WATER QUALITY SIMULATIONS IN DRINKING WATER NETWORK. CASE STUDY OF BUCHAREST NETWORK

Mădălin MIHAILOVICI[1], Valentin ZAHARIA[2] and Andrei ZARESCU[3]

[1]General Manager for Veolia Romania and Apa Nova București, Associate Professor at Technical University of Civil Engineering Bucharest – Faculty of Hydrotechnics, Bucharest, Romania, Tunari Street, no. 60A, e-mail: madalin.mihailovici@veolia.com
[2]Director of Water Supply and Sewage Systems Optimization at Apa Nova București, Ph.D. Student at Technical University of Civil Engineering Bucharest – Faculty of Hydrotechnics, Splaiul Independenței Street, no. 235-237, Bucharest, Romania, e-mail: valentin.zaharia@veolia.com
[3]Hydraulic Modeling Engineer at Apa Nova București, Splaiul Independenței Street, no. 235-237, Romania, e-mail: andrei.zarescu@apanovabucuresti.ro

Abstract
One of the main concerns of drinking water networks (DWN) is represented by the water quality, defined through many indicators such as residual chlorine concentration. The decay rate of residual chlorine in the drinking water network is a complex process because of different pipe materials, conditions, ages, velocities, etc. Mathematical models are used in order to achieve a better understanding regarding water quality in drinking water networks and further to optimize the system operation through the analysis of potential solutions.
Through water quality simulations it could be determined how the concentration of a dissolved substance varies over time into the drinking water network under a specific set of hydraulic loads and based on the certain condition and configuration of the pipes.
The case study presents the process of chlorine concentration decay into a part of the drinking water network of Bucharest, which represents a priority due to the high rate of city's expansion and pipe condition in that area.
Using data collected from the field and water quality simulation, it was possible to calibrate the model and further to analyze how the initial concentration of residual chlorine decays during the water transport process through the distribution network over 72 hours. Based on these results two opposing issues are revealed: (1) high residual chlorine concentration in existing areas close to the pumping stations (inlets in the model), (2) low residual chlorine concentration in new areas (dead – ends), due to extensions of current drinking water network which are located mainly to the border of city's administrative area.
The calibrated model is used continously to optimize network functioning for both objectives: hydraulic/energy efficiency and water quality requirements.

Keywords
Water quality modeling, chlorine concentration decay, drinking water network.

1. INTRODUCTION

Drinking water networks (DWN) are in a continous development and optimization process, thus representing a vital sector for the population. Because, above all, this is a safety requirement, any method and/or solution dedicated to improve/guarantee water quality should be analyzed and used. Some solutions could be: real-time monitoring of the DWN (especially critical points), optimization of DWN operation through isolation valves, pumping schedule, maintenance plan, installation of sprinklers at dead-end nodes, replacement of aged pipes, etc.

The objectives for a water quality model are: (1) identify potential areas where water quality issues could appear, (2) analyze solutions to reduce/remove risks related to potential water quality issues, (3) improve operation efficiency.

The steps needed to build a water quality model are:

- geometry of the model (GIS);

• collect input data, such as: pump type and pumping schedule, tanks – water level variation, pressures, flow rates and water quality indicators (e.g. residual chlorine);

• calibrate the model based on physical parameters (flow rates, pressure);

• calibrate the model based on water quality parameters;

• simulate various scenerios according to potential solutions and assess their impact over the entire DWN.

2. CASE STUDY. DRINKING WATER NETWORK OF BUCHAREST

The DWN of Bucharest has a length of approximately 2550 km and a efficiency of 76%. From the pressure regime perspective, the DWN is divided in two pressure management areas (PMA): the low pressure zone, supplied by four pumping stations and the high pressure zone, supplied by two pumping stations.

Water quality is adjusted in the Water Treatment Plants (3) and is monitored in real-time at each pumping station. In case of exceeding any water quality indicator, the water treatment plants and pumping stations are stopped. In the DWN there are 52 monitoring points for water quality, most of them located in critical points.

The case study is adressed to the high pressure zone presented in Figure 1.

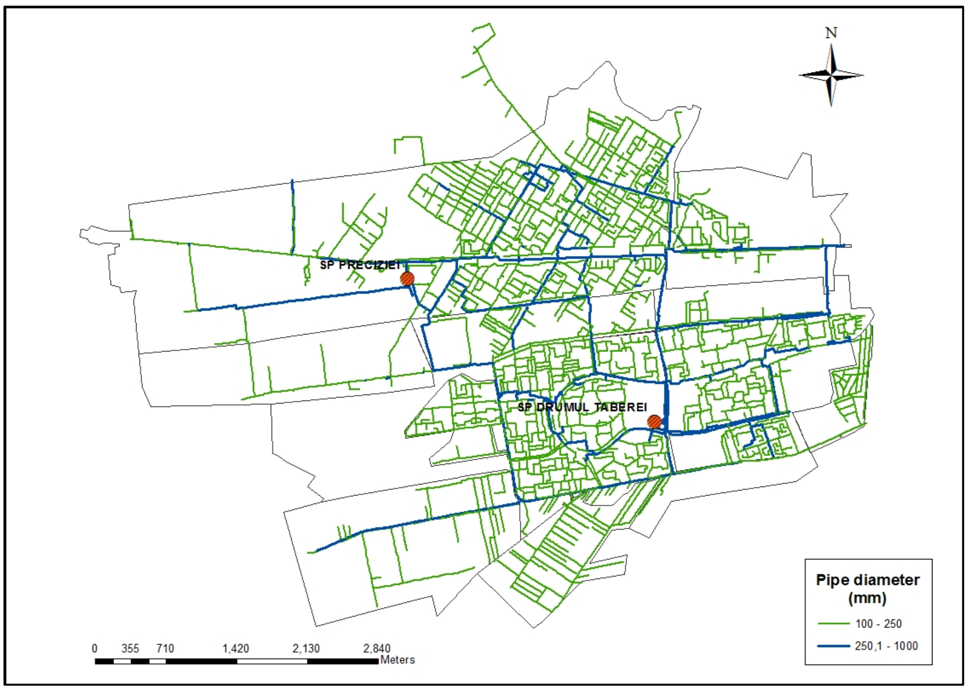


Figure 1. DWN for the high pressure zone

3. DETAILED MODEL OF HIGH PRESSURE ZONE FOR WATER QUALITY ANALYSIS

The analysis of the chlorine concentration was conducted in the high pressure zone of Bucharest supplied by two pumping stations, which has a lenght of 258 km (pipes diameter varies from 100 mm to 1000 mm). 8000 customers and around 300000 people are supplied with water through this network, with a pressure varying between 4.5 – 4.8 bars providing pressure for buildings up to ten floors.

This area represents a priority due to the high rate of city's expansion and pipe condition. The analysis was conducted in order to determine the residual chlorine decay in DWN. The decay simulation of the chlorine was made considering the phenomenon of chlorine reaction at bulk fluid and with pipe walls. The simulation period was 72 hours with a time step of 15 minutes.

4. SIMULATION RESULTS OF THE RESIDUAL CHLORINE DECAY IN DWN

The model was built using a software that can determine the hydraulic and water quality parameters in steady state and extended period simulations. The process of changing the concentration of the residual chlorine is achieved using an exponential variation law which will be used in the water quality simulation. The kinetic law takes the form of an equation which allows us to calculate the concentration of chlorine in the water, throught the transportation time. Reactions within the volume of water are influenced by the elements of the present concentrations, the rate and the reaction order.

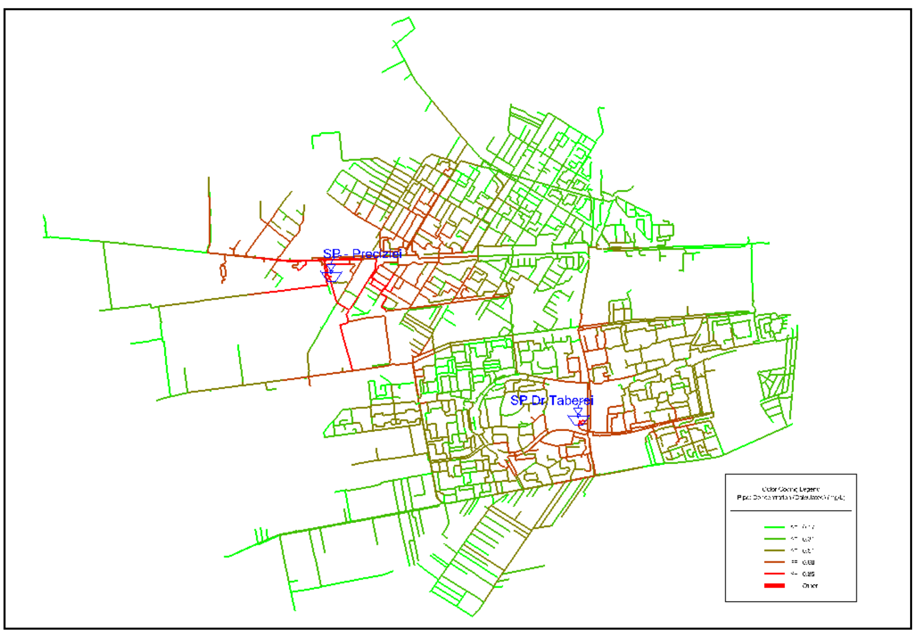
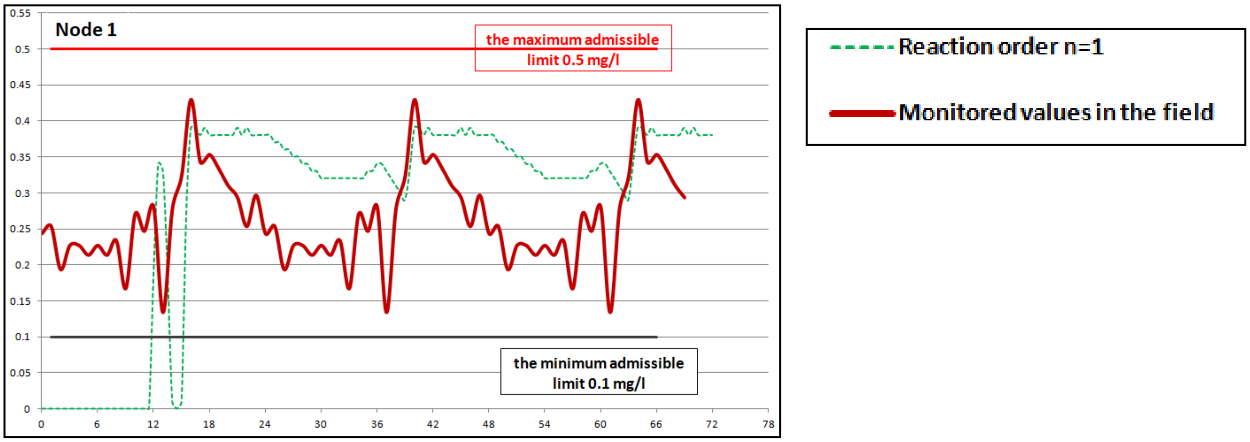


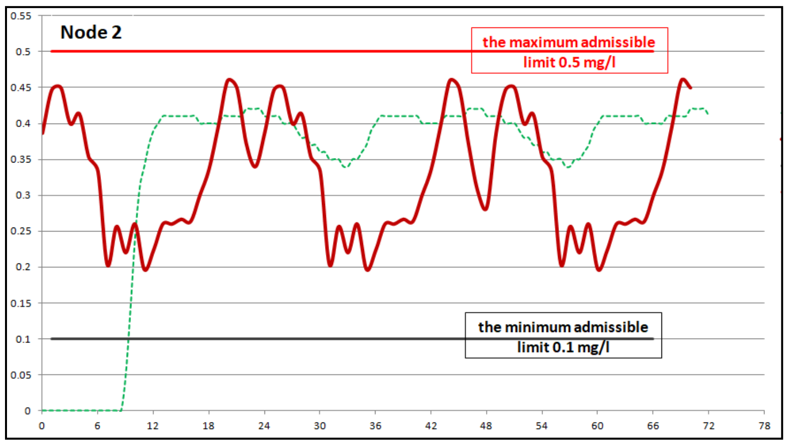
Figure 2. Residual chlorine concentration in the water network model

In Figure 2 we have showed the influence of the residual chlorine obtained by analysing the initial decay of chlorine concentration in the simulated model over a 24 hour period.

The graphs in Figure 3 represents the calibration results for the coefficient of the reaction rate (k) and the simulations for 1st reaction order for three locations in the DWN.

The „*k*" coefficient was termed as bulk reaction coefficient and will have the value of - 0.125 hour^{-1}. The value is preceded by a minus sign in order to indicate a disappearance coefficient. Samples were taken for extremity areas (dead – ends) in relation to the pump stations.





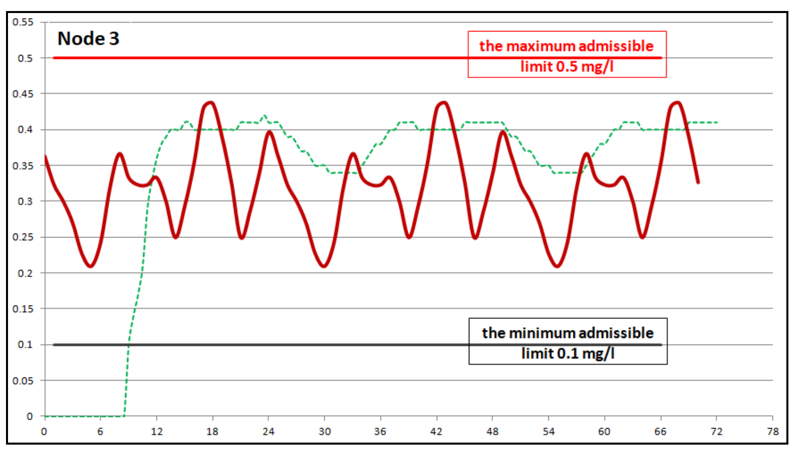


Figure 3. Simulation results for nodes 1, 2 and 3 after "*k*" calibration with those two reaction orders

5. CONCLUSIONS

As water utility we need constant monitoring for real field data from the system to achieve more reliable analysis and management of the network and this is accomplished only using tools as geographic information system (GIS) and supervisory control and data acquisition (SCADA).

Two opposing issues were revealed by the results: (1) high residual chlorine concentration in existing areas close to the pumping stations (inlets in the model), (2) low residual chlorine concentration in new areas (dead – ends), due to extensions of current drinking water network which are located mainly to the border of city's administrative area.

The distance, respectively the transport of water in the system, has been shown to be the main cause of the decrease of the chlorine concentration. The reaction order and water temperature are the dynamic elements that affect the decay rate of the chlorine concentration in the model.

On the other hand, we need to be aware of the residual chlorine's influence in the system because it will cause taste and odor problems and also can accelerate the corrosion process on pipelines in the distribution system.

The operations performed in the field, such as the closing or the opening of valves in the network can cause the degradation of the water quality parameters, because of the changes in flow conditions. The calibrated model is used continously to optimize network functioning for both objectives: hydraulic/energy efficiency and water quality requirements.

6. PROPOSING SOLUTIONS

For this area it is necessary to install an on-line monitoring system for several points in the DWN to achieve physical parameteres and water quality indicators (chlorine, conductivity, temperature, turbidity, pH and color).

Determination of the maximum allowable concentration of residual chlorine at the considerent injection points (pumping stations) to ensure the optimum concentration in the DWN.

Performing simulations in the theory of changing consumption in relation to the future urban developments.

7. REFERENCES

[1] Sandu M., Tutuianu A.E. - *Program de calcul pentru monitorizarea calității apei în rețelele de distribuție a apei*, București, 2013.

[2] Castro, P., Neves, M. – *Chlorine Decay in Water Distribution Systems. Case Study* – University of Porto, Portugal, 2003.

[3] Monteiro, L., Figueiredo, D., Dias, S., Freitas, R., Covas, D., Menaia, J., Coelho, S.T. – *Modeling of chlorine decay in drinking water supply systems using EPANET MSX*, Elsevier.

[4] Walski, T., Chase, D., Savic, D., Grayman, W., Beckwith, S., Koelle, E. – *Advanced water distribution modeling and Management*, Bentley Institute Press;

[5] Apa Nova București – Internal Sources.