International Water Association

# Specialist Group on Water and Wastewater Technologies in Ancient Civilisations

## Newsletter
## May 2008

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## PROLEGOMENA

Progress in water sciences in the twentieth century has been significant. At the same time, a great deal of unresolved problems related to the adequacy of water supply and irrigation water and the protection from floods and droughts were evidenced. In some areas, owing to the explosive population growth, such problems were intensified in an unprecedented degree. Moreover, new problems have arisen such as the increased contamination of surface and ground waters. Naturally, intensification of unresolved problems led societies to revisit the past and to investigate well-tried and successful ancient solutions. To their surprise, those who attempted this retrospect, based on archaeological and historical evidence, were impressed by two things: the similarity of problems with modern ones and the advanced level of solutions, technology and management used by our ancestors.

Thus, it is now well documented that most of the technological solutions related to water are not achievements of present day engineers but date back to two to four thousand years ago. These achievements include massive hydraulic constructions such as dams, polders and levees, and urban systems for water conveyance (aqueducts) and removal (sewer and drainage systems). These hydraulic works reflect also advanced scientific knowledge, which for instance allowed the construction of tunnels from two openings (geometry, geodesy) and the transportation of water both by open channels and closed conduits under pressure (hydraulics). Related to this is the departing from the mythological and hyperphysical views of the world and the development of scientific theories and ideas, for instance for the hydrological cycle; this occurred for the first time in history in ancient Greece by Ionian philosophers. Certainly, technological developments were driven by the necessities to make efficient use of natural resources, to make civilizations more resistant to destructive natural and human elements, and to improve the standards of life, both at the private and public level. With respect to the latter, certain civilizations developed an advanced, comfortable and hygienic lifestyle, as manifested from public and private bathrooms and flushing toilets, which can only be compared to the modern one, re-established in Europe and North America at most a century and a half ago. Technological developments were combined with advanced management practices that included water legislation and institutions both for the operation and maintenance of existing systems as well as for the construction of new works.

Apparent characteristics of technologies and management practices in many ancient civilizations are the durability and sustainability. For instance, there exist several ancient hydraulic works that have been in operation since the Classical period which are still in operation up to now. Also, there have been integrated management practices, combining both large scale and small scale constructions and measures that have allowed cities to sustain for millennia. The notion of long-term durability is missing in present day engineering designs and constructions, whereas the notion of sustainability was re-considered only in the last couple of decades, yet its meaning being unclear and further explored to date.

With the increasing worldwide awareness of the importance of water resources achievements in the ancient civilizations, the responsibility for organizing a Specialist Group on Water and Wastewater Technologies in Ancient Civilizations was undertaken by IWA Head Quarters in early 2004. In addition, the 1st IWA Symposium on Water and Wastewater Technologies in Ancient Civilizations was organized at Iraklion, Greece in October 2006. In parallel the IWA

Specialist Group on Water and Wastewater Technologies in Ancient Civilizations was established. Also, the 2nd IWA Symposium will be held at Bari, Italy in May 28-30, 2009.

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## ESTABLISHMENT OF THE SPECIALIST GROUP ON WATER AND WASTEWATER TECHNOLOGIES IN ANCIENT CIVILIZATIONS

The 1st IWA International Symposium on 'Water and Wastewater Technologies in Ancient Civilizations' was held in Iraklion, Greece on 28–30 October 2006. During that event a Specialist Group (SG) on Water and Wastewater in Ancient Civilizations, within the frame of IWA, was established. The aims of the SG can be summarized:

(a) To reveal the cultural heritage and to make visible remnants of water-related technologies from ancient civilisations which have contributed to the development of the existing technologies in water and wastewater management.

(b) To describe and evaluate the old technologies, which on a long term may contribute to the existing water and wastewater management systems and to the development of integrated treatment methodologies.

(c) To develop small systems based on old technologies using new equipment, which may be of great significance for water, wastewater and environmental management in the future. During the establishment of the IWA Specialist Group on Water and Wastewater in Ancient Civilizations, the President of International Water History Association (IWHA), Prof. F. Hassan, also member of the Specialized Group, was in favour to open a dialogue to harmonize the work of the two Associations on water related issues in ancient civilizations. This task should be undertaken by IWA. The organization of a 2nd IWA Symposium in Italy, late 2008 or early 2009 was proposed.

The Water and Wastewater in Ancient Civilizations Group counts at present with 180 members from 23 countries; mainly from Greece, Belgium, Canada, Germany, Iran, Italy, Spain, UK, and USA.

## MANAGEMENT COMMITTEE OF THE SPECIALIST GROUP ON WATER AND WASTEWATER TECHNOLOGIES IN ANCIENT CIVILIZATION

The members of the interim Management Committee of IWA SG are:

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# THE 1ST IWA INTERNATIONAL SYMPOSIUM ON WATER AND WASTEWATER TECHNOLOGIES IN ANCIENT CIVILIZATIONS: OVERVIEW AND CONCLUSIONS

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The Symposium on Ancient Water and Wastewater Technologies came to its end after three fruitful conference days and several months of preparation, which demanded substantial efforts from the Organizing Committee and Programme Committee and, of course, all the contributors. It is to note that the Symposium was initiated by the EU-INCO-CT-2004-509110 Project two years before its implementation.

It is a joint conviction of all participants that the Symposium succeeded in its objectives. The organizing committee was impressed by the large participation, the diverse subjects of the presentations and the substantial advancement of a topic which is not well studied to date. 80 full papers shaping a volume of 800 pages, and 179 contributors and participants are some statistical data giving to this impression an objective character. The Symposium was an international one, with scientists and professionals from 23 countries (Table 1). Simultaneously, it was a perfect example of an interdisciplinary Symposium, with representatives of several scientific and technological disciplines and with additional participation of the industry (Table 2).

Table 1: Distribution of contributors and participants of the Symposium by country.

| Country | No participants | Country | No participants | Country | No participants |
|---|---|---|---|---|---|
| Algeria | 2 | Hungary | 1 | Mexico | 1 |
| Belgium | 6 | Iran | 8 | Palestine | 2 |
| Canada | 7 | Ireland | 3 | Slovakia | 1 |
| China | 2 | Israel | 2 | Spain | 6 |
| Finland | 3 | Italy | 12 | Turkey | 2 |
| Germany | 5 | Japan | 2 | UK | 8 |
| Greece | 95 | Jordan | 2 | USA | 7 |
| Hong Kong | 1 | Libya | 1 | **Total** | **179** |

Table 2: Scientific, technological and professional fields of the contributors and participants of the Symposium.

| | | |
|---|---|---|
| Agriculture | Environment | Meteorology |
| Archaeology | Geology | Mineralogy |
| Architecture | Governance | Public Health |
| Biology | History | Photography |
| Classical Studies | Hydrology | Physics |
| Chemistry | Jewellery | Soil Science |
| Economics | Land Management | Tourism |
| Engineering | Life Sciences | Water Resources |

We have attempted to draw a few general conclusions that summarize the state of the art in the field and the Symposium contribution. Here is the list of the five most outstanding conclusions in our opinion:

1. The history of water science and technology …
   … is currently not widely known;
   … contains biased, inaccurate or inconsistent bits of information and has a lot of gaps;
   … is important to know; and
   … should be re-written, particularly in those chapters where biases and inaccuracies have been already located.
2. There is interest on revisiting past water technologies and management practices, which is justified by the understanding …
   … of the diachronic similarity of problems;
   … of the deadlocks and intensification of problems in the current situation;
   … that history is the best teacher for future (the past is the key to the future); and
   … that ancient civilizations have developed advanced knowledge, wisdom and sustainable practices.
3. History teaches that water management is important for sustaining civilizations and that sightless or insufficient management may result in civilization collapses; particularly, civilization collapses have been resulted from …
   … inability to deal with climate changes, which seem to have been occurred several times in the past;
   … persistent, multiyear droughts;
   … destructive and recurrent floods that destroyed hydraulic infrastructures; and
   … negative human impacts on the environment (deforestation, erosion, desertification).
4. History teaches that many civilizations all over the world have developed magnificent technologies and management practices characterized by …
   … sustainability and durability (operation for millennia, as opposed to today's design horizons of 20-50 years);
   … safety and security (as opposed to today's insecure structures);
   … wise combinations of small-scale and large-scale projects and measures (as opposed to today's dominance of large- or mega-scale projects);
5. There is a lot to learn from ancient water and wastewater technologies and practices; the current Symposium is a successful first step and the continuation of this research will certainly suggest improved solutions for current and future problems.
6. For the continuation of this research the Symposium proposes the establishment of a Specialist Group on Water and Wastewater in Ancient Civilizations, within the frame of International Water Association (IWA).
7. The President of the International Water History Association (IWHA), also member of the Specialized Group, favours to open a dialogue for harmonizing the work of the two Associations on water and wastewater technologies in ancient civilizations. This task should be undertaken by IWA. Finally, the organization of a 2$^{nd}$ IWA Symposium in Italy, late 2008 or early 2009 was proposed. Furthermore, the Symposium, taking into consideration the importance of archaeological monuments and remnants as the main source of information of the ancient water and wastewater technologies, addresses an appeal to national and international organizations for the protection of these monuments.
8. An interim Management Committee is appointed as indicated.

## 2ND IWA INTERNATIONAL SYMPOSIUM ON WATER AND WASTEWATER TECHNOLOGIES IN ANCIENT CIVILIZATIONS, BARI, ITALY, MAY 28–30 2009: 1ST ANNOUNCEMENT AND CALL FOR PAPERS

**Objectives**
The principal aims of the Conference are:

(a) To reveal the cultural heritage in several regions of the world and to make visible the archaeological remnants of practices which have contributed to the development of the existing technologies in water and wastewater management.

(b) To describe and evaluate the old technologies, which on a long term may contribute to water and wastewater management systems and to the development of integrated methodologies.

(c) To develop small systems based on old technologies using new equipment, which may be of great significance for water, wastewater and environmental management in the future.

(d) Water knowledge related to the water services and juridical/economic aspects.

**Topics**
Topics of interest include but are not limited to:
(a) Methods, practices, and techniques of water resources management.
(b) Farmers and citizens: The socio-economic role of water.
(c) Urban water use.
(d) Urban wastewater and stormwater technologies.
(e) Historical development of aqueducts and other water technologies: From mythology to water sciences.
(f) Old influence in modern water and wastewater technologies.
(g) Iconographic aspects of water in ancient civilizations.
(h) Sociological and economical issues.
(i) Juridical aspects.

**Call for Papers**
Authors are invited to submit the manuscripts of maximum 8 pages in English, including figures and tables (as MS Word file single interspace). The manuscripts should be submitted electronically at **http://www.federutility.it/** or via e-mail to: **acqua@federutility.it**, no later than **30 November 2008**. Please refer to the dedicated website page for the submission details.

Manuscripts will be accepted based on quality, originality and relevance to the Symposium themes. All accepted manuscripts (papers or posters) will be published as the Symposium Proceedings. Contributions (papers and posters) will also be reviewed, on their quality, originality and relevance to the Symposium themes, by the International Scientific Committee for publication in a special edition of *Water Science and Technology*. €40.00 discount will be applied to the registration fee for authors whose manuscript is accepted.

## CALL FOR SPONSORS AND EXHIBITORS FOR WWTAC09

Don't miss the chance to expose your company's experience, brand your products, and trade on the opportunities by becoming an Exhibitor or Sponsor of the 2nd International Symposium on Water and Wastewater Technologies in Ancient Civilizations (WWTAC09). If you would like to have more information about sponsoring or exhibiting at Hotel Villa Romanazzi Carducci, please contact: **Noema srl, Via Orefici, 4, 40124 Bologna, Italy. Phone + 39 051 230385; Fax + 39 051 221894; E-mail info@noemacongressi.it**

**Registration Fees (20% VAT included)**

| | Before 30 January 2009 | After 30 January 2009 |
|---|---|---|
| IWA members | €420.00 | €480.00 |
| Non-members | €540.00 | €600.00 |
| Students | €240.00 | €300.00 |
| Accompanying persons | €180.00 | €240.00 |

€40.00 discount will be applied to the fee for authors whose manuscript has been accepted.

It will be possible to register by sending the attached form to the Organizing Secretariat Noema Srl to the indicated address. It will also be possible to register online at the conference homepage www.federutility.it.

**Participant's registration fee includes**: admittance to all sessions; congress material; Proceedings published and mailed to participants after the Conference; certificate of attendance; coffee-breaks; lunch on May 28; Gala Dinner on May 28; post-conference excursion to Matera.

**Students' registration fee includes**: admittance to all sessions; congress material; certificate of attendance; coffee-breaks; lunch on May 28; post-conference excursion to Matera.

**Accompanying person's registration fee includes**: Gala Dinner on May 28; post-conference excursion to Matera.

**Important Dates to Remember**

| | |
|---|---|
| Manuscripts submission (up to 8 pages): | **November 30, 2008** |
| Notification to authors regarding manuscripts' acceptance: | **January 30, 2009** |
| Registration at a reduced rate: | **January 30, 2009** |
| Receipt of the final version manuscript: | **March 30, 2009** |

**Participation at both the IWA Specialist Conference and XVI European Conference H2Obiettivo 2000**

Fees (20% vat included):

IWA members: €1.250.00 before January 30, 2009; €1.400.00 after January 30, 2009
Non-members: €1.600,00 before January 30, 2009; €1.700.00 after January 30, 2009
Students: €600.00 before January 30, 2009; €650.00 after January 30, 2009

€40.00 discount will be applied to the fee for authors whose manuscript has been accepted.

Sasso caveoso (Pietro Laureano, ‘Giardini di Pietra’, Bollati Boringhieri, 1993)

Assonometria dei Sassi (Pietro Laureano, ‘Giardini di Pietra’, Bollati Boringhieri, 1993)

**Organizers**

(a) FederUtility (Rome, Italy)

(b) N.AG.RE.F. National Agricultural Research Foundation (Iraklion, Greece)

(c) IWA International Water Association (London, UK)

(d) Federculture (Rome, Italy)

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(f) AII Associazione Idrotecnica Italiana (Rome, Italy)

(g) AQP Acquedotto Pugliese SpA (Bari, Italy)

(h) Fondazione AMGA (Genoa, Italy)

(i) EUREAU European Union of National Associations of Water Suppliers and Waste Water Service (Brussels, Belgium)

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**Bari and Matera**

The city of the Conference, Bari, has been founded by the mythical heroes of the Hellenic world. Influences from the Romans to the Arabs and the Byzantines, under whose rule Bari lived its apex in wealth and cultural prestige, were subsequently followed by the Norman invasion. Afterwards the town was conquered by the Angevin rulers, Aragonese, Sforza, and Bourbons down to Napoleon's time when Gioacchino Murat decreed that the town should become the provincial capital in 1813. The main monuments of the old town centre are the basilica of San Nicola, the Cathedral of San Sabino and the Norman-Swabian Castle.

An historical and cultural post-conference excursion to Matera will be organised for the participants and their accompanying persons on March 30th.

The route's stop over will be the city of Matera, one of Southern Italy's most charming locality and one of the most ancient towns in the world, famous for its Sassi or caves from the Paleolithic age (dating back to 1500 B.C.). Built on a rocky plateau and sliced in two by the Gravina ravine, Matera's cave dwellings were inhabited by man as early as the Palaeolithic era. To link the dwellings in the Sassi, there is a complex network of narrow streets and flights of steps climbing up to the fronts of houses.

Matera is one of the most fascinating historic centres in Italy which was formally recognized in 1993 as a UNESCO world heritage site.

**Additional Information**

Additional information on the 2nd International Symposium on Water and Wastewater Technologies on Ancient Civilizations (venue, climate, access to Bari, travel and stay) can be found in the following URL www.federutility.it or contact Dr Renato Drussiani (acqua@ federutility.it ) or organising secretariat (info@noemacongressi.it)

## THE PISCINA MIRABILIS IN MISENO, SOUTHERN ITALY

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For this first number of the Newsletter, I have focused my attention on a relevant piece of Roman hydraulic engineering: the *Piscina Mirabilis*, in the Campania Region, in Southern Italy.

During the war against *Pompeius*, *Augustus* ordered the construction of a harbour complex just west of *Puteoli* (Pozzuoli), named *Portus Iulius* (Fig. 1), where an old Greek dam was restored to create an artificial lake, *Lacus Lucrinus*, which was then connected by a channel to another lake, *Lacus Avernus*, which was traditionally one of the entrances to the underworld. Later, this harbour was seen as less ideal, because of silting problems, and a new complex was built further west at *Misenum* (Miseno), where two lakes were connected to become the basis of the western Mediterranean war fleet. This major naval base needed large quantities of fresh water for the base itself and for the ships, which was the principal reason why *Augustus* had a new aqueduct built (Passchier and Schram, 2005; De Feo and Napoli, 2007).

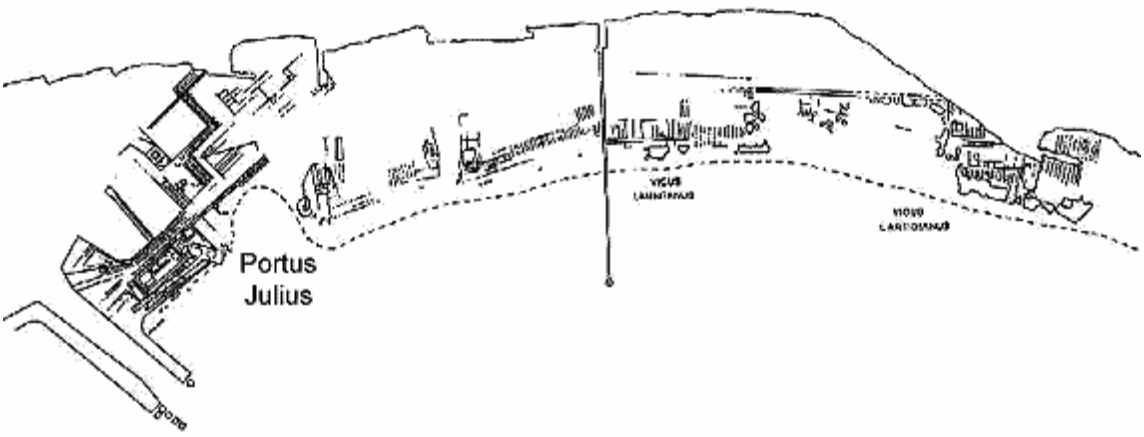


Figure 1. *Portus Iulius*.

For this purpose, the 'Serino aqueduct' was constructed, probably between 33 and 12 B.C. when *Marcus Vipsanius Agrippa* was *curator aquarum* in Rome. The *caput aquae* (starting point) of the aqueduct was the Acquaro-Pelosi spring in the village of Serino in the province of Avellino (the ancient *Abellinum*). The aqueduct refurnished the Roman fleet of *Misenum* and supplied water for the demand of the important commercial harbour of *Puteoli* as well as drinking water for big cities such as *Cumae* (Cuma) and *Neapolis* (Naples). The main channel of the aqueduct was approximately 96 km long, whit 7 main branches corresponding to approximately 49 km. The total length of the Serino aqueduct was around 145 km. With this numbers, the Serino aqueduct is the largest aqueduct system in the Roman world (De Feo and Napoli, 2007).

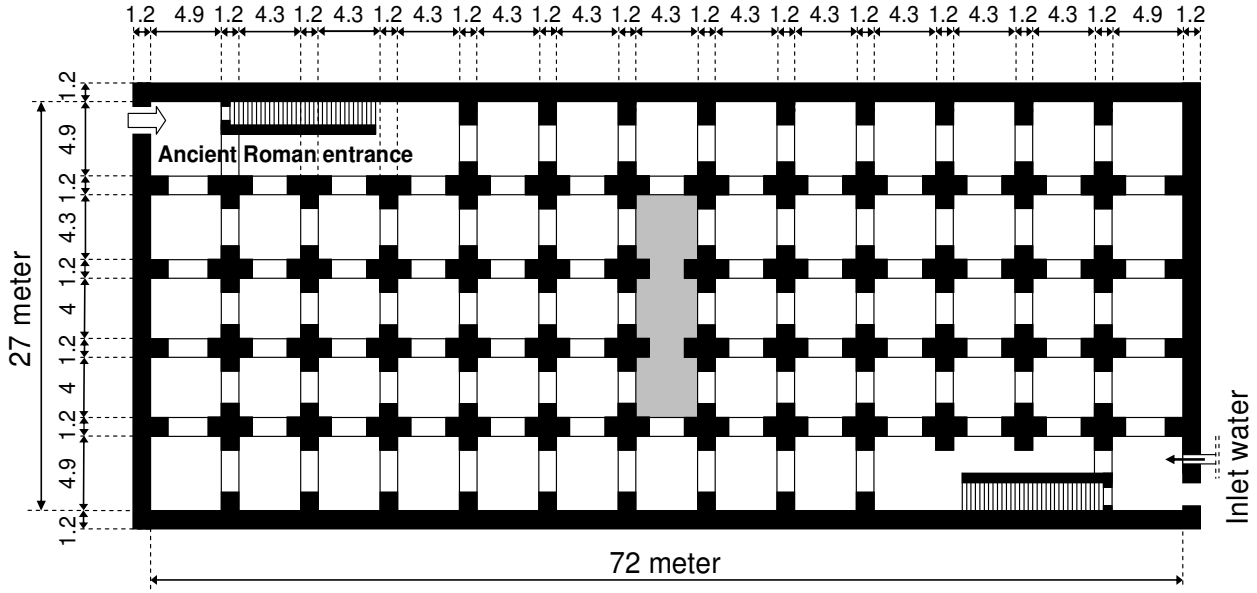


Figure 2. Plant of the *Piscina Mirabilis* (De Feo and Napoli, 2007).

Figure 3. The ancient Roman entrance to the *Piscina Mirabilis*.

The Serino aqueduct filled several cisterns in the section beyond Naples. The main cistern filled by the aqueduct is the spectacular *Piscina Mirabilis* in Miseno (Adam, 1988; Potenza, 1996; Catalano, 2003; Passchier and Schram, 2005; De Feo and Napoli, 2007).

The *Piscina Mirabilis*, situated up the hill facing the sea in order to provide the *Classis Praetoria Misenensis*, is a gigantic reservoir 72 m long and 27 m large, which derives its name from the eighteenth century antiquarian tradition, with clear reference to the impressiveness of its plan as well as the remarkable architectonic effect (Fig. 2). It is dug in a tufa (tuff) hill and has two step entrances in the north-west, the Ancient Roman entrance (Fig. 3) and south-east corners, this latter closed nowadays.

Forty-eight pillars, arranged on four rows serving as a support to the barrel vault, divide it in five aisles on the long sides and thirteen aisles on the short sides, lending to it the majestic look of a cathedral (Fig. 4).

The Piscina Mirabilis can be considered one of the biggest Roman cisterns ever known until now with a volumetric capacity of 12.600 $m^3$ of water. The water coming from Serino flew into it near the north-west entrance. The long wall were realized in *opus reticulatum* (reticular work) with brick bonding courses and by the technique of the tufa (tuff) stone pillars, both covered with a thick waterproof layer of *opus signinum* (pounded terracotta). The seventh short aisle, just in the middle of the reservoir, appears embedded in it for about 1 m, with the plane inclined in the direction of an outlet at the south end. It was used as a *Piscina limaria* for the periodical cleaning of the reservoir. There is a basin of 1.10 m, probably a polishing pool, that is a waste-bath for the maintenance of the cistern, in the floor of the nave The water, through a series of doors opening in the vault along the central nave, was raised through hydraulic engines on the covering terrace of the reservoir, which was also floored with *signinum* and from there, canalized towards the built-up area.

Figure 4. An inside look of the *Piscina Mirabilis*.

Along the north-west external side, in the course of the first century A.D. were added twelve vault-covered little rooms in *opus reticulatum* with angular brick bonding courses, in the second of which is kept a *signinum* floor with labyrinth-shaped mosaic *tesserae* and a central white inlaid panel with limestone polychrome tiles, which seems to date back to a more ancient phase (Adam, 1988; Potenza, 1996; Hodge, 2002; Catalano, 2003; Passchier and Schram, 2005; De Feo and Napoli, 2007).

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# BATHROOMS AND OTHER SANITARY AND PURGATORY STRUCTURES IN ANCIENT GREECE

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## Introduction

Many remains of sanitary and purgatory structures have been found in the greater region of the ancient Greek world. Some of them are dated even in the Minoan era (i.e., Knossos' Palace). The installations of hygiene can be classified as a characteristic factor of living's standard and economic prosperity, both in domestic and public uses. Because of these reasons lavatories have become, and often still are, showing off luxury elements.

The bathing facilities remained mainly public until the end of the Roman times with few exceptions in palaces and large ancient mansion houses. Nevertheless, this is a tradition still maintained in several communities in the Middle East. On the other hand, the sanitary and purgatory facilities had been widely applied in domestic-residential buildings. According to the up-to-date research it is evident that during the Hellenistic period had occurred a great technical and functional progress in this kind of structures. It must also be mentioned that many of the terms used on defecation in ancient Greek, are still in use in the Modern Greek language.

## Bathrooms in Minoan Crete

Cultural advancements can be observed throughout the third and second millennia B.C., but great progress was made in Crete, especially in the Middle Bronze Age (*ca*. 2,100–1,600 B.C.) when the population in its central and southern regions increased, towns were developed, the first palaces were built, and Crete achieved a prosperous and uniform culture. In the early phases of the Late Bronze Age (*ca*. 1,600-1,400 B.C.), Crete appears to have prospered even more, as evidenced by the larger houses and more luxurious palaces of this period (Koutsoyiannis *et al.,* 2008). At this time, the flourishing arts, improvements in metal-work along with the construction of better-equipped palaces, and an excellent road system, reveal a wealthy, highly cultured, well-organized society and government in Crete. Subsequently, the importance and power of the island decreased following the destruction of the Minoan palaces ca. 1,400 B.C. (Angelakis and Spyridakis, 1996).

It is evident that in Minoan civilization extensive systems and elaborate structures for water supply, irrigation and drainage were planned, designed and built to supply the growing population centers and agriculture with water (Angelakis and Koutsoyiannis, 2003; Angelakis and Spyridakis, 1996). Thus, in several Minoan Palaces discovered by archaeologists in the 20th century, one of the most important elements was the provision and distribution of water by means of sophisticated hydraulic systems. It should be noted that at the time, bathrooms and sewers were not considered necessary, merely convenient, and most palaces did not have them. Although the function of Minoan rooms is difficult to define, Evans, the famous archaeologist who discovered the Knossos Palace, identified three rooms as bathrooms.

One of the most interesting rooms in the ground-floor in the residential quarter of the Knossos Palace was identified as a toilet. Remains of a clay tube were found just outside the door of the room. Apparently, water was poured through a hole in the floor immediately outside the lavatory door; an under-floor channel linked the hole with the vertical clay pipe

under the toilet seat (Castleden, 1993). The toilet could thus be flushed even during a rainless summer, either by an attendant outside the lavatory or by the user. This flushing toilet, probably the earliest in history, with a wooden seat and a small flushing conduit is shown in Figure 1 (Graham, 1987).

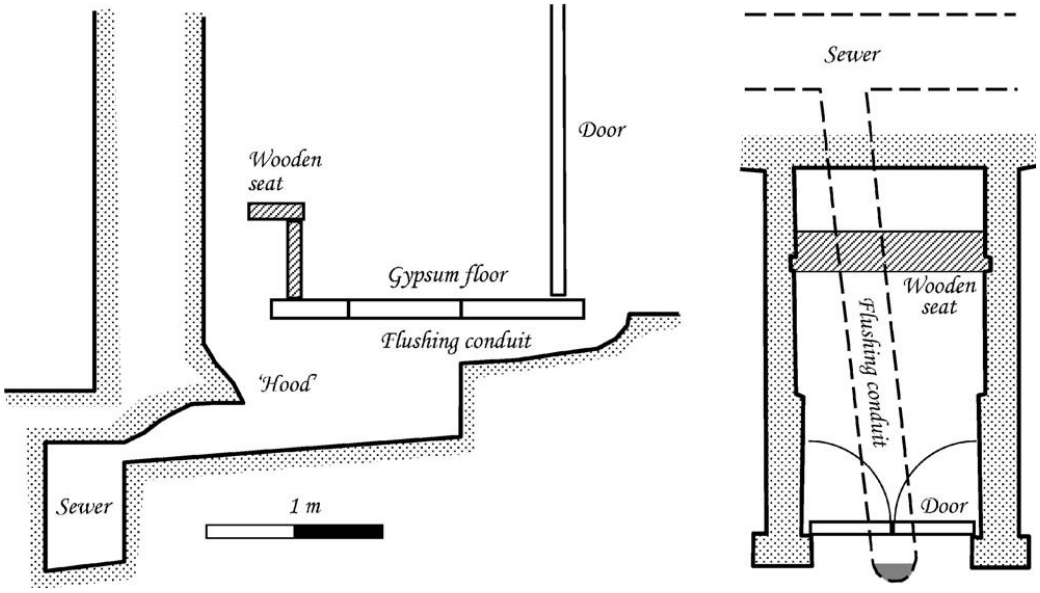


Figure 1. Section and Plan of Ground-floor Toilet in the Residential Quarter of Palace of Minos (Angelakis et al., 2005).

The toilet is similar in function to that of the so called Queen's Hall and the toilets found in the Phaistos and Mallia palaces and in some of the houses as well. Fortunately, one of the houses near the Palace at Mallia, known as Da, contains a toilet seat in nearly perfect condition, since it was made not of wood, like the seat of the Palace of Minos in Knossos but of solid stone. This stone seat is 68.60 cm long by 45.70 cm wide front to back and its surface is 35-38 cm above the floor. It is built directly against an outside wall through which a large sewer passes. Like the Knossos find, the structure was evidently intended to be used as a seat rather than a stand; thus, it resembles the 'Egyptian' toilet more closely than the so-called 'Turkish' type found in the Palaces at Mari and Alalakh in Syria (Angelakis *et al*., 2005). A similar toilet has been discovered in the west side of the so called 'Queen's Apartment' at Phaistos. It was connected to a closed sewer, part of which still exists. Another toilet sewer was discovered in House C at Tylissos (Angelakis and Spyridakis, 1996).

At certain times of the year the sewers in the Palace of Minos may have been flushed out adequately by the rain that fell into the light-wells; however, it appears that water was poured into the toilets to flush them. In fact, Evans noted the existence of sufficient space for placing a large pitcher at one end of the seat at Knossos and so concluded with evident delight (Evans, 1964): '*As an anticipation of scientific methods of sanitation, the system of which we have here the record has been attained by few nations even at the present day'*.

Similar bathrooms have been reported in other Minoan sites. Platon (1990) has provided us with some preliminary statistical data on Minoan cisterns, bathrooms and other sanitary and purgatory facilities. She concluded that, in terms of chronology, most of them should be placed in the Middle Minoan period; in regards to location, 16 are found next to domestic rooms, seven near holy altars and two in palace entrances. In only two instances various facilities for baths were found, seven were filled up with earth and two had been rebuilt and converted into bathrooms. Also, in 14 of these sites various holy objects were found, while in

9 cement coats were indicated (Platon, 1990). Finally, frescoes related mainly to various holy subjects, were found only in two purgatory cisterns located in the south house of the Knossos Palace and in one cistern-bathroom at the north-eastern part of the Zakros Palace. It must be noted that, in spite of the view of some scholars (Alexiou, 1964), the absence of bath facilities in some purgatory cisterns and their existence in other places, should not be considered coincidental. Graham (1987) and Platon (1974) have reported that purgatory cisterns were used for the cleansing of both body and soul. Note also that most Minoan baths were connected to independent septic systems in the outside, a practice indicative of the advanced water resources management and environmental techniques of that period (Angelakis *et al*., 2005).

The clay tubs in the Minoan bathrooms must have been filled and emptied by hand rather than directly connected to the sewers. However, on the 'Caravanserai', a rest house just south of palace, a footbath for the weary travellers was supplied by a direct pipe, and the overflow discharged by another conduit; a branch of the water channel also served as a drinking trough (Angelakis and Spyridakis, 1996).

**Sanitary and Purgatory Structures in Late Classical and Hellenistic Period**

Only few ruins from the Geometric and Archaic periods can be attributed to sanitary structures. On the other hand, there are some findings from the classical and late classical periods, as well as many literal references on these structures at the ancient sources. The comedies of Aristophanes are the main ancient sources about the terminology of the sanitary structures in ancient Greece (Orlandos and Travlos, 1986).

The archaeological findings of small cesspits and sewerage ducts dated in the 5th *ca*. B.C. could be related with many traces of sanitary and purgatory structures found in Olynthus, a city destroyed by King Philipp II in 348 B.C. There have been found not only small swage ducts made of clay or led, but also well formed sanitary clay vessels. All these utensils can be easily dated in the 5th century B.C.

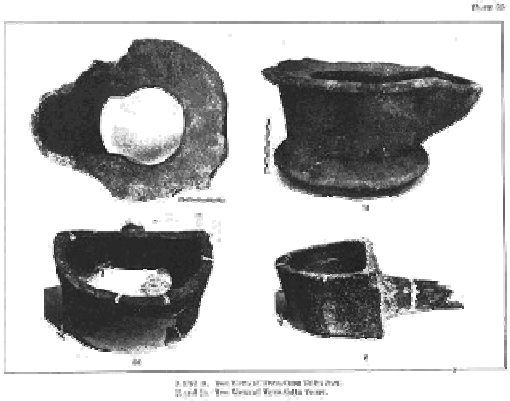

Figure 2. Earthen toilet seat and defecation vessel, Olynthos (Robinson, 1934).

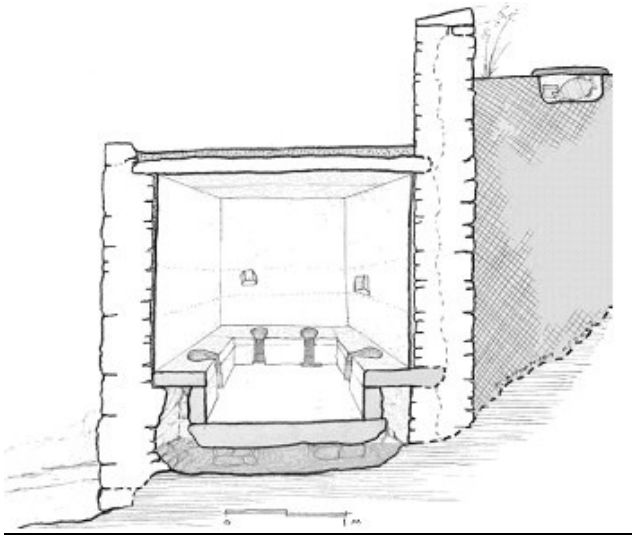

Figure 3. Restored view of the lavatory at the Gymnasium on Amorgos.

It is evident that by that time the lavatory had still a private use. On the other hand, the typical ancient Greek lavatory is being characterized by the possible use of more than one person on the same time. The ancient terms also refer to a private type of use and the main term derives from the apochorisis (withdrawal) (Antoniou, 2007).

The well-formed type of the ancient Greek lavatory was characterized by some typical features which remained more or less the same for all the lifetime of the structure. These features were: the input water conduit, the flushing duct below the floor level, the bench type seats with the keyhole shaped defecation openings, the front covers of the bench type seats, and the sewage duct. Beside these there were also other secondary constructions as the central shallow tank for cleaning the *sponghia* (out of sponge) the toilet paper of that period, the urine sewage conduit, small sedimentation tank, etc. The seats' supporting presents interesting differentiation and typology. Four types can be distinguished. All of them are cantilevered, mostly covered except the type in Philippoi (Delorme, 1960) and Efessos. More specific there are (see Fig. 4): (a) the cantilevered stone slab protruding out of the wall, (b) the freely supported slab over stone beams, cantilevered or not, (c) the similar to the previous type where the stone joists protrude out the vertical plates and have been formed as neck mouldings of benches and exedras, and (d) finally the type where the freely supported seat slab is also supported by stone cantilever beams which are shorter and less wide than the seat.

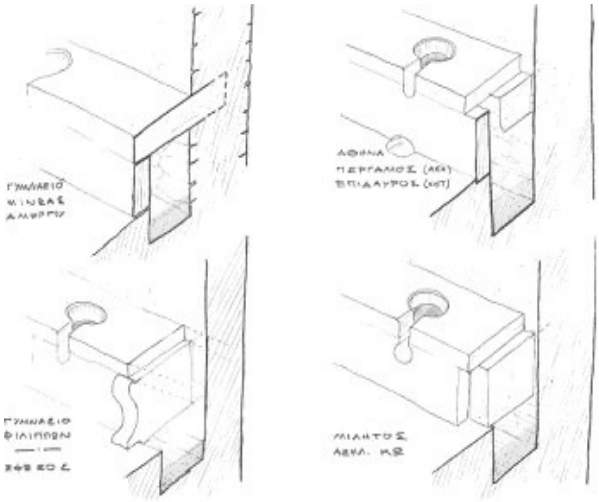

Figure 4. Formation and types of lavatory seat support.

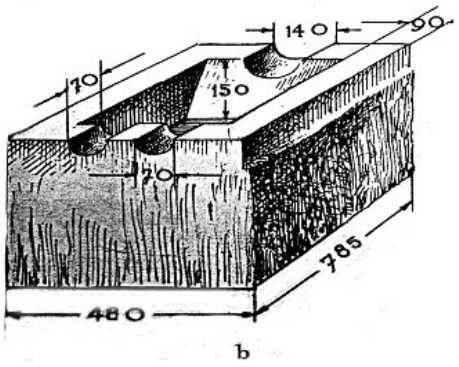


Figure 5. Small sedimentation tank from Askleipieion of Kos (Herzog and Scatzmann, 1932).

The element of the keyhole shaped opening became a feature of the lavatory with some ornamental forms. Although it is obvious that the functionality was always very important. There is also some evidence that existed covers for the openings made out of clay. The seats in small domestic lavatories were just wooden benches, probably with similarly shaped openings.

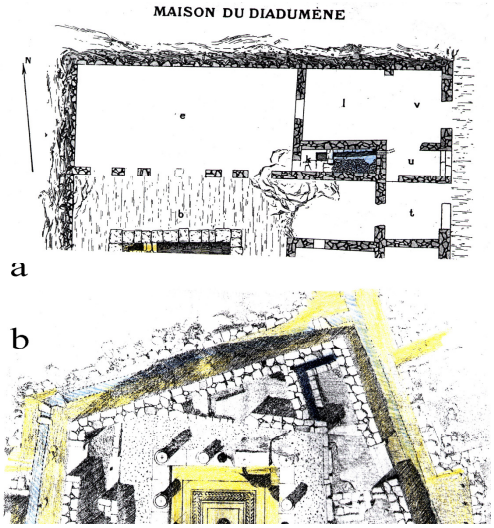


Figure 6. Delos, houses' Lavatories :(a) With flushing hole and (b) L shaped (Chamonard, 1924)

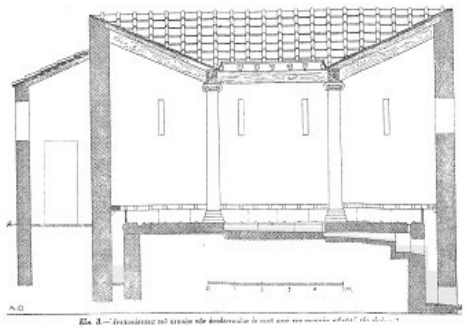

Figure 7. The lavatory outside Roman Agora, Athens (Orlandos, 1940) Restored longitudinal section

The main difference between private and public toilets was their size and the number of users. On the other hand the method for the water supply differs sometimes, since the domestic lavatories require less water for the flushing. The public ones had usually supply with running water, reused or not. The sewage used the ducts of the city running usually along the streets or beside the buildings. Sometimes in small residencies there was no sewerage and the waste was running outside the house (i.e. in Dystos).

In the Hellenistic period there are also bathing facilities mostly in mansion houses. The system using combination of cold, warm and hot pools and rooms of public baths at Iniades in Acarnania, dated in the 2nd century BC (Lawrence, 1957) is also reported. These facilities were heated either with bronze boilers or with warm air under the floor (Gortyna in Arcadia). Some marble bath tabs have been found in Delos but they can be attributed either to the late Hellenistic or to the Roman period as well (Neudecker, 1994), and the water was carried in and out with buckets.

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## VARIOUS

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