SMARTCHLOR PROJECT
THE INTELLIGENT CHLORINATION SYSTEM

PROJECT OVERVIEW

JUNE 2018

ANITA SZABÓ, INNO-WATER INC.

NATIONAL RESEARCH, DEVELOPMENT AND INNOVATION OFFICE
HUNGARY

PROJECT FINANCED FROM THE NRDI FUND
MOMENTUM OF INNOVATION

Aims of the Project (I.)

- To develop a **smart electrochlorination system** by optimizing the required chlorine dosages:
  - Several smaller post-chlorination units inside the network controlled based on water flow and quality.
  - Intelligent control system and the algorythm for that.
  - Safeand cost-efficient on-site production of disinfectants.
- Decreased and optimized chlorine dosage system that will improve the organoleptic properties of the drinking water while maintaining the low risk water quality.
- The proposed electrochlorination system is able to adopt to the diurnal and seasonal changes of water flows and water quality distributed in the water network.
- System is based on the **detailed hydraulic model** of the distribution system with an integrated **water quality module**.

Aims of the Project (II.)

- **Adapt the new, patent pending C.Q.M. electrochlorination unit** that will be integrated into an intelligent water treatment and water distribution technology environment.
- Create a **demonstration** unit in the living (operational) system of the Budapest WaterWorks.
- Develop further the existent hydraulic model of the Budapest by integrating a water quality model module into it that will serve a **predictor for the required chlorine dosage** based on the water age, flow rates, water quality, type and age of pipelines within the distribution network.
- Mitigate the problem of the secondary water quality deterioration.
- Develop a methodology for novel **process control**.

Electrochlorination

- Electrochlorination is an **electrolysis** process where either natural seawater or an artificial brine solution (fresh water + salt) is converted into sodium hypochlorite solution.
- Salt is composed of sodium and chloride. When in solution and DC is passed through titanium electrodes, the chlorides will disassociate to form **chlorine**.
- At the **anode**:

  $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

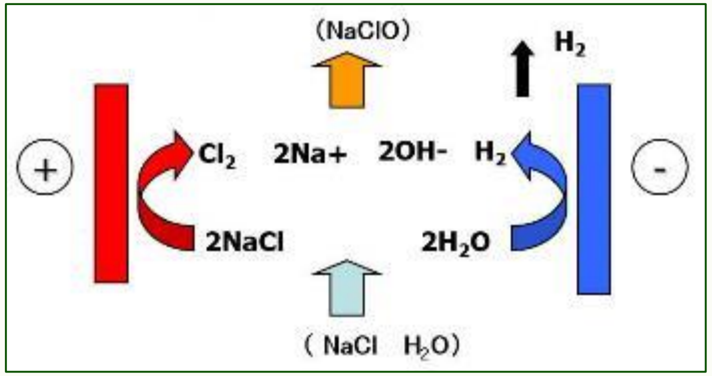
  $2Cl^- \rightarrow \mathbf{Cl_2} + 2e^-$

- On the **cathode**:

  $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

  $2Na^+ + OH^- \rightarrow \mathbf{2NaOH}$

- $2NaOH + Cl_2 \rightarrow NaCl + \mathbf{NaClO} + H_2O$



$2NaCl$ (salt) + H_2O (water)
▽
$NaOCl$ (hypo) + $NaCl$ (salt)
+ H_2 (hydrogen)

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Electrochemical production of chlorine and disinfection efficiency

- Dependent on
  - Chloride concentration in water
  - Current
  - Electrode materials
- The chlorine produced at the anode is hydrolyzed to hypochlorous acid, which forms a pH dependent equilibrium with the hypochlorite anion:
  - $Cl_2 + H_2O \rightarrow \mathbf{HOCl} + H^+ + Cl^-$
  - $HOCl \rightarrow \mathbf{OCl^-} + H^+$
- Increased effectiveness due to formation of hydroxyl radicals besides the above

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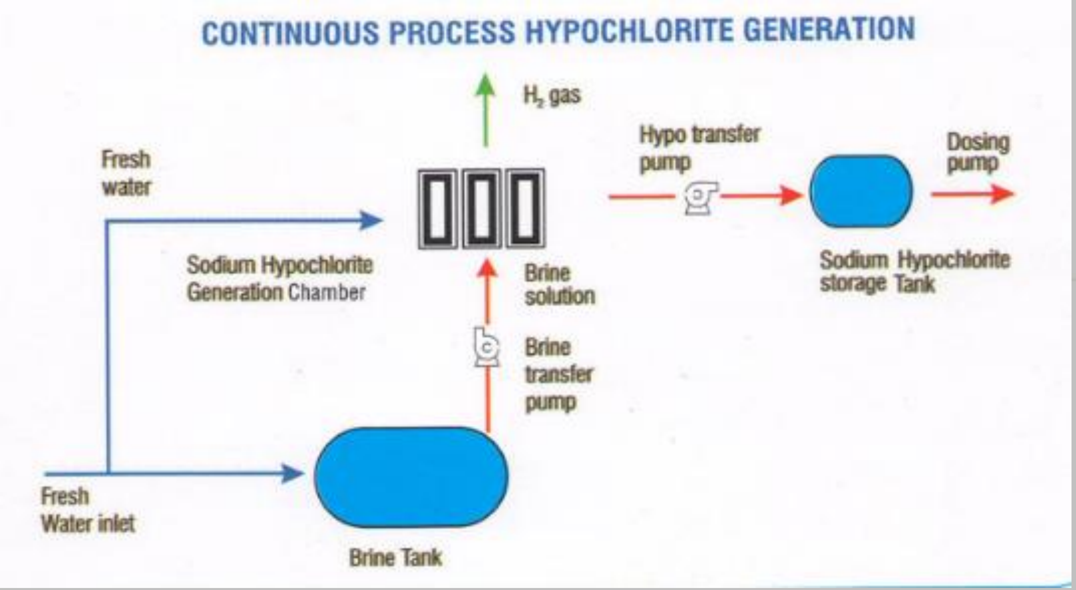

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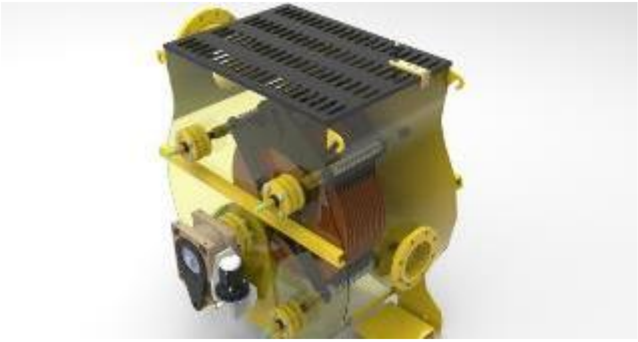

C.Q.M. novelty

- Due to alkaline conditions, calcium carbonate ($CaCO_3$) and magnesium hydroxide ($Mg(OH)_2$) tend to precipitate onto the cathode which over time damages the electrodes and therefore requires periodic cleaning.
- “Reverse Polarity” shortens electrode life.
- C.Q.M. has developed special automatic cleaning – „SELF CLEANINC CATHODE”.

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Advantages of the proposed system

- The savings on chlorination costs by dosing only the required amount of disinfectant at the points where needed.
- Stable free chlorine concentrations within the whole system due to strictly regulated chlorine production (regulated by water flow and quality)
- Increased water safety and security (stable operation under emergencies, such as sabotage, or natural catastrophes).
- Improved labor and health safety (no need to store and manage large volumes of chlorine gas)
- Decrease of corrosion problems in pipelines.
- Adaptability to water quality changes (plus diurnal, seasonal changes of raw water quality).

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Planned studies and experiments

- The adaptation of the hydraulic model system of the distribution network for the determination of the **exact residence times of the water** at different points of the network (water ages).
- Determination and **prediction of the residual free chlorine concentrations** on the operating distribution network.
- Laboratory and pilot scale experiments for the **determination of the boundary conditions** of the operation of the electrochlorination units.

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INNO-WATER Inc. – Project role

- **Project management and coordination**
  - Information transfer inside the consortium (e-mails, meetings, etc.).
  - Contact with the national support agency and the EUREKA office.
  - Organization of kick off meeting, site visit, knowledge transfer, etc.
  - Organization of preparation of project reports (input is needed from each participants – reporting in Hungarian and in English).

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INNO-WATER Inc. – Project role

- **Professional tasks**

  - Examine the behavior of free chlorine in the network.
  - Carry out experiments in the drinking water distribution system in order to determine the algorithm of free chlorine utilization in the network.
  - Develop an automatic control system for the electro-chlorination system - together with Budapest WaterWorks.

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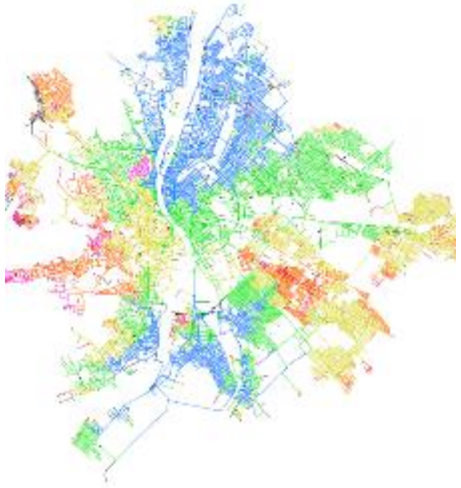
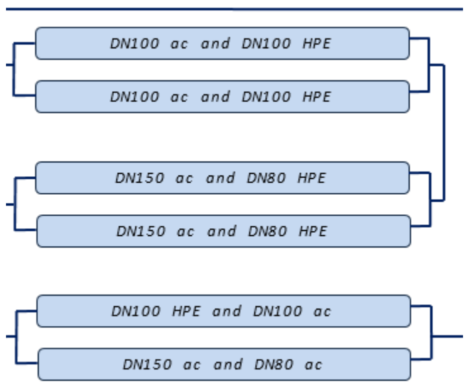
BWW – Project role





ibution Network Model Device (DNMB) flow chart and material an

- Modelling - Further development of hydraulic model of Budapest drinking water distribution system with the aim of determining the necessary chlorine dose
- Operation of pilot system in order to determine chlorine dose and to plan operational parameters
- Calibration and validation of control system of chlorine dosage and the module calculating the actual level of active chlorine

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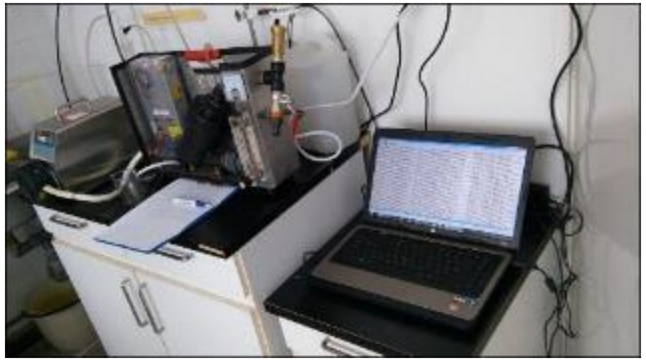

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National Univ. of Public Services – Project role

- Conduct laboratory scale experiments with different raw water compositions to examine the effect of pollutant substances and natural components on the change of free chlorine concentration.
- Examine the effect of drinking water treatment technologies on the necessary amount of added chlorine.
- Cost-benefit analysis of the proposed technology.

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CQM – Project role

- Fully design of the applied technology and manufacturing of the system.
- Test of the prototype system in CQM premises prior to manufacturing the alfa system.
- Do the necessary modifications required due to tests results.
- Supply the tested and modified system to the site and than supervise the installation and the on-site tests.

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Tasks fulfilled

I. **Literature summary and conclusions (IW)**
   I. **Parameters affecting chlorine decay in networks**
   II. **Approaches of modelling chlorine decay in networks**
   III. **Our own approach of modelling chlorine decay in networks**

II. Laboratory research (NUPS)
   I. Testing the technological parameters of the laboratory scale chlorination device
   II. Laboratory measurements of the effects of referred parameters on chlorine decay

III. Network experiments (BWW)
   I. Installing the pilot network (Engine house)
   II. Assigning sample areas on the real network

IV. Installation of pilot (CQM)
   I. Installing the pilot chlorinator (Engine house)
   II. Education of operators

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Mechanisms affecting chlorine decay

Main reasons for decrease in residual chlorine concentration in networks:

- Contamination from external sources
  - Pipe bursts (breakage)
  - Maintenance
- Natural decay processes in pipelines and tanks
  - Reactions in the bulk water
  - Reactions on the pipe walls
  - Volatilisation

Parameters affecting chlorine decay in bulk phase

- Inorganic matters concentration
  - Iron, manganese, hydrogen sulphide, cyanides, other inorganic reducing agents
- Organic matters concentration
  - Organic nitrogen compounds, humic substances, phenols, etc.
- Physical parameters
  - Temperature
  - pH
  - Contact time (water age)

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Parameters affecting chlorine decay in proximity of pipe walls

- Pipe material and corrosion rate
- Pipe diameter
- Biofilm
- Flow rates

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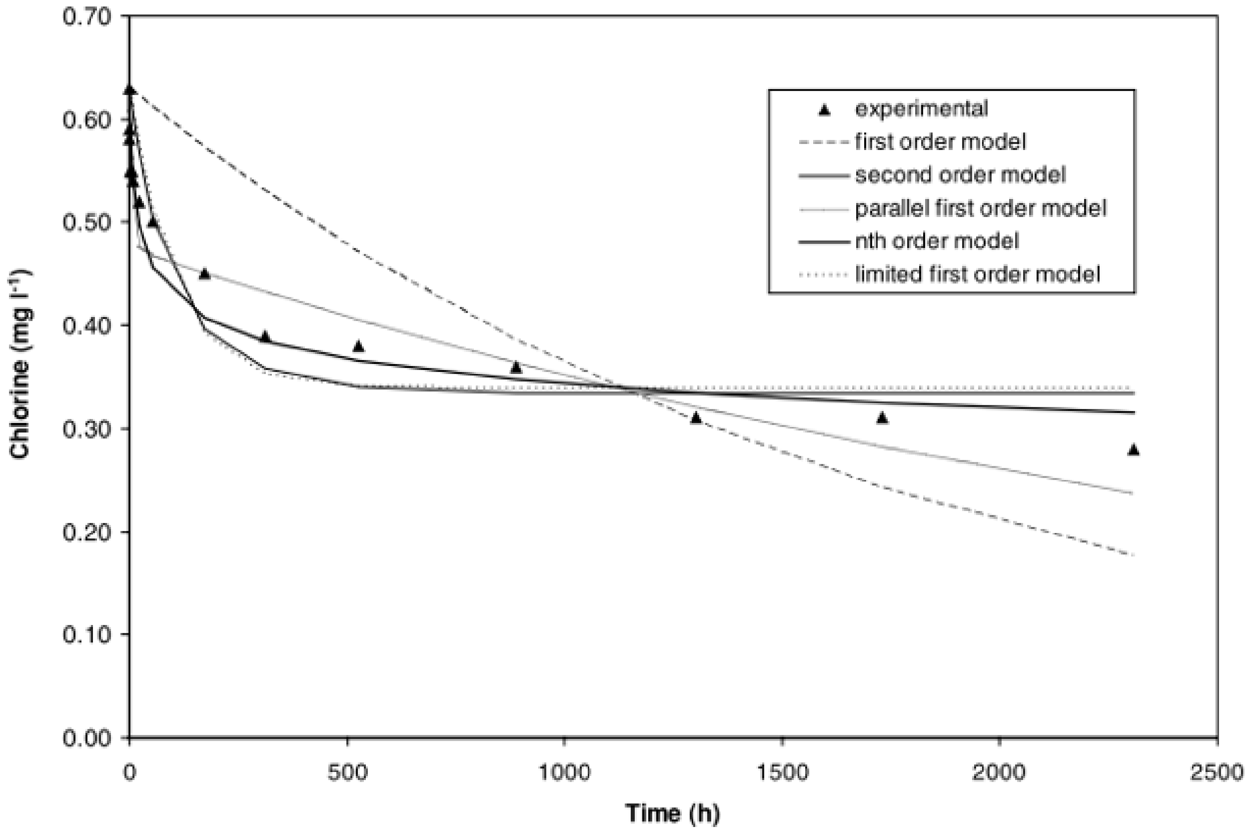
Chlorine decay modelling approaches I.

- First order
  - Reaction rate is proportional to chlorine concentration
  - Can’t describe first fast reactions
- Limited models
  - There is always non-reacted residual chlorine present (C_*)
- Parallel first order
  - Two decay rate constants – for fast and slow reactions



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Our own approach of modeling chlorine decay in networks

Identification of the most important parameters affecting chlorine decay

→

Determination of the relations between the compounds and the chlorine consumption (lab experiments) – different *k* values and equations for different parameters

↓

Development of a model calculating chlorine consumption by the most important compounds that can be measured on site

→

Validation of the model by field samplings

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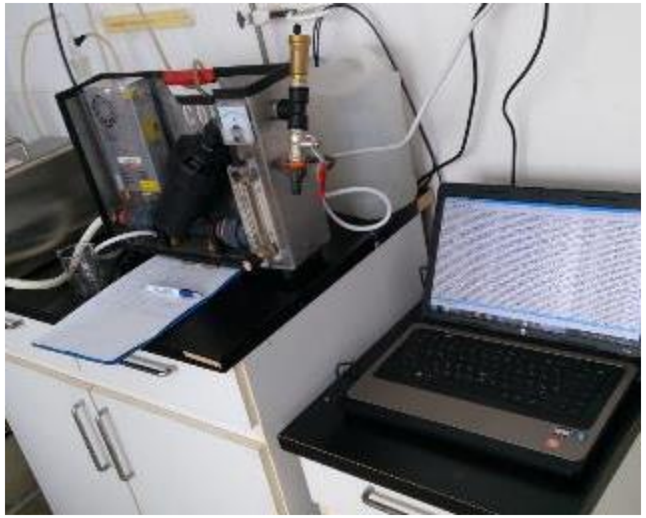
Experiments

- **Chlorine production capacity of C.Q.M. electrochlorinator**
  - Varied parameters
    - Flowrate (retention time)
    - NaCl concentration (in desalinated water)
    - Voltage (3-6-9 electric current)
    - With/without recirculation
  - Measured parameters
    - Active Cl_2 concentration – DPD-test and iodometry
    - pH, T, ORP, conductivity, Cl^-, gas volume



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Experiments

- Chlorine decay rates in varied circumstances
- Measurement with low chloride concentration (1 – 1000 mg/L)
- Detailed analysis of produced gas.

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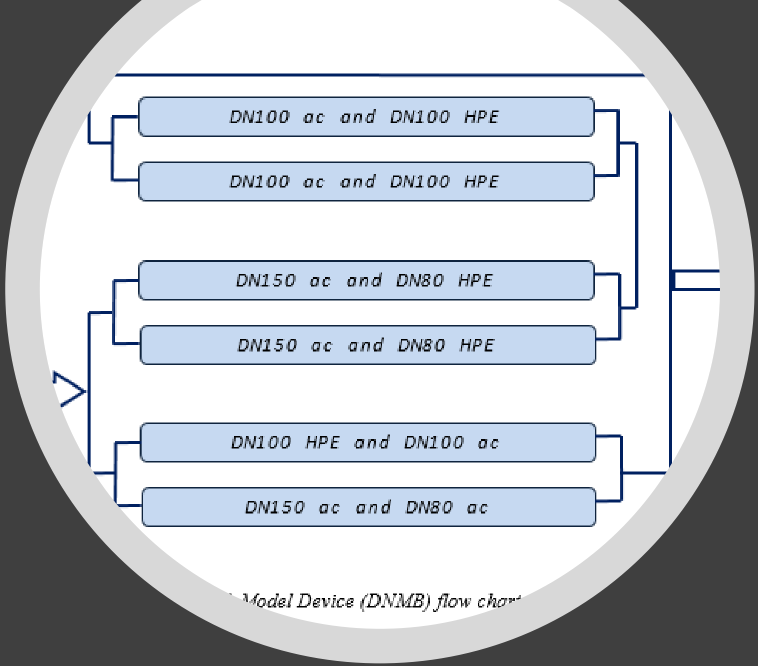

Installing pilot network

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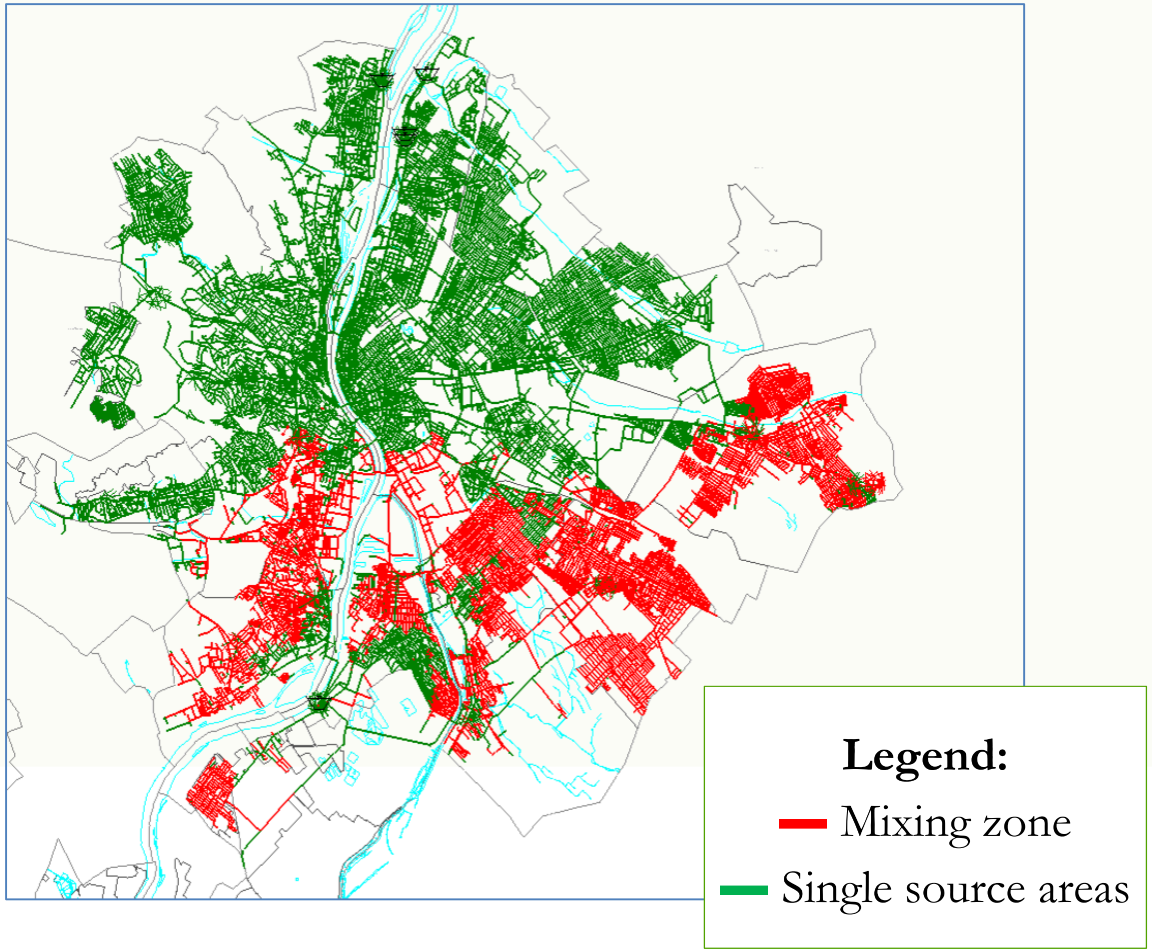
Selection of pilot areas



- Two main sources of water supply:
  - Northern pumping stations
  - Csepel-island pumping stations
- Criterias:
  - Available hydrants for sampling
  - Residence time: 48-96 hours
  - Pressure zone supplied from:
    - Northern aquifers
    - Southern aquifers
    - Both sources – mixing zone

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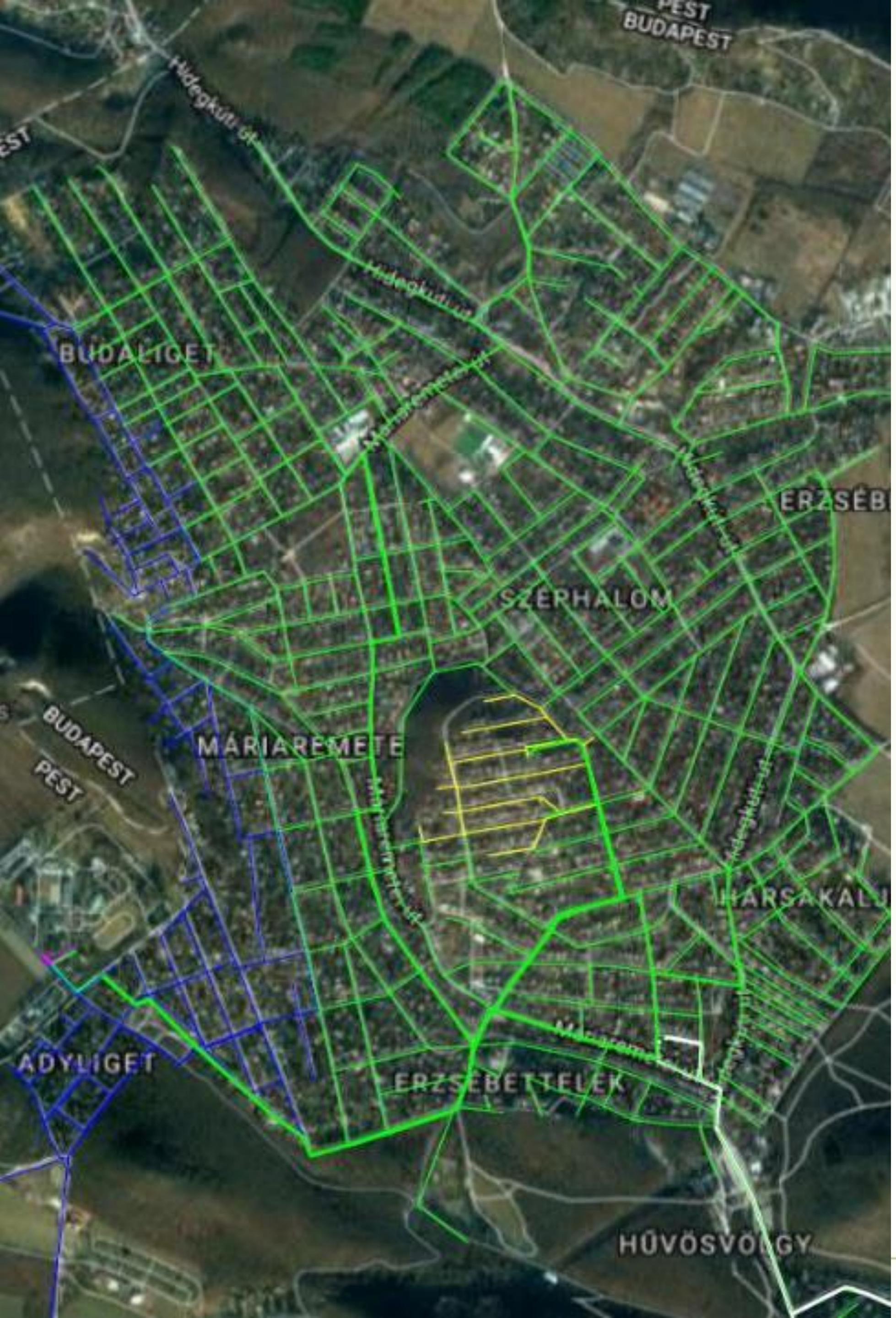

Results

- Selected Zones
  - Pesthidegkut – Mikes
  - Szigetszentmiklos
  - Kelet-Pest (Preduced zone Nr1)
- Each zone has it's own characteristics and properties
- The ratio of supplies in the mixing zone depends on the water demand

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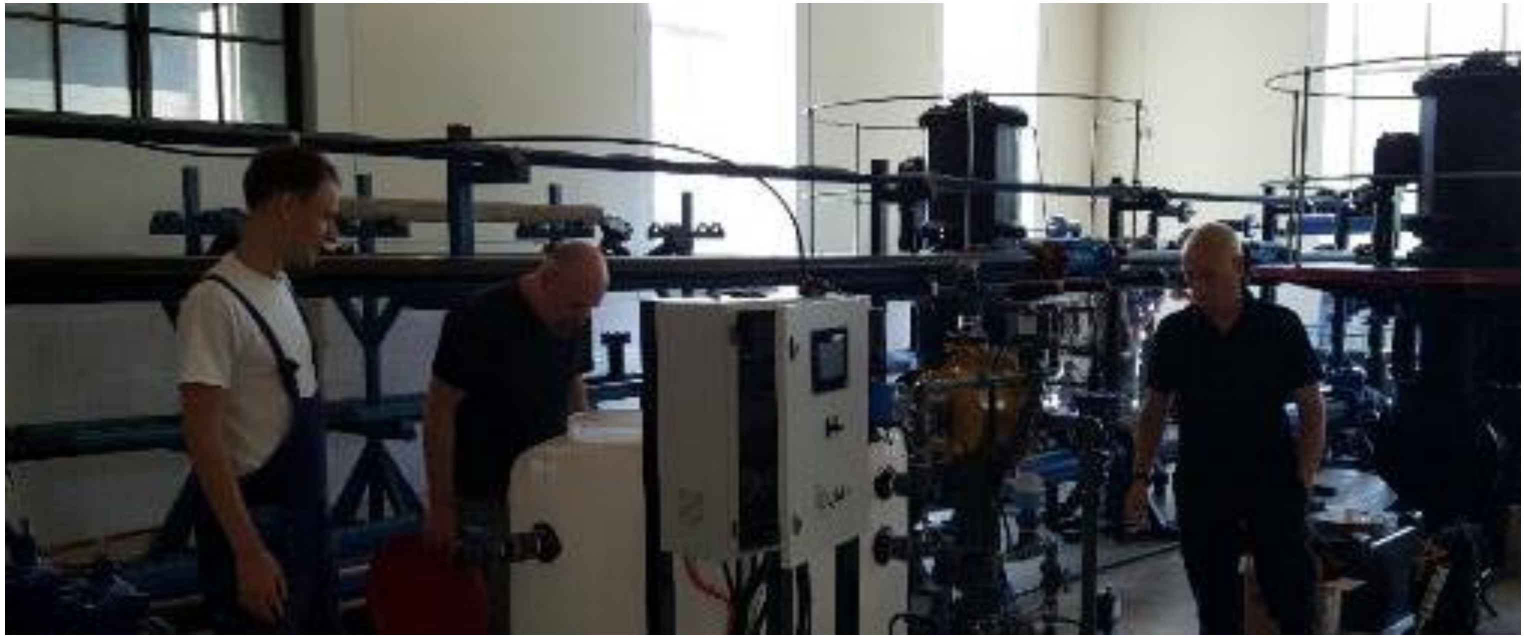

Installing pilot system

Thank you for your attention

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