

WATER SUPPLY AND WASTEWATER DISPOSAL IN POMPEII: AN OVERVIEW

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The getting of water and its domestic, commercial and industrial use were daily activities for many of the inhabitants of Pompeii. The related infrastructure, such as the aqueduct, *Castellum Aquae* and many water towers and fountains, was a very visible part of Pompeii, as was the use of the streets for wastewater disposal. Indeed extensive provision and use of water was a characteristic part of Roman urbanisation all over the empire, and generally a sign of 'Romanisation'¹. This article reviews the water system in Pompeii from early times through to the city's destruction in 79 AD through the literature on this subject which has blossomed over the last two decades. For the purposes of this article I have confined myself to English language scholarship, with the occasional German and Italian exception.

Written Sources

There are few written sources dealing specifically with the water system of Pompeii. The exceptions are the occasional graffito and inscription, mainly related to the baths of the town. The situation is rather better when we consider texts on Roman water systems in general from the time of Pompeii. Latin writers include Frontinus, Vitruvius and the two Plinys. Frontinus had the *cura aquarum* (care of waters) in Rome under Nerva and wrote the treatise *De aquaeductu urbis Romae* ('On the aqueducts of the city of Rome') (Rodgers [1986] 353). Vitruvius, an architect in the first century BC devoted a chapter of his *De architectura* to water systems. The younger Pliny, who managed the drains of Rome early in his career (Sherwin-White [1969] xi), had much discussion of water systems in his correspondence, particularly when he was imperial legate in Pontus and Bithynia, while his uncle made many statements on water, its provision, use and disposal in his voluminous *Naturalis Historia*. In Greek we also have the writings of Hero of Alexandria, who wrote an advanced, although now difficult to understand, work on hydraulic engineering.

There is often tension between these written sources, especially Vitruvius, and the archaeological evidence. The writer can perhaps best be understood as having described how a water system should be constructed, rather than how they actually were being made.

¹ There is even evidence of the Roman Army building temporary wooden baths at their camps rather than go without entirely (Fagan, G. G. [2002] 56).

Early Systems

The early water systems found at Pompeii made use of water from three main sources: river water, rainwater and groundwater. The Sarno river, which flowed close to the western and southern walls of Pompeii, was a source of water which would have been used from early in the settlement of the Oscan town (Adam [1994] 235). The development of the Sarno plain for agriculture may have compromised this water source, and the Sarno river was polluted by wastewater from Pompeii itself (see below).

The site of Pompeii is now subject to violent rainstorms, and, presuming this was the case in antiquity, the houses of Pompeii were well adapted to make use of them. Cisterns for the storage of rainwater date back to the 6th Century BC. From the beginning of the 3rd Century BC, many Pompeiian houses had an atrium, near the entrance to the house which had a rectangular void in the centre of the roof – a *compluvium* (Adam [1994] 235). This allowed rain and runoff from the roof to fall into a shallow pool in the floor – an *impluvium*. After the first flush had cleared the roof of leaf litter and other impurities, the water caught in the *impluvium* was diverted into a cistern beneath the house. From here the water was collected as needed, generally using a rope and bucket, and used for drinking etc. Runoff from other roof surfaces, such as those around peristyle courtyards, was also sometimes similarly used. (Jashemski [1996] 51-4).

Rain and collected runoff was used to water gardens in many Pompeiian houses. At this early stage, the gardens were composed mainly of trees, which, once established, required less water than many other plantings. The types of trees have been determined using a combination of palynology (pollen analysis) and careful excavation and examination of root cavities. Large produce gardens that relied on rain and roof runoff have been excavated. Produce grown included lemons, olives, cherries and flowers (Jashemski [1996] 52-56).

Groundwater was accessed by means of wells, which date from the second half of the sixth century BC (Adam [1994] 235). This was a more reliable form of supply in dry season and also in time of siege. However, as the water table in Pompeii was generally 15-40m below the surface, wells were few and often necessitated the use of mechanical water lifting devices. Five public wells have been found in streets and squares, as well as some private ones. Evidence of three, possibly four, water-lifting devices has been found in Pompeii: two or three at some of the older baths in the city and one in association with a tannery (Oleson [1996] 67-72). All were of the chain and

bucket type where a long chain with many buckets attached was rotated up from the well and then down again once it had emptied its contents. Human labour seems to have been preferred to animal due to the space requirements, and slaves trod a large wheel to provide the power to raise the water.

Aqueduct-fed Systems

At some point in the first century BC or AD (see below), Pompeii was connected to an aqueduct. Roman water engineering was based on the principle that water, given the opportunity, will flow downhill. It was essentially a gravity-powered system. *Aquae ductus* means 'leading of water' and this is a good explanation of the function of the aqueduct. In general, the water flowed through the pipes of an aqueduct in an open channel, where the water did not fill the pipe completely, but left an air-space at the top. This also means that the pipe was not pressurised. To keep the water flowing marginally downhill, often over tens of kilometres, required an amazing feat of surveying, planning and construction. Should the gradient become too steep at any point, the flow would accelerate, causing various problems including possible damage to the aqueduct itself. A too steep gradient is also an unnecessary use of the finite height between the source and the point of use, possibly leaving insufficient 'fall' to complete the aqueduct. The provision of water to towns in this manner was characteristic of Roman urban living in all parts of the empire.

So, to supply Pompeii with water via an aqueduct required a clean water source sufficiently high above the town to conduct the water over the required distance. When we take a look at the geography of the area around Pompeii in this period, we see that such water sources were to be found in the mountains to the west and south of the town.

Archaeological remains of aqueducts bringing water from these regions to Pompeii have been found. One such aqueduct stretched from springs at Serino to the west of Pompeii, past Pompeii to Misenum to the east, where there was a large naval base. This aqueduct has been dated to the Augustan period both by the construction techniques (*opus reticulatum*) of surviving sections and by an inscription discovered in Serino in 1938 describing the Constantinian repair of the *Fontis Augustei Aquaeductum* (Sgobbo [1938] 75-77). Remains of a branch line that led from the Serino aqueduct to Pompeii have also been found. Until recently it had been assumed that the branch line was of the same Augustan date as the Serino aqueduct. However, the recent work of Christoph Ohlig using sinter samples has cast doubt upon this dating (Lafer 2002; Ohlig 2004). Sinter is the mineral deposit left behind by 'hard'

water as it flows. The salts dissolved in this water form a deposit, similar to limestone, on the inside of the pipe or channel conveying the water. Water from a different source has a different composition of dissolved salts and so leaves a different sinter. Ohlig has sampled the sinter deposits in the Pompeian branch line and in the Serino aqueduct both before and after the estimated junction point with the branch line to Pompeii. The analysis of these samples showed that there were two separate deposits in the branch line. The upper, and thus more recent, deposit matched the samples from the Serino aqueduct from both before and after the junction with the branch line. The lower, and thus older, sample did not. It seems that the branch line to Pompeii carried water from another source prior to its being joined to the Serino aqueduct. This casts doubt upon its Augustan dating. Ohlig now dates the first arrival of the aqueduct to Pompeii to shortly after the founding of the *colonia* in 80 BC, chiefly on historical grounds, although supported by archaeological finds and the sinter results. The sinter also revealed that the first source of water flowed only for part of the year but still provided a greater annual flow to Pompeii than the Serino aqueduct. The implications of this revised dating have yet to be fully worked out. It remains to be seen whether Ohlig's dating will be fully accepted and, if so, which other datings of the water distribution system in Pompeii and associated elements will have to be revised.

The date of the cessation of water supply to Pompeii via the aqueduct is also disputed. There is debate as to whether the large earthquake of 62 AD cut off the aqueduct supply and, if so, whether it had been reconnected before the eruption of Vesuvius in 79 AD (Koloski-Ostrow [1996] 83; Oleson [1996] 70).

The *castellum aquae* was the connection between the aqueduct and the water distribution system within the city walls. This building was located at one of the highest points of the city, just inside the walls near the Porta Vesuviana. Its purpose was to divide the incoming water into three lead mains pipes for distribution within the city. The exact mechanics of this, and the rationale behind them, are complex and incompletely understood. It does seem that the division did not conform to that described by Vitruvius in *De Architectura* 8.6.1-2 (Hodge [1996] 13).

The three mains pipes were the first part of the distribution system. The internal lead piped system of the town differed from the aqueduct in that generally all the pipe cross-section was filled with water. The pipes were pressurised, giving them the ability to push water uphill. One of the problems with such a system is that pressure at any point increases the greater the

height of water that is above it. This can result in damage to the system and also the pressure can be too great for the applications of the water. Hypothetically, if the height difference between the *castellum aquae* and a particular house was 30m, then the fountain in the dining room of that house has the potential to send water up to 30m in the air (disregarding any pressure loss). While use of wider nozzles can lower the pressure, this situation is undesirable. The engineers at Pompeii avoided this problem by installing open basins periodically at points along the system (Wiggers [1996] 29-31). These basins, being open, re-set the pressure at this point in the system back to atmospheric pressure. They were located at the tops of towers, ensuring that there was still enough pressure for the end use (Jansen [2000] 113). Evidence of raising of these towers has been found, suggesting that a certain amount of trial and error was involved in setting up the system (Wiggers [1996] 31-32). From these towers also lines branched off to the eventual users, discussed below. They also allowed parts of the system to be isolated for maintenance. Eventually this system covered almost all of the city.

Unlike most modern systems, where water sits in pipes until it is needed and a tap is turned on, water in the Pompeian system seems to have flowed continually, assuming there was supply from the source, whether required or not (Hodge [1981] 489-491). While this seems quite wasteful to us, from one point of view it has a certain logic. Essentially, the Roman engineers had diverted a stream through their town, and since streams flow continually, why should this one not? In this way water would be on hand whenever required, while the source did not fail. To stop the flow would require the costly provision of a large amount of water storage, although taps may have been used at points along the system for the stopping of flow and storage of water (Hodge [1996] 273).

Use of Water in Pompeii

Once distributed, water was put to many different uses, most obviously for human consumption. Once the aqueduct was built, a large number of public fountains were constructed. In the roughly two-thirds of the town that has been excavated, over forty such fountains have been discovered. It appears that most houses were within 50m of one (Jansen [2000] 113). These fountains would have been social hubs for their local neighbourhood. The same people would have gathered there every day to collect the daily water supply, and, no doubt, to pass on the latest gossip. These fountains also had a similar function to the water towers in re-setting the head and preventing back flow.

In the post-Augustan period, some private houses were also connected to the piped water system. This water was generally used in fountains for drinking and for display (see below). In one sense, the piped system was grafted onto the existing rainwater system. The pipes generally ran from the street to the *impluvium*, where there would be one or more fountains (Jansen [2000] 115). Occasionally the system was extended to the peristyle, where more fountains were located.

It is commonly believed that lead poisoning was a serious problem with Roman water systems. Written sources show that some Romans were aware of the possibility. Vitruvius states his preference for terracotta pipes over lead ones for this reason, while acknowledging the ease of working and maintenance of lead (8.6.10). Once installed, lead pipes could be cut open, cleaned out and soldered back together. Archaeological evidence, especially from Pompeii, demonstrates the popularity of lead over terracotta for distribution systems within towns. As well as being easy to work, lead was a by-product of silver production (although its cost is debated) and was good under pressure (Hodge [1981] 487).

So was lead poisoning attributable to water supply a big problem for the Romans? Many scholars think not. A study of skeletons from Herculaneum found that few had elevated lead levels in their bodies (Deiss 1985). In fact, lead pipes in houses are standard in many parts of Europe, without widespread lead poisoning, and installation has only recently ceased (Hodge [1981] 488). Hodge suggests a number of factors that would have limited the lead concentration in ancient Roman drinking water (Hodge [1981] 489-491). One is the sinter build-up already discussed. Where there was hard water, as in Pompeii, an impervious layer would rapidly form that prevented contact between the water and the lead pipe. Another is the probable continuously flowing nature of the system. Lead takes time to contaminate the water it is in contact with. In modern systems, water can be in contact with pipes for hours before it is used, particularly overnight. In Pompeii, however, water flowing through the pipes had less time to pick up lead contamination. Lead glazed pottery and wine additives may have been a more important source of lead for ancient Pompeians.

Bathing was another significant use of water in Pompeii. The oldest baths yet discovered, the Stabian baths, predate the founding of the *colonia* in 80 BC (Fagan [2002] 57). A water-lifting device attached to a well was installed to provide the necessary water. After the founding of the *colonia* there was steady growth in bathing in Pompeii (Fagan [2002] 58-59). The Stabian baths were enlarged, and new sets of baths, known today as the Forum and

Republican baths, were constructed. This was followed by a lull in such building, at least inside the city walls, during the early imperial period (Fagan [2002] 61-64). Outside the walls, however, the Suburban baths and the *Thermae* of M. Crassus Frugi were constructed. The last two decades of the town's life saw a surge in bath construction (Fagan [2002] 64-68). Seismic activity led to repairs and renovations of the Stabian, Forum and Suburban baths. New complexes, called the Central and the Palaestra/Sarno baths and the *Praedia Iuliae Felicis*, were constructed. Some of the houses belonging to the wealthy elite had private baths installed after they were connected to the piped water supply in the post-Augustan period. There is literary evidence that those with private facilities still regularly used the public baths (Petronius *Satyricon* 26-27, 72; Pliny *Epistulae* 2.17.26).

A change in the gardens of Pompeii also occurred after the introduction of the aqueduct. Thirstier plantings, such as shrubs, are found in greater numbers. Aquatic displays, such as fountains and pools, became more popular both in gardens and in *triclinia* (dining rooms). For example, the House of the Vettii (*Regio VI Insula 15*, 1.27) had 14 fountains, the House of M. Loreius Tiburtinus (*II 2*, 2) has an even more elaborate water display and the House of the Bracelet (*VI 17*, 42-44) had a spectacular mosaic fountain with 29 water jets in its *triclinium* (Jashemski [1996] 53). The water from these displays was generally recycled to the cistern or the toilet and thence to the drains.

Industries in the town also made use of water. A well with a chain and bucket mechanism dating the late 2nd or early 1st Century BC has been found in a tannery in the House of the Queen of England (*Regio VII Insula 14*, 5.17-19) (Oleson [1996] 72). Later industries such as bakeries, fullers (mentioned below) and wool-dyers made use of connections to the piped water system. Water power was utilised in flour mills and dough kneading machines.

In discussing the toilets of this period in Pompeii it is worth mentioning that the majority of bodily wastes in Pompeii were disposed of without the use of water. Almost every house had a cesspit and many had chamber pots and commodes, the contents of which were probably disposed of in the streets or in public dung heaps (Koloski-Ostrow 1996). Three public dung heaps have so far been uncovered in Pompeii. Their contents were probably periodically removed and used as fertilizer in agriculture just outside the town. Augustus had awarded fullers in Rome the right to leave jars on street corners for the purpose of collecting urine, which they used to prepare wool for dyeing. This practice is probably referred to in a graffito from Pompeii, suggesting its use there also. Several other graffiti condemned public urination and defecation,

which suggests that the practice, while not universally accepted, was common enough to be noticeable (and annoying!).

Disposal of human waste with water was a late development in Pompeii. Some of the houses connected to the piped water supply in the post-Augustan period did install flushing toilets (Koloski-Ostrow 1996). Some *foricae*, or continuously flushing public toilets, were built in the forum, the *palaestra* and some of the baths after the earthquake in 62 AD. The staggered entrance to toilets in the forum may allude to the distaste of some for public urination and defecation noted above.

Sewerage and Drainage

We have already seen the streets of Pompeii would have contained a fair amount of human waste. The overflow from the cisterns (via outlet pipes to the street) and the road-side fountains and towers of the piped distribution system, after its introduction, would have helped remove both the human and animal waste from the streets. In effect the streets were both the stormwater and sewerage system of Pompeii. The presence and height of the well-known pedestrian stepping-stones on the roads is a testament to the carriage of significant volumes of water (and refuse) on them. At the downhill gates on the south and west sides of the city, the *Portae Noceria, Stabia, Nola and Sarno*, gutters in the thresholds allowed the flow of the untreated sewage and stormwater into the Sarnus river and thence into the Bay of Naples (Koga [1991] 58ff; Koloski-Ostrow [1996] 84). The *Via Stabia* was the major artery in this drainage system. There were a few underground drains, mainly in the area of the *Foro civile* and the old city. Some of these were former streets reused as drains after the raising of the street level. Mostly these took water from depressions within the town (Koga [1991] 58ff). However, this underground drainage system does not seem to have been investigated yet.

Rome had an extensive drainage system, as did some of the *coloniae* that were built from scratch. But the money was probably not forthcoming to retrofit such a system at Pompeii when it became a *colonia* and the slope of the streets in Pompeii allowed their use for drainage. However evidence of substantial drainage systems has been found in some premises such as the fullers' workshops (Koga [1991] 62).

Conclusion

By way of conclusion I make a few comments regarding chronological interpretation of the water system of Pompeii. The history of water supply at

Pompeii can be divided into a number of periods. The pre-*colonia* period was marked by use of rain, ground and river water. This less abundant water supply did not prevent the opening of the first public baths towards the end of this period, nor the existence of produce gardens or trees. The founding of the Sullan *colonia* in 80 BC may have been closely followed by the first water supply system in Pompeii fed by an aqueduct. The major changes accompanying the arrival of the aqueduct were the proliferation of public fountains and also the greater availability of water for baths, which grew steadily in number and opulence during this period. The year round Serino aqueduct was built in Augustan times, probably incorporating the previous seasonal aqueduct, mentioned above. There was little growth in the building of baths inside the town at this time, but some growth outside the walls. However use of water in gardens and for ornamentation did become more prevalent at this time. In the post-Augustan period, some private houses were connected to the piped system. After the earthquake of 62 AD a number of changes occurred in the water system. New baths were once more built in the town proper, and new features such as public toilets appeared. This may be due to an increasing 'Romanisation' of the town, and also may be indicative of 'urban renewal' arising from the opportunity to build on land left vacant by the earthquake. At the same time, the direct effect of the earthquake on the water system in terms of interruption of supply is a debated point. There seems to be evidence that some baths and houses returned to the use of earlier rain and groundwater systems.

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