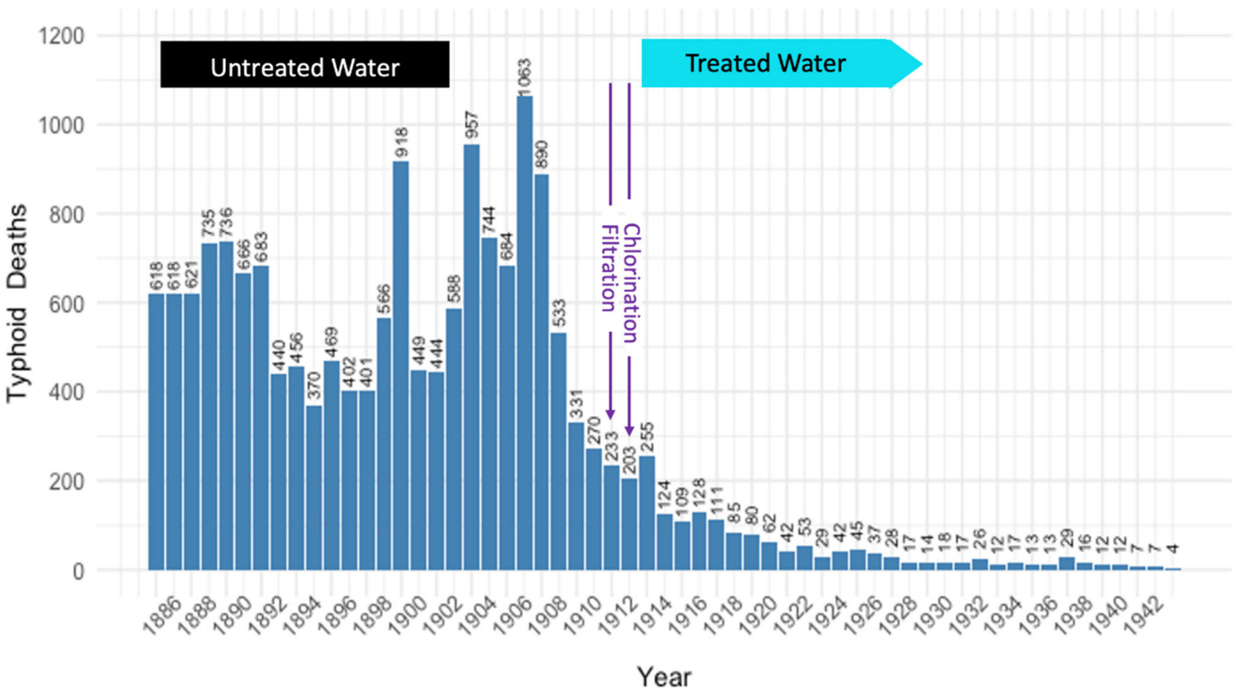

Figure 2. Typhoid deaths in Philadelphia drastically dropped after city-wide water filtration (1912) and chlorination (1913) [Adapted from [53]. Data from the Philadelphia Water Department Collection].

Urban sanitation was not only happening at the core of Europe. The impact of piped water, sewers, and chlorination on mortality was also evident in the periphery of Europe in the late 1800s and early 1900s, as seen in declining infant mortality in Finnish cities and towns between 1870 and 1938 [54]. Most of the measurable effects, estimated to be about a 32% decrease in infant mortality, came from small- and medium-sized cities adopting more advanced technology in the 20th century [54]. However, in the periphery of

Europe, there were still problems in the early 20th century due to sluggishness in adopting appropriate technologies, as shown in Tampere, Finland. In Tampere, since slow sand filtration was rejected and outlets of sewers were located too close to water intake pipes, typhoid fever spread fast over a wide area through the water pipe network in 1916. A death toll of hundreds of people finally prompted correct decision-making, and in 1917, water chlorination started. Since then, typhoid epidemics in Finland have disappeared [55,56].

In Finland, many towns still drew their water from wells in the late 1800s and early 1900s as organized water supply systems existed in only a few cities. Despite various reforms, the bucket remained the key implement for water supply, latrines. and waste disposal until the end of the 19th century. Sewers were laid to remove rain water that flowed into basements. People still believed in the so-called "miasma" theory, according to which humidity and dirty air spread disease. However, this belief, for its part, facilitated the introduction of sewerage [55]. After the quality of water of many wells became poor, and the water levels fell, new ways to satisfy water needs had to be invented. Additionally, the risk of fires sped up the creation of a well-organized water supply and sewerage systems Hence, in Finland, sixteen such urban systems were established by 1917.

On a national scale, public health improved and the incidence of typhoid fever decreased, with the exception of a few epidemics during the civil war in 1918, after the introduction of water purification. In 1919, infant mortality decreased in the cities, but remained high in the countryside, making cities healthier places to live [57].

A good example of how improvements in urban sanitation are needed all over the world comes from the rapidly urbanizing China. Over the centuries, the inhabitants of Shanghai used to drink water from the river, wells, and that collected from rainfall. Knowing that rivers in the area were characterized by a heavy alluvial deposit brought by the tides, local people developed the technique of bailing clean water as the tide was coming and then used to purify it by adding alum. However, along with rapid urbanization after 1842, the water quality deteriorated: first in creeks, then in the Suzhou River and, eventually, in the Huangpu River, rendering Shanghai a city with a lack of clean water. The response of authorities was slow, resulting in a water crisis. It became apparent that improving the drinking water quality was not a simple shift of water sources. However, maintaining high potable water quality has been proven to be a dynamic process. There is an urgent need to involve other factors such as effective administration, improved technology, and realistic equilibrium of water consumption between rural and urban areas [58].

3.3. Contemporary Times (1900–Present)

Disinfection has played a critical role in improving drinking water quality in the USA. In 1908, Jersey City, New Jersey, was the first city in USA to begin routine disinfection of community drinking water. Over the next decade, thousands of cities and towns followed, contributing to a dramatic decrease in morbidity all over the country (Figure 3).

The incidence of cholera and typhoid fever in the USA has dropped dramatically since the mid-20th century. In 1900, the occurrence of typhoid fever was approximately 100 cases per 100,000 people. By 1920, it had dropped to 33.8, and by 2006, to 0.1 (353 cases total), with approximately 75% occurring among international travelers [59]. The disease became rare in cities as water disinfection was instituted along with improvements in sanitation, hygiene, and the overall level of public health.

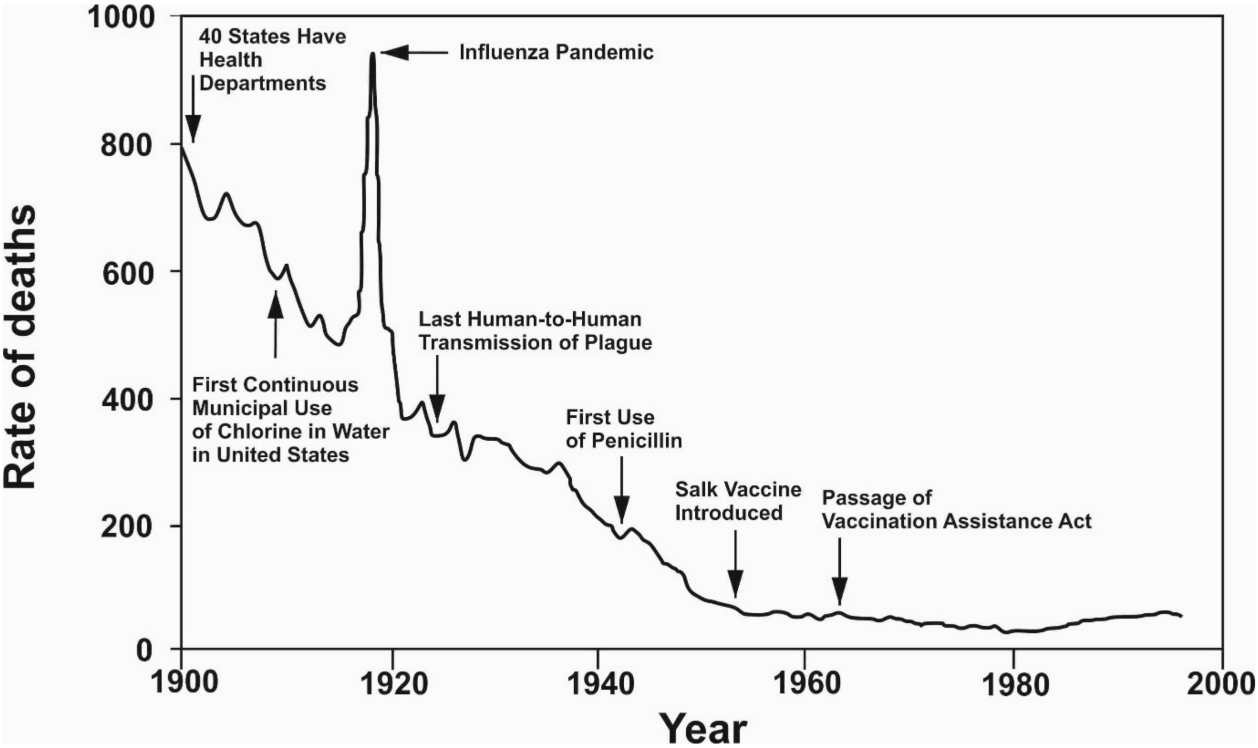

Figure 3. Death rate per 100,000 inhabitants per year from water related infectious diseases in the USA from 1900 to 1996 (Adapted from [59]).

Esrey et al. undertook a study regarding improved water quality, supply, and sanitation on health benefits based on 144 surveys [60]. They concluded that the lack of water purity and sanitation was causing 875 million cases of diarrheal diseases and 4,600,000 deaths per annum globally. According to some of these surveys, the expected reduction in morbidity, following water disinfection, ranged from 0% to 100% (median 22%), while according to others, from 0% to 68% (median 26%). Among them, the overall impact on guinea worm and hookworm disease, ascariasis, schistosomiasis, and trachoma on child mortality, ranged from 20% to 82% (median 55%).

Jeuland et al. presented country-level projections in developing regions from 1975 to 2050 including economic estimates of mortality reductions [61]. Their analysis showed *steady and substantial improvements in water, sanitation and hygiene (WaSH) improvements and declining mortality rates across many developing regions, namely East Asia and the Pacific, Latin America and the Caribbean, Eastern Europe and the Middle East*. However, in parts of South Asia and much of Sub-Saharan Africa, health losses are expected to remain high over the medium term, making clear that additional efforts will be needed to improve access to quality water and sanitation.

A review on sanitation by Carter [62] suggests that when water services are poor, sanitation and hygiene improvements are unlikely to have significant health impacts. Furthermore, *a high level of practices, following sanitation rules (well over 65%) and widespread handwashing, are necessary to achieve significant health impacts*. Actions should focus on prerequisites for health impacts (e.g., handwashing, latrine or toilet use, elimination of open defecation) even in affluent countries, where sophisticated water supply systems have been established and are functioning. The authorities must be on alert, since outbreaks of waterborne diseases may still occur [63]. Additionally, the safe delivery of good quality water requires continuous maintenance of the water supply system, a need that the Roman Frontinus well described almost 2000 years ago [30].

There are other factors, along with water purity, that affect life expectancy and quality (e.g., child mortality, diseases, medicines, nutrition, environmental and other risks, and standards of living). However, several lines of evidence support the theory that the dramatic increase in life longevity during the last two centuries (from 30 to over 80 years) is partly due to improved sanitation and water quality, taking into account that for millennia (since prehistoric times), life expectancy was ca. 30 years [64–66].

Regarding Greece, it is noteworthy that according to historical data, life expectancy during the Prehistoric and Minoan era (ca. 3200–1100 BC) was a little less than 30 years, during the Classical and Hellenistic era (ca. 500–100 BC), it was just a little over 30, while in the 20th century, in 1947, in particular, it was 45 years, and at present, it is 84 for women and 81.5 for men, with an increasing trend. It is widely believed that water sanitation and purity, well organized water supply systems, better conditions of hygiene, and standards of living have played a major role.

This is true for both Western Europe and the USA in the last two centuries. Since then—and after water quality was established—other factors such as better access to care, advances in medicine, and changes in demographic and epidemiological characteristics of populations may have contributed to additional gains in life expectancy (from 60 to 80 years).

Overall life expectancy worldwide has almost doubled in the last 118 years, increasing from 31 years in 1900 to 72 in 2016 [67]. This has been particularly true for well-developed countries. A good European example is Finland, where an increase from 42.8 years in 1900 to 81.4 in 2018 was observed. This is the result of several factors, but water purification and a well-organized water supply system played a major role. In the control of communicable diseases, the crucial role of water was expressed in a handbook: "Handwashing is the single most important part of infection control" [68]. This has recently been shown again to be very relevant in the times of COVID-19.

There is no indication that prehistoric civilizations were aware on the causes of human illness. During those times, explanations based on theocratic elements dominated. These hypotheses were tested empirically with data from 190 countries in contemporary times. The empirical estimates confirmed that both theocratic and autocratic regimes provided lower average delivery quality than democracies [24,69].

Despite the unquestionable triumphs in life expectancy and in the level of public health in developed countries, a large proportion of the world population still has no access to drinking water and adequate sanitation. According to the World Health Organization (WHO), 2.6 billion people lack access to basic hygiene, while 1.8 million die each year from water-related diseases [70]. Diarrheal diseases were responsible for 499,000 deaths among children younger than five years in 2015, representing 8.6% of all deaths in this age group. The highest rates have been reported in sub-Saharan Africa, particularly in Chad (594 deaths per 100,000) and Niger (485 deaths per 100,000); when compared to high-income countries, the corresponding rates are very low (1.2 deaths per 100,000). Furthermore, India and Nigeria, due to their large populations and poor sanitation conditions, have contributed to 42% to the global deaths from diarrheal diseases among children under the age of five [71].

In 2015, diarrheal diseases globally caused 71.6 million disability-adjusted years (DALYs). Most DALYs (92%) were due to years of life lost (YLLs), confirming the paramount role of water quality and sanitation. At a global level, between 2005 and 2015, diarrhea DALYs, attributable to unsafe water and poor sanitation, decreased by 13.4%. Diarrhea incidence decreased by 10.4% in children under five, and by 5.9% among all ages from 2005 to 2015. Diarrhea DALYs attributable to unsafe WaSH decreased in all countries, with the greatest reduction observed in Vietnam (35.2%) and the smallest in eastern sub-Saharan Africa (7.2%) [71].

Efficient water supply became the goal of the Shanghai authorities after the 1980s. Moreover, after 2000, the required measures were taken and problems of "secondary pollution" due to water pipes and roof tank rust were solved, and at the same time, specific relevant jobs were created and promoted. The use of modern technology and standardized testing methods has gradually improved water quality and supply systems [72].

China's recent vision of accelerating industrial optimization and upgrading social information is included in the "Urban City for Excellence" project, organized by the "Shanghai Urban Master Plan". Water treatment companies, represented by the "Shanghai State-Owned Drinking Water Company", have made considerable progress using computer network management, improved customer service, efficient pipe network dispatching systems, and strengthening the development and utilization of water supply information resources. The city is carrying out water purification by optimizing its treatment. Additionally, a new pipe network aims to prevent secondary pollution and leakage in distribution units, improve operation reliability, and increase production and automation. Furthermore, reduced power consumption is a way of looking toward the future [72,73].

Modern wastewater treatment and management were not largely developed and used before the 1970s and 1980s. During the last decades, water pollution control with modern wastewater treatment has become widely used in the North, whereas globally, 80 percent of urban wastewaters still remain completely untreated.

Significant gains have been observed in industrialized countries during the 19th and early 20th century, with positive long-term impacts on water quality and human health. In the last 120 years, life expectancy has increased by over 50 years globally. In 1900, the global average lifespan was just 31 years, and below 50 years, even in developed countries. By the mid-20th century, the average life expectancy had risen to 48 years. At the end of the 20th century, the average lifespan reached 65 years, and over 80 years in some countries [74]. By 2050, according to estimates, average life expectancy at birth for women in countries like the USA will be 91.5 years [75]. However, the increase in life expectancy has slowed down or even declined in some developed countries such as in USA recently [76].

Data from the Global Burden Diseases (GBD) show that water-related deaths have substantially decreased worldwide, especially in children under the age of five over the last 50 years, contributing to the observed gains in life expectancy. In sub-Saharan Africa, in particular, life expectancy has increased from 40.4 years in 1960 to 60.8 in 2017 [77].

Using a tighter criteria, the joint monitoring program of the WHO and United Nations International Children's Emergency Fund (UNICEF) noted in 2017 that on the global scale, we still have 2.1 billion people without clean water, 4.5 billion people lacking proper sanitation, and almost one billion have to practice open defecation [78]. The most recent reminder of the importance of clean water is the current COVID-19 pandemic. To stop the spread of the disease, the first advice is to wash your hands with warm water and soap, which is not possible for far too many people in developing economies.

4. Conclusions

The present historical research represents an effort to investigate water-related health problems and the progress achieved in this field through time. This review investigated the historical facts regarding water and health from the early Neolithic era until the present time. All these facts have made clear that the contribution of water treatment and sanitation has undoubtedly left a strong mark on human health throughout the course of civilization.

The presented data indicate that water technology and engineering have an unequivocal role on human health and on life expectancy. Despite the reduction in mortality, however, water-related deaths remain an important preventable burden in south Asia and sub-Saharan Africa.

Related to water quality, a major challenge is making the aging infrastructure systems more visible to policy-makers, decision-makers, and citizens. This is as big a challenge as proper water pollution control that cities and many industries in the Western world has largely resolved. However, this challenge was visible when surface waters were polluted. In the case of aging infrastructure and networks, in particular, the challenge is much more demanding due to its invisible nature. The timeframe of local government decisions is just a few years for elected officials, whereas there is also the need for thinking several decades ahead with a strategic (five to 10 years) or visionary timeframe (up to 50 years).

Being able to drink clean water is closely tied to human health, as clearly expressed by the renowned physician Lewis Thomas: *There is no question that our health has improved spectacularly in the past century. One thing seems certain: it did not happen because of improvements in medicine, or medical science or even the presence of doctors, much of the credit should go to plumbers and sanitary engineers of the western world* (Thomas' speech, 1984 in [64]). As such, it should always be remembered that *Water is life; but water quality is health* [74]. Efforts have to continue for further improvement in developing countries around the world.

Based on the findings of the present historical research, it has become clear that modern water technology and engineering must also be applied in developing countries in need of water sanitation improvement. National and international organizations should move toward this direction.

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