Characteristics and performance of small and medium wastewater treatment plants in Greece

Evina Gavalakis, Civil-Environmental Engineer- PhD ♦ EMVIS SA
Polina Poulou, Chemical Engineer- MSc ♦ Special Secretariat for Water
Apostolos Tzimas, Civil-Environmental Engineer- MSc ♦ EMVIS SA
MAIN TOPICS

WASTEWATER MANAGEMENT IN GREECE
Legal framework • Agglomerations • P.E. • Recipients • Treatment provided

OPERATIONAL CHARACTERISTICS
Components Loads • Ratios

PERFORMANCE INDICATORS
BOD • COD • SS • Nutrients
LEGAL FRAMEWORK

Urban Wastewater Treatment Directive
- Main EU legal document established in 1991
- Minimum requirements for collection and treatment of urban wastewater
- Implementation criteria
  - Agglomeration size in p.e.
  - Character of recipient with respect to its’ sensitivity to eutrophication

UWWTD was adopted in 1997 in Greece
- Considerable progress has been made
- WWTPs that would serve smaller agglomerations (<10,000 p.e.) are still pending, the main constraint being the availability of adequate funding
AGGLOMERATIONS P.E.

In Greece 457 agglomerations with p.e. greater than 2000, are identified corresponding to 11.8 million p.e. in total.

337 agglomerations for the two smaller classes (2000-10000 p.e.) contribute to 12-13% of the generated load.

Population in smaller communities adds up to 2.5 million.
POPULATION SERVED

- Large cities and agglomerations with more than **25,000 p.e.** have practically complied with the UWWTD provisions.
- A small number of agglomerations (5) in the **south-east Attica Region** with total generated load **110,000 p.e.** is still lacking infrastructure.
- As the agglomeration class becomes smaller, the percentage of areas that are not served by wastewater treatment plants significantly increases reaching **65%** for agglomerations with population **below 5000 p.e.** with generating load corresponding to **420,000 p.e.**
TREATMENT PROVIDED

- **Secondary treatment** for the removal of organic load is applied, which in most cases is supplemented by **nitrogen removal** (for more than 85% of the WWTPs) and/or **phosphorus removal** (60%).

- **Similar practices** are used for small and larger wastewater treatment plants.

- **Chlorination** is the preferred method for disinfection.

- Tertiary treatment including **filtration** is not widely practiced → low percentage of wastewater reuse applications (less than 2% of the total wastewater produced).

- **Sludge treatment**: **thickening-dewatering** unit, supplemented by some form of **stabilization** (aerobic or anaerobic). Almost 40% of the plants perform anaerobic digestion and only 8% provide further treatment of sludge in drying plants.
Data from more than **200 WWTPs** were used.

More than **230,000 data entries** for influent and effluent concentrations were processed for the period **2011-2015**.

77% of data were reported by the operators of wastewater treatment plants with a capacity greater than **10000 p.e.**.

The average number of samples collected per year is 12 for the small and medium sized wastewater treatment plants and almost double for the larger plants.

**Quality parameters** of BOD$_5$, COD, SS, TN, NH$_4$-N, NO$_3$-N and TP were observed.

Open data source: [http://astikalimata.ypeka.gr/](http://astikalimata.ypeka.gr/) is the official national platform for data storage and presentation of operational results from wastewater treatment plants in Greece.
## Influent Characteristics

<table>
<thead>
<tr>
<th>(mg/l)</th>
<th>All data</th>
<th>WWTP capacity</th>
<th>Typical composition of raw municipal wastewater with minor contributions of industrial wastewater</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt;10000 p.e.</td>
</tr>
<tr>
<td>BOD</td>
<td>292</td>
<td>304</td>
<td>250</td>
</tr>
<tr>
<td>COD</td>
<td>603</td>
<td>639</td>
<td>472</td>
</tr>
<tr>
<td>SS</td>
<td>282</td>
<td>305</td>
<td>197</td>
</tr>
<tr>
<td>TN</td>
<td>54</td>
<td>55</td>
<td>51.4</td>
</tr>
<tr>
<td>TP</td>
<td>10</td>
<td>10.2</td>
<td>9.75</td>
</tr>
</tbody>
</table>

Mean influent concentrations suggest sewage of low to medium strength.
Person Loads

<table>
<thead>
<tr>
<th>g/p.e./d</th>
<th>All data</th>
<th>WWTP capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt;10000 p.e.</td>
<td>&lt;10000 p.e.</td>
</tr>
<tr>
<td>BOD</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>COD</td>
<td>112</td>
<td>98</td>
</tr>
<tr>
<td>SS</td>
<td>51</td>
<td>48</td>
</tr>
<tr>
<td>TN</td>
<td>13.4</td>
<td>12.9</td>
</tr>
<tr>
<td>TP</td>
<td>2.4</td>
<td>2.2</td>
</tr>
<tr>
<td>Flow-L/p.e./d</td>
<td>275</td>
<td>300</td>
</tr>
</tbody>
</table>

**Graphs:**
- BOD, COD, SS, TN, TP, Flow plotted against percentage of population.

**Legend:**
- all
- >10000 p.e.
- <10000 p.e.
COMPONENTS’ RATIOS

- Wastewater with high COD to BOD ratio indicates that a substantial part of the organic matter will be difficult to degrade biologically.

- Wastewater with low carbon to nitrogen ratio may need external carbon source addition in order that biological denitrification functions fast and efficiently.

<table>
<thead>
<tr>
<th></th>
<th>All data</th>
<th>WWTP capacity</th>
<th>Typical ratios in municipal wastewater</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&gt;10000 p.e.</td>
<td>&lt;10000 p.e.</td>
</tr>
<tr>
<td>COD/BOD</td>
<td>2.0</td>
<td>2.1</td>
<td>1.8</td>
</tr>
<tr>
<td>COD/TN</td>
<td>4.6</td>
<td>4.3</td>
<td>6.7</td>
</tr>
<tr>
<td>COD/TP</td>
<td>26.6</td>
<td>27.3</td>
<td>24.0</td>
</tr>
<tr>
<td>BOD/TN</td>
<td>2.2</td>
<td>2.1</td>
<td>3.1</td>
</tr>
<tr>
<td>BOD/TP</td>
<td>14.6</td>
<td>16.2</td>
<td>10.9</td>
</tr>
</tbody>
</table>

\[ y = 2.0136x \]
\[ R^2 = 0.5096 \]
Operational characteristics and design assumptions

- $\text{BOD}_5 (p90) / \text{BOD}_5 (p50) = 1.32$ to $1.60$
- Lower ratios corresponding to the smaller scale treatment plants.
  - more consistent effluent quality is obtained, perhaps due to limited in number and magnitude shock loads, which overshadow possible disadvantages in terms of personnel and experience.
- $\text{BOD}_5 (p90) / \text{BOD}_5 (p50) = 1.60$
  - 25 mg/l requirement from the Directive refers to the value to be achieved for 88%-93% of the samples, it is wise to design a plant aiming at a median $\text{BOD}_5$ concentration of 15 mg/l.
Most design models are based on the expected soluble BOD₅ in the reactor.

The presence of SS in the effluent results in particulate BOD₅ in the effluent.

The ratio of SS/BOD₅ is approximately 1.

1 mg of SS corresponds to 0.60-0.70 in terms of particular BOD₅.

A safe design value for the soluble BOD₅ to be achieved is to the order of 4-5 mg/l.
Compliance with the provisions of the UWWTD refers to effluent concentrations of BOD, COD and SS and depending on the type of the recipient nitrogen and phosphorus.

<table>
<thead>
<tr>
<th></th>
<th>UWWTD discharge limits, mg/l</th>
<th>All WWTPs</th>
<th>&lt;10000 p.e.</th>
<th>&gt;10000 p.e.</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD-p90</td>
<td>25</td>
<td>86%</td>
<td>87%</td>
<td>86%</td>
</tr>
<tr>
<td>COD-p90</td>
<td>125</td>
<td>94%</td>
<td>94%</td>
<td>94%</td>
</tr>
<tr>
<td>SS-p90</td>
<td>35</td>
<td>87%</td>
<td>87%</td>
<td>87%</td>
</tr>
<tr>
<td>TN-p50</td>
<td>15</td>
<td>80%</td>
<td>79%</td>
<td>79%</td>
</tr>
<tr>
<td>TP-p50</td>
<td>2</td>
<td>46%</td>
<td>43%</td>
<td>43%</td>
</tr>
</tbody>
</table>
CONCLUSIONS

MANAGEMENT
Wastewater treatment on Greece is satisfactory both in terms of the infrastructure, i.e. the WWTPs constructed and respective population served. There are still challenges that have to be addressed...

OPERATION
Wastewater characteristics are in good agreement with low or medium strength wastewater which is expected considering the relatively limited industrial activity in the country.

PERFORMANCE
Almost 90% of the wastewater treatment plants meet the effluent standards set by the UWWTD for BOD, COD and SS. 80% of the plants adequately remove nitrogen.
FUTURE CHALLENGES

- Meet the requirements of the UWWTD with respect to small to medium sized areas (>200 agglomerations of 2000-10000 p.e.)
- Promote sustainable wastewater management for communities with <2000 p.e. (SSW Guide)
- Optimise the operation of WWTPs
- Adopt wastewater reuse practices
Thanks are due to the Special Secretariat for Water for facilitating the provision of the data regarding Urban Wastewater Treatment in Greece. All data are open and available from the web site http://astikalimata.ypeka.gr/ which is the official national platform for data storage and presentation of wastewater treatment plants in Greece.
Thank you for your attention