Pollution Transformation within the Sewer Network, Case Study of Milan Network

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DHI

Introduction

- Nowadays role of sewer systems as chemical and biological reactors are well accepted.

- The chemical and biological processes of sewers depend mainly on the ‘reduction and oxidation of substances’ (Hvitved-Jacobsen et al. 2013), or the redox potential.

- The characteristics of the network assign whether aerobic, anaerobic or anoxic condition may happen

- The hydrodynamic and quality models of the network should be integrated to model the transformation of domestic organic matters.

Case Study

- ❑ Milan sewer system total pipeline length: 1446 km
- ❑ wastewater flows into the sewer network: 280 million m^3 $year^{-1}$
- ❑ Sewer network type is combined and a gravity system.
- ❑ Three WWTP : Milano San Rocco, Milano Nosedo, and Peschiera Borromeo.
- ❑ The wastewater treatment service of Milan can serve up to 2,550,000 population equivalent.
- ❑ 320 different types of pipe cross-sections: circular, oval or polycentric cross-sections.

Hydraulic Model

- The raw data of the network i.e. geometry characteristics and network elements such as manholes diameters, pipes diameters and length and materials, weirs crest level, valves etc. was provided by Metropolitana Milanese.
- The hydrodynamic module provided in MOUSE model network by DHI used to integrate these properties with GIS based coordinate system.
- MOUSE is a powerful engine for modeling complex hydrology, advanced hydraulics and bio-chemical processes in sewer systems

Modeling procedure in MOUSE (MOUSE TRAP user manual)

Hydraulic Model

- The sewer network of the city divided to three main catchments regarding the treatment plants they discharge to

- The west catchment divided to 355 subcatchments in order to track the flow more precisely

- Daily wastewater production= 270 ($L.p^{-1}d^{-1}$) Dry Weather Flow (DWF) condition, PE=912,472

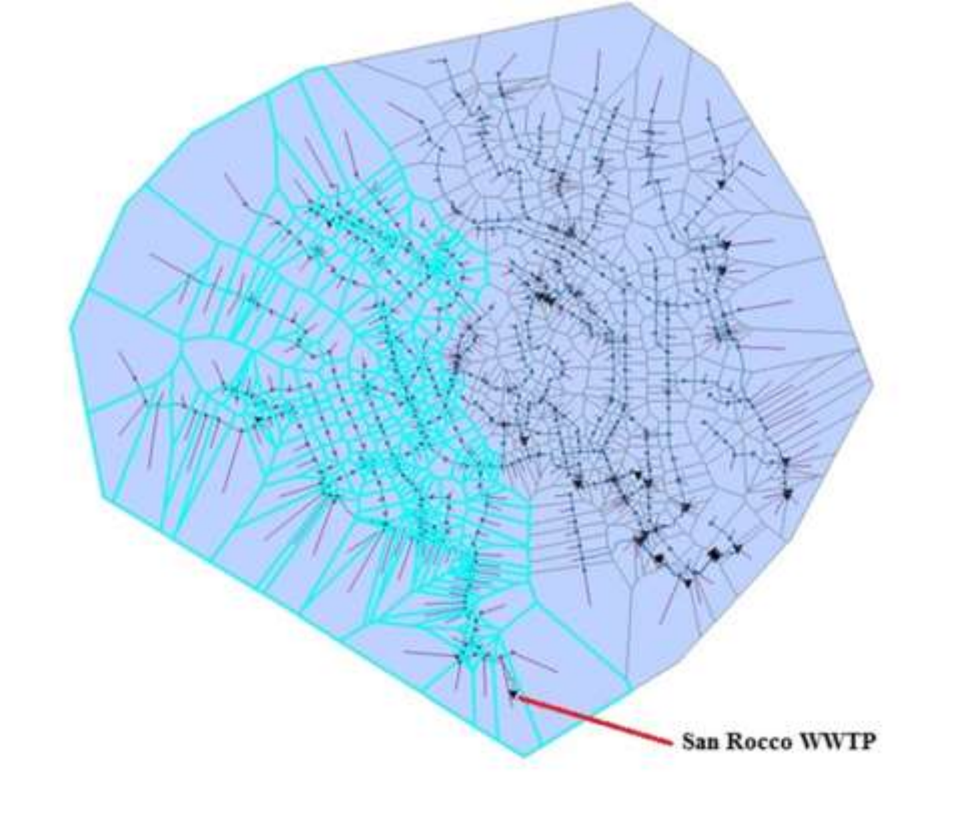
- The flow in a gravity sewer network, described by continuity and momentum equations.

- $$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0$$

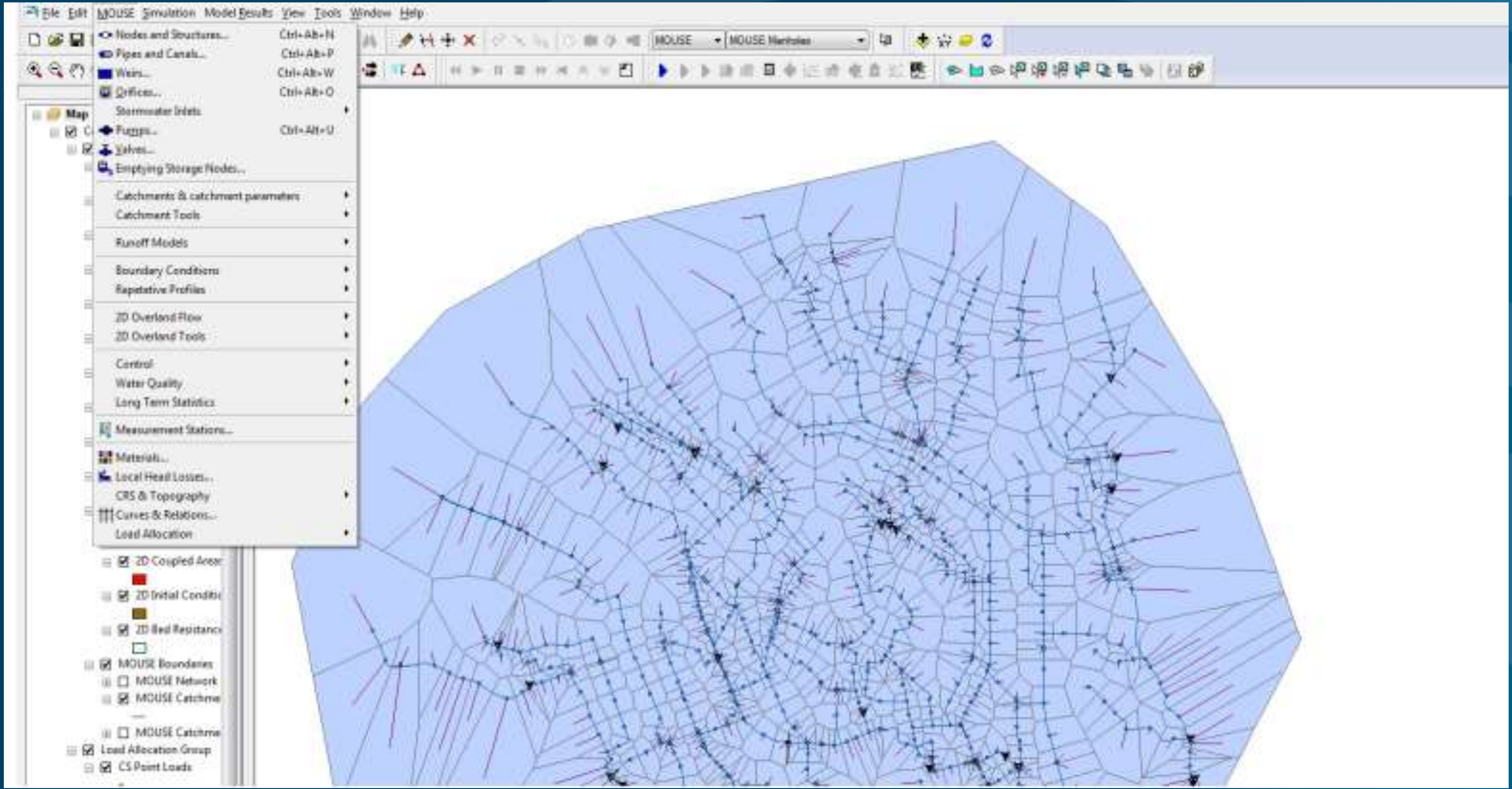
  $$\frac{\partial Q}{\partial t} + \frac{\partial\left(\alpha \frac{Q^2}{A}\right)}{\partial x} + gA\frac{\partial y}{\partial x} + g\,AI_f = gAI_0$$

- Q discharge (m^3s^{-1}) , x distance (m), y flow depth coordinate (m), t time (s), A the flow area (m^2), g the gravitational acceleration ($m\ s^{-2}$), I_f the friction slope, α velocity distribution coefficient and I_0 is the bottom slope

Milan sewer network



Model Setup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Nodes and Structures... Ctrl+Alt+N
Pipes and Canals... Ctrl+Alt+P
Weirs... Ctrl+Alt+W
Orifices... Ctrl+Alt+O
Stormwater Inlets
Pumps... Ctrl+Alt+U
Valves...
Emptying Storage Nodes...
Catchments & catchment parameters
Catchment Tools
Runoff Models
Boundary Conditions
Repetative Profiles
2D Overland Flow
2D Overland Tools
Control
Water Quality
Long Term Statistics
Measurement Stations...
Materials...
Local Head Losses...
CRS & Topography
Curves & Relations...
Load Allocation
MOUSE
Map
MOUSE Boundaries
MOUSE Network
Load Allocation Group
CS Point Loads

Applying Boundary Conditions

Profile calender	Diurnal patterns	Cyclic profiles	Catchment load	Network load
Applied days for domestic and industrial WW production	Domestic graph	Connecting calendar and diurnal patterns	Domestic WW production (All west basin catchments)	Apply catchment loads
	Industrial graph		Industrial Waste profile (16 catchments)	
			Pollutant (Defined in AD module and specified to catchmwnts)	

Advection-Dispersion equation

- Advection, transporting by flow of water, and Dispersion, caused by velocity variation and turbulent conditions, determines dissolved substances and wash load transport in sewers

- 1. The substance is completely mixed over the water column i.e. source/sink term is considered to mix instantaneously.

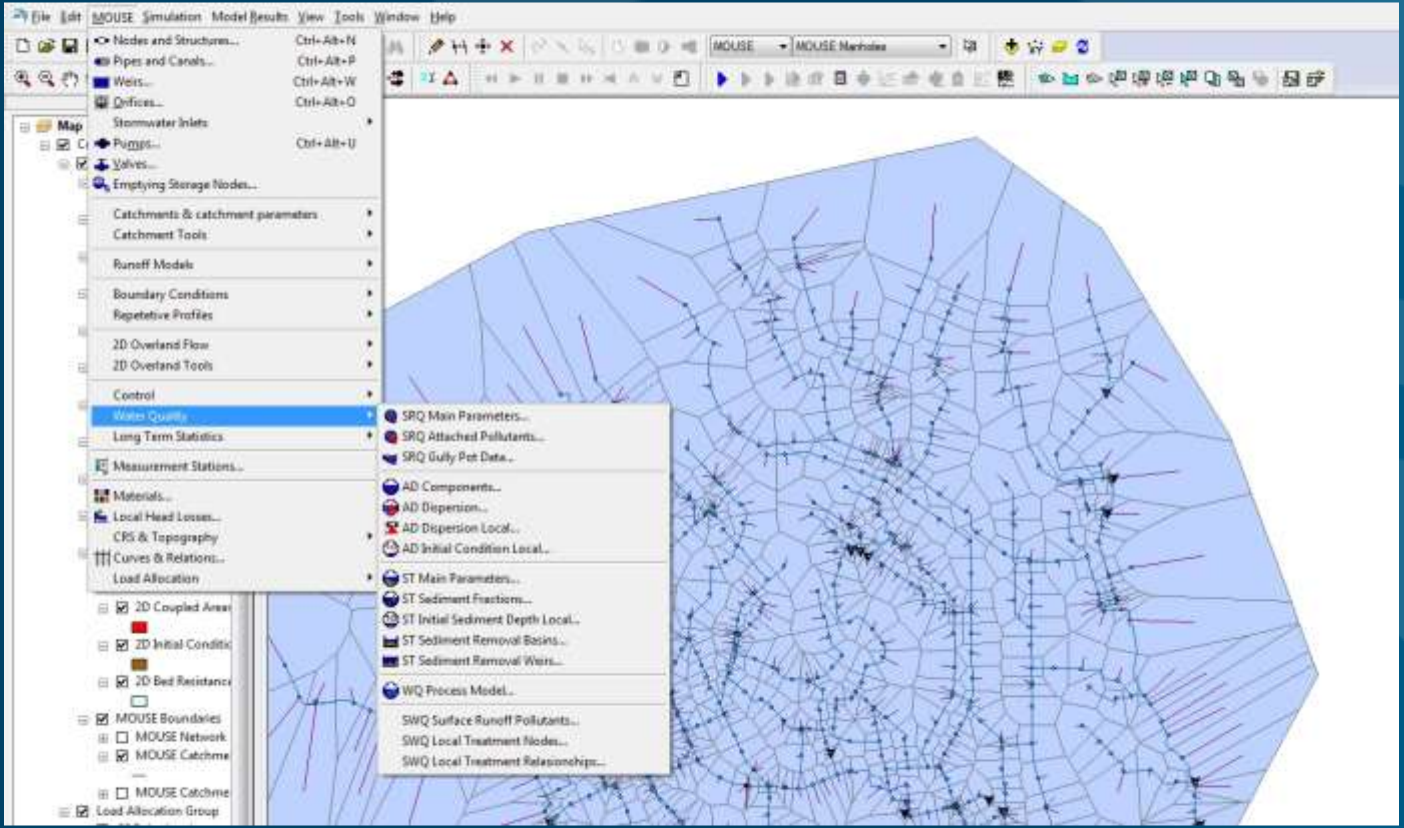
- 2. The substance is conservative or subject to a first order decay

- 3. Fick’s diffusion law applied, i.e. the dispersive transport is proportional to the gradient of the concentration

- $$\frac{\partial (AC)}{\partial t} + \frac{\partial (QC)}{\partial x} - \frac{\partial}{\partial x}\left(AD\frac{\partial C}{\partial x}\right) = -A.K.C + C_S.q$$

- Where: A is cross-sectional area (m^2), C is concentration (kg m^{-3}), t is time (s), Q is discharge (m^3/s), x is space coordinate (m), D is the dispersion coefficient (m^2/s), K is linear decay coefficient (s^{-1}) and C_S is the source/sink concentration.

Model Setup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Load Allocation
SRQ Main Parameters...
SRQ Attached Pollutants...
SRQ Gully Pot Data...
AD Components...
AD Dispersion...
AD Dispersion Local...
AD Initial Condition Local...
ST Main Parameters...
ST Sediment Fractions...
ST Initial Sediment Depth Local...
ST Sediment Removal Basins...
ST Sediment Removal Weirs...
WQ Process Model...
SWQ Surface Runoff Pollutants...
SWQ Local Treatment Nodes...
SWQ Local Treatment Relationships...
MOUSE
MOUSE Manholes
Map
MOUSE Boundaries
Load Allocation Group

Quality Model

- In aerobic sewers, considering long residence time, significant changes in wastewater quality occur; reduction in amount of biodegradable substrate and production of biomass

- The occurrence of aerobic transformations of organic substances depends on existence of heterotrophic biomass, electron acceptor and donor

- The limiting factors for such a transformation is reaeration and the presence of DO.

- Sewer systems are dynamic in comparison to treatment plants and the model should reflect the dynamic between the layers in the water current

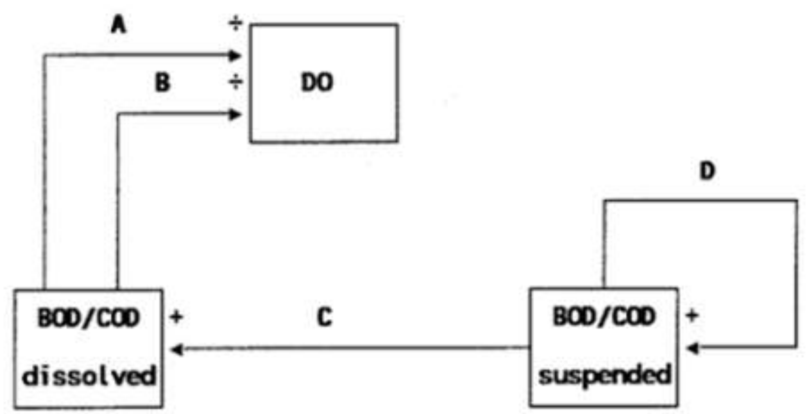
- The concentrations and type of substances discharged into the sewer system depend on local conditions such as number of inhabitants and type of industrial sites and vary hourly and daily.

Quality Model

- In the water phase, the heterotrophic biomass is generated by growth on readily biodegradable substrate
- $BOD_{degra} = K_s . \theta^{temp-20} . BOD/(BOD + k_{m,BOD}) . DO/(DO + k_{m,DO)} . B_x$
- Where:
- K_s is μ_{max}/Y_{max} (Max growth rate at 20 C°/max yield constant), Θ is temperature constant, $k_{m,BOD}$ is half-saturation constant of BOD dissolved, $k_{m,DO}$ is half-saturation constant of DO and B_x is biomass of active heterotrophic organisms.

Conceptual diagram of BOD/COD-DO model

- Process A : Degradation in biofilm
- Process B: Degradation in water phase
- Process C: Hydrolysis
- Process D: Growth of heterotrophic



(MOUSE user manual, Water Quality)

Model Setup

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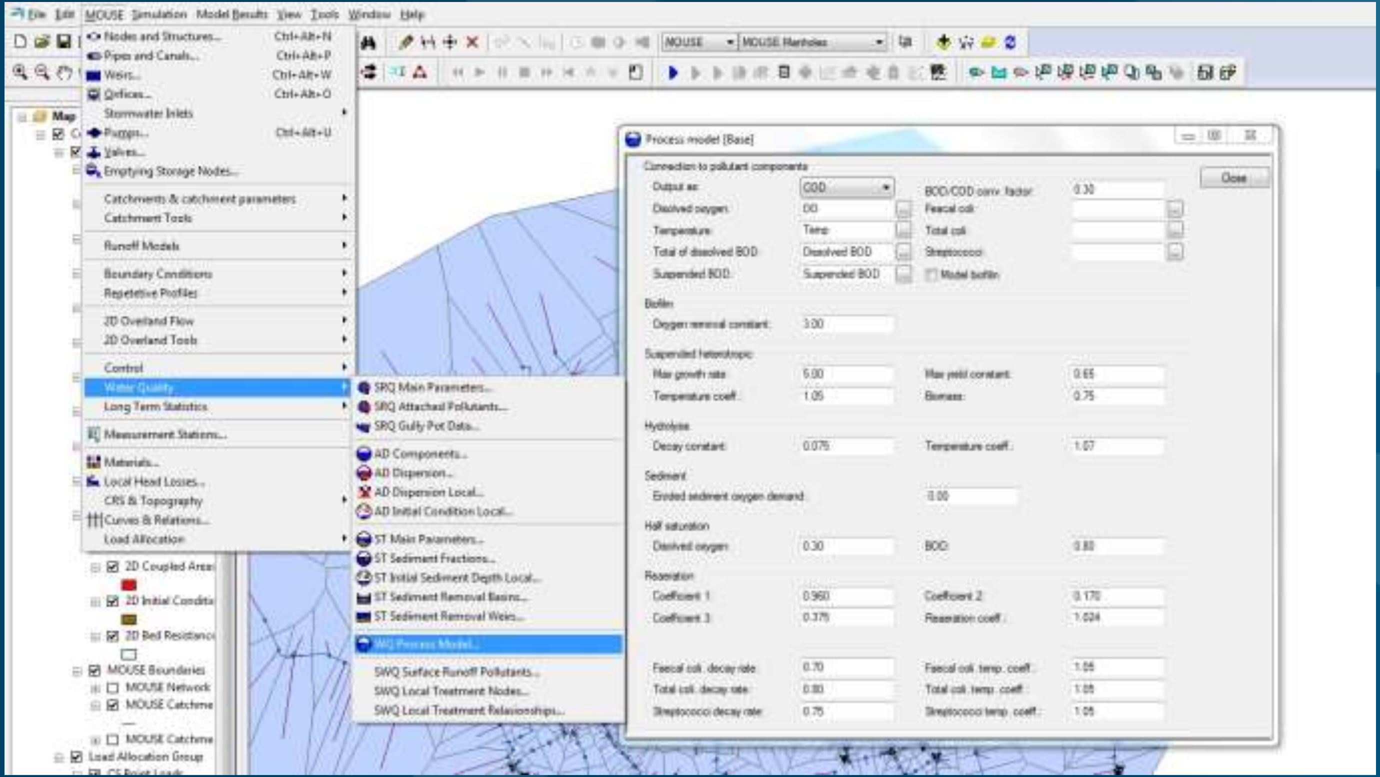
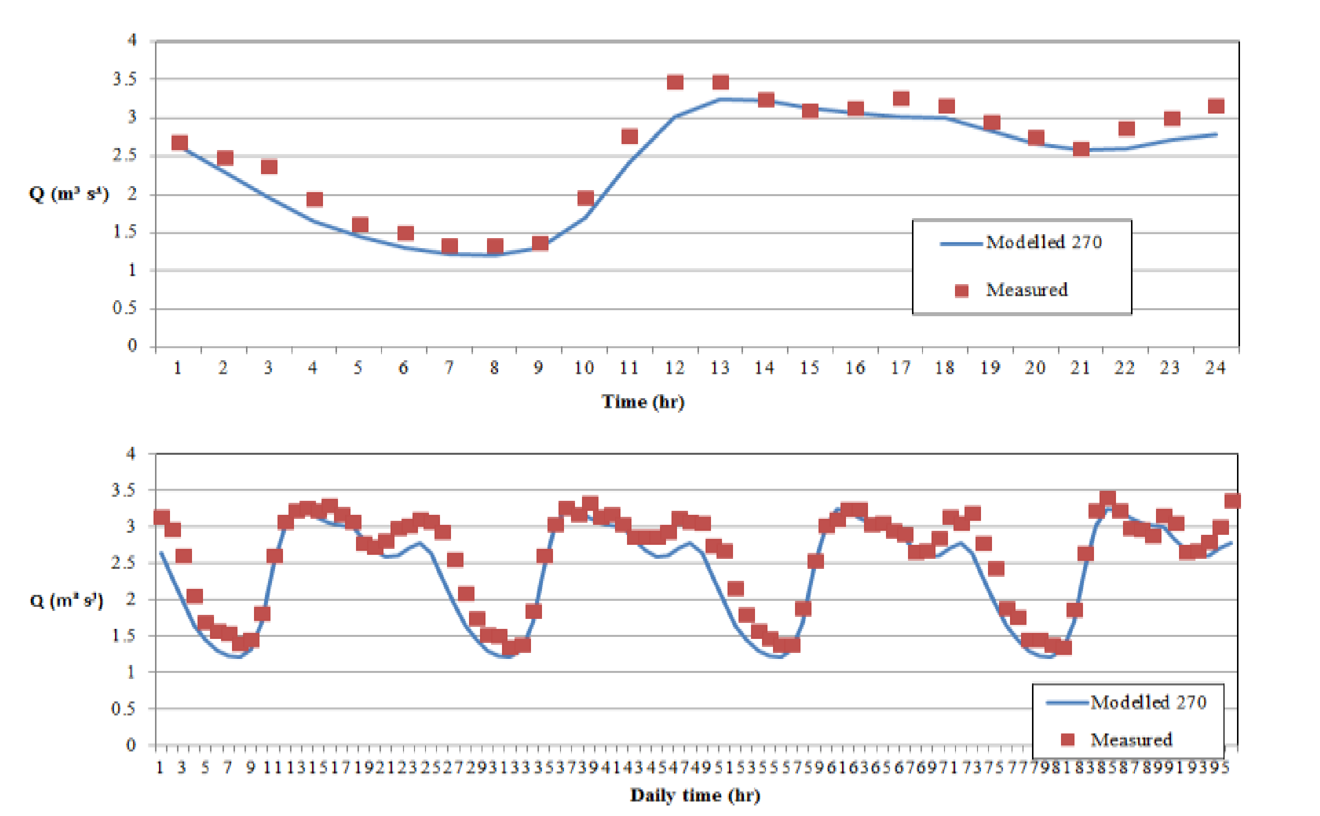


Results Hydraulic modeling (MSE=0.05)



Daily measurement of COD in WWTP

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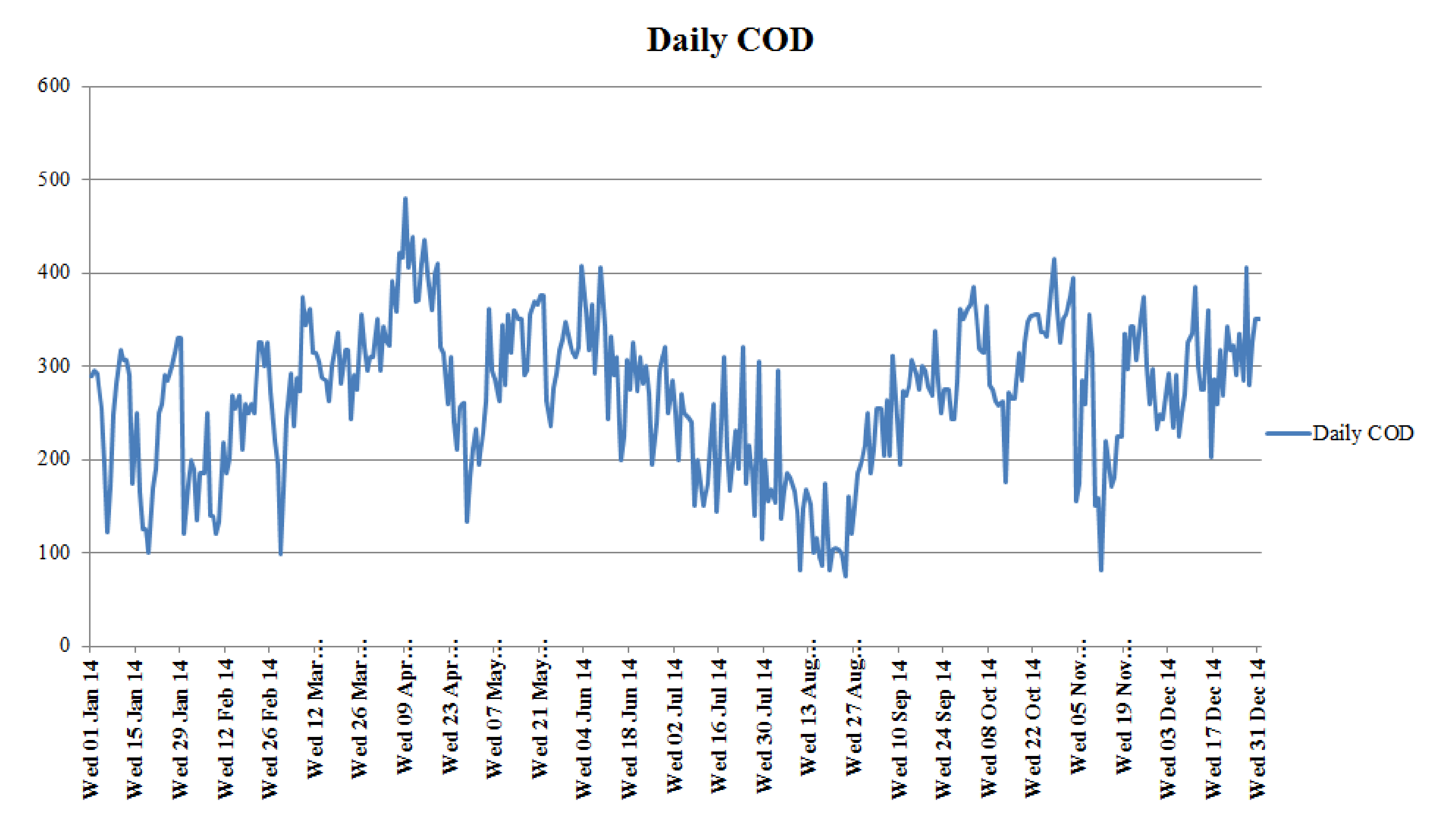
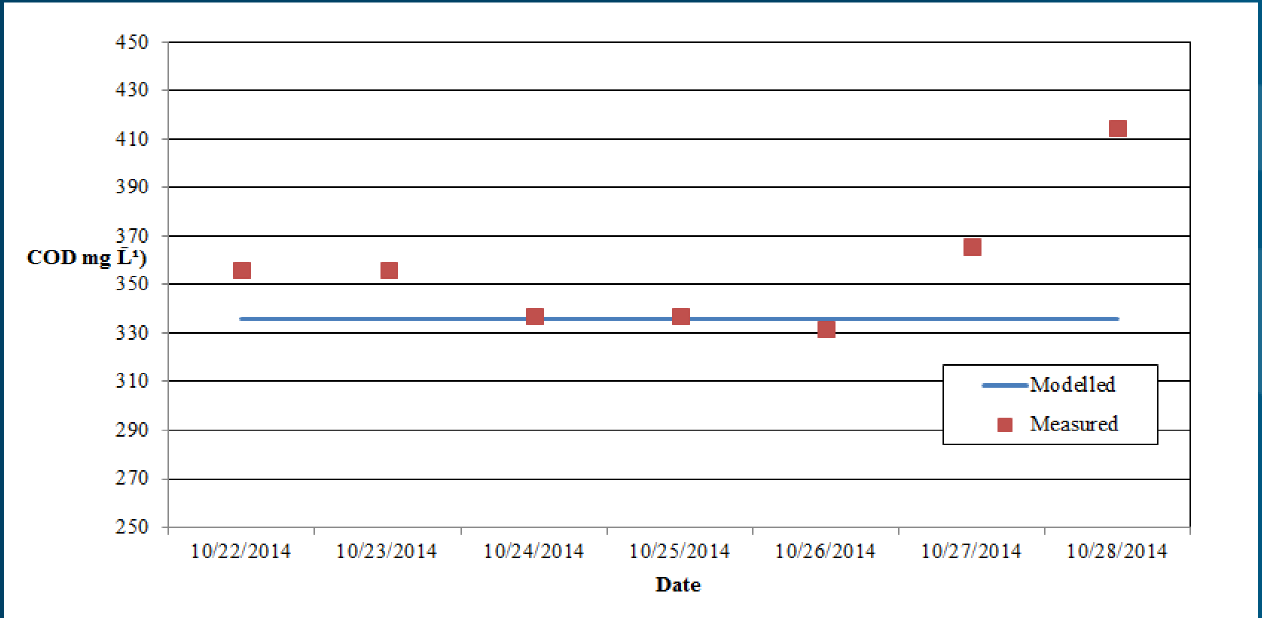


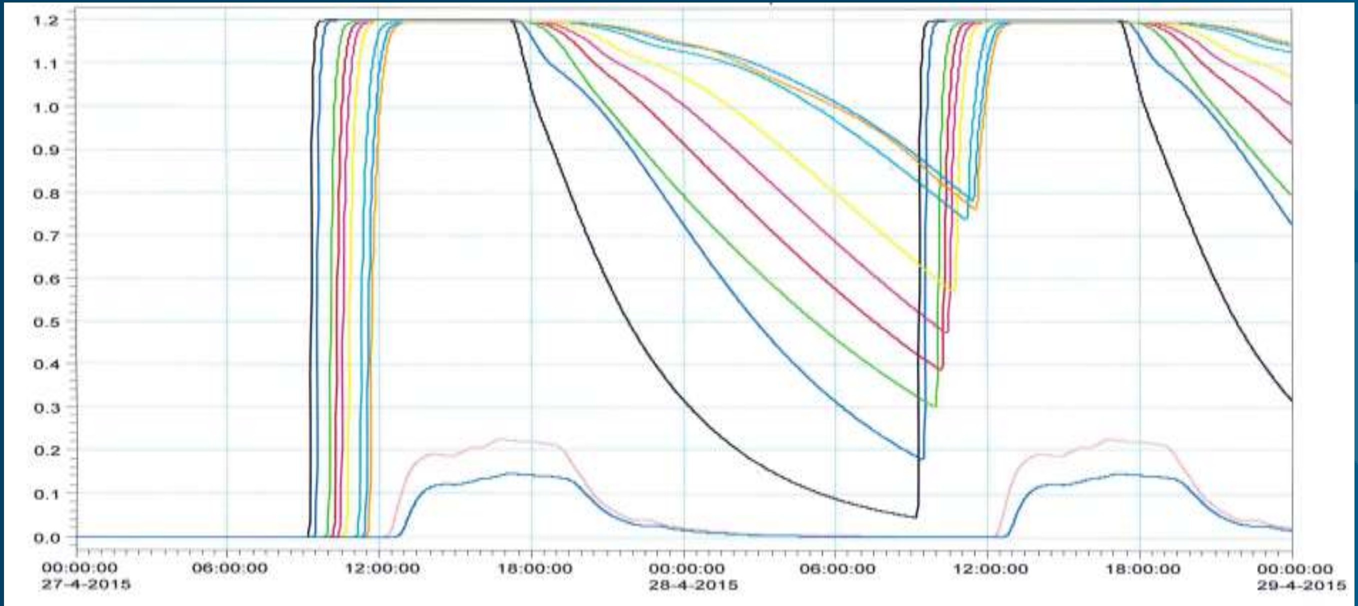
Results, Quality Model

- simulated values: fixed value of 336.23 (mg L^{-1}) .
- BOD= 60 g/p. day
- Varying number of city inhabitants, the discharge loads from industrial and commercial sites etc.



Behavior of the heavy metal Cadmium

- In first 8 pipes, only Cadmium is flowing and no other source of discharge.
- from pipe 9 the residential flow has been added, 2500 PE.
- sudden decrease in the concentration occurs (from maximum of 1.2 mg L^{-1} to 0.2 mg l^{-1})



Grazie

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