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INCREASING THE PERFORMANCE AND ECONOMIC ANALYSIS OF THE WATER DISTRIBUTION NETWORK USING PRESSURE MANAGEMENT

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ABSTRACT: *Pressure management is one of the most constructive strategies of leakage management in water distribution networks. The aim of this paper is an economic analysis taking into consideration the numerous aspects of the implementation of pressure management. For this reason, a mathematical model was elaborated in EPANET software for determining the advantages starting from implementing pressure management on the reduction of leakage, active leakage control and energy consumption. As a case study, the advanced pressure management system was applied through the installation of time modulated and flow modulated pressure reducing valves in a district metered area (DMA) located in Ia i city. Pressure management is now perceived as having an increasingly wide extent of benefits not only covering environmental and water conservation benefits of reducing leak flow rates and some parts of consumption.*

Keywords: *pressure management; economic analysis; energy consumption; district metered area;*

1. Introduction

In Romania, water management is still faces many problems, especially in the field of providing water services that meet the standards European standards [Giurma I., Crăciun I.]. A major difficult task meeting many municipalities is how to deal with high levels of water loss, or non-revenue water [NRW]. Even though not all NRW is leakage, inefficient management of distribution system pressures is known to produce considerable avoidable leakage and burst pipes; it also comes with it other adverse effects such as reduced infrastructure life [Crăciun I., Giurma I.].

Pressure management permits dynamic and smart water control, assisting water utilities to reach savings of water loss [Giurma I., Giurma-Handley C.R.]. Pressure management valves are joined to automatic controllers that modify the valve set point between low nighttime consumption to peak hours. By tracing flow and pressure and optimizing pressure in real time, it saves water and energy [Vicente, D.J et al.; Moslehi, I. et al.; Koşucu, M.M. et al.].

Pressure management gives a multitude of benefits, [Adedeji, K.B. et al.; Campisano, A. Et al.] such as:

- Improving customer service through suitable service pressures and decreased service interruptions;
- Diminishing leakage volumes by dropping-off both the frequency of leaks and the flow rate of any given leak [P.V. Fanner et al.; H.E. Mutikanga et al.];
- Providing asset life by reducing stress on infrastructure [especially in the form of pressure transients];
- Reducing energy expenditures in systems with pumping infrastructure by selecting pressure reductions and as the result the energy costs related with supplying pressure [Giurma I.];

For flow models the mathematical model can be solved analytically only in certain cases. Most methods are based on an analytical solution of the flow equation in cylindrical coordinates [Giurma-Handley C.R.].

2. Methodology

The methodology involved first data collection for gathering relevant information about the network system and hydraulic parameters of interest. The network design was done using the hydraulic EPANET software to create a schematic representation. To ensure model accuracy a calibration process was assess. Several analysis and simulations were performed to evaluate network performance. The results were evaluated to identify the areas of low and high pressure within the network. In order to assess various system configurations several scenarios were evaluated. To improve the performance of the system, appropriate solutions and recommendations were proposed.

3. Results

The results obtained from EPANET model provides valuable information on the hydraulic performance of a water distribution network. The model generated comprehensive information on pressure parameter. By analyzing the pressure results was possible to identify areas of low or high pressure, which can indicate potential problems such as improper pipe sizing, pump inefficiency, or excessive demand. The results of two different scenarios were discussed below.

A. Basic scenario: constant pressure 24/24 hours for a simulation period of 7 days and the influence on the value of the recorded flow.

When the pressure is approximately constant at the value of 55.5 mCA for 24/24 hours, the flow rates recorded on each pipe section can be seen on the third simulation day out of the 7 simulated days, at 12:00 AM, in the figure 1. So, when a single pressure is set, for the node with the ID 8245, it can be observed that the recorded value of the pressure is almost constant and is in the range of 49.8 - 50.2 mCA, for the entire period of 7 simulated days [figure 2].

On the third simulation day out of the 7 simulated days, at 12:00 AM, for the pipeline with the ID 5436, it can be observed that the value of the recorded flow rate is 32.90 m^3/h [figure 3]. The present analysis strictly refers to the time interval 23:00-04:00, as night flows tend to be constant and show similar hourly variations, including in the long term.

A detail of the minimum flow recorded during the simulated period during the night time, for the pipe with the ID 5436 can be seen in the figure 4.

In this scenario, 2.54 Kw-hr/m^3 is consumed in the pumping station for supplying water to the system, according to the figure 5.

B. The scenario by applying two pressure settings during 24 hours for a simulation period of 7 days and the influence on the value of the recorded flow

To optimize this district metered area, the proposed solution following the simulation of the calibrated hydraulic model is to set pressure in the system according to consumption.

Because, in any network, the pressure increases during the night since there is no consumption, an effective measure is to reduce the pressure for a few hours.

Thus, for the group of pumps in this area, the pressure was set to two values, 55.5 mCA for the time interval 04:00-23:00 and 50.5 mCA for the time interval 23:00-04:00 [figure 6].

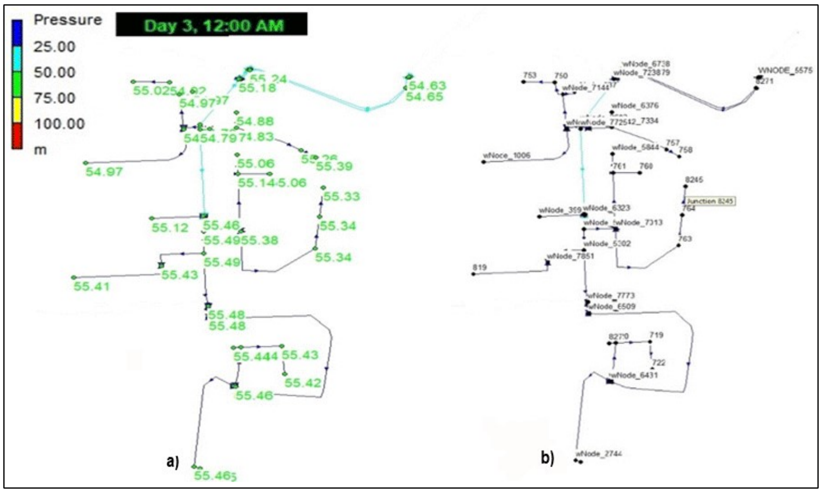

Fig. 1. Recorded pressure values:
a – pressure values recorded for the third day out of 7 days at 12:00 AM; b – the ID of the junctions in the water distribution system.

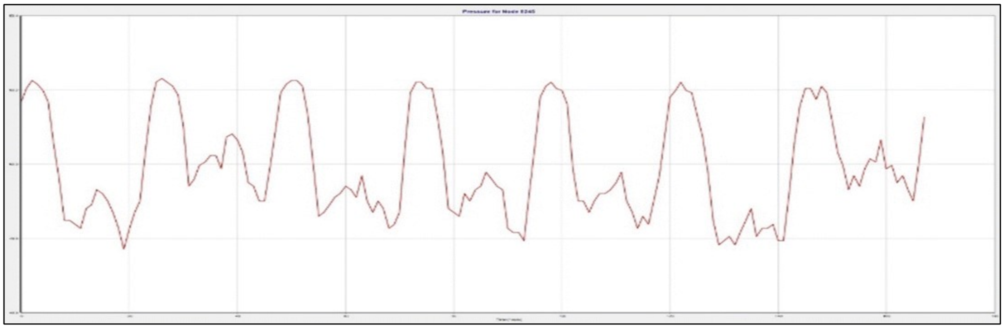

Fig. 2. Pressure details for extended simulation (7 days), for the node with ID 8245

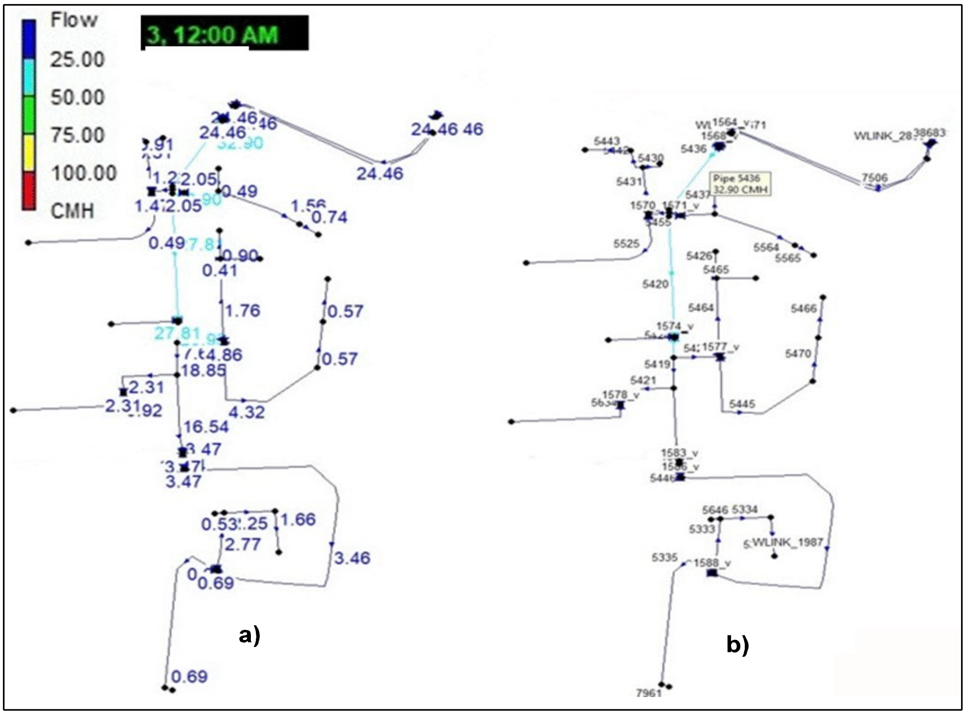

Fig. 3. Recorded flow rates:
a – flow rates recorded for the third day out of 7 days at 12:00 AM;
b – the ID of the pipes in the water distribution system.

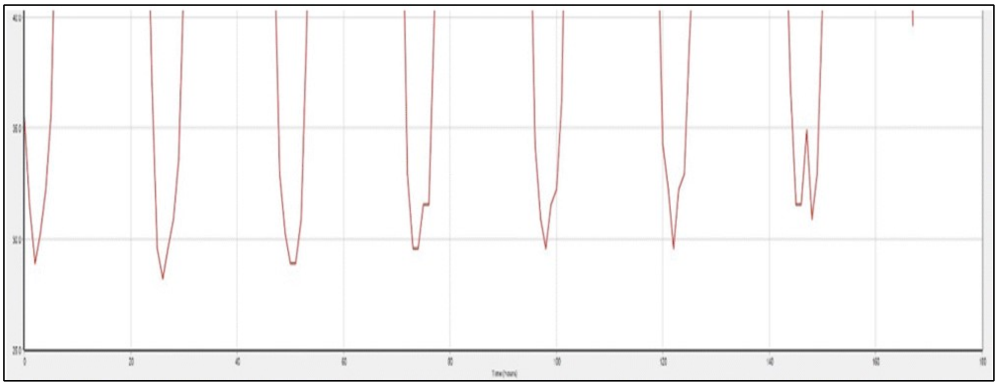

Fig. 4. Flow rates details for extended simulation (7 days), for the pipe with ID 5436

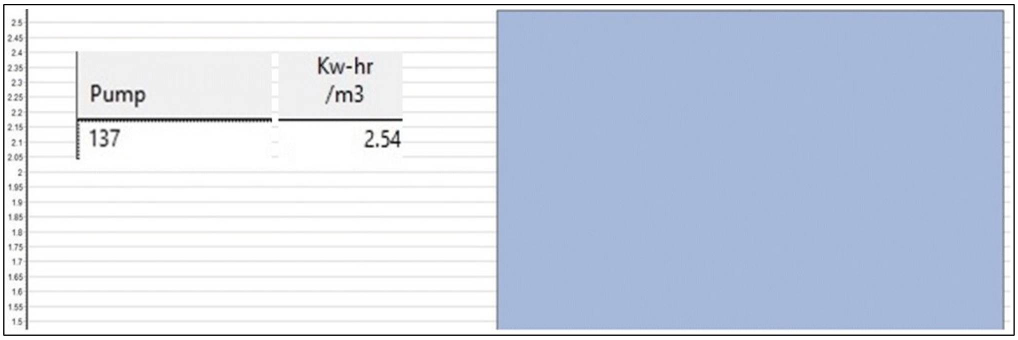

Fig. 5. Recorded values of electrical energy for the pumping group

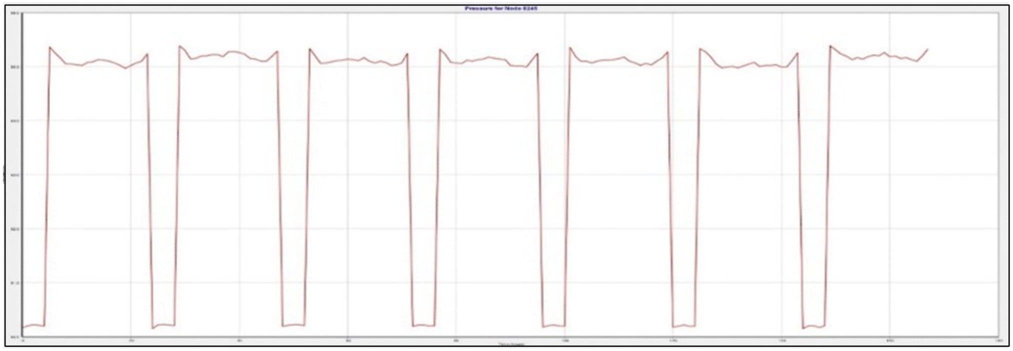

Fig. 6. Pressure details for extended simulation (7 days), for the node with ID 8245

The scenario realized and already put into practice, following the calibration process of the built hydraulic model, simulates the pressure management in the pipeline network by implementing the pressure setting at two values, day and night, and highlighting the impact on the system performance.

So, when the pressure is set with two values, for the node with ID 8245, it can be seen the recorded pressure values on the third simulation day out of the 7 simulated days, at 12:00 AM, in the figure 7.

Following the simulations in the EPANET program [Rossman, L A], it was concluded that reducing the pressure by 5 mCA in the time interval 23:00-04:00 does not negatively influence the system, but on the contrary, the measure is extremely useful.

First of all, the basic condition related to the providing of water supply in all nodes is respected, which is demonstrated by figure 6 where it is observed that the fluctuations are in the range of 50.30 mCA - 49.43 mCA. Thus, ensuring pressure in all nodes, including the critical point, reflects the success of this measure.

After applying pressure management, on the third simulation day out of the 7 simulated days, at 12:00 AM, for the pipeline with the ID 5436, it can be observed that the value of the recorded flow rate is 31.23 m^3/h [figure 8].

As a result of this measure, a reduction ofthe minimum flow recorded during the simulated period during the night, for the pipe with ID 5436, can be seen in the figure 9 compared to the base scenario. In this scenario, 2.41 Kw-hr/m^3 is consumed in the pumping station for supplying water to the system, according to the figure 10.

4. Conclusions

The conclusion is that, according to the simulations carried out, the impact of the pressure reduction on the minimum night flow and the benefits of this measure are clearly observed, and if a calculation is made, it would result in a reduction of the flow distributed in this DMA by 5.08%. At the same time, another great and extremely important advantage through the implementation of this measure is the reduction of the electricity consumption required for water supply, which is practically lost and does not bring any income.

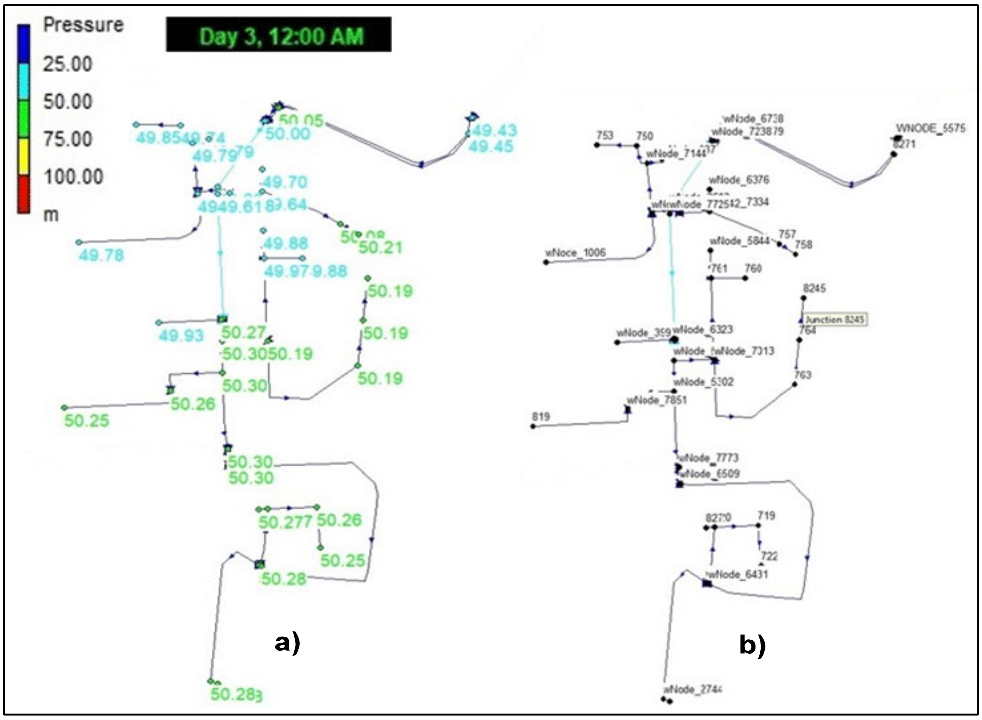

Fig. 7. Recorded pressure values:
a – pressure values recorded for the third day out of 7 days at 12:00 AM; b – the ID of the junctions in the water distribution system.

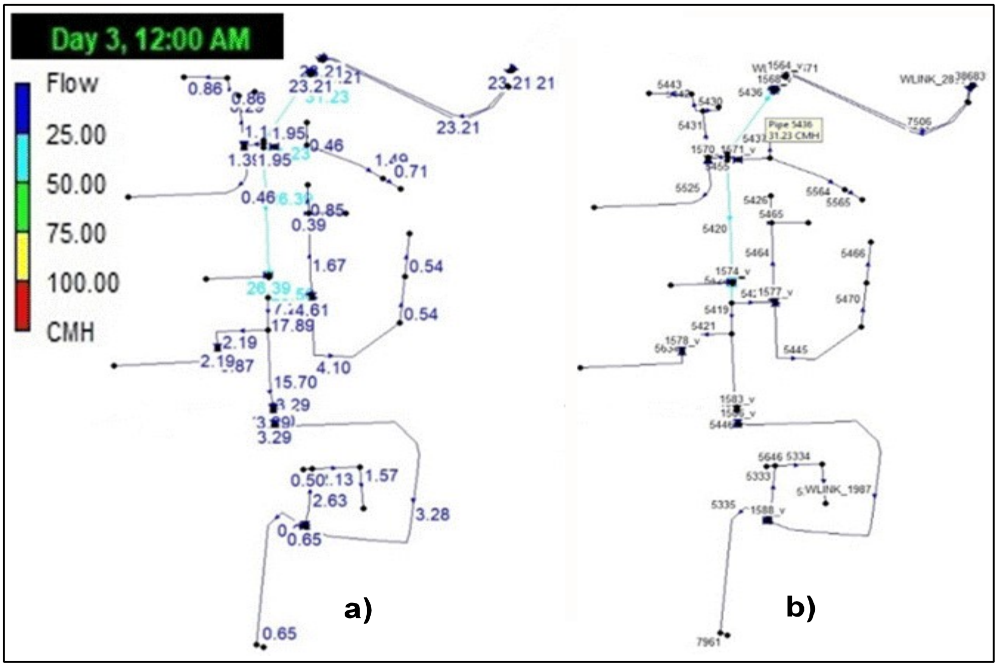

Fig. 8. Recorded flow rates:
a – flow rates recorded for the third day out of 7 days at 12:00 AM; b – the ID of the pipes in the water distribution system.

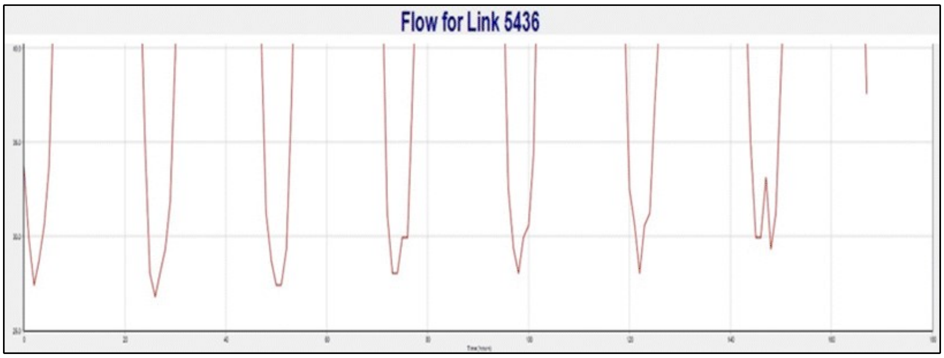

Fig. 9. Flow rates details for extended simulation (7 days), for the pipe with ID 5436

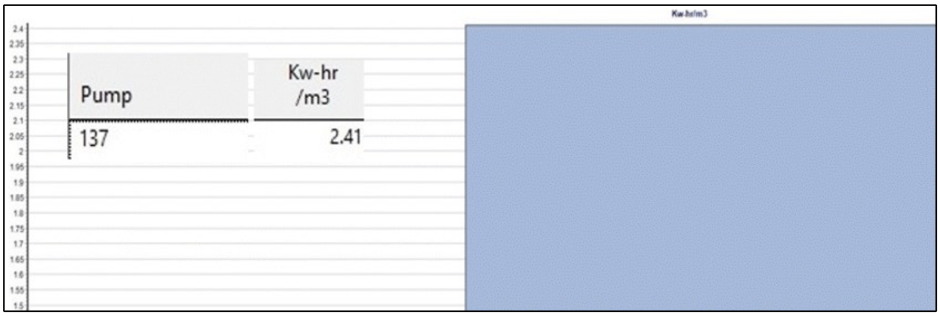

Fig. 10. Recorded values of electrical energy for the pumping group

For the presented case study, if a calculation is made per Kw-hr/m3, because of the application of pressure management, regarding the electrical energy required for pumping water in the distribution system, it results a reduction of 5.39%.

Although there is still much work to be done to refin e the optimization framework, simulations show promising results with the proposed system.

Energy optimization is very important for the efficient operation of the water system due to the increasing cost of energy. Energy optimization involves a delicate balance between supply, pumping and storage, based on cost differences between different energy sources, by type.

References

1. Giurma, I., Crăciun I., *Managementul integrat al resurselor de apă*, Ed. Politehnium, Iaşi, 2010;
2. Crăciun I., Giurma, I., Giurma-Handley C.R., Telişcă M., *Integrated quantitative and qualitative monitoring system of water resources,* 6th International Conference on the management of technological changes, 3-5 sep., 2009, Alexandroupulis, Greece;
3. Giurma I., Giurma-Handley C.R., *Elemente de hidrologie avansată*, Ed. Performatica, Iaşi, 2022;
4. Adedeji, K.B., Hamam, Y., Abe, B.T., Abu-Mahfouz, A.M. - *Pressure Management Strategies for Water Loss Reduction in Large-Scale Water Piping Networks*: A Review. In Advances in Hydroinformatics, Springer: Singapore, pp. 465–480, 2018;
5. Campisano, A., Modica, C., Reitano, S., Ugarelli, R., Bagherian, S. - *Field-oriented methodology for real-time pressure control to reduce leakage in water distribution networks*. J. Water Resour. Plan. Manag. 2016, 142, 04016057;

6. Fanner P.V., Sturm R., Thornton J., Liemberger R. - *Leakage Management Technologies*, AWWA Research Foundation Denver, Colorado, U.S.A., AWWA Research Foundation, American Water Works Association and International Water Association (IWA), 2007;
7. Giurma, I., *Water management system*, Ed. Press, Iaşi, 2000;
8. Giurma-Handley, C.R., *Modele numerice de simulare a curgerii apelor subterane şi transportului de poluanţi în acvifere*, Ed. Politehnium, Iaşi, 2006;
9. Giurma-Handley C.R., Crăciun I., Giurma I., Telişcă M., *Modelling techniques of the groundwater pollution risk*, 6th International Conference on the Management of Technological Changes, 3-5 sep 2009, Alexandroupolis, Greece, 2009;
10. Koşucu, M.M., Demirel, M.C. - *Smart pressure management extension for EPANET*: Source code enhancement with a dynamic pressure reducing valve model. J. Hydroinform. 24, pp. 642–658, 2022;
11. Moslehi, I., Ghazizadeh, M.J., Yousefi-Khoshqalb, E. - An economic valuation model for alternative pressure management schemes in water distribution networks. Util. Policy 67, 101129, 2020;
12. Mutikanga, H.E. - *Water Loss Management: Tools and Methods for Developing Countries*, Master of Science in Sanitary Engineering UNESCO-IHE, the Netherlands, 2012;
13. Rossman, L A. EPANET 2 USERS MANUAL. U.S. *Environmental Protection Agency*, Washington, D.C., EPA/600/R-00/057, 2000;
14. Vicente, D.J., Garrote, L., Sanchez, R., Santillan, D. - *Pressure Management in Water Distribution Systems: Current Status, Proposals, and Future Trends*. J. Water Resour. Plan. Manag. —ASCE 142, pp. 13, 2016.