WATER REUSE IN SPAIN: DATA OVERVIEW AND COSTS ESTIMATION OF SUITABLE TREATMENT TRAINS

Raquel Iglesias Esteban
(Hydrology Research Center (CEH) of CEDEX, Spain)

Presentation

1. Some aspects have enhanced the development of water reuse in Spain
2. Spanish Reuse Database. Development and Main Results
4. Proposal of treatment trains to meet legal requirements. General estimated cost of investment and operational are including.
1. Introduction

- The need of water
- Treated effluents:
  - Directive 91/271/EEC
  - Water Framework Directive
  - Others: Bathing Water Directive; Programmes for Pollution Monitoring or priority or emerging pollutants
- The development of regeneration technologies
- Reuse regulation development

The enforcement of Directives and other regulations:

- Royal Decree 1620/2007 water reuse regulation
- State Water Reuse Plan
- Programa A.G.U.A. and River Basin District Plans or Autonomous Region Reuse Programs

- Water treatment plants: 2,533 (> 5,000 h-e)
- Treating volume: 3,370 Hm³ per year
- Treated volume for reuse (2015): 1.200 Hm³

(Source: The Ministry of the Environment, 2007)
2. Spanish Reuse Database

- **The requester:** Ministry of Environment (2005-2008)

- **Aim:** Gather the main information about water reuse in Spain in order to make a first approach

- **Main stages:**
  - Database design
  - fieldwork collection of data
  - checking and storage of data
  - integration of this Database in Geographic Information System (GIS).

- **Final report:** delivered to the requester in 2008
Database design

Contents of Spanish Reuse Database

A) General data: system reuse and authorization requirements:
- date of completion of the questionnaire
- autonomous region, municipality, town and area
- owns and manages
- the reclaimed water volume and uses permitted

B) Information concerning the wastewater treatment plants:
- name, type of treatment, designed and treated volume
- quality in four basic parameters; BOD₅, SS, turbidity and EC

C) Data relating to the water reclamation plant:
- state of water reclamation plant
- capacity, delivery point
- number of days per year is operated
- reclaimed water quality in order to RD1620/2007
- O&M costs
State of Water Reuse in Spain

- Nº reuse systems 322
- 10.6% of the total treated wastewater
- The volume of reclaimed water was 447.34 Hm³ in 2008 according to the Ministry of Environmental

### Locations and volume per year of water reuse broken down by regions and uses (2007)

<table>
<thead>
<tr>
<th>ZONES</th>
<th>Hm³/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comunidad Valenciana</td>
<td>149.60</td>
</tr>
<tr>
<td>Comunidad de Murcia</td>
<td>94.02</td>
</tr>
<tr>
<td>Islas Canarias</td>
<td>1.3</td>
</tr>
<tr>
<td>Islas Baleares</td>
<td>26.34</td>
</tr>
<tr>
<td>Canarias</td>
<td>44.06</td>
</tr>
<tr>
<td>Andalucía</td>
<td>24.21</td>
</tr>
<tr>
<td>País Vasco</td>
<td>1.2</td>
</tr>
<tr>
<td>Aragón</td>
<td>9.17</td>
</tr>
<tr>
<td>Castilla la Mancha</td>
<td>2.96</td>
</tr>
<tr>
<td>Madrid</td>
<td>5.48</td>
</tr>
<tr>
<td>TOTAL</td>
<td>308.2</td>
</tr>
</tbody>
</table>

### Percentages over total water reuse volume by uses

- Irrigation of crops
- Watering of urban green areas
- Irrigation of golf courses
- Recharge of aquifers

<table>
<thead>
<tr>
<th>% per USES</th>
<th>Hm³/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>URBAN</td>
<td>71.0%</td>
</tr>
<tr>
<td>AGRICULTURAL</td>
<td>4.0%</td>
</tr>
<tr>
<td>INDUSTRIAL</td>
<td>0.3%</td>
</tr>
<tr>
<td>RECREATIVE</td>
<td>17.7%</td>
</tr>
<tr>
<td>ENVIRONMENTAL</td>
<td>7.1%</td>
</tr>
</tbody>
</table>

- It is observed agricultural irrigation is the most frequent use, although the percentage of environmental or urban use are increasing recently.
• There are an important Autonomous Region Reuse Programs and specific rules to reuse.

• The future of water reuse is essentially focused on the coastal areas of the Mediterranean and South-Atlantic Arc, and the Balearic and Canary Islands where it is strategic non-conventional resource.
### Treated Wastewater Reuse Regulations

- **At the EU level**
  - It is not a Directive
  - Directive 91/271/EEC concerning urban waste-water treatment

- **At the national level**
  - Royal Decree 1/2001: the Government shall establish the basic requisites for water reuse
  - The Regulation on Public Water Domain (Royal Decree 849/1986): defines the requisites and steps for obtaining a concession for water reuse
  - Royal Decree 1620/2007 of December 7th, which lays down the legal regime for the reuse of treated wastewater, establishes both the basic requisites for water reuse, and the necessary procedures to obtain the concessions and authorizations

Maximum allowed values in 4 parameters: nematodes; E.coli; SS and Turbidity

<table>
<thead>
<tr>
<th>URBAN USES (2)</th>
<th>AGRICULTURAL (3)</th>
<th>INDUSTRIAL (3)</th>
<th>RECREATIONAL (2)</th>
<th>ENVIRONMENTAL (4)</th>
</tr>
</thead>
</table>
| 1.1 Residential:  
a) Private garden  
   watering.  
b) Discharge of  
bathroom appliances  
1.2 Urban services:  
a) Watering of urban  
green areas (parks,  
sports grounds, etc.)  
b) Hosing down streets  
c) Fire-fighting systems  
d) Industrial car wash  
2.1. a) Irrigation of fresh food crops  
direct contact of regenerated water  
with edible parts  
2.2a) systems not  
avoiding direct contact of  
regenerated water  
with edible parts.  
b) Irrigation of pastureland for milk  
or meat-producing animals  
c) Aquaculture  
2.3a) Localized irrigation of ligneous crops  
b) ornamental flowers  
3.1a) Process and cleaning water  
except in food industry  
b) Other industrial uses  
3.2a) Refrigeration towers and evaporation condensers  
4.1. a) Irrigation of golf courses  
4.2. a) Ponds, bodies of water and running water  
with no public access  
5.1. a) Recharge of aquifers by localized seepage through the soil  
5.2. a) Recharge of aquifers by direct injection  
5.3. a) Irrigation of forests, green zones and similar areas  
with no public access  
b) Forestry  
5.4. a) Other environmental uses  
(maintenance of wetlands, minimum flows and similar uses)  

Forbidden uses  
- drinking water, except catastrophe  
- hospitals  
- molluscs in aquaculture  
- bath water  
- Ponds, bodies of water and running water  
with public access

4. Technologies and Systems for Water Reclamation according to Royal Decree 1620/2007

- Current situation
  - It necessary to adapt an important part of the reuse systems
  - Royal Decree 1620/2007 sets a 2-year deadline to comply with the requisites
  - The development of programs for planned reuse of wastewater has spurred MARM to study technology issues and important factors in the selections of treatment processes for water reuse

- A proposal of regeneration treatments to meet legal requirements
  - During 2008, Department of Wastewater Treatments, Reclamation and Reuse of CEDEX was working on the treatment trains efficiency to meet different applications criteria regulated by Royal Decree 1620/2007 as to estimate costs

Based on
- running water reclamation plants set up in Spain
- the provision of multiple barriers
Quality groups according to the bacteriological limits established on the RD 1620/2007

<table>
<thead>
<tr>
<th>APPLICATIONS</th>
<th>Quality</th>
<th>Enterococcus CFU/100 ml</th>
<th>Nematode eggs/10 L</th>
<th>Legionella spp. CFU/100 ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial 3.2 a)</td>
<td>A</td>
<td>Absence</td>
<td>Absence</td>
<td>Absence</td>
</tr>
<tr>
<td>Residential 1.1 a) y b)</td>
<td>A</td>
<td>Absence</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Direct Recharge 5.2 a)</td>
<td>A</td>
<td>Absence</td>
<td>1</td>
<td>No limit set</td>
</tr>
<tr>
<td>Urban 1.2 a), b), c), d)</td>
<td>B</td>
<td>100-200</td>
<td>&lt; 1</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>Agricultural 2.1 a)</td>
<td>B</td>
<td>&lt; 1</td>
<td>No limit set</td>
<td></td>
</tr>
<tr>
<td>Recreational 4.1 a)</td>
<td>C</td>
<td>&lt; 1.000</td>
<td>&lt; 1</td>
<td>No limit set</td>
</tr>
<tr>
<td>Agricultural 2.2 a), b) y c)</td>
<td>D</td>
<td>&lt; 10.000</td>
<td>&lt; 1</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>Industrial 3.1 c)</td>
<td>D</td>
<td>&lt; 10.000</td>
<td>&lt; 1</td>
<td>No limit set</td>
</tr>
<tr>
<td>Environmental 5.1 a)</td>
<td>E</td>
<td>No limit set</td>
<td>No limit set</td>
<td>No limit set</td>
</tr>
<tr>
<td>Agricultural 2.3 a), b) y c)</td>
<td>E</td>
<td>No limit set</td>
<td>No limit set</td>
<td>No limit set</td>
</tr>
<tr>
<td>Industrial 3.1 y b)</td>
<td>E</td>
<td>No limit set</td>
<td>No limit set</td>
<td>No limit set</td>
</tr>
<tr>
<td>Recreational 4.2 a)</td>
<td>E</td>
<td>No limit set</td>
<td>No limit set</td>
<td>No limit set</td>
</tr>
<tr>
<td>Environmental 5.3 a) y b)</td>
<td>F</td>
<td>No limit set</td>
<td>No limit set</td>
<td>No limit set</td>
</tr>
<tr>
<td>Environmental 5.4 a)</td>
<td>F</td>
<td>No limit set</td>
<td>No limit set</td>
<td>No limit set</td>
</tr>
</tbody>
</table>

The minimum quality required is studied on a case by case basis.

Treatment processes flow diagram (1)

<table>
<thead>
<tr>
<th>Quality</th>
<th>Type</th>
<th>Treatment train without desalination</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>Chemical precipitation, filtration with membranes, and Disinfection (residual chlorine may be needed in distribution system)</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>Chemical precipitation, depth filtration and disinfection (ultraviolet radiation together with chlorination; residual chlorine may be needed in distribution system)</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>Filtration and disinfection (tendency to use ultraviolet radiation followed by residual chlorine)</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>Filtration</td>
</tr>
<tr>
<td>E</td>
<td>-</td>
<td>It is studied on a case by case.</td>
</tr>
</tbody>
</table>

- Physical-chemical treatment with a lamella settling system. With regular concentrations of constituents in treated wastewater which are meeting RD 11/1995 requirements [13], this unit operation can be omitted.
- Cases studied have ultrafiltration.
- All treatment trains in Spain include RO to remove nutrients and trace constituents.
- With regular treated wastewater quality standards but it is recommended any surface or depth filtration for distribution system management.
Treatment processes flow diagram (2)

<table>
<thead>
<tr>
<th>Quality</th>
<th>Type</th>
<th>Treatment train with desalination</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-F</td>
<td>5a</td>
<td>Chemical precipitation, Filtration, Filtration with membranes, RO desalination and residual chlorine.</td>
</tr>
<tr>
<td>B, C, D, E</td>
<td>5b</td>
<td>Chemical precipitation, Filtration, EDR desalination and Disinfection (tendency to use ultraviolet radiation followed by residual chlorine).</td>
</tr>
</tbody>
</table>

Establishment and Operation Cost of Selected Treatment Trains

<table>
<thead>
<tr>
<th>Treatment train</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Establishment</td>
</tr>
<tr>
<td></td>
<td>€/(m³ designed/100)</td>
</tr>
<tr>
<td>Type 1</td>
<td>164 - 351</td>
</tr>
<tr>
<td>Type 2</td>
<td>27 - 47</td>
</tr>
<tr>
<td>Type 3</td>
<td>9 - 22</td>
</tr>
<tr>
<td>Type 4</td>
<td>5 - 11</td>
</tr>
<tr>
<td>Type 5.a</td>
<td>259 - 458</td>
</tr>
<tr>
<td>Type 5.b</td>
<td>248 - 405</td>
</tr>
</tbody>
</table>

- Physical-chemical treatment with a lamella settling system.
- Typical process flow diagrams incorporating membranes before RO as protective barrier.
- Physical-chemical treatment with a lamella settling system.
- Double depth filtration with continuous washing is being used.

This treatment train is used for industrial applications 3.1a), b) and c) due to E. coli and Turbidity requirements.
- Disinfection means €0.005 per m³ produced so this unit process is not seen in the displayed value.
- Cases where physical-chemical treatment operation can be left out, cost may be ranging from €0.30 to €0.40 per m³ produced.
- Cases where physical-chemical treatment operation can be left out, cost may be ranging from €0.30 to €0.40 per m³ produced.
WATER REUSE IN SPAIN: DATA OVERVIEW AND COSTS
ESTIMATION OF SUITABLE TREATMENT TRAINS

Thank you for your attention

raquel.iglesias@cedex.es