Monitoring and Investigation Technologies Workshop
Athens 16-18 March 2016

Monitoring system at the Sant’Alessio Induced RiverBank Filtration plant
(Lucca, Italy)

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The Lucca plain hosts the most important aquifer of Tuscany providing supply to Pisa, Lucca and Livorno and to a large paper mill industrial hub. The Serchio River, hydraulically connected, greatly recharges the aquifer.
Along the Serchio River groundwater is pumped enhancing riverbank filtration into the sand and gravel aquifer. At Sant’Alessio, River head is artificially raised and 20 pumping wells withdraw about 600 l/s.
IRBF MAR system

- S. Alessio plain
- S. Alessio well field
- Serchio River
- Weir
- M. S. Quirico bridge
IRBF MAR system
Pesticides in surface water and in groundwater

The MAR plant is not at present monitored on routinely basis.
Stratigraphy and IRBF MAR

S. Alessio well field

Weir

Serchio River
WP8/Managing river bank filtration at the Serchio River well field

**Objective** To merge existing and proved technologies to produce a Decision Support System (DSS) **based on remote data acquisition and transmission** and GIS physically-based fully distributed numerical modelling to continuously monitor and manage the well field.

The DSS, the installed sensors, data transmission and storage tools will constitute a prototype whose potential market exploitation will be tested.

**Deliver contingency measures plan (mixing options...???)**

**Task 8.1:** Installing and operating the monitoring system (SSSA, Lucca, TEA)

**Task 8.2:** Demo site analysis (UFZ, SSSA, Lucca)

**Task 8.3:** Decision Support System development and testing (TEA, SSSA)

**Task 8.4:** Model implementation and calibration (SSSA, Lucca)

**Task 8.5:** Application of the DSS at the Serchio IRF well field (SSSA, TEA, Lucca)
Task 8.1: **Installing and operating the monitoring system** (SSSA, Lucca, TEA)

**Objective**

*To provide the IRBF plant with a monitoring system to control:*

- **Safety of the MAR plant (water quality)**

A Wireless Sensor Network (WSN) to monitor:

- Surface water and groundwater T, EC & hydraulic head

Additional, Surface and groundwater quality monitoring by means of onsite spectrometer

Water temperature & water EC to be used as natural tracer

As derived information: sw/gw interaction behavior

The WSN is based on several data loggers «client» connected via radio to 1 server point (Gateway), transmitting to the Database DB via GSM-GPRS
**Monitoring design** (SSSA, Lucca)

6 borehole clusters were finally set in place at:

- 12 m / 15m / 20m depth (15 & 20 m 2 inches)
Piezometer cluster
GW Monitoring

This part of WSN is based on several data loggers connected via RF within a mesh. 1 central point is included in the mesh (Gateway), transmitting via GSM/GPRS to DB.
A low cost and open source (=customized) approach

A mesh-type WSN: any mesh node (n.6) transmits to others via radio modem (XBEE PRO 868).

1 point in the mesh serves as GATEWAY, transmitting via GSM/GPRS to a GeoDatabase.

In-house assembled, low cost data logging system: based on ARDUINO BOARD

Data transmission is implemented within a RaspberryPi

Post-REST
As API for transmission to PostgrSQL DB
Task 8.1: **Installing and operating the monitoring system** (SSSA, Lucca, TEA)
Acquisition and transmission frequency

- Data acquired 6 times per hour (every 10 min.)
  - Every 10 minutes: a time window of 30 sec. for acquisition. Then data are averaged and the average value is saved and sent to the central node via RF.
- Every hour, data are sent from the central node to the server, and then fed to GeoDB

**WSN: examples of recorded data**

Data recorded at probe 1 (temperature, EC, water table level)  
GW temperature (in °C)
WSN: examples of recorded data
SW Monitoring

GeoDB is connected to the regional Service for Hydrology (a sensor for automated detection of hydrometric level)

Hourly-based data

Data are automatically retrieved and saved in our GeoDB
Water quality

Two points to be installed – one gw – one sw using S::CAN SPECTRO::LYSER probe

spectro::lyser™

These two (expensive) probes will be used to calibrate the low-data and low-expensive monitoring system and to finalise the alarm system ...

However ... how to cope with supply in case of pollution accident? NEXT TO COME
Monitoring: critical points, and solutions

An *exciting* but *tough* experience: we experienced several problems, here summarized.

- Initial WSN Concept was simpler: a *mesh* without a dedicated central point (the Gateway was only 1 simple point in the mesh).
  - Advantage was a lower power consumption
  - Weakness: lower transmission power

However…. It was not possible to implement such a design. Actually, the main criticality… vandalism!!!

Electronics and Antenna have to be protected, and hidden inside a concrete manhole

This implied to find a more powerful scheme for the WSN … and also a long delay on WSN installation and test
LIMITATIONS

Vandalism

Loss of signals between the sensor and the antenna due to:
- cable connection’s;
- concrete or other materials to protect the installations if the antenna is inside the piezometer box – need for lower frequency transmission;

The use of antennas is regulated: population fears

Landowners resistance to allow the installation

Obstacles may require you to use SIM cards
Monitoring: critical points, and solutions

Additional problems experienced, which caused the delay on running the WSN.

• Some problem with moisture/water infiltration, even in manholes
  ➢ All points have been revised, with exception of Point 4, which has been eliminated from the WSN
• An event of electricity overloading occurred at the central node
  ➢ Electronics were destroyed and a completely new installation of central node was necessary
• Some problems in the electricity switching system at nodes
  ➢ This device allows to switch off/on the electronics, to save battery.
  ➢ The devices broke down (probably they were not suitable for outdoor conditions) and this caused an abrupt consumption of batteries.
  ➢ In turn, data logging system was compromised, requiring a long additional assistance.
  ➢ The switching devices have been completely substituted
Monitoring: lesson learned

WSN design and installation have to face (possible) power consumption problems:

- Vandalism problems imply that if solar panels can not be used, another source of energy is needed.
- Car battery is now the solution, but is quite demanding in terms of maintenance.

The OPEN solution has great advantages (as stated before).

In the meantime, the *in-house* installation implies a lot of manpower and management of some criticalities, at list for the current stage of prototype.

- It is envisaged that with an industrialized solution a lot of problems may be avoided.
**WSN: a comparison of costs**

<table>
<thead>
<tr>
<th>Single node (datalogger, transmission)</th>
<th>Cost (~ €)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xbee 2.4 Ghz 1.5 Km 63mW</td>
<td>30</td>
</tr>
<tr>
<td>Shield Arduino for Xbee</td>
<td>17</td>
</tr>
<tr>
<td>Antenna 1.8 dBi</td>
<td>17</td>
</tr>
<tr>
<td>Arduino Leonardo</td>
<td>22</td>
</tr>
<tr>
<td>Arduino Proto</td>
<td>7</td>
</tr>
<tr>
<td>Relè to switch on/off electricity supply</td>
<td>35</td>
</tr>
<tr>
<td>DC Converter</td>
<td>50</td>
</tr>
<tr>
<td>Box IP66</td>
<td>34</td>
</tr>
<tr>
<td><strong>Total for 1 node</strong></td>
<td><strong>212</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Central node</th>
<th>Cost (~ €)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xbee 2.4 Ghz 1.5 Km 63mW</td>
<td>30</td>
</tr>
<tr>
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<td>DC Converter</td>
<td>50</td>
</tr>
<tr>
<td>Box IP66</td>
<td>34</td>
</tr>
<tr>
<td>Raspberry Pi</td>
<td>53</td>
</tr>
<tr>
<td>SD Memory</td>
<td>10</td>
</tr>
<tr>
<td>Modem GPRS</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>286</strong></td>
</tr>
</tbody>
</table>

| Total for a 6-point WSN                                      | **1558** |

<table>
<thead>
<tr>
<th>Commercial solution</th>
<th>Cost (~ €)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single node (datalogger, transmission)</td>
<td></td>
</tr>
<tr>
<td>Datalogger D200X client 3 inputs in box IP65.</td>
<td>408</td>
</tr>
<tr>
<td>Antenna 1.8 dBi</td>
<td>17</td>
</tr>
<tr>
<td>Modem GSM-GPRS for central datalogger</td>
<td>280</td>
</tr>
<tr>
<td><strong>Total for 1 node</strong></td>
<td><strong>705</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Central node</th>
<th>Cost (~ €)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datalogger D2000X server in box IP65.</td>
<td>1190</td>
</tr>
<tr>
<td>Modem GSM-GPRS for central datalogger</td>
<td>280</td>
</tr>
<tr>
<td>Antenna 2.4 Ghz (with cable and connector)</td>
<td>190</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1660</strong></td>
</tr>
</tbody>
</table>

| Total for a 6-point WSN                                      | **5890**   |

**Remark. In both cases:**
- No cost for manpower is considered
- Batteries and probes are not included, since they do not differ

- the great advantage is the **OPEN SOLUTION**: you get data in XML format, which can be connected with any standard
- This is of great importance if dealing with interoperability and standardization, like WaterXML, for instance.
Task 8.3: **Decision Support System development and testing** (TEA, SSSA)

**DSS (Decision Support System)** aiming at:

(a) Controlling and analyzing measured parameters
(b) Suggesting new scenarios for RBF plant

The DSS consists of 4 main pillars:

1) Alert system service
2) Short-cut modeling (directly included in DB, as stored procedures)
3) (GIS-embedded) statistical data analysis
4) (GIS-integrated) numerical modeling
Session 6.02 - Treated Waste water REUSE for groundwater recharge: addressing the challenge

Water scarcity and the overexploitation of conventional water resources are two of the main drivers to treated wastewater (TWW) REUSE. TWW groundwater recharge projects are blooming in the world especially in coastal areas and in the Mediterranean area where increasing pressures on the resource cause deep depletion and high salinization impacts. TWW can either be directly reinjected or indirectly through dedicated infiltration basins (Northern Gaza strip, Tunisia, ...). This practice enables to restore groundwater in terms of quantity and quality, but also to limit salt intrusion and mitigate climate change impacts. TWW could then be pumped from the groundwater for indirect surface reuse like agricultural irrigation. Ground properties are used and considered as a way to improve TWW quality (Korba in Tunisia) but most of the time much attention is often paid to TWW quality (pathogens, salinity, etc.) prior to recharge to avoid groundwater contamination.
Thank you!
Some hydrological data

Rainfall (hydrologic year from oct 1973)

Temperature

River discharge (i.e. 2009)
Task 8.2: **Demo site analysis** (UFZ, SSSA, Lucca) / to be completed, refined

- Site investigation performed between May and September 2014
- Several preliminary issues to be dealt with:
  - UXO clearance
  - utility clearance
  - landowners resistance to collaborate due to results of a previous LIFE project

*great help from Lucca Province (not with landowners !) ://
Task 8.2: **Demo site analysis** (UFZ, SSSA, Lucca) / to be refined
Serchio River well field: Understanding well field hydraulics for Managed Aquifer Recharge

**Task 1:**
Subsurface Characterization

**Task 2:**
Monitoring of flow regime

- Direct Push profiling (DPIL, EC)
- Direct Push profiling with 1” GW well installation
Serchio River well field: Understanding well field hydraulics for managed aquifer recharge

- Direct Push Injection Logging
- Direct Push Electrical Conductivity Logging

![Graphs showing depth, electrical conductivity, and rate of penetration](image)