Saverio De Vito - ENEA presents:

A pervasive data assimilation system for wastewater processing plant protection

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CQWM 2016
Citizen Observatories for Water Management

Summary

- Background
- The S.I.Mon.A. Project
- S.I.Mon.A. Approach & Architecture
- The Smart Cyber Physical System
- Test Deployment Site & Measurement Campaign
- Results
- Conclusions

Background…

Discharges of toxic substances that reach the waste water management plants, may adversely affect the plants themselves, causing the release into the environment of pollutants at illegal and harmful concentrations.

Anomalous load due to dairy products processing.

Effects on sea water of overflow discharge of waste waters

Current monitoring strategies do not allow to forecast/prevent/mitigate such issues because water quality assessment occurs to sparsely in space and time!

We need a completely new paradigm for this critical infrastructure protection.

The Simona Project

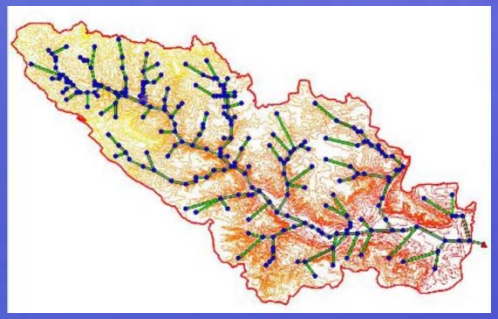
The Simona Project investigates new strategies for waste water management plant protection.

Funded by POR Campania, It involved actual stakeholders (Large and SME Enterprises) and a research agency. It aims to tackle the problem with a both innovative and practical approach with an on-field trial.

The Simona Concept

In order to avoid unnecessary latencies and delays, in order to detect timely and mitigate impacts SIMONA propose a simple data assimilation scheme:

Initial Model Calibration
Data Feeds



Sensor Recalibration

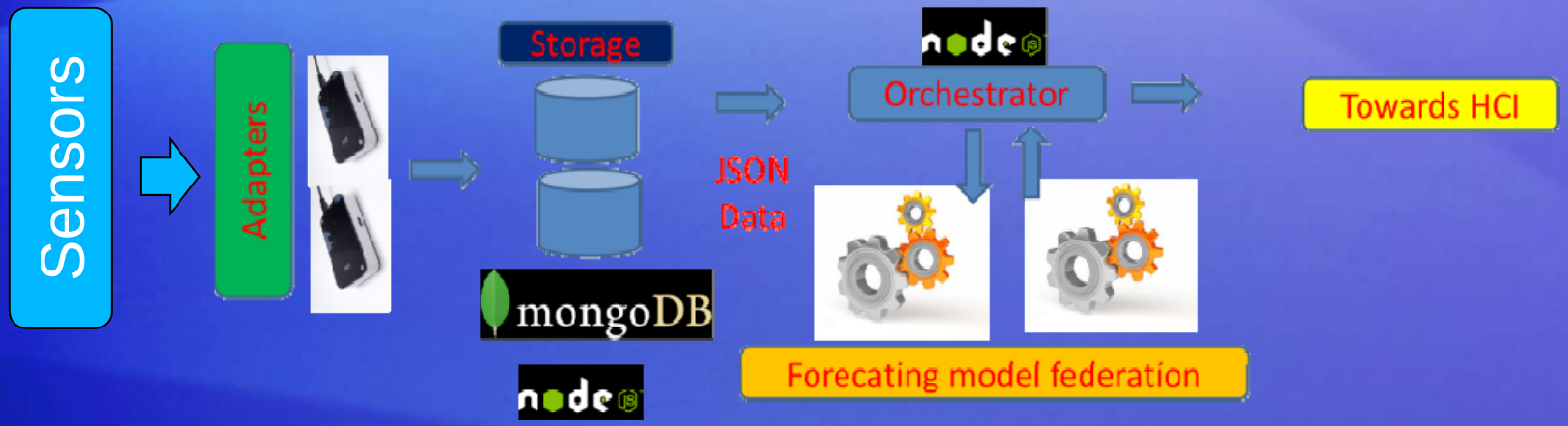
Pervasive Intelligent Sensing Network

Timely measurements
Pervasive data quality assessment
Early Warning via Anomaly Detection

Forecasting and Inverse Models

Diffuse Assessment
Water Quality Forecasting
Backtracing of Illicit Immissions

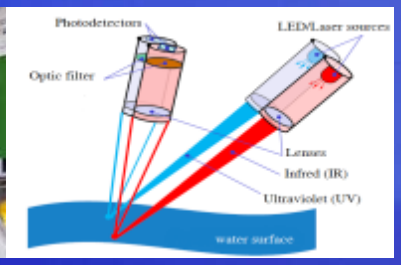
The Simona ICT Architecture



- An Heterogeneous sensor network feeding a scalable storage and process architecture with water physical chemical parameters data stream.
- The orchestrator control the exectuiion of forecasting models and rule-based alarm generators
- A SOS SensorWEB architecture provide standard GIS visualization functionalities to the end-user

Smart Cyber Physical Systems

Commercial Systems:
S::CAN Model
Params:
TSS, COD, pH,NH4+,Conductivity,Flow, Temperature.



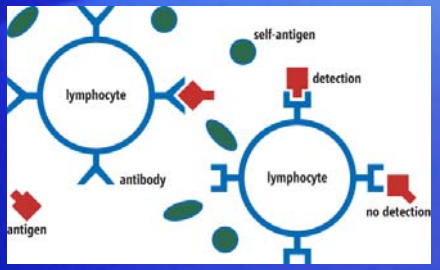
LOADMON:
Infrared – UltraViolet Reflection spectroscopy system -> TSS,COD
Water Research Center Patented

Low Cost Prototype Systems
Non Contact: Low Mainteinance
-> Anomaly Multisensor device
-Off-Gas (NH3/H2S), Temperature, Level
->Wastewater presence sensors
Contact water presence in harsh environment

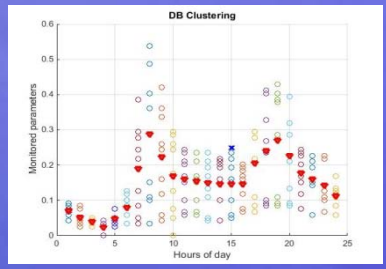
- Connectivity based on cellular networks availability

Data Processing Techniques

Artificial Immune Systems for Local Anomaly Detection



Based on AIS bioinspired framework
Adaptively describe local (space/time) normality
Descriptors evolve to take care of seasonality
(Relatively) Easy to implement on board



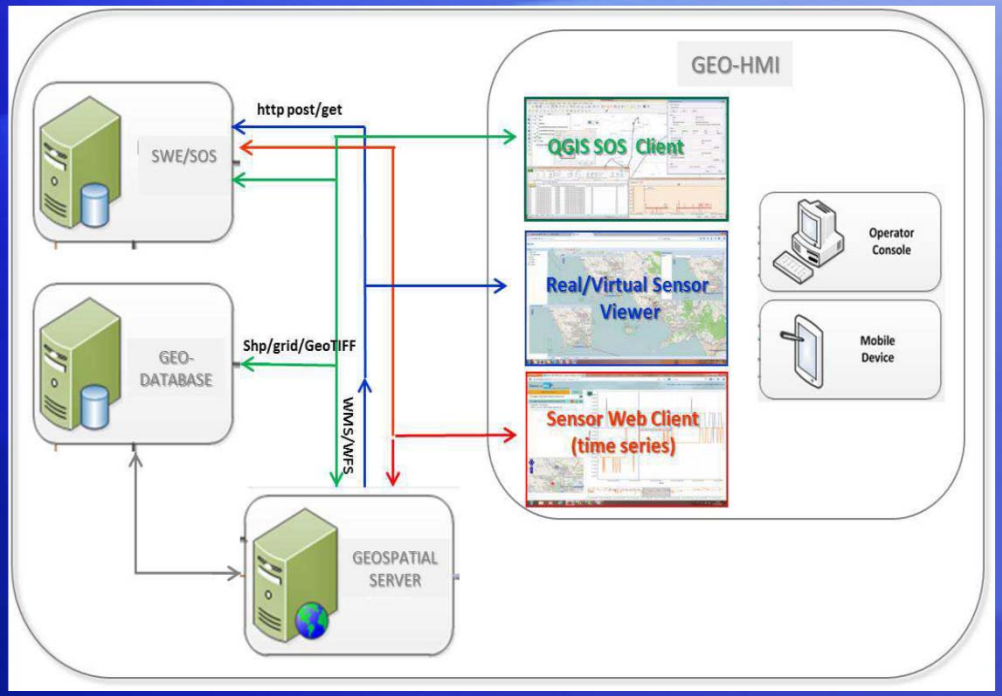
On line detection of multivariate anomaly values, That is early detection of significant changes of the holistic response of the prototype multi-sensor device

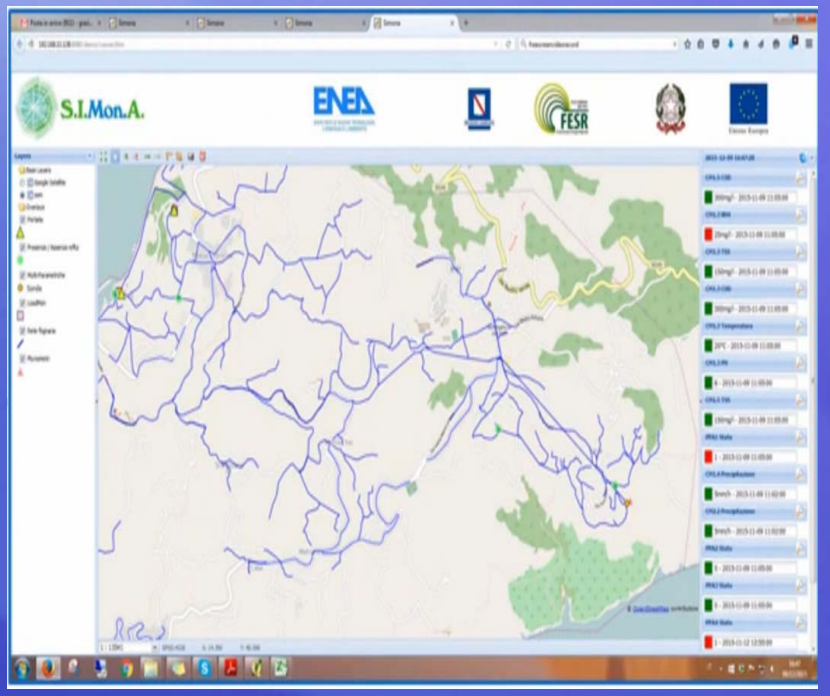
Rule based system for Event Detection

Drools

Simple Rule based anomalies detection
[e.g. *Water presence in Arc H & Not(Rain)*]

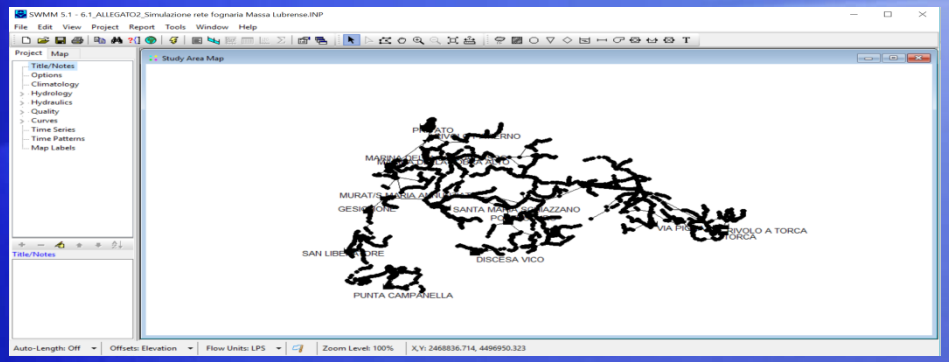
webGIS Technologies





- A multiview GEO Human Machine Interface based on the SensorWeb Framework including…
- An End User interface for alert monitoring, time series and water quality forecasts access.

Diffusion (Transport) and Source Location Models



1928 junctions
1930 conduits
7 pumping plants

Genetic Algorithm based Source Localization Approach

Objective function score

Selection
Crossover
Mutation
Fitness score

GALib

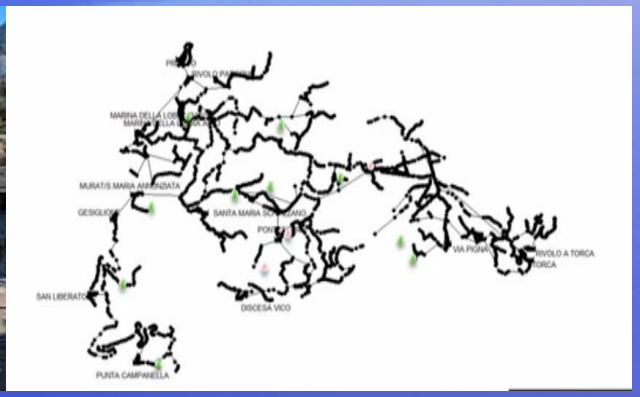
SWMM

Hydraulic & Water Quality simulation

(Wall, 1996)

Unknown variables
L, C_0, T_0, D

Deployment Site and Specification



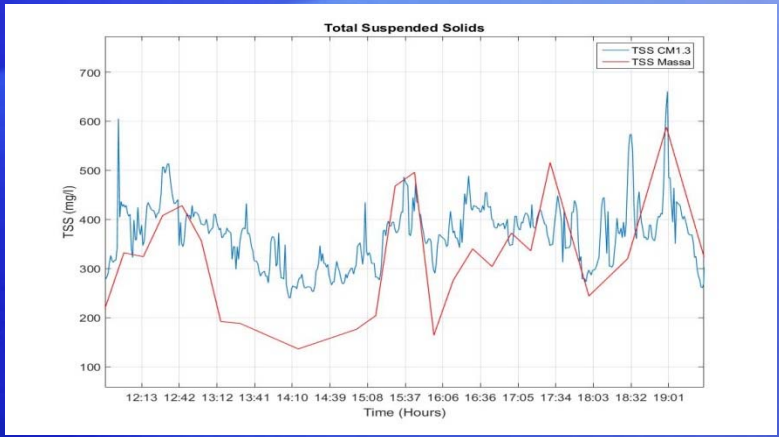
Massalubrense Town
#14.000 Inhabitants
Marine Protected Area
Single WWM Plant

4 Multisensor Prototype @ (Internodes)
4 Commercial S::CAN Devices @ (Main Fac.)
8 Water Presence Devices @ (Distributed)
1 Loadmon Device @ (CM1.3)

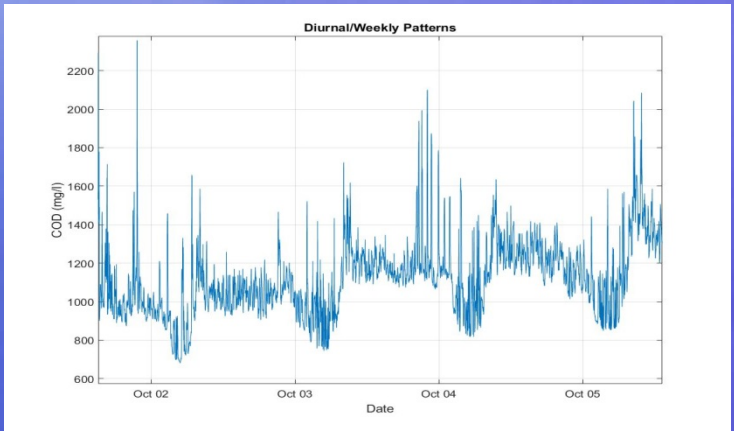
From Oct, 2015 to Feb, 2016

Some Results (Mid Term)

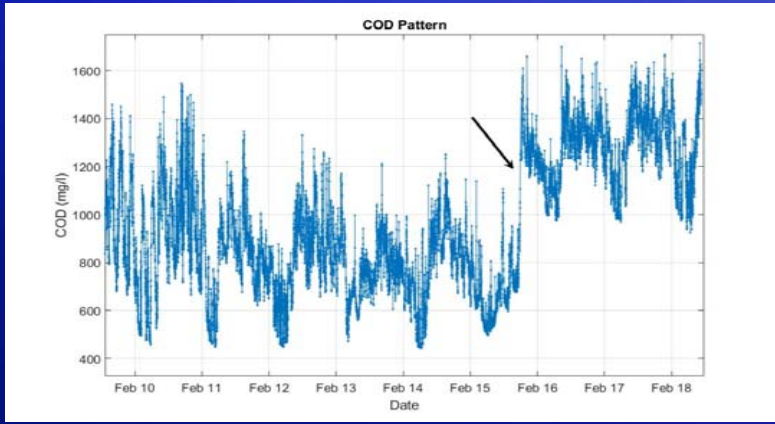
Data Availability



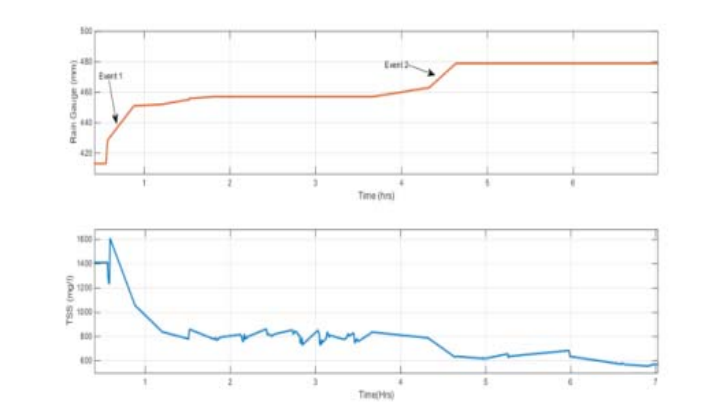
Analytical vs Sensors
(The value of High Frequency Measurements)



Follow Diurnal/Weekly Patterns

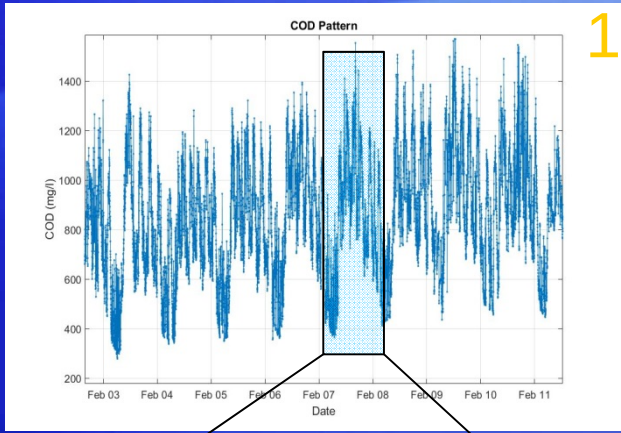


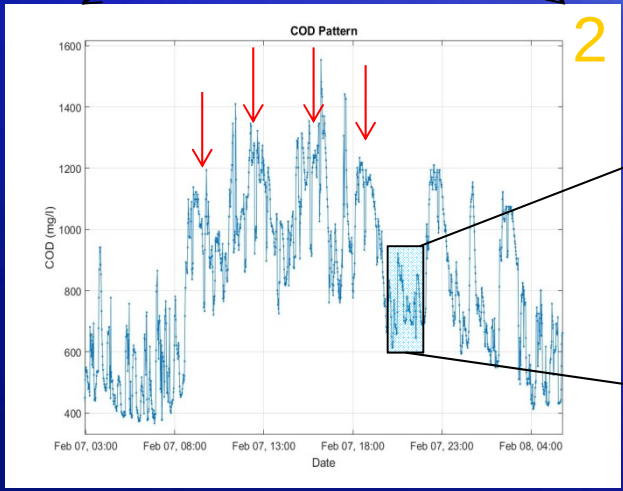
S::CAN Level Errors+Drift

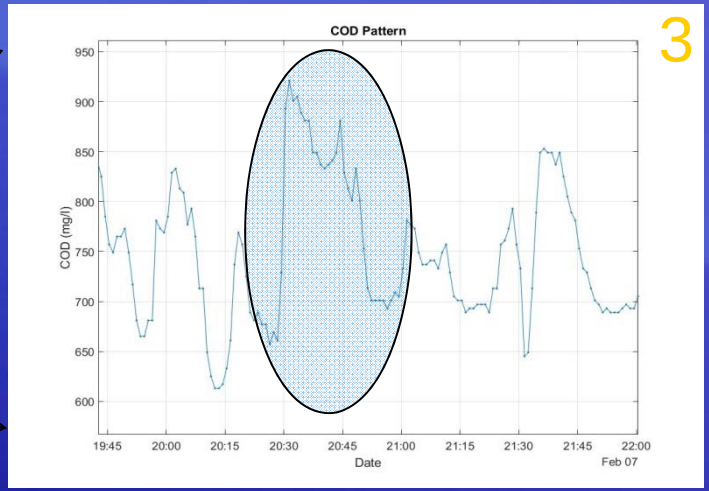


Rain Events: Flush and Dilution Effects

Some results Mid Term

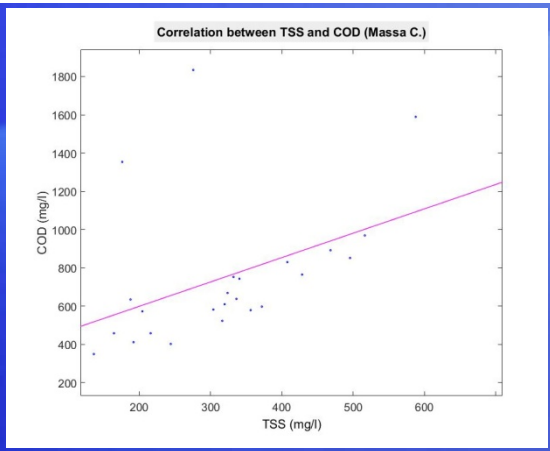




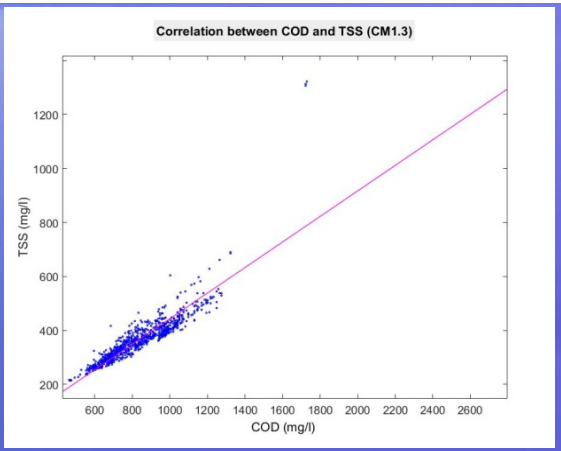


1. Diurnal Pattern Identification (Antropic Origin)
2. Identification of superimposed periodical events (Commercial Activities)
3. Identification of Rapid transients

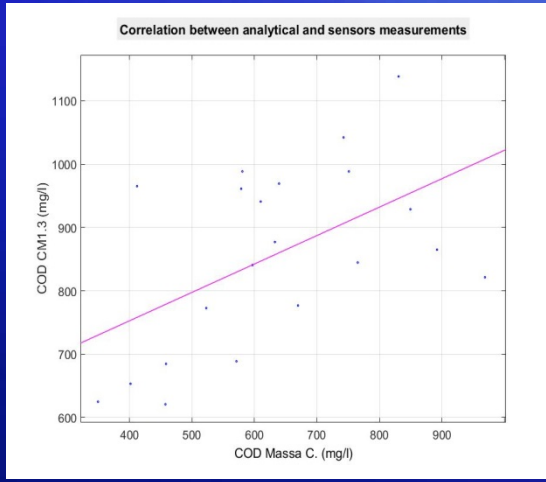
Some Results (February 2016)



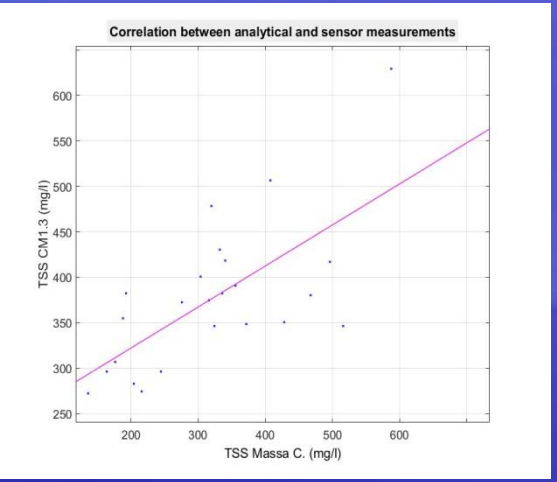
COD/TSS Correlation (Analytical, r=0.7)



COD/TSS Correlation (S::CAN Sensors, r=0.9)

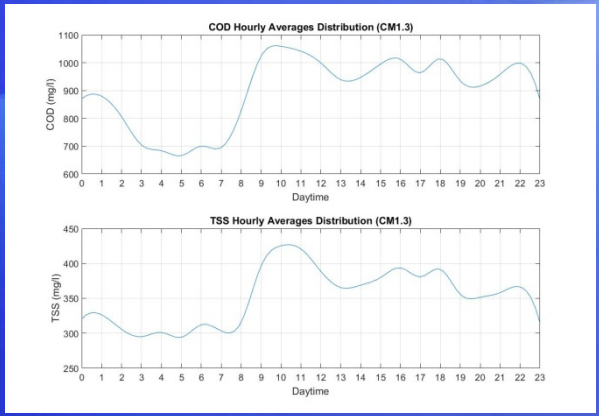


COD Analytical vs S::CAN Sensors r=0.6

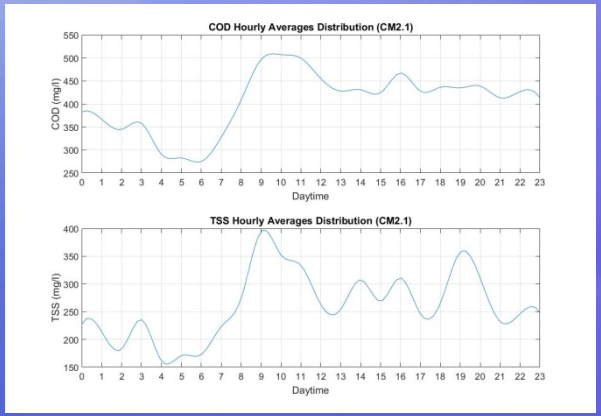


TSS Analytical vs S::CAN Sensors r=0.65

Some Results (February 2016)



Averaged Diurnal Pattern



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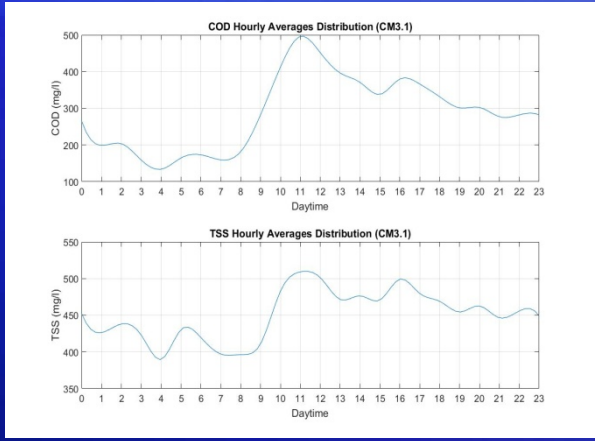
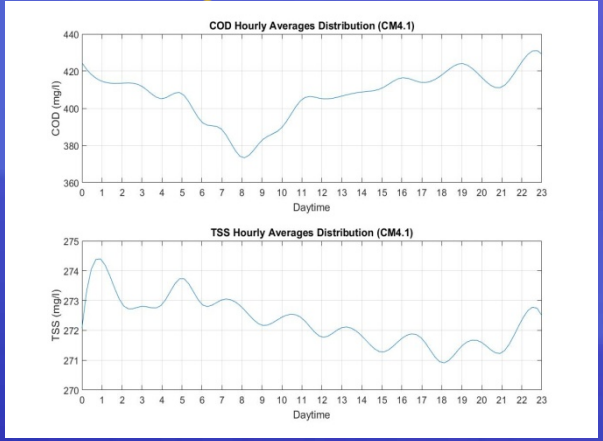


Averaged Diurnal Pattern



Averaged Diurnal Pattern

Diurnal Patterns helps to characterize measurement site and identify high load network segments
Providing feedback on citizen's impact on water quality patterns could improve their environmental awareness eventually leading to behavioural changes!

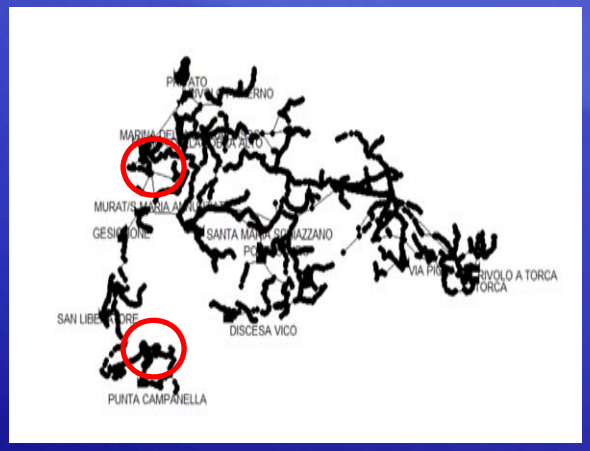
The Stress Test

On February 2° 2016, a stress test has been planned allowing the evaluation of the operating network.
300+300 liters of Nutrient™ have been injected in the network at two different sites:

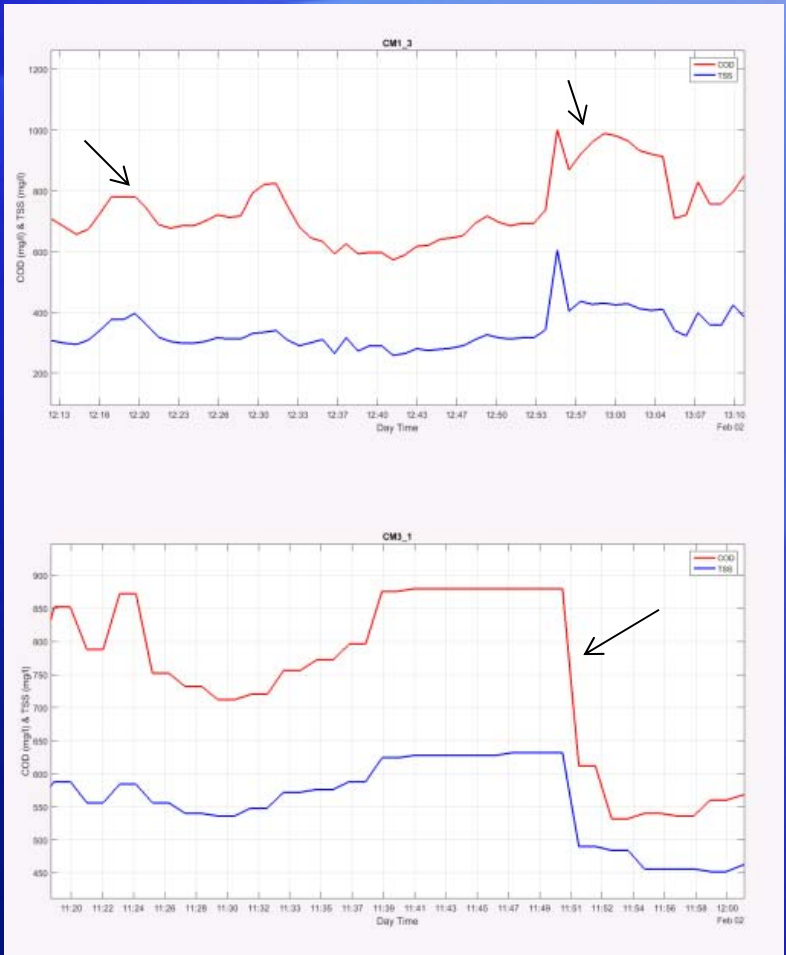
- Punta Campanella (22x25l in 5mins)
- Patierno (12x25l in 3 mins)

with 40 mins interval.

Nutrient discharge was expected to increase both the COD and the TSS value.

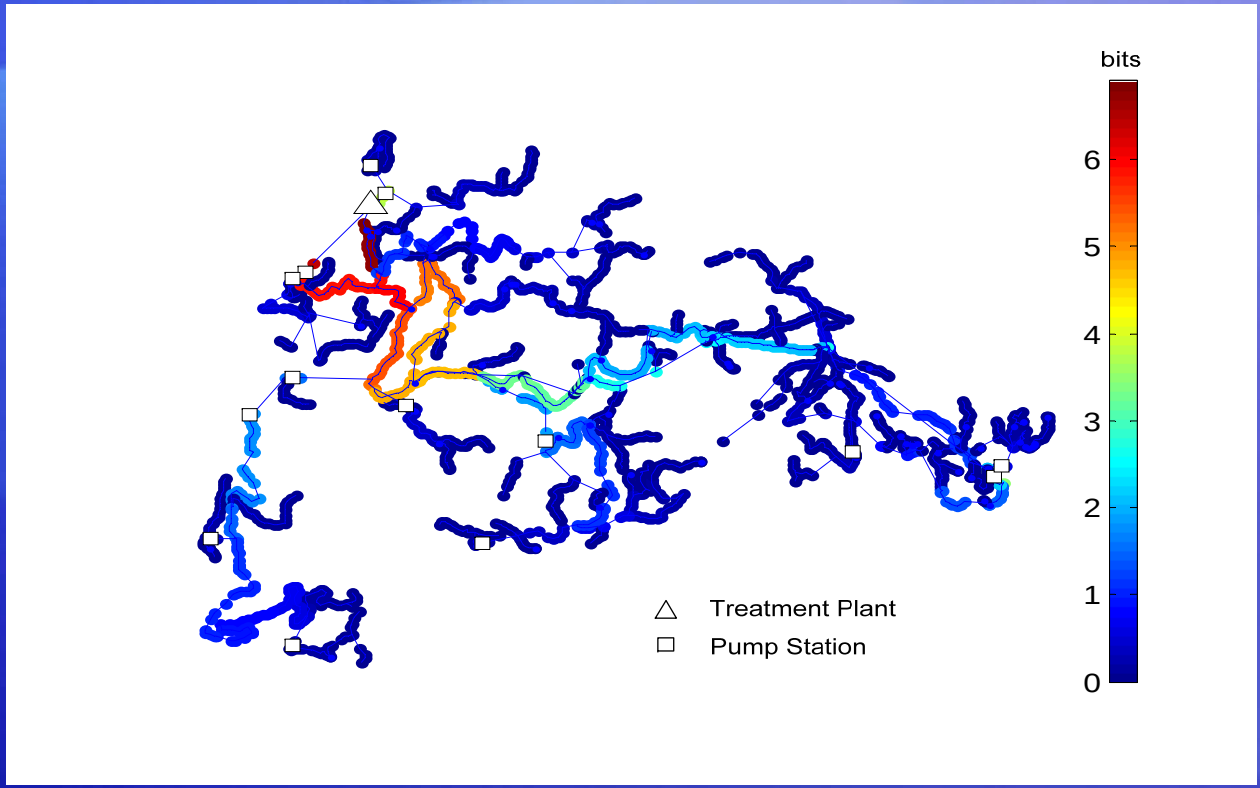


Some Results (Stress test)



Deployed sensors have recorded and transmitted the simulated event propagation throughout the waste water network. It can be observed that the first detection of contaminant was read at 12:17 and second at 13:00 by CM1.3, the plumes transition was dected at 11:39 at CM3.1.

SWMM Model Attuning



Sensor Measurements have hence been used to tune the free parameters of the SWMM model.
The model is now capable to be fed by sensor data in order to obtain Clear and network wide assessments f water quality.

Conclusions

- A novel approach to WWMP protection, based on pervasive SCPS paradigm have been developed and implemented.
- Diffusion and source appraisal models have been integrated with sensor measurements for enhanced forecasting accuracy and illicit discharge localization.
- A pilot test study have been conducted on the high sensitive Massa Lubrense sewage network during several months.
- Some interesting and unforeseen information arised from the analysis of high space/time density data revealing the power of the proposed approach
- This information could be used for rising citizen and company awareness about their environmental impact.
- Integration of citizen based measurements (pics) is currently ongoing.

THANKS FOR YOUR ATTENTION

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