

## History of water and health from ancient civilizations to modern times

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**Abstract** This paper examines the influence of water on public health throughout history. Farming, settling down and building of villages and towns meant the start of the problems mankind suffers from this very day – how to get drinkable water for humans and cattle and how to manage the waste we produce. The availability of water in large quantities has been considered an essential part of a civilized way of life in different periods: Roman baths needed a lot of water as does the current Western way of life with water closets and showers. The importance of good quality drinking water was realized already in antiquity, yet the importance of proper sanitation was not understood until the 19th century.

**Keywords** History; public health; sanitation; water supply

### Introduction

Water is life – and life on earth is linked to water. Our existence is dependent on water – or the lack of it – in many ways, and one could say that our whole civilization is built on the use of water. This paper summarizes the general outline and some of the main results soon to be published in a book by IWA Publishers (Juuti *et al.*, 2007)<sup>1</sup>. Special emphasis is given to the first urbanization of ancient civilizations focusing on ancient Greece and Rome (Vuorinen, 2007).

### First urbanization: early systems and innovations

Modern humans (*Homo sapiens*) have dwelled on this earth for some 200 000 years, most of that time as hunter-gatherers and gradually growing in number. Approximately 50 000 years ago modern man began to inhabit every corner of the world and people were constantly on the move. Occasionally people were troubled by pathogens transmitted by contaminated water, but general aversion for water that tasted revolting, stunk and looked disgusting must have developed quite early during the biological and cultural evolution of humankind. It has been postulated that the waterborne health risks of hunter-gatherers were small.

Yet, archaeological and written sources concerning water and sanitation can be found only in relatively recent times. Thus, in reconstructing the history of water and sanitation of this hunter-gatherer phase, we have to rely on analogies with later societies. Modern anthropological studies and recorded mythologies of indigenous peoples play an important role in these analogies while observing primates and other more evolved mammals can also give us useful information.

<sup>1</sup> This article summarizes two papers presented at the 1st IWA International Symposium on Water and Wastewater Technologies in Ancient Civilizations held in Iraklio, Greece, 28–30 October 2006: “Water and Health in Ancient Civilizations” by Heikki S. Vuorinen and “Environmental History of Water: Global View of Community Water Supply and Sanitation” by Petri S. Juuti, Tapio S. Katko and Heikki S. Vuorinen.

Humankind established permanent settlements about 10 000 years ago, when people adopted an agrarian way of life. This new type of livelihood spread everywhere and the population began to expand faster than ever before. Sedentary agricultural life made it possible to construct villages, cities and eventually states all of which were highly dependent on water. This created a brand new relation between humans and water. Pathogens transmitted by contaminated water became a very serious health risk for the sedentary agriculturists. This was a world in which guaranteeing pure water for people became a prerequisite for successful urbanization and state formation.

The earliest known permanent settlement which can be classified as urban is Jericho from 8000–7000 BC, located near springs and other bodies of water. In Egypt there are traces of wells, and in Mesopotamia of stone rainwater channels, from 3000 BC. From the early Bronze Age city of Mohenjo-Daro, located in modern Pakistan, archaeologists have found hundreds of ancient wells, water pipes and toilets. The first evidence of the purposeful construction of the water supply, bathrooms, toilets and drainage in Europe comes from Bronze Age Minoan (and Mycenaean) Crete in the second millennium BC.

The experience of humankind from the very beginning testifies to the importance and safety of groundwater as a water source, particularly springs and wells. The way in which water supply and sanitation was organized was essential for early agricultural societies. If wells and toilets were in good shape, health problems and environmental risks could be avoided. The realization of the importance of pure water for people is evident already from the myths of ancient cultures. Religious cleanliness and water were important in various ancient cults. Ideas of the salubrity of water were connected to the general “scientific” level of the society. The first known Greek philosophical thinkers and medical writers also recognized the importance of water for the health of people.

### **First urbanization: ancient Greece and Rome**

The first urbanization in Europe occurred during antiquity (500 BC – AD 500) around the Mediterranean region. The share of urban population reached some 10–20% in the centuries around the birth of Christ. The most urbanized areas were the Eastern Mediterranean, Egypt, North Africa (modern Tunisia), the Apennine Peninsula (modern Italy), and the southern part of the Iberian Peninsula, most of which were areas of quite modest rainfall. In this period the archaeological and written sources become richer, and consequently improve our possibilities to study the relationship between water and health of people.

Alcmaeon of Croton (floruit ca. 470 BC) was the first Greek doctor to state that the quality of water may influence the health of people (*Aëtius, On the opinions of the philosophers* V.30.1). The Hippocratic treatise *Airs, Waters, Places* (around 400 BC) deals at length with the different sources, qualities and health effects of water. (*Airs, Waters, Places*. 1, 7, 8, 9). Various other Hippocratic treatises (mostly written around 400 BC) contain short comments on the influence of water on the health of people (*Internal Affections*. 6, 21, 23, 26, 34, 45, 47; *Diseases I*. 24; *Epidemics II*. 2.11; *Epidemics VI*. 4.8, 4.17; *Aphorisms*. 5.26; *Humours*. 12; *Regimen IV or Dreams*. 93). According to the late first century BC author Vitruvius, marshy areas must be avoided when the site of a city is chosen (*De Architectura*. I.iv.1). Pliny the Elder in the first century AD had in his works a long section concerning the different opinions on what kind of water is the best. (Plinius *NH*, XXXI, xxi–xxiii). One of the most famous doctors during antiquity, Galen (2nd century AD) summarises the preferable qualities of water (*Galen. De Sanitate Tuenda*. I.xi).

The quality of the water was examined by the senses: taste, smell, appearance and temperature. Also the health of the people and animals using a water source was considered (*Vitruvius De Architectura*. I.iv,9,10; VIII, iv,1,2). Throughout antiquity tasty or

tasteless, cool, odourless and colourless water was considered the best, and stagnant, marshy water was avoided. These ideas were held until the end of antiquity as expressed by Palladius (5th century, *Opus Agriculturae*. I, 4) or Paulus Aeginata (7th century, Paulus Aeginata I.50). The ancient Greeks and Romans were also quite aware of the dangers of water coming from hills and mountains where mining was carried out (*Airs, Waters, Places*. 7; Vitruvius. *De Architectura*. VIII,iii,5).

The ancient authors have thus made some comments about the influence of different kinds of water on the health of people, but whether these comments had any influence on the health of people is hard to infer. Because of the inadequacy of sources, it is practically impossible to evaluate the health of ancient populations and the role of water in it. It is, however, quite safe to conclude that despite the impressive measures used to obtain pure potable water, urban centres had serious public health problems. The ancient Greek or Roman society did not have the interest or the means to deal adequately with matters of public health (Nutton, 2005: 26).

The Greeks and Romans used different methods to improve the quality of the water if it did not satisfy their quality requirements. From written sources and archaeological excavations, we know that using settling tanks, sieves, filters and the boiling of water were methods used during antiquity. At least boiling of water, which was widely recommended by the medical authors during antiquity, would have diminished the biological risks of poor quality water. Although the boiling of water might have been feasible from a hygienic point of view, it was ecologically and economically not feasible in extensive use since firewood and other combustibles would sooner or later have become a scarce resource around the Mediterranean.

The poor level of waste management, including wastewater, most probably involved a major risk for public health during antiquity. For instance, toilet hygiene must have been quite poor. The abundance of water that was conducted to the bath could also be used to flush a public toilet. The Romans, however, lacked our toilet paper. They probably commonly used sponges or moss or something similar, which was moistened in the conduit in front of the seat and then used to rinse their bottoms. In public toilets facilities were common to all; they were cramped, without any privacy, and had no decent way to wash one's hands. The private toilets most likely usually lacked running water and they were commonly located near the kitchens. All this created an excellent opportunity for the spreading of intestinal pathogens.

Water-borne infections must have been among the main causes of death. Dysentery and different kinds of diarrhoeas must have played havoc with the populations. Although the ancient medical writers described different kinds of intestinal diseases, the retrospective diagnoses are difficult and the causative agents cannot be identified. Summer and early autumn, when water resources were meagre in the Mediterranean world, must have been a time when drinking water was easily contaminated, and intestinal diseases were rife as presented in several passages in the Hippocratic writings (e.g. *Airs, Waters, Places*. 7; *Aphorisms*. III, 11, 21, 22; *Internal Affections*. 26, 45). The mortality of children, especially recently weaned, must have been high (*Prorrhetic II*. 22)

It should also be kept in mind that the salubrity of the water supply must have differed markedly in accordance with the social status of people in the Roman towns. The rich had running water in their homes; the poor had to fetch their water from public fountains. The rich had their own baths and toilets, the poor had to use public toilets and baths. All this must have caused differences in the health of rich and poor people.

A lot of the water in a Roman town was consumed in bath(s) connected to the aqueduct(s) (Figure 1). Ideally shining marble walls and limpid water were considered a feature of a bath in Rome, the cleanliness of which was watched over by aediles (Seneca.



**Figure 1** Roman aqueduct in Segovia, Spain (Photo: T. Katko)

*Ad Lucilium epistulae morales*. 86). Baths were probably also beneficial for public health in towns where there was an abundance and rapid turnover of water. However, in towns where water was in short supply, cisterns had to be used and the turnover of water was slow, the role of baths was probably negative for public health.

Water supply and sanitation for military needs was a primary concern of the authorities of an imperial power like the Roman Empire needing a strong military machine. The Romans did know how to obtain adequate amounts of drinking water for their garrisons, cities and troops in the field and thus successfully planned their operations according to the availability of water. Army veterans were well accustomed to baths and to an ample water supply during their active service, and they may have been a quite important pressure group for building an aqueduct and bath in a town.

The contamination of water by lead has been a topic in the discussions concerning the health of people in Roman times. Roman authors expressed doubts concerning the use of lead pipes and recommended the use of ceramic pipes (Vitruvius. *De Architectura*. 8.6.10–11; Palladius. *Opus Agriculturae*. 9.11; Columella. *Rei Rusticae* 1.5.2; Plinius. *NH*. XXXI.31.57). However, in practice it seems that although ceramic pipes were used, water was in many situations routinely distributed by lead pipes, as revealed by both written sources (Vitruvius *De Architectura*. 8.6.1, 4–6; Frontinus. 25.2, 27.3, 29.1, 30.1, 39–63, 105.5, 106.3, 115.3, 118.4, 129.4–6) and archaeological remains (Bruun, 1991: 124–127; Hodge, 1992: 307–315). Yet, there are two reasons to believe that exposure through water was quite minimal, as pointed out by A. Trevor Hodge (Hodge, 1981 and 1992: 308). Firstly, as a consequence of the quality of the water, a calcium carbonate coating separated the lead and the water in most cases. Secondly, because of the constant flow, the contact time of water in the pipe was too short for contamination by lead.

The indirect public health effects of water might have been greater than the direct effects during antiquity. Agriculture depended on the proper amount of available water. Droughts and floods led to food shortages and famines. Food, people and pathogens moved most easily by water during antiquity. Maritime trade was especially vigorous around the Mediterranean in the period 200 BC– AD 200. This meant that the Mediterranean world became more or less a common pool of infectious diseases (McNeill, 1979: 78–140). Two important diseases caused by parasites were intimately connected with water and the ways water was managed during antiquity: malaria and schistosomiasis.

The breeding of mosquitoes depended on water and mosquitoes spread malaria, which was a serious and widespread health problem around the Mediterranean during antiquity. Malaria was well documented by Greek and Roman medical authors from the Hippocratic writings onwards. Among the cases in *Epidemics I and III*, a serious complication of chronic

malaria, blackwater fever, has been identified by Mirko D. Grmek at least in one patient, Philiscus, but probably also in another, Pythion (*Epidemics I*, fourteen cases, case 1; *Epidemics III*, sixteen cases, case 3; Grmek, 1989: 295–304). A fine description of malarial cachexia is to be found in *Airs, Waters, Places*, (*Airs, Waters, Places*, 7; Grmek, 1989: 281).

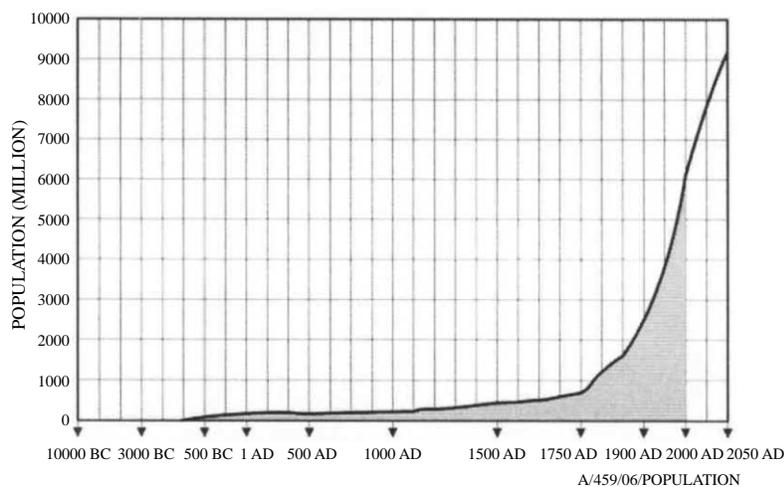
Schistosomiasis (bilharzia) has been for millennia a scourge in Egypt. The parasite (blood-vessel inhabiting worms) has an intricate relationship between the human host and a snail intermediate host. The type of agriculture (irrigation, flooding of the Nile) must have spread the disease. Although the evidence from ancient Egyptian medical papyri remains hard to interpret, there is strong paleopathological evidence of schistosomiasis in human remains from ancient Egypt.

Frontinus expressed clearly that a water system needed constant maintenance to function efficiently (Frontinus 116–123). For instance, calcium carbonate incrustation that formed inside the conduits needed constant removal, otherwise the flow of water would eventually stop (Hodge, 1992: 227–232). In Italy aqueducts and baths seem to have been maintained even after other monumental buildings in the towns, with the exception of town walls and palaces, fell into disuse in late antiquity (Ward-Perkins, 1984: 31, 128). In Antioch and other Near Eastern towns, at least part of the ancient water system was maintained into the Byzantine period and possibly up to the Era of Islam (Kennedy, 1992). Although there were continuities from antiquity to the Middle Ages, the water supply was more limited and the Christian water patronage replaced the classical one: it was a move from luxuria to necessitas (Ward-Perkins, 1984: 152).

### Second urbanization: the long 19th century

After the fall of the Roman Empire, water supply and sewage systems experienced fundamental changes in Europe. Medieval cities, castles and monasteries had their own wells, fountains or cisterns. Usually towns built a few modest latrines for the inhabitants, but these were mostly inadequate for the size of the population. The lack of proper sanitation increased the effects of epidemics in medieval towns in Europe.

Fundamental changes began to appear: science and knowledge were institutionalized for the first time when the development of modern universities started in the 13th century, and the agricultural world set out to industrialize from the 18th century onwards. Consequently, the growth of world population increased (Figure 2). All this profoundly affected water supply



**Figure 2** Estimated human population growth from 10 000 BC until year 2050 (Source: Juuti et al., 2006: 13)

and sanitation. Along with the industrialization and urbanization of the Western world, enlightened people were fascinated with the idea of progress. Ever since the 18th century, science and reason were considered to be able to lead humankind towards an ever-happier future. This was the period when the first actual water closet was developed. By 1900, the water closet became a generally accepted cultural necessity in the Western world – the same way aqueducts had been in the Roman Empire. The water closet was seen as a victory for public health without any consideration for where the human excreta went through sewer pipes. The start of industrialization and the related growth of cities created a situation where public health and environmental problems overwhelmed city governments to a greater degree than before, and novel technology was often seen as the solution. In the 19th century, Great Britain was seen as the forerunner of modern water supply and sanitation systems, but the innovations soon spread to Germany, other parts of Europe, USA and later also elsewhere.

Sanitation in towns around Europe was one of the great achievements of the 19th century. During the century the role of water in the transmission of several important diseases – cholera, dysentery, typhoid fever and diarrhoeas – was realized. The final proof came when the microbes causing these diseases were discovered. Especially cholera served as a justification for the sanitary movement around the world in the 19th century. Sensory evaluation of water quality was complemented with chemical and microbiological examination. During the 19th century, filtering of the entire water supply of a town was introduced and the systematic chlorination of drinking water started in the early 20th century. The discovery of microbes and the introduction of efficient ways of treating large amounts of water paved the way to an era in which the public health problems caused by polluted water seemed to belong to history.

### **Third urbanization: modern urban infrastructure**

The 1900s was a period of extensive population growth – the global population about quadrupled while the urban population increased 13-fold (Figure 2). By AD 2000, in almost every country, over half of the population lived in urban areas. During the century industrial production increased 40-fold and the consumption of energy by a factor of tens. Water and sanitation services had a definite role in this rapid socio-economic change of the entire globe.

In the early 20th century the health problems associated with water pollution seemed to have been resolved in the industrialized countries when chlorination and other water treatment techniques were developed and widely taken into use. Microbiological problems related to water were largely considered a problem of the developing world. However, in the late 20th century the biological hazards transmitted by water emerged again in the post-modern Western world. Anxiety about chemical and radioactive environmental hazards and their impacts on human health mounted in the 1960s. The overall amount of known biological and chemical health hazards transmitted by water increased manifold during the last half of the 20th century.

In today's world around 10 000 people die every day due to diseases like dysentery, cholera, and various diarrhoeal diseases, caused by a lack of safe water and adequate sanitation. Yet, since most of those who die are children and old people, whose death is considered “natural”, or people who are more or less marginalized in their societies (e.g. refugees, the poor) or living outside areas that are important for the global economy, mortality due to these waterborne diseases is too often considered unavoidable.

#### **Fourth urbanization: future challenges, the relevance of history**

In the historical context, the growth of urban centres has been a continuous and even an escalating trend. Many of these centres are today located in developing economies, while the ensuing problems are concentrated on the poorest people – as always. The most severe constraints include poor living conditions, a lack of democracy, poor hygiene, illiteracy, corruption and a lack of proper water and sanitation services. Especially women and children suffer from these constraints.

Today there is a global shortage of potable water. When making fundamental decisions concerning water supply and sewerage, it is also necessary to be ready to make big investments. Services that are now at a high operational level were not achieved easily and without massive inputs and efforts. This is something to keep in mind when assessing future options and considering required strategies. The level of water supply and sanitation in a society is not necessarily bound with time and place as much as the capability of that society to take responsibility for developing the living environment of its citizens and proper policies. In some cases, the situation was even better earlier than nowadays. Decisions have been made concerning water and sanitation systems – e.g. the universal acceptance of the water closet as a cultural necessity – that through path dependence have limited future options. There have also been situations where the choice of a technology has been regarded as problematic from the first beginning but has been chosen anyway. For instance, lead pipes were considered hazardous for health already in antiquity but continued to be used in house connections until recently.

Water supply and sanitation systems have always required continuous maintenance and adequate rehabilitation. This was already evident with the Roman aqueducts: calcium carbonate incrustation forming within the conduits needed to be removed constantly or it would have stopped the flow of water. The same is true for modern systems: they must be maintained to function properly. In the historical context, we can see both a continuation and a change in the perception of good quality drinking water and waterborne health hazards, which are both highly dependent on the scientific and technological level of a society. The importance of good quality drinking water for urban populations was realized already in antiquity. Yet, the importance of proper sanitation for the health of townspeople was not understood until the 19th century. The building of “modern” urban sewerage systems started then in Britain and rapidly spread all over the globe.

#### **Conclusion**

The availability of water in large quantities has been considered an essential part of a civilized way of life in different periods: Roman baths needed a lot of water as does the current Western way of life with water closets and showers. Particularly high rates of water use occur when it is not properly charged for. Evidence indicates that as soon as water and wastewater are charged based on real costs, wastage diminishes remarkably. There are numerous development paths that water supply and sanitation can take. From the point of view of the wellbeing of man and the environment, it is essential that water is good and safe – regardless of whether it is from piped systems or point sources like wells. The same applies to sanitation — it is a question of being connected either to the sewer or using proper on-site sanitation solutions. Local conditions, traditions and people have to be in the core of decision making when future solutions are considered. In the long historical perspective, it is evident that regardless of the political system, good local solutions can be found based on local conditions, needs and traditions. Although water – and particularly water services – is largely dependent on local conditions, it is useful to

make comparative studies between various regions and cultures, and identify possibly applicable and replicable principles and practices.

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### References

- Aëtius, *On the Opinions of the Philosophers* V.30.1. In Longrigg, J. *Greek Medicine. From the Heroic to the Hellenistic Age. A Source Book*. London: Duckworth, 1998, p. 31.
- Airs, Waters, Places. In *Hippocrates* Volume I, with an English translation by W.H.S. Jones. The Loeb Classical Library.
- Aphorisms. In *Hippocrates* Volume IV, with an English translation by W.H.S. Jones. The Loeb Classical Library.
- Bruun, C. (1991). *The Water Supply of Ancient Rome. A study of Roman Imperial Administration*, Societas Scientiarum Fennica. Commentationes Humanarum Litterarum, Helsinki, 93.
- Columella. *Rei Rusticae. Lucius Junius Moderatus Columella on Agriculture in three volumes*; with a recension of the text and an English translation by Harrison Boyd Ash. The Loeb Classical Library.
- Diseases I. In *Hippocrates* Volume V, with an English translation by Paul Potter. The Loeb Classical Library.
- Epidemics I. In *Hippocrates* Volume I, with an English translation by W.H.S. Jones. The Loeb Classical Library.
- Epidemics II. In *Hippocrates* Volume VII, edited and translated by Wesley D. Smith. The Loeb Classical Library.
- Epidemics III. In *Hippocrates* Volume I, with an English translation by W.H.S. Jones. The Loeb Classical Library.
- Epidemics VI. In *Hippocrates* Volume VII, edited and translated by Wesley D. Smith. The Loeb Classical Library.
- Frontinus Sex. Julius. *De aquaeductu urbis Romae. The stratagems and The aqueducts of Rome*; with an English translation by Charles E. Bennett; edited and prepared for the press by Mary B. McElwain, The Loeb Classical Library.
- Galen. *De Sanitate Tuenda. A Translation of Galen's Hygiene (De Sanitate Tuenda)* by Robert Montraville Green. With an introduction by Henry E. Sigerist. Springfield: Charles C. Thomas, 1951.
- Grmek, M.D. (1989). *Diseases in the Ancient Greek World*, The Johns Hopkins University Press, Baltimore. Translated by Muellner, M. and L.
- Hodge, A.T. (1981). *Vitruvius, lead pipes and lead poisoning*. *American Journal of Archaeology*, **85**, 486–491.
- Hodge, A.T. (1992). *Roman Aqueducts & Water Supply*, Duckworth, London.
- Humours. In *Hippocrates* Volume IV, with an English translation by W.H.S. Jones. The Loeb Classical Library.
- Internal Affections. In *Hippocrates* Volume VI, with an English translation by Paul Potter. The Loeb Classical Library.
- Juuti, P.S., Katko, T.S. and Vuorinen, H.S. (Eds.), (2007). *Environmental History of Water – Global View of Community Water Supply and Sanitation*, IWA Publishing, London.
- Kennedy, H. (1992). Antioch: from Byzantium to Islam and back again. In *The City in Late Antiquity*, J. Rich (Ed.), Routledge, London, 181–198.
- McNeill, W.H. (1979). *Plagues and Peoples*, Penguin Books, Harmondsworth.
- Nutton, V. (2005). *Ancient Medicine*, Routledge, London and New York.
- Palladius. *Opus Agriculturae*. In *Palladii Rutilii Tauri Aemilian Vri Inlustris. Opus Agriculturae, De Veterinaria Medicina, De Insitione*. Bibliotheca Scriptorum Graecorum et Romanorum Teubneriana. Leipzig: B.G. Teubner Verlagsgesellschaft, 1975.
- Paulus Aeginata. *Paulos von Aegina des besten Arztes Sieben Bücher*. Uebersetzt und mit Erläuterungen versehen von I. Berendes. Leiden: E.J. Brill, 1914.

- Pliny (the Elder). *Natural History*; in ten volumes; with an English translation by H. Rackham, The Loeb Classical Library.
- Prorrhetic II. In *Hippocrates* Volume VIII, edited and translated by Paul Potter. The Loeb Classical Library.
- Regimen IV or Dreams*. In *Hippocrates* Volume IV, with an English translation by W.H.S. Jones. The Loeb Classical Library.
- Seneca L. Annaeus minor. *Ad Lucilium epistulae morales*; in three volumes; with an English translation by Richard M. Gummere, The Loeb Classical Library.
- Vitruvius. *On Architecture*; in two volumes; translated into English by Frank Granger, The Loeb Classical Library.
- Vuorinen, H.S. (2007). Water and health in antiquity: Europe's legacy. In *Environmental History of Water—Global View of Community Water Supply and Sanitation*, P.S. Juuti, T.S. Katko and H.S. Vuorinen (Eds), IWA Publishing, 49–71.
- Ward-Perkins, B. (1984). *From Classical Antiquity to the Middle Ages. Urban Public Building in Northern and Central Italy AD 300–850*, Oxford University Press, Oxford.