Evolution of Water Supply and waste- and storm-waters Management in Urban Areas Focusing in Hellenic Cities

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Topics for discussion

Prolegomena

Bronze Age (ca. 3200-1100 BC)
  Minoan era
  Mycenaean civilization

Historical Times (ca. 490 BC - 330 AD)
  Classical and Hellenistic periods
  Roman period

Byzantine Times (ca. 330-1453 AD)

Ottoman Period (ca. 1453-1832 AD)

Modern Times (1832 to present times)

Future Trends

Epilogue & Conclusions
Prolegomena

Όμοια γάρ ως επί το πολύ τα μέλλοντα τοις γεγονόσι

Most future facts are based on those in the past
Aristotle (384–322 BC), Ancient Greek Philosopher

Study the past before you draw something for the future
Confucius (551 – 479 BC), Ancient Chinese philosopher
Minoan sewerage systems: (a) the output of the central system of the Phaistos palace and (b) part of the central system of the villa Hagia Triada.
Part of the sewerage and drainage system in the palace of Knossos
During the Minoan Era nothing was more remarkable and elaborate than the stormwater and sewerage systems.

I doubt if any other case of stormwater drainage system that works 4,000 years after its construction. Mosso (1907).

Each quarter of the palace had its own subsidiary drainage system connected to the central drain. These systems had vertical shafts of ample size which acted both as roof drains and as ventilation ducts, the latter in much the same manner as do the soil stacks in our the modern house. Perhaps we also may permitted to doubt whether our modern sewerage systems will still be functioning after even one thousand years...

Minoan rainwater cisterns: (a) in Chamaizi village and (b) sand filter and water cistern in Phaistos palace.
Tylissos aqueduct: (a) part of the central conduit located at the entrance of the three villas and in front of the little cistern and (b) secondary conduit, small stone cistern used for removing solid particles from water before storage in the main cistern (Angelakis et al., 2007).
Classical period examples

Olynthos
bottled shaped Cistern with its
Sedimentation tank and debris
Concentration shallow cavity
Hellenistic period

Hellenistic cisterns: (a) the main cistern (possibly originally covered) at Plevrona and (b) that in the island of Delos. Its roof was supported by the eight arches dressed with granite blocks.
Kassope is considered one of the best remaining examples of a city built on a rectilinear street grid of a Hippodamian plan in Greece.
Remnants of sewerage and drainage system in Kassope
Quadruple sewerage opening at the fortifications of Amphipolis
Parts of sewers and drains in Hellenistic period: (a) Sewer covered with prefabricated ceramic well ring sectors in south foothills of Acropolis and (b) Cross section of a bridged section of the Great drain in Hellenistic Agora in Athens
The Theatre of Dodoni in Epirus: (a) general view and (b) detail of the drainage channel (A. N. Angelakis)
Roman period (ca. 67 BC - 330 AD)
Latrines at the Housesteads Roman fort, flushed by water channels supplemented by a cistern located at the back of the latrines (Haut et al., 2015).
Roman time sewers in island of Thassos
Parts of Roman aqueducts: (a) Cistern in Elyros, (b) conduit in Falassarna, and (c) conduit in Minoa (Marathi).
Roman time sewers in Thessaloniki: (a) closed to walls and (b) central sewer covered with stone-build apsis
The Cistern of Aetius in Istanbul known since 1928 of 290,000 (244x85x14) m³ total volume. It is now a football stadium.
Byzantine Times (ca. 330-1453 AD)

Stone-build sewers of Byzantine time (6th c.): (a) in Pastier road and (b) in Egnatia road.
Medieval times water cisterns: (a) The Fildami cistern in Istanbul of Byzantine time, and (b) Venetian water cistern at Gramvousa in northwestern Crete, Greece.
Remnants of the Venetian aqueduct (Morozini) in: (a) the area of Karidaki and (b) the area of Knossos, Iraklion
Ottoman Period (ca. 1453-1828 AD)

In the medieval Islamic world, hydraulic hygiene facilities were remarkable as a latrine connected to a sewer or cesspits was widely used and was found in the most of the houses. The importance of defecation hygiene etiquette related to religion, should not be excluded as an aspect to the evolution of the toilet.
Ottoman times cisterns: (a) Domed circular in southwest Anatolia, Turkey and (b) at the castle of island Mytelene, Greece.
Ottomann toilets (a) In the women's section, Abid Efendi or Hammam of the Winds, Athens and (b) in Lesvos, Mytilene in Karavangeli hammam (Antoniou et al., 2014).
Present Times

1. Since the end of 19th c. Water supply was by fountains/cisterns/springs and all Wastewater systems were CSS

2. After the World War I, beginning of the 20th century, Greece state was established as it is known today and the modern wastewater technologies started to be developed which were expanded after the World War II

3. The total length of water supply network is \( \text{ca.} \) 70,000 and sewage system is estimated to be \( \text{ca.} \) 36,000 km and more than 90 % of the total population is covered with it. Today most of the systems (80 %) are SSS.
## Water Supply and Wastewater Services in Greece

<table>
<thead>
<tr>
<th>Company/ Enterprise</th>
<th>Population serviced</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEYA</td>
<td>5,240,000</td>
<td>47.00</td>
</tr>
<tr>
<td>EYDAP</td>
<td>3,800,000</td>
<td>34.00</td>
</tr>
<tr>
<td>EYATH</td>
<td>1,110,000</td>
<td>10.00</td>
</tr>
<tr>
<td>Municipalities (TY)</td>
<td>1,000,000</td>
<td>9.00</td>
</tr>
</tbody>
</table>
Compliance results per Member State for Articles 3 of the UWWTD (collection), 4 (secondary treatment), and 5 (more stringent treatment).
## WWTP IN GREECE (2015)

<table>
<thead>
<tr>
<th>Category (p.e.)</th>
<th>No of WWTP</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2000</td>
<td>600-700α</td>
<td>Implementation of effective non conventional treatment systems to a large number of projects, serving 20% of the total e.p. of the country.</td>
</tr>
<tr>
<td>2,000-10,000</td>
<td>370</td>
<td>With completion of the projects under implementation the e.p. serviced pe with such projects will be 16% of the total.</td>
</tr>
<tr>
<td>10,000-15,000</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>15,000-100,000</td>
<td>72</td>
<td>Still to be implemented 3-4 (Eastern Attica)</td>
</tr>
<tr>
<td>100,000-150,000</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>&gt;150,000</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1142</td>
<td></td>
</tr>
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αEstimation
Future Trends

1. Population Growth. It is estimated that by 2050 the world population will increase by an additional 2 billion people (e.g. a city of ~145000 inh./d).

2. Urbanization. The great majority of these additional people will settle in urban areas further stressing the pollution pressures and health risks in these areas.

3. Climate Change (variability). For sure, it is predicted that the world will experience more extreme climatic conditions (bigger floods and more severe droughts).

4. Ageing Infrastructure Assets. Many networks and installations in mature economies are ageing and deteriorating.
The Major Global Water and wastewater Challenge

The World in 2050 (Data from IWA SG on Future Cities):
✓ 2 billion more people (~145,000 inh./d);
✓ 90% of this growth in developing countries;
✓ 80% of this growth in urban areas;
✓ Flood risks; and
✓ 2/3 of countries with water scarcity (1/3 in 2000)

Importance of harvesting and storage rain water.
Development of cost-effective water supply sustainable technologies such as harvesting and storage rain water.
Distribution of the world’s urban population by size of urban settlement

- Megacities of 10 million or more
- Large cities of 5 to 10 million
- Medium-sized cities of 1 to 5 million
- Cities of 500,000 to 1 million
- Cities of 300,000 to 500,000
- Urban areas with fewer than 300,000

Year:
- 1970: 3 cities, 15 cities, 126 cities, 186 cities, 227 cities
- 1990: 10 cities, 21 cities, 239 cities, 294 cities, 412 cities
- 2014: 28 cities, 43 cities, 417 cities, 525 cities, 679 cities
- 2030: 41 cities, 63 cities, 558 cities, 731 cities, 832 cities
World Mega cities: Tokyo
Future Trends

Urbanization has had a drastic impact on the natural process of storm water runoff. It has increased both the peak and the volume of runoff, has reduced infiltration, and has caused water pollution. Structural stormwater control measures are designed to:
(a) Reduce the volume and pollution of storm water by harvesting.
(b) Reuse it.
(c) Facilitate infiltration into porous surfaces. And
(d) Facilitate its evaporation.
Use of existing collection system for source separated resource streams

Lateral connection for blackwater and greywater

Lateral connection for source separated urine

Existing collection system to transport source separated wastes and/or stormwater
Conclusions

1. In Greece, water supply and sewerage and drainage systems were of great importance since the prehistoric times.
2. These systems were further improved mainly by increasing their scale during the historical times.
3. The rapid growth and urbanization has increased both the importance of sustainable water and wastewater management and the complexity of implementation which will have serial impacts to the future considerations.
4. Therefore, an expected increase in decentralized self-supporting, small (local) systems will emerge.
5. In the future, water and wastewater management systems based on reaplication of old practices using new equipment and knowledge could be of great significance.
6. Historical studies on rainwater harvesting, collection, and storage technologies provide insights into possible responses of modern societies to the future sustainable management of water resource.
More on this

2nd IWA Regional Symposium on

Workshop on
What and how do we learn from the past?
General view of toilet in the residential quarter of palace of Minos

Thank you for listening