W-SMART 2017 International Workshop

SUNRISE: Large Scale demonstrator of Smart Water

Early Detection of Leaks & Bio-Contaminations in Water Distribution Systems

Lille University Campus

Professor Isam Shahrour & Professor Ilan Juran & Silvia Tinelli

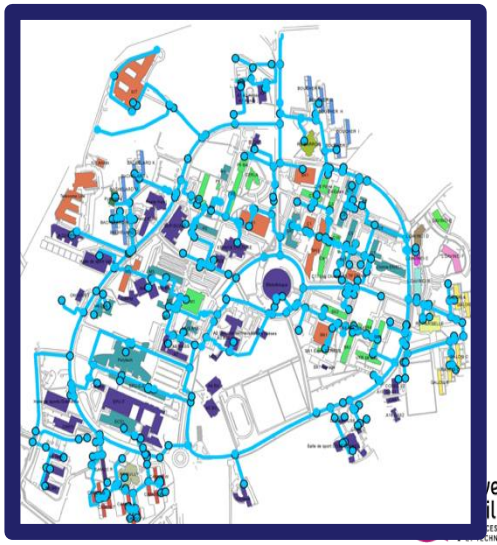
W-SMART 2017 International Workshop,
November 3°-4°, 2017
Amsterdam

SCIENTIFIC CAMPUS, LILLE

- 110 hectares
- 25 000 users
- 140 Buildings

WATER NETWORK

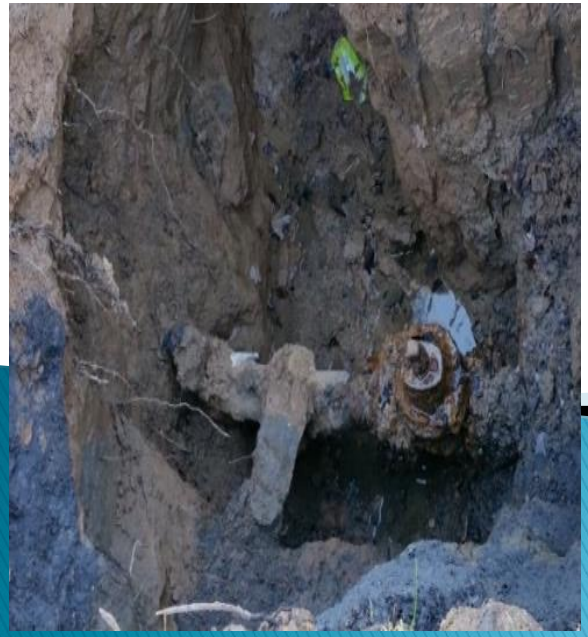
- 15 km, highly meshed
- usages : research, teaching, residence, restaurant, green space,...
- Yearly Consumption : 250 000 m3
- 50 - years old

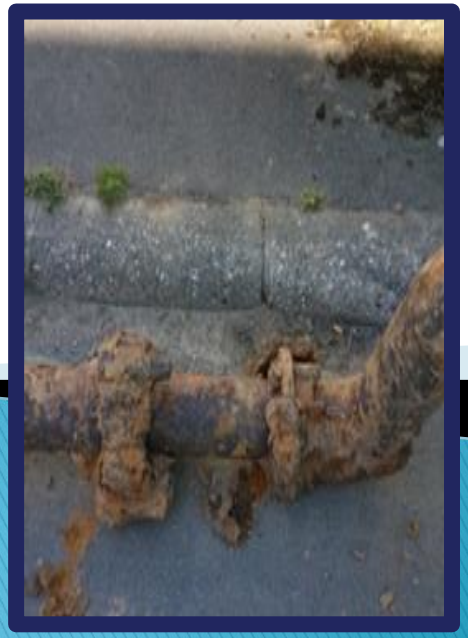


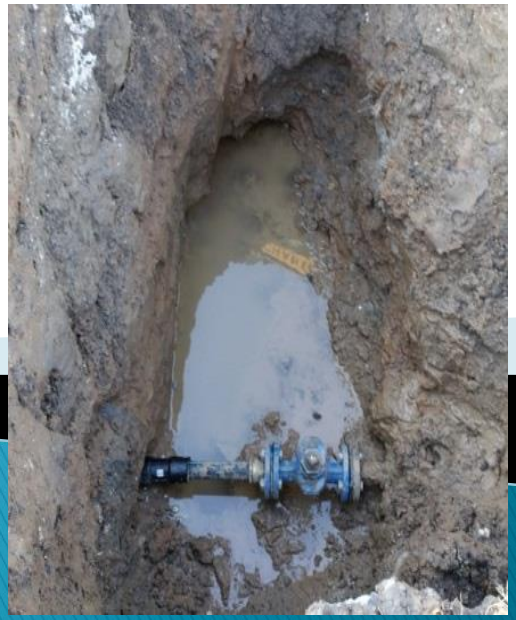
Campus challenges

Old water network (60 years old) with severe leakage and some concern about water quality

Development of an academic activity in the field smart cities based on living-Lab (PhD and master degree programs)







AI Applications

- **Leak Detection and Geo-localization**

DMA Monitoring → AI → Multi-parameter/multi-spots Analysis

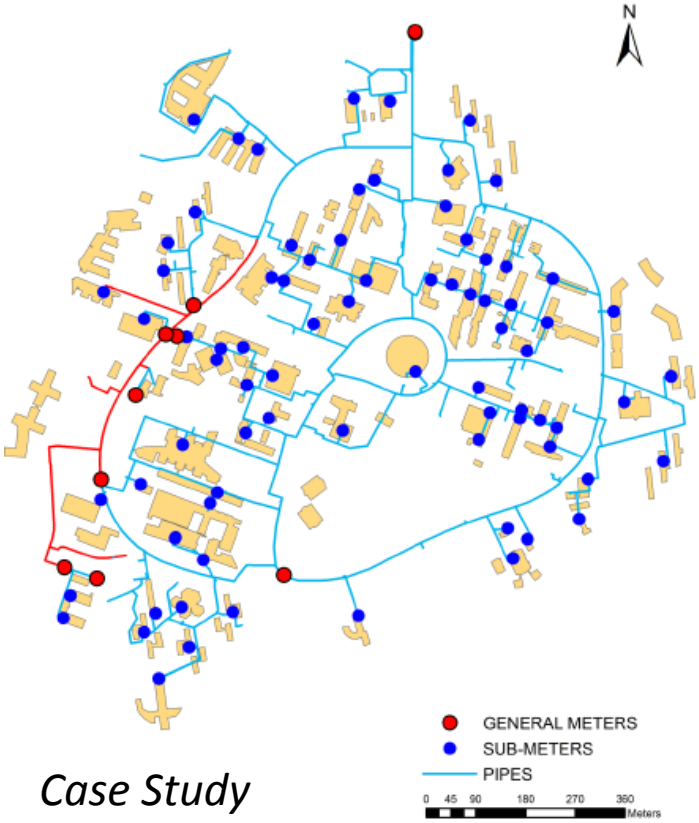
- **Bio-Contamination**

Sensors Data → AI → Signature-based bio recognition

- **Lack of bio-contamination data**

Numerical Analysis
- Epanet
- Epanet - MSX

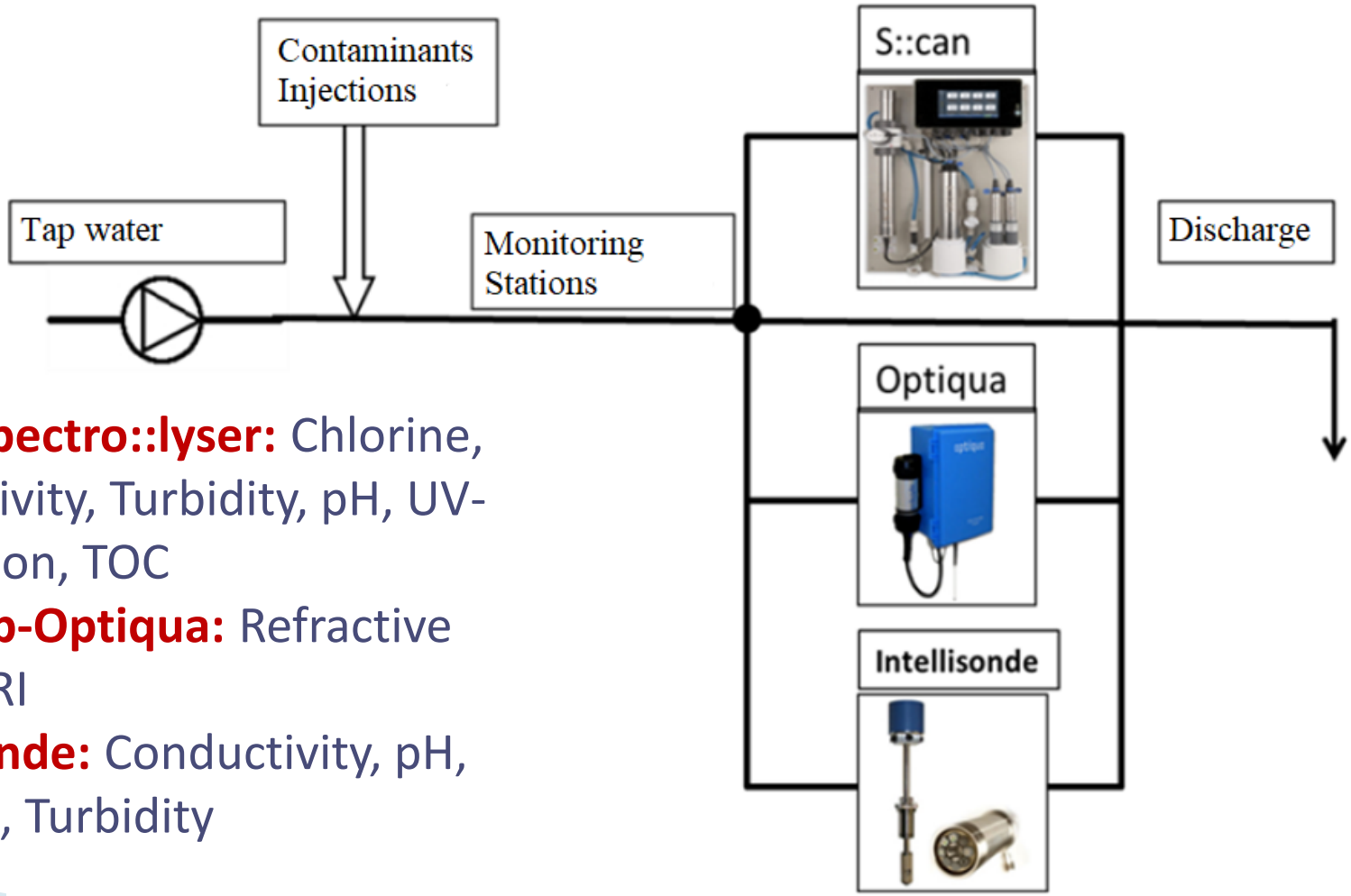
→ Database: Water quality parameters (Chlorine, TOC etc.)



Case Study

Monitoring Stations

[*Lille Demo-Site*]



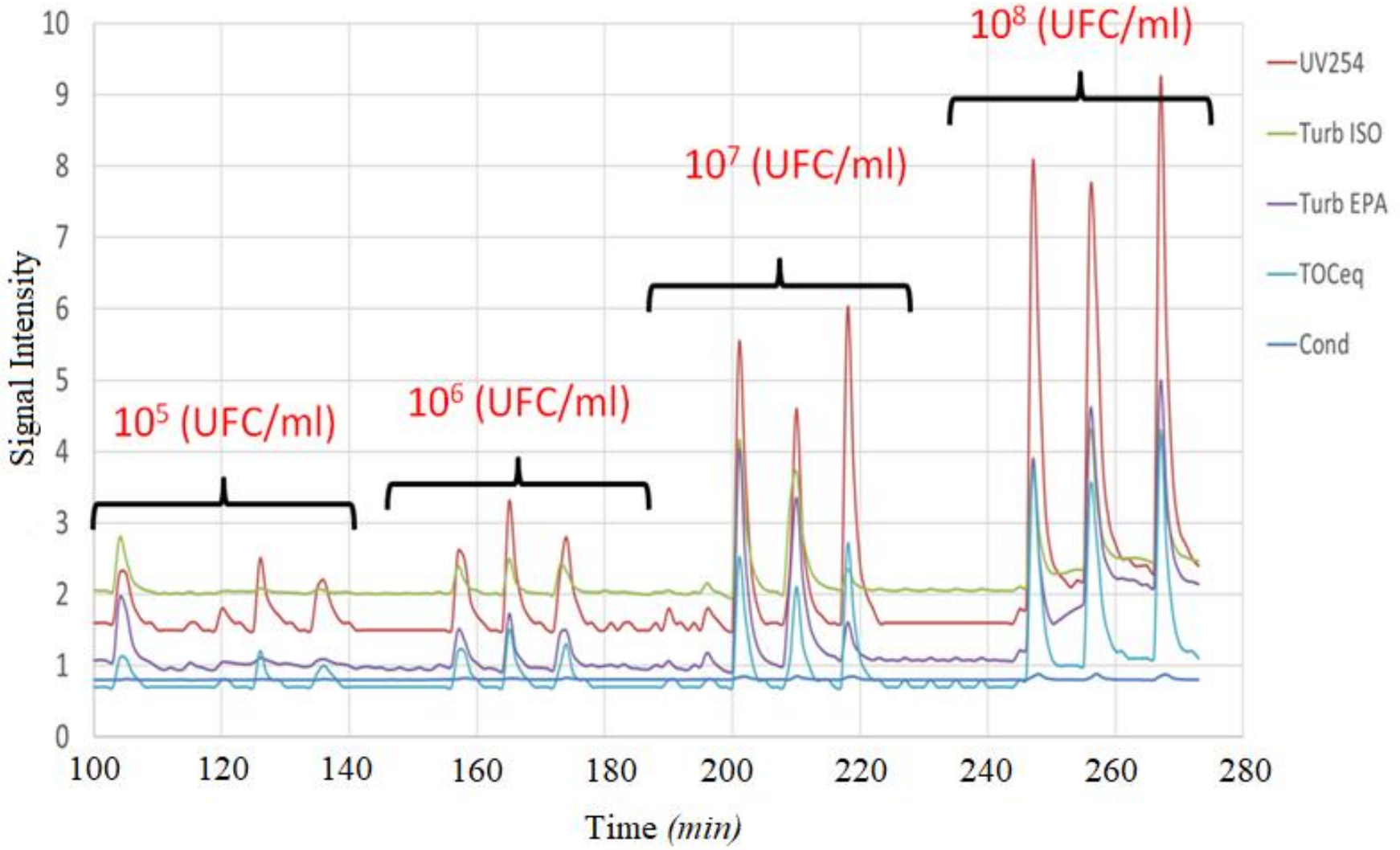
S::can-spectro::lyser: Chlorine, Conductivity, Turbidity, pH, UV-Absorption, TOC

EventLab-Optiqua: Refractive Index – RI

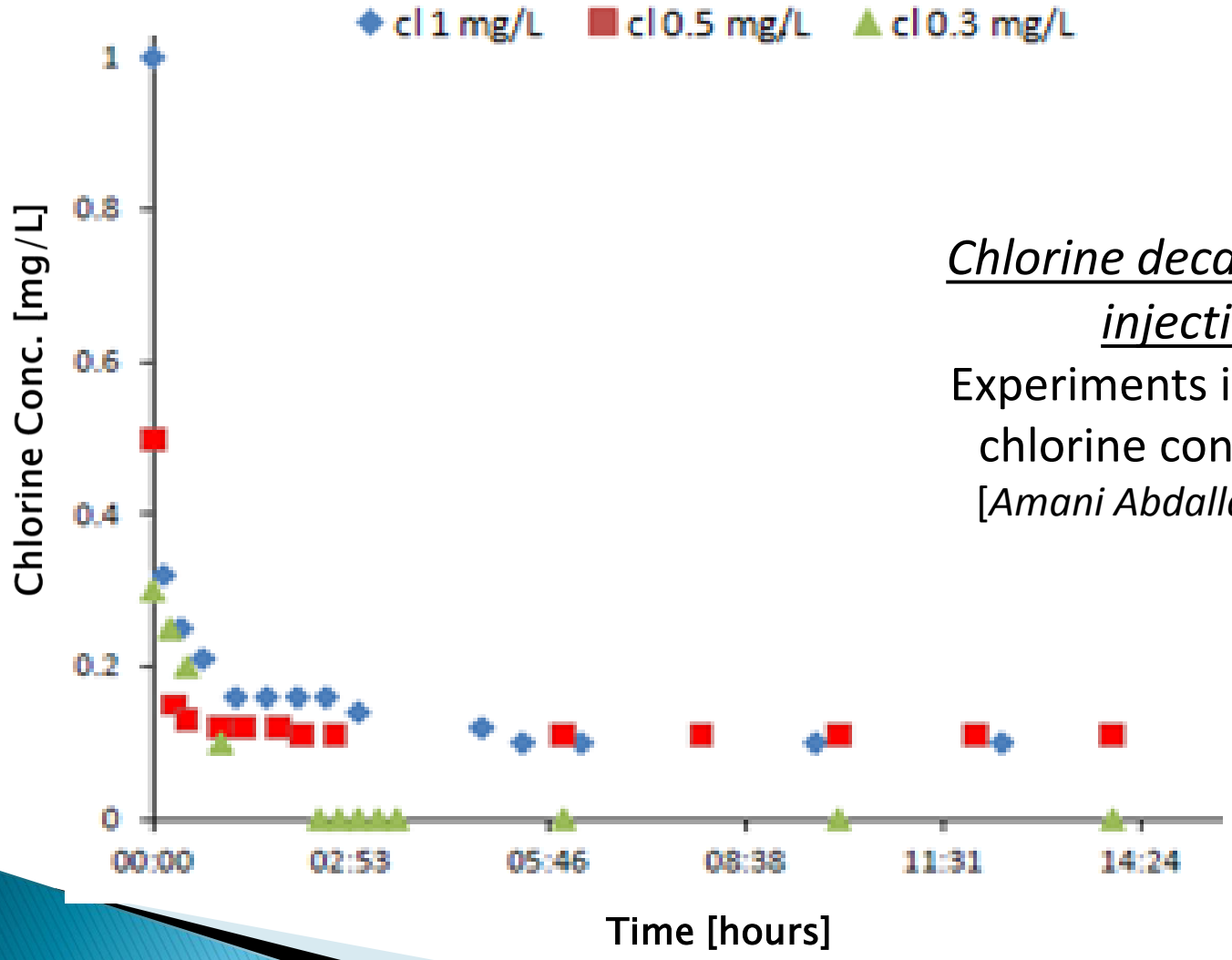
Intellisonde: Conductivity, pH, Chlorine, Turbidity

S::can SENSITIVITY *with different* ***E. coli injections***

[*Amani Abdallah, PhD Thesis, 2015*]



Bio-Anomaly Detection



Chlorine decay with a 10^5 CFU/L injection of E.coli:

Experiments in the lab of Lille for chlorine conc. along with time

[*Amani Abdallah, PhD Thesis, 2015*]

Numerical Analysis Models

EPANET

- Hydraulic Testing
- Quality Analysis

→ Contaminants transportation with conservative assumption

EPANET-MSX

- Multi-species Analysis

→
- Non-conservative assumption;
- Modeling chemical/bio-contamination effects on water quality parameters

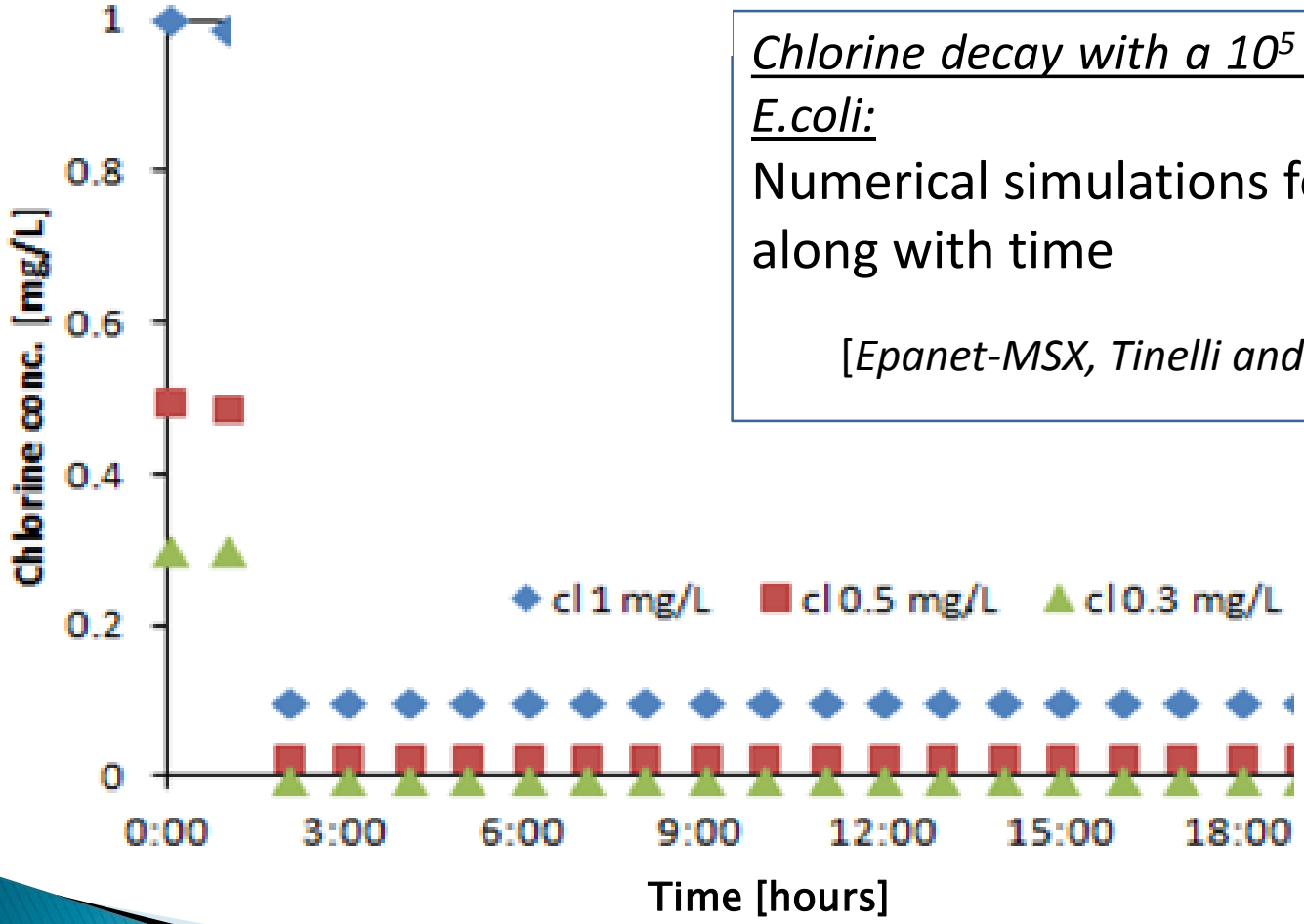
OUTPUT

- Fate & Transport Models

→ E. coli bacteria in Chlorine presence

Numerical Analysis Results

[*Silvia Tinelli, PhD Thesis, 2017*]

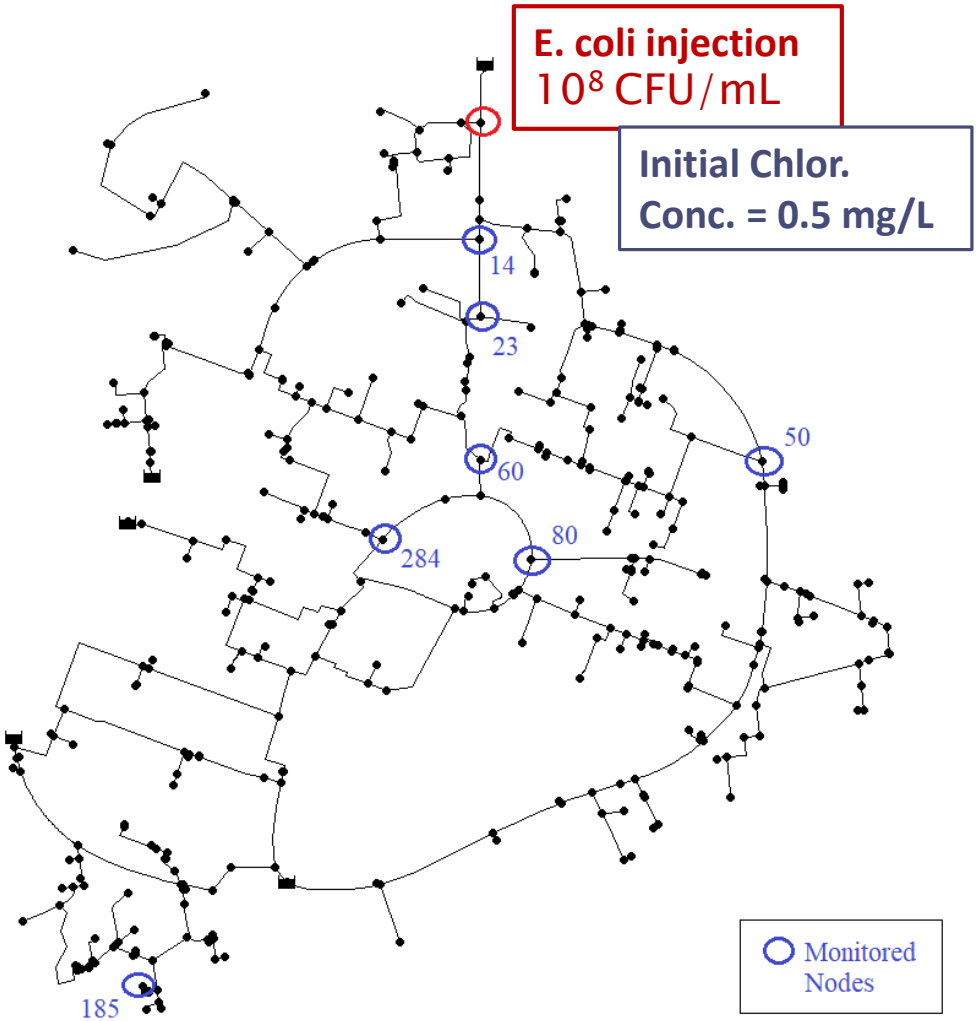


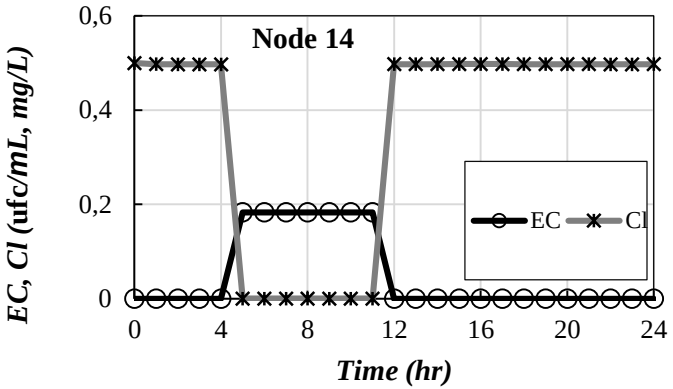
Chlorine decay with a 10^5 CFU/L injection of E.coli:

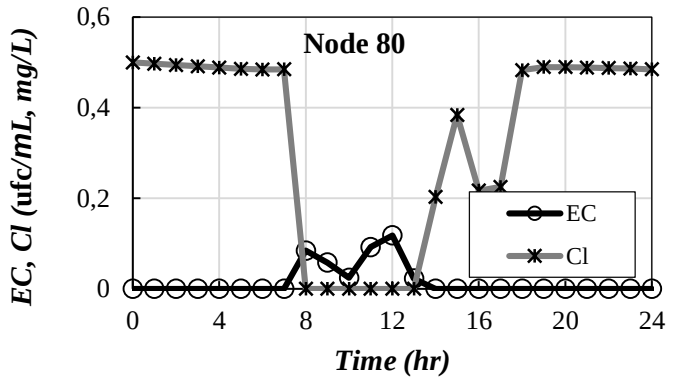
Numerical simulations for chlorine conc. along with time

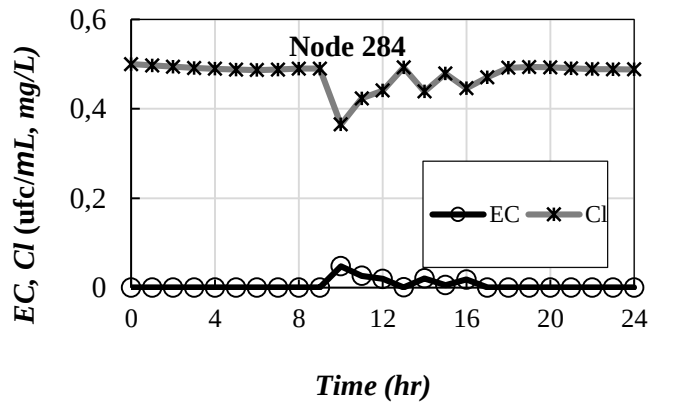
[*Epanet-MSX, Tinelli and Juran, in press*]

E. Coli and Chlorine trends after E. coli injection

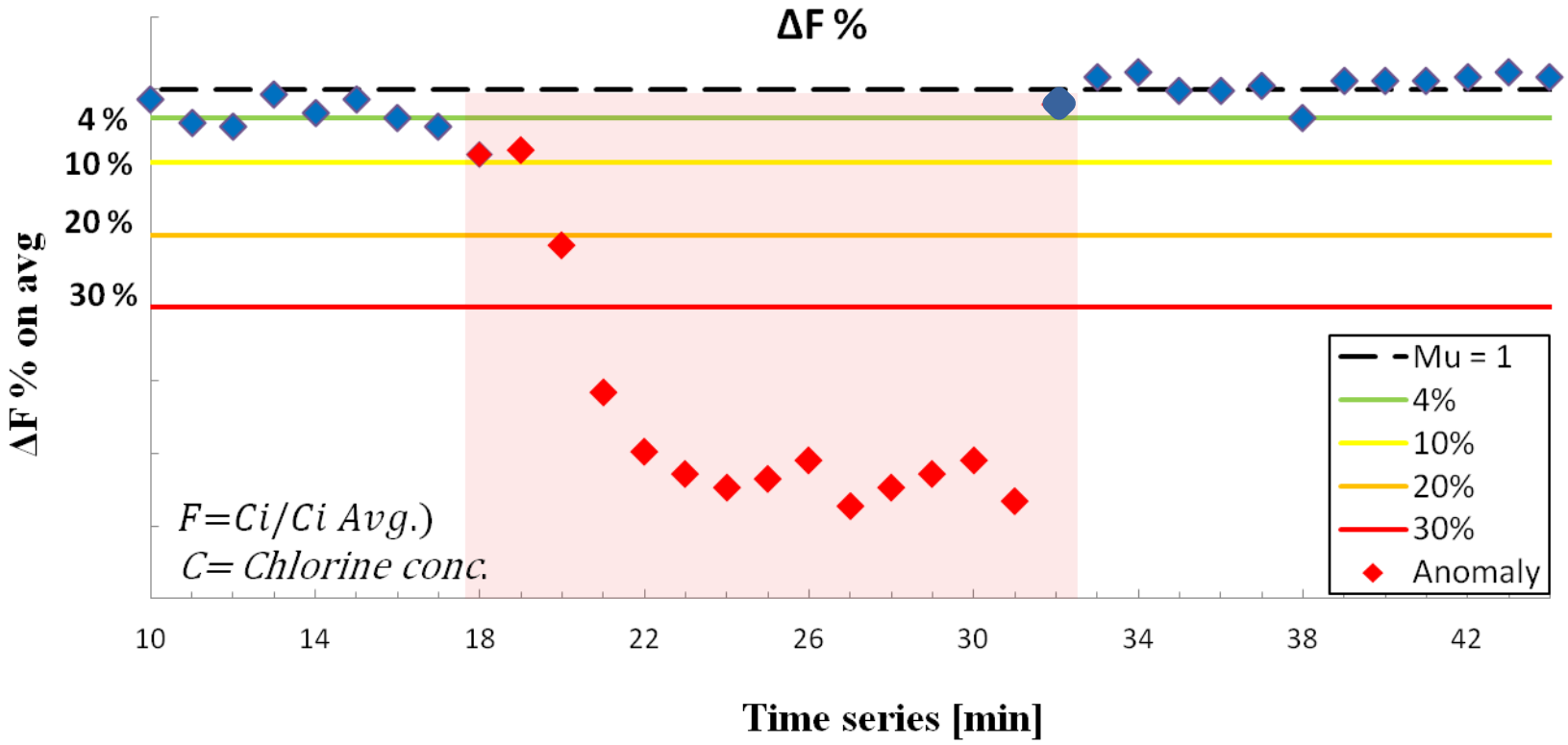






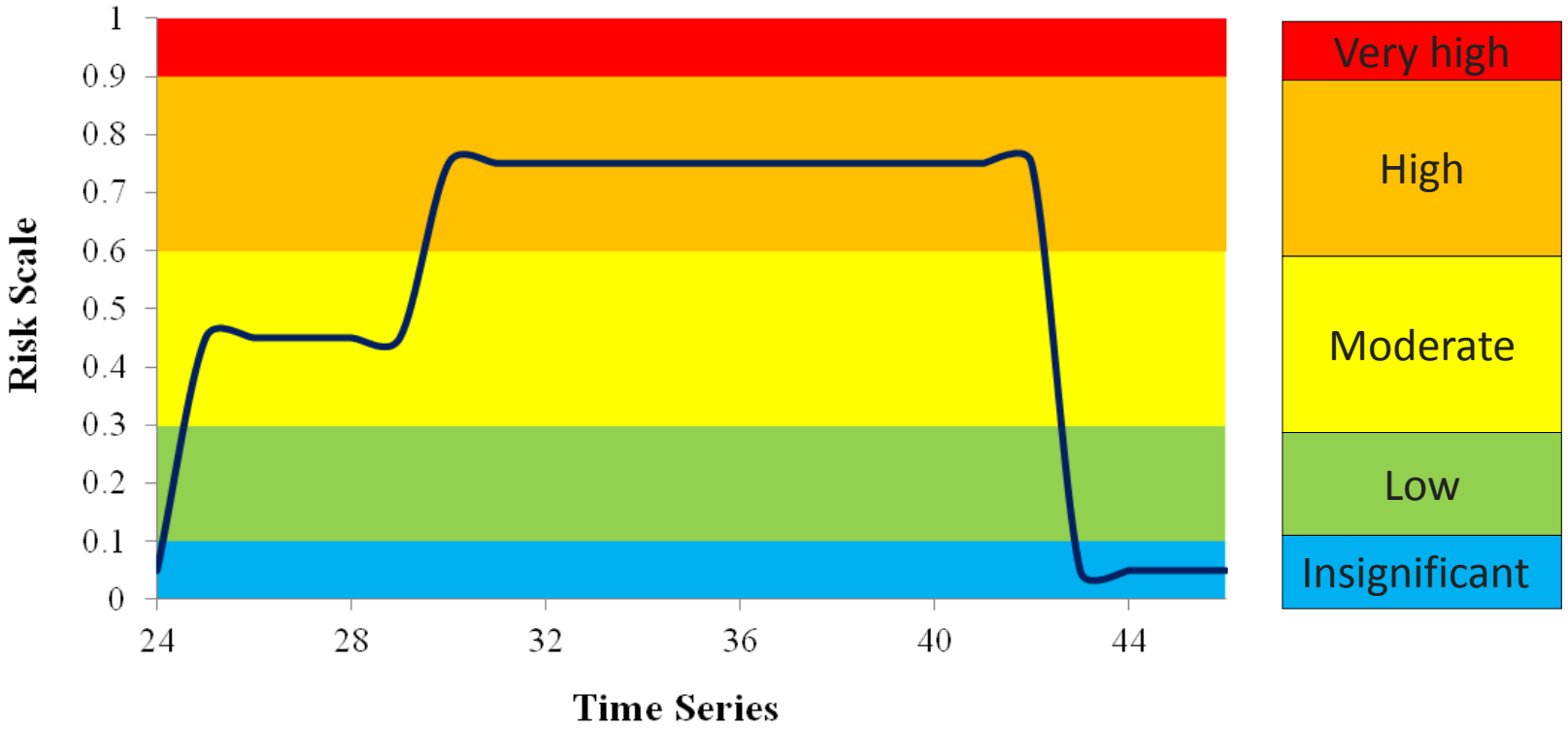


Numerical Bio-anomaly Simulation of Chlorscans Data



Normalization of data to the average (F) with a Contamination Likelihood Assessment

Risk indicator for Chlorscan Data in Lille Demo-Site



Statistical Data Analysis - 1st 2nd and 3rd standard deviations

Operators input - threshold levels based on their experience

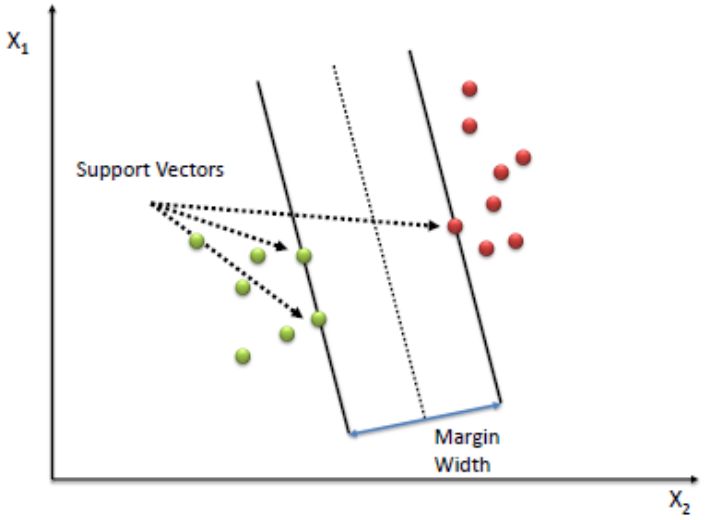
AI-based Algorithm

Tested Pattern recognizers: Supported Vector Machines (SVMs) and Artificial Neural Network (ANN)

SVMs

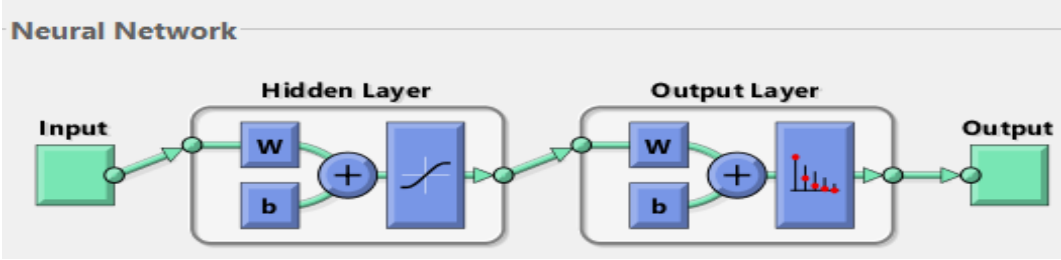
Classification:
(ΔF–ΔT)
- Likelihood
- Severity
- Risk

ANN



SVM ALGORITHMs

The Optimal hyperplane is used for the classification of upcoming data, after being trained from two data categories

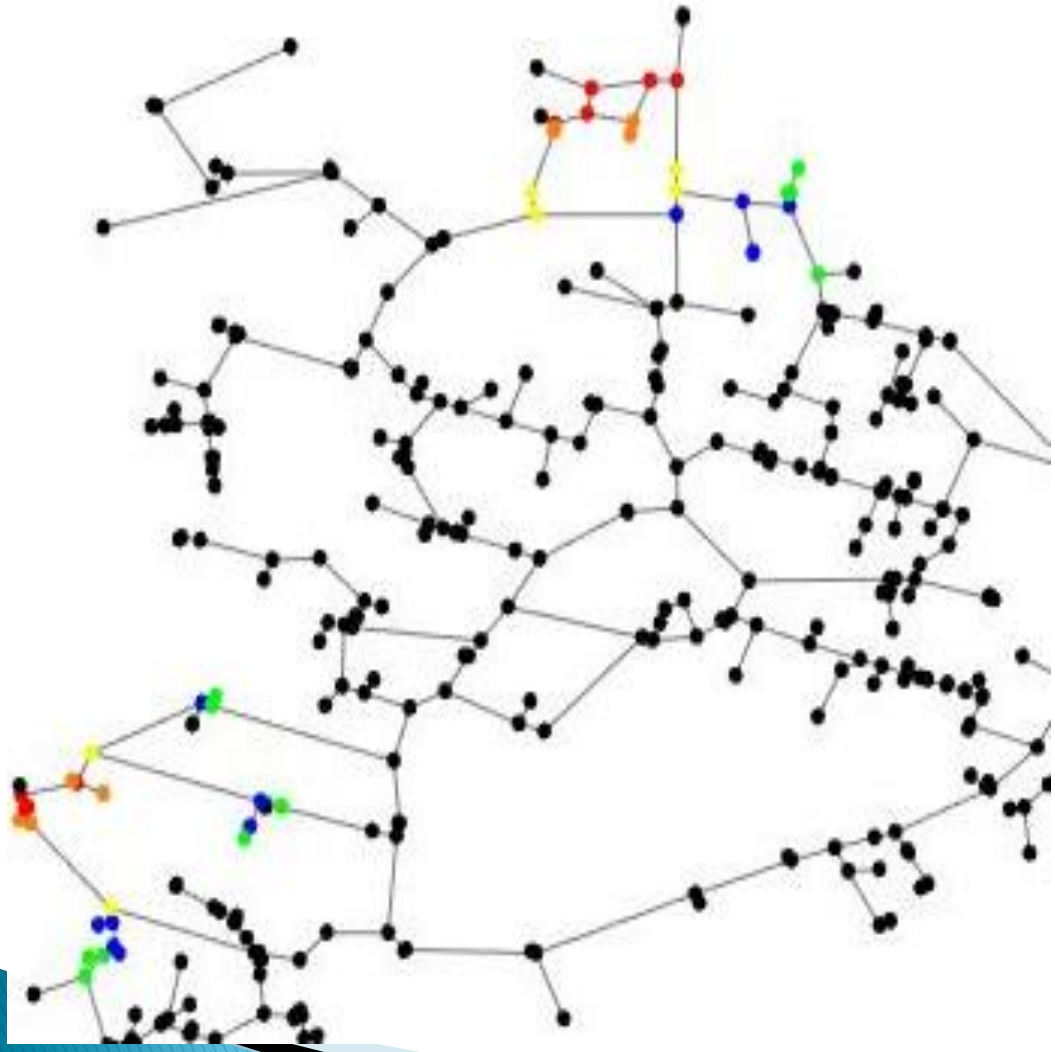


ANN

The Artificial Neural can classify vectors arbitrarily in n-dimensionale space, given enough neurons in its structure

Multi-parameters/Multi-injections Analysis

[SW4EU Research report 2017]

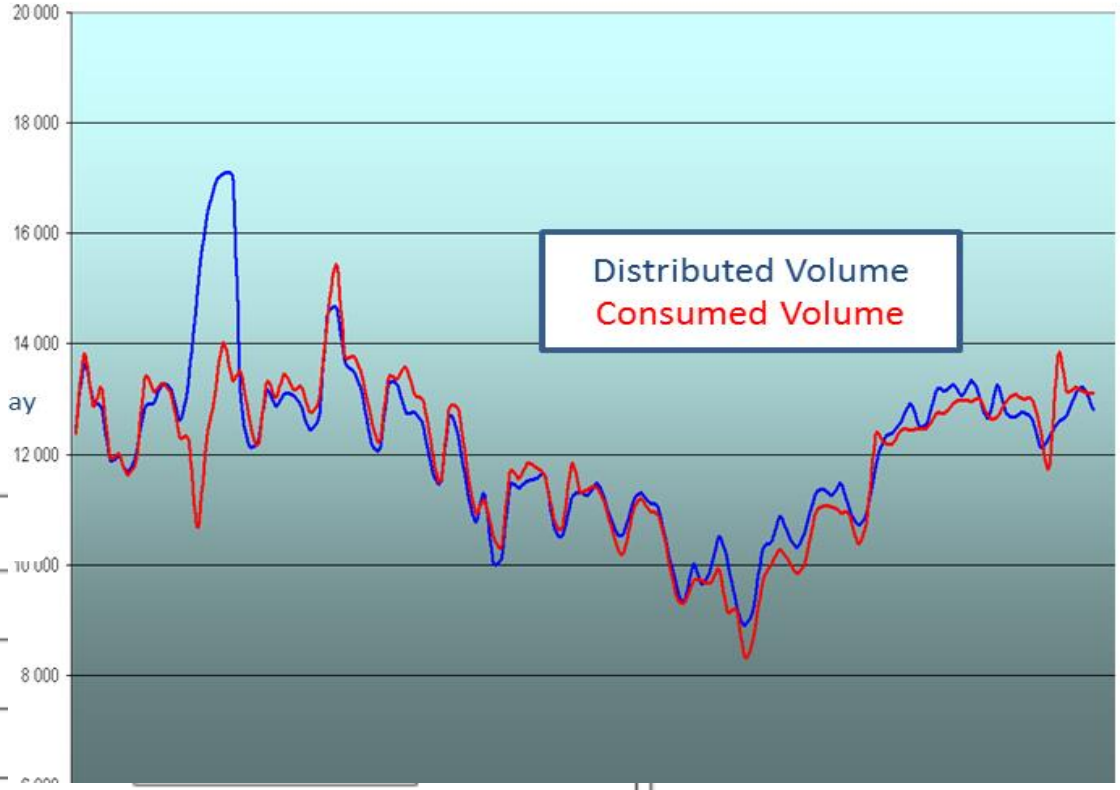


SVM – Classification Loss ≈ 0%
ANN – Classification Error = $5.26*10^{-7}$

Anomalies
1 Insignificant
2 Low
3 Moderate
4 High
5 Very High

Distributed Volume
Consumed Volume

[Montiel, F., Nguyen, B., Juran, I. & Shahrour, I. (2013)]

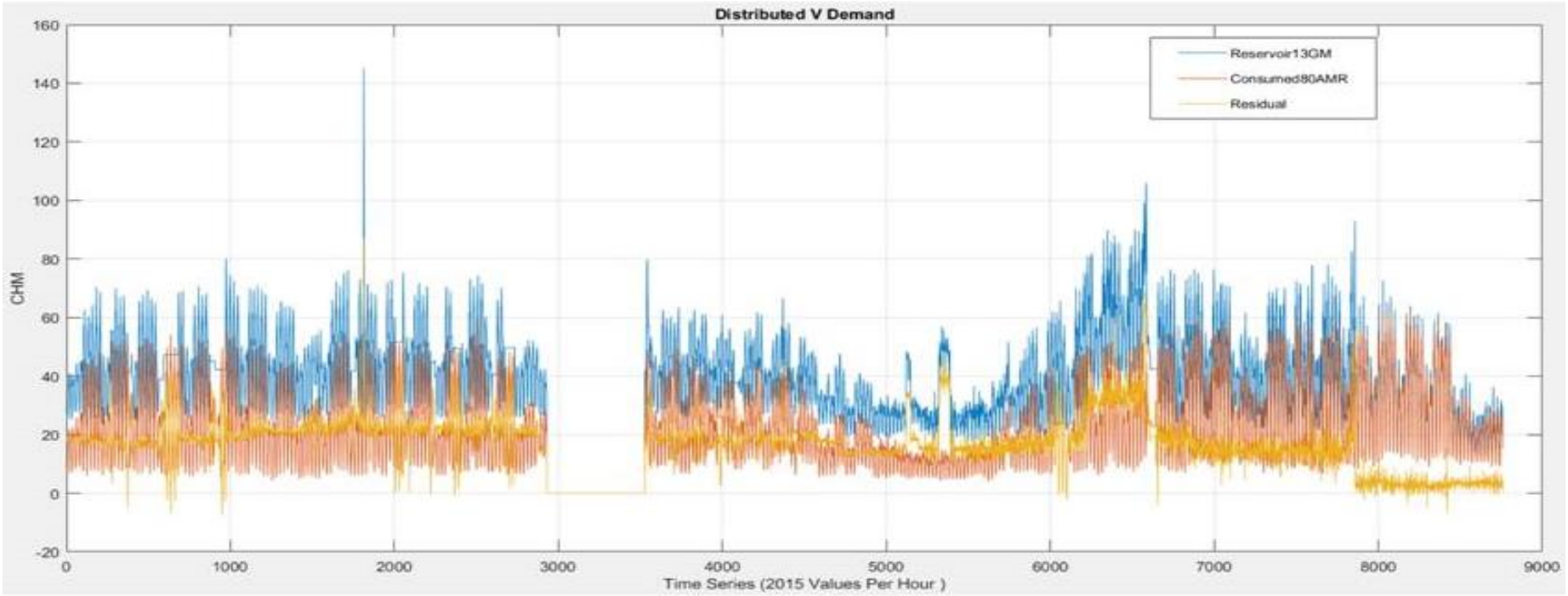


Reference Curve
Real-Time Curve

Data Presentation – Raw Data Lille University

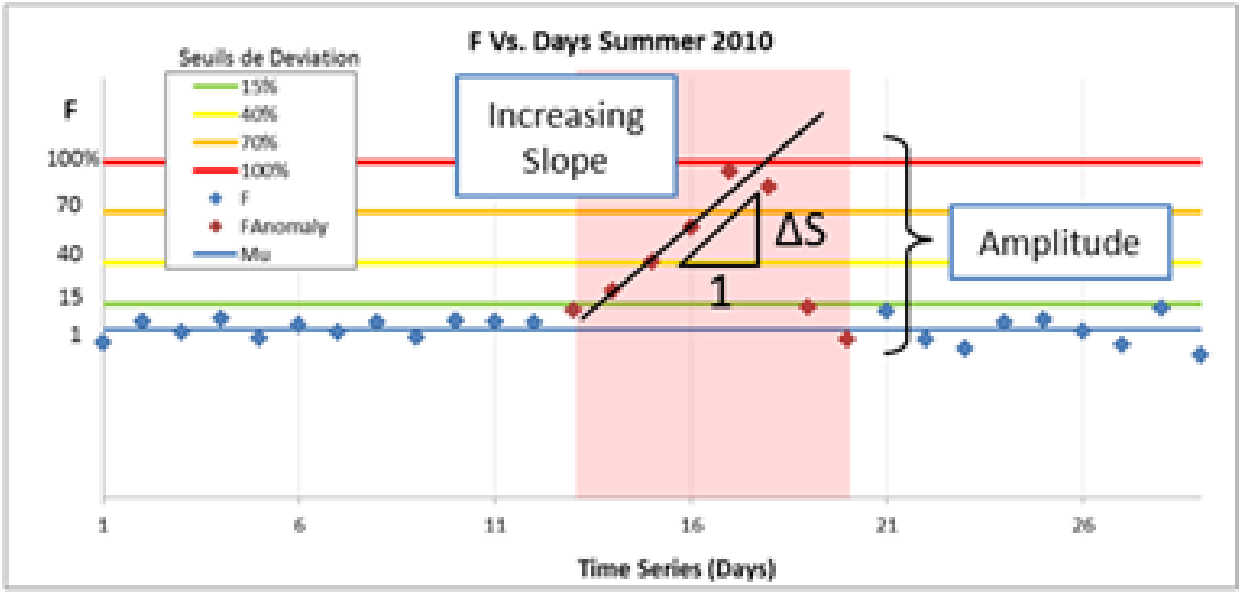
[Farah, E. (2016)]

Distributed (Reservoir 13 GM)
Consumed
Residual



Raw Consumption Data (AMR) – Distributed (13 General Meters – 338,256.1)
V Demand (80 AMRs – 212320 m3.) =
Lille University Consumption (93AMR) in 2015 (EDIT)

Typical MNF Time Series for **DATA ANALYSIS:** *Relevant indicators of potential Leak Detection*

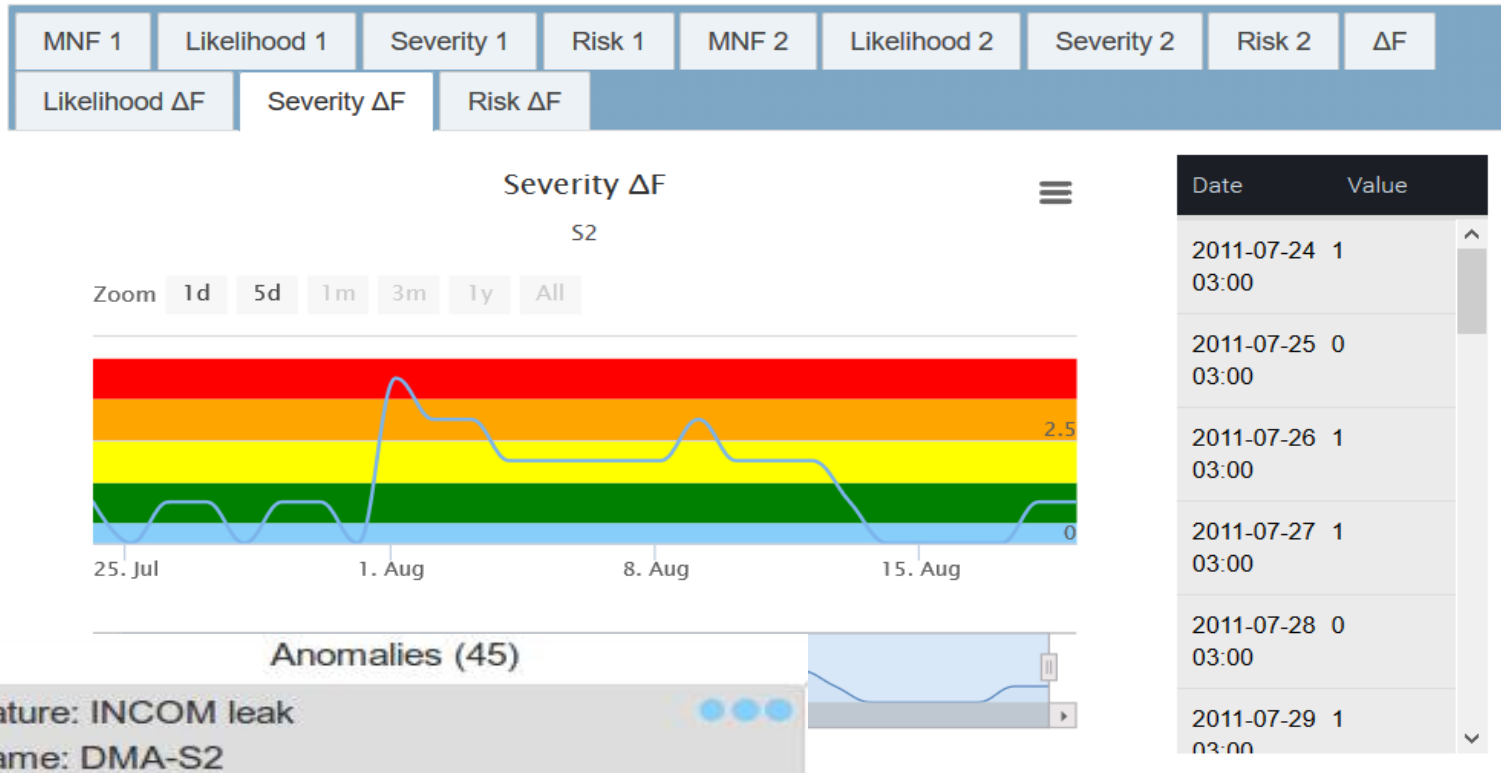


Normalization of MNF data to the average (F) & Deviations from the threshold in a Leak Likelihood Assessment

Risk Assessment Analysis

- **Likelihood matrix**: function of amplitude (ΔF) and elapsed time period (ΔT) of the detected anomaly
- **Risk severity matrix**: function of amplitude increase rate (ΔS) and ΔF
- **Risk matrix**: combination of the likelihood scale and the severity scale

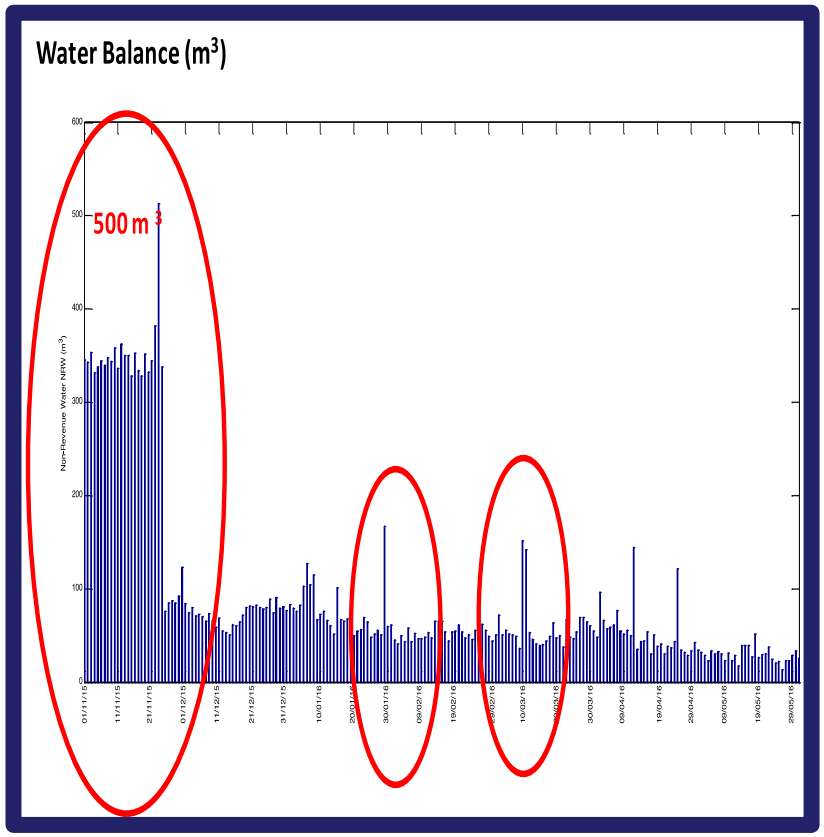
NETLEAK Prototype System – and the support software

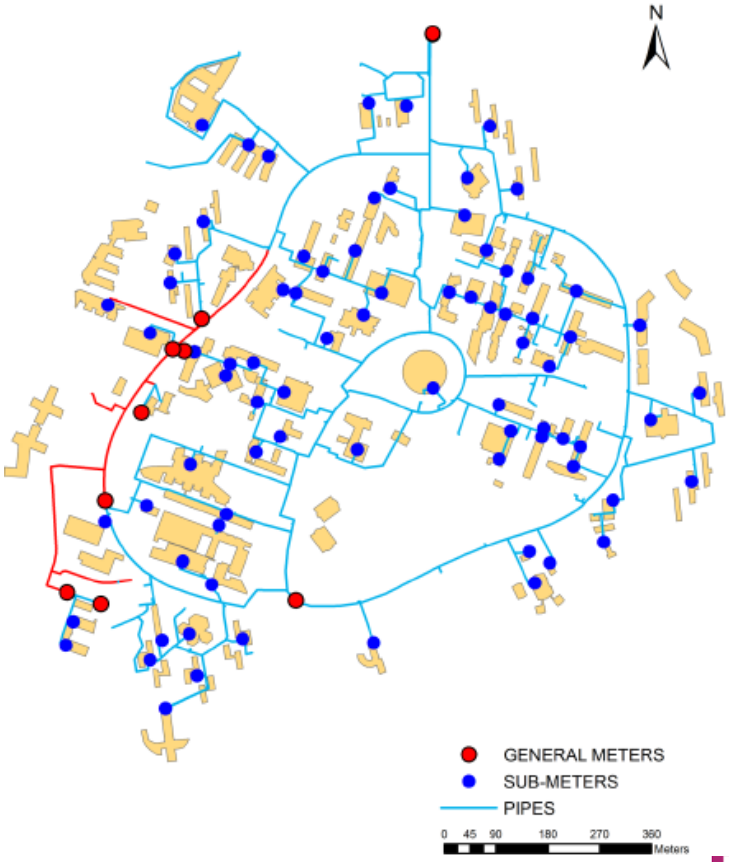


- Likelihood-severity-risk graphs for uploaded datasets;
- Alarm panel with the detected anomalies

SOME RESULTS

DETECTION OF WATER LEAKAGE





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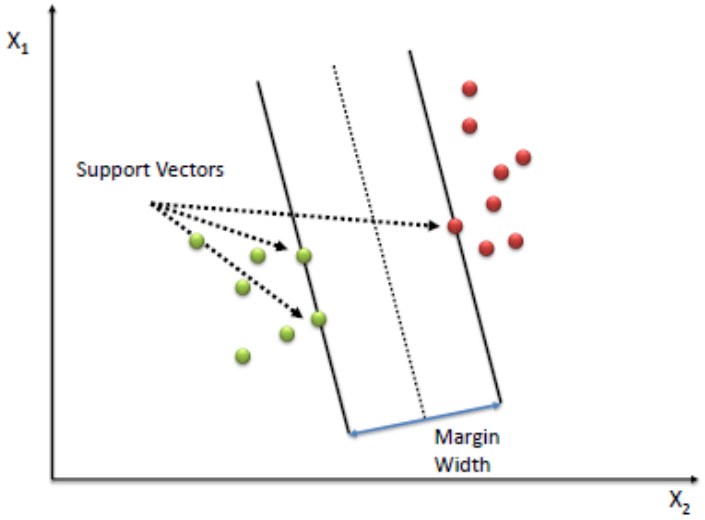

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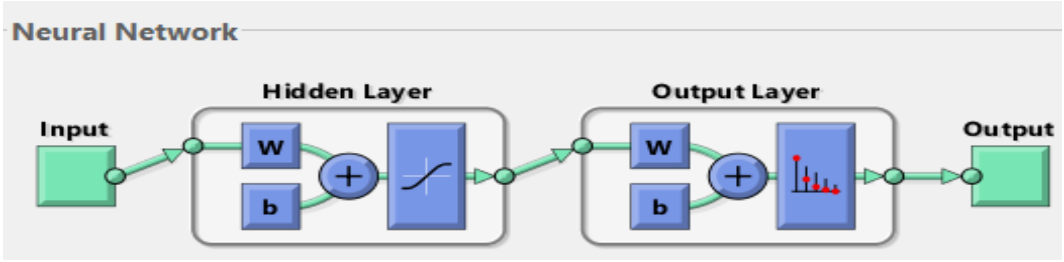


ANN

The Artificial Neural can classify vectors arbitrarily in n-dimensionale space, given enough neurons in its structure

Mono-parameter Analysis

[SW4EU Research report 2017]

Input:
water flow

Training Phase

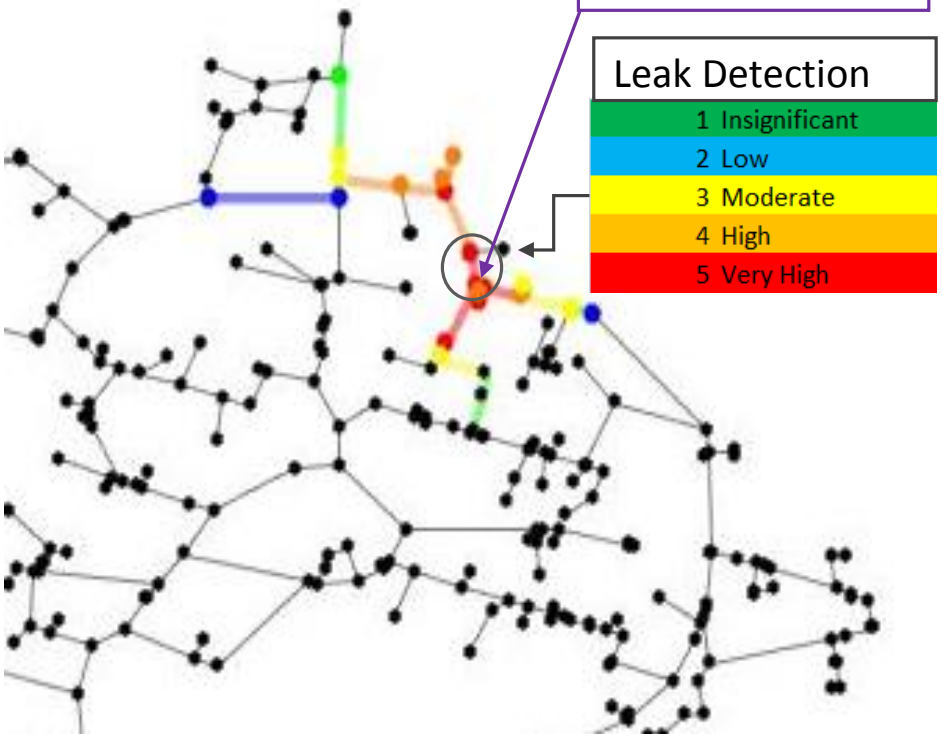
- SVM Matlab Model
- ANN Matlab Tool

Output

Selected pipe for illustration

Anomaly Detection

Leak Visualization on the map



Accuracy Rating

SVM – Classification Loss = 0,0417 (4.2%)
ANN – Classification Error = 0.05 (5%)

Multi-parameter Analysis

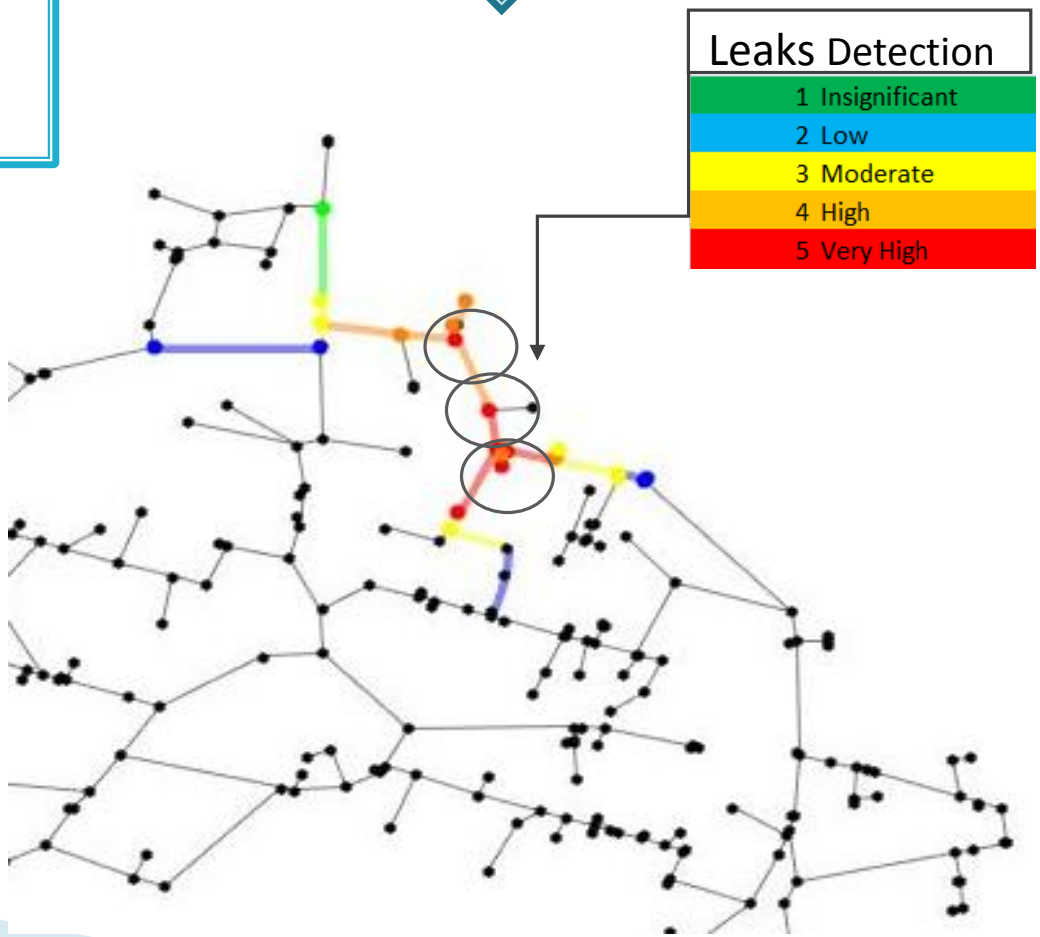
[SW4EU Research report 2017]

Multi-parameter Input:

- *Node:* Demand - Pressure
- *Pipe:* Flow – Velocity – Head Loss

Output

SVM – Classification Loss ≈ 0%
ANN – Classification Error = $5.26*10^{-7}$



Conclusions

I. Epanet-MSX is an essential support for bio-contamination scenario simulations

II. Model validation through comparison with laboratory model test results

III. Results demo-illustrate the Role of chlorine in the fate and transportation of the organic matter (E. coli)

IV. Color-based risk assessment statistical data analysis model for early bio-contamination and leak detection

V. Demo-illustration of the Prototype Systems for early warning systems with likelihood & risk indicators

VI. Feasibility demo-illustration of AI-based models with mono/multi-parameters pattern recognition features for reliable bio-contamination & leak detection filtering false alarms

VII. Multi-parameters analysis improves leak detection geo-localization reliability

AKNOWLEDGEMENTS

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Thank you!