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Editorial

Advances in Leakage Control and Energy Consumption Optimization in Drinking Water Distribution Networks

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1. Introduction

Water is an essential element for life. Humans, since their origin, have developed their existence in the environment of rivers, lakes or springs from which to obtain water. Over the course of time, taking into account its importance for the development of societies and their economy, humans have developed water purification systems that allow its consumption and have channeled it through piping systems capable of transporting water under pressure to the different urban areas [1–3].

Importantly, Sustainable Development Goal 6 aims to achieve universal and equitable access to safe drinking water and adequate sanitation and hygiene and to improve water quality globally. To this end, the water utilities must sustainably manage water resources in the creation of its products and services [4].

Different authors have focused on the study of water leakage in piping systems. The difference between the amount of water that leaves a treatment plant to the distribution system and the water that is registered by the metering systems by the users is known as water losses. Controlling these losses is an important part of a water efficiency program, as they can be a significant cost overrun for water utility operators [5–8].

The proper management of these leaks is important because: (a) it avoids treating and pumping additional volumes of water, (b) leaks introduce air into the system, increasing energy consumption, making flow meters unreliable and increasing oxidation in the system due to the presence of air, (c) it causes damage to the foundations of buildings, (d) it overloads the sewerage networks, (e) it reduces the service pressure and (f) it increases the probability of the contamination of the transported water [9,10].

Therefore, pressure management in drinking water distribution systems is internationally recognized as one of the key activities in the reduction in water losses. It also has a direct impact on the reduction in the frequency and occurrence of breaks in distribution networks and associated elements [5,11,12].

Drinking water distribution systems are designed to meet certain service standards. One of these is to ensure a minimum operating pressure at all points in the network 24 h a day.

In the distribution system, the minimum pressure is generally only reached at certain critical points in the network due to their altimetric position, their distance from the water source or the demand pattern of the network. Additionally, water distribution networks are subject to peaks of demand. For residential areas, these peaks usually occur in the morning and afternoon hours; generating the amount of water that the system distributes varies from one day to another. Water distribution networks also have periods of low consumption, mainly during the night and certain hours of the day. Considering that the system is designed to ensure minimum pressure throughout the day, this same minimum is only really reached during short periods of time that coincide with peaks in system demand; this design results in the distribution system being subject to excessive pressures for a large part of the day [13].

Figure 1 shows the principal keywords related to advances in leakage control and energy consumption optimization in drinking water distribution networks.

Figure 1. Principal keywords on advances in leakage control and energy consumption optimization in drinking water distribution networks.

2. Pressure Management Methods in Water Distribution Networks to Reduce Leakage

According to the International Water Association (IWA), pressure management consists of managing the pressure of a system at an optimum level and ensuring sufficient and efficient service to legitimate uses and consumers, while, at the same time, it facilitates the reduction in unnecessary or excessive pressures and the elimination of transient phenomena that are affecting assets lifespan, as both have direct negative impacts on physical efficiency [7].

One of the methods used for pressure management is the use of storage tanks to optimize water levels, so that the lowest level is maintained at night because demand is lower and less pressure is required [14].

Another possible method involves programming and optimizing the operation of pumps but has the disadvantage of the energy cost associated with the use of these elements [15].

The most common and cost-effective method is to use pressure reducing valves, which reduce a high inlet pressure to a lower outlet pressure. By adding electronics to the valves, the pressure in the zone can be adjusted according to real-time data collected at strategic points, thus adapting to demand. The pipeline network will, therefore, be protected against overpressure and stress, which increases the lifetime of the system and reduces the overall leakage rate [16].

Figure 2 shows the main pressure management methods used in water distribution networks to reduce leakage.

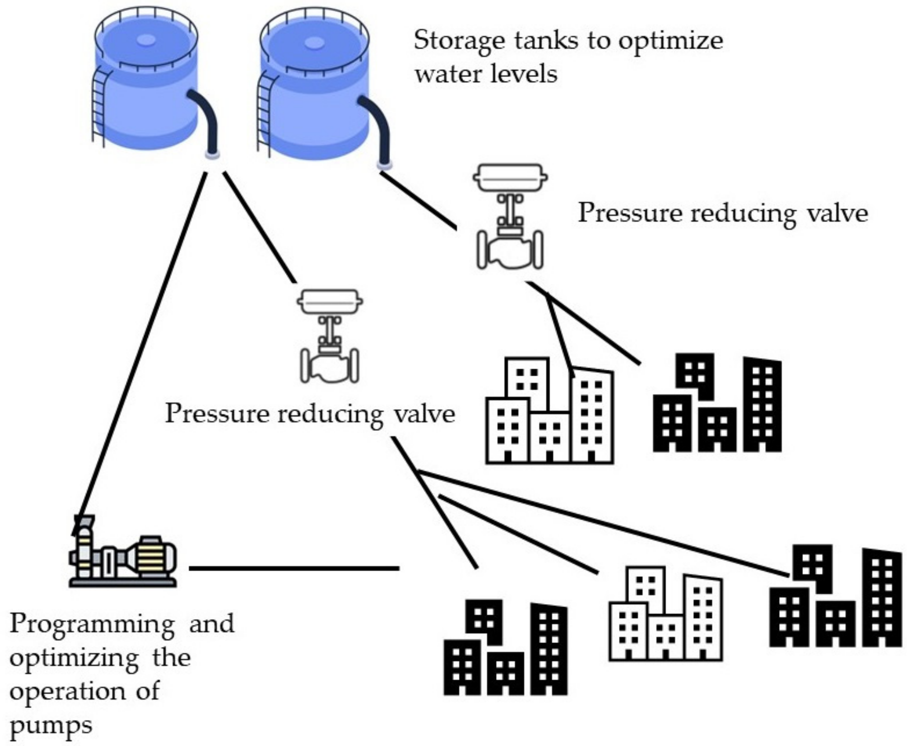

Figure 2. Principals pressure management methods in water distribution networks to reduce leakage.

In this field, the following scientific contributions for the optimization of pressure to reduce leaks in drinking water networks are worth mentioning:

Puleo et al. [17] propose different measures to improve the water supply system in the city of Palermo. The different improvements should achieve lower energy consumption, reduction in water leakage and reduction in greenhouse gas emissions, specifically CO.

De Marchis et al. [18] study the installation of pumps as turbine (PATs) that harness excess pressure in the water supply system to produce renewable energy. To do so, they analyze, by means of a mathematical model, the installation of this type of pump in a water distribution system, which features private tanks that store water for times of shortage, demonstrating the advantage of this type of pump.

Fagiani et al. [19] carried out a study by applying various statistical models that allow water and gas supply networks to be transformed into intelligent networks, just like electricity distribution networks, thus identifying leaks. The study is carried out both in residential environments and in office buildings. It is in the latter environment that the proposed approach obtains the best results.

Shao et al. [20] employ a genetic algorithm considering, as decision variables, the position and configuration of gear pumps and the working state of variable speed gear pumps to reduce losses and energy consumption. They conclude that by acting jointly on the decision variables and not acting separately, they achieve the best results for the set objectives.

Gupta et al. [21] also use and modify a genetic algorithm to decide the position of pressure reducing valves in a real network. With the modification of the algorithm, the number of ideal positions of where to place the valves for improved pressure management in the network is reduced from 22 to 4, and the leakage in the network is reduced by 20.08%.

Pietrucha-Urbanik et al. [22] developed a methodology for failure mode analysis of water leakage in order to develop new strategies for water supply system management in normal operation and in crisis situations.

Macharia et al. [23] conducted a study on the current status of water demand and associated energy demand for water supply in sub-Saharan Africa. They also studied the expected increase in water demand and calculated a potential leakage reduction in the water supply system of up to 70% and energy savings of up to 12 MWh/year.

Morani et al. [24] study a new design for a turbine to improve the efficiency of hydroelectric power plants. They use computational fluid dynamics together with experimental tests to study the performance of the new turbine. In the last stage of the study, the scale and position of the centrifugal microturbines and pressure reducing valves in a real distribution network are optimized.

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References

1. Nayl, A.A.; Abd-Elhamid, A.I.; Awwad, N.S.; Abdelgawad, M.A.; Wu, J.; Mo, X.; Gomha, S.M.; Aly, A.A.; Bräse, S. Review of the Recent Advances in Electrospun Nanofibers Applications in Water Purification. *Polymers* **2022**, *14*, 1594. [CrossRef] [PubMed]
2. Padilla González, P.; Bautista-Capetillo, C.; Ruiz-Canales, A.; González-Trinidad, J.; Júnez-Ferreira, H.E.; Contreras Rodríguez, A.R.; Robles Rovelo, C.O. Characterization of Scale Deposits in a Drinking Water Network in a Semi-Arid Region. *Int. J. Environ. Res. Public Health* **2022**, *19*, 3257. [CrossRef] [PubMed]
3. Hewawasam, V.; Matsui, K. Traditional Water Governance Practices for Flood Mitigation in Ancient Sri Lanka. *Climate* **2022**, *10*, 69. [CrossRef]
4. ONU. Available online: https://www.un.org/sustainabledevelopment/es/objetivos-de-desarrollo-sostenible/ (accessed on 18 July 2022).
5. Mathye, R.P.; Scholz, M.; Nyende-Byakika, S. Optimal Pressure Management in Water Distribution Systems: Efficiency Indexes for Volumetric Cost Performance, Consumption and Linear Leakage Measurements. *Water* **2022**, *14*, 805. [CrossRef]
6. Zaman, D.; Gupta, A.K.; Uddameri, V.; Tiwari, M.K.; Sen, D. Exploring the key facets of leakage dynamics in water distribution networks: Experimental verification, hydraulic modeling, and sensitivity analysis. *J. Clean. Prod.* **2022**, *362*, 132236. [CrossRef]
7. Ortega-Ballesteros, A.; Manzano-Agugliaro, F.; Perea-Moreno, A.-J. Water Utilities Challenges: A Bibliometric Analysis. *Sustainability* **2021**, *13*, 7726. [CrossRef]
8. Li, X.; Wu, X.; Sun, M.; Yang, S.; Song, W. A Novel Intelligent Leakage Monitoring-Warning System for Sustainable Rural Drinking Water Supply. *Sustainability* **2022**, *14*, 6079. [CrossRef]
9. Zhou, M.; Xu, Y.; Cui, B.; Hu, Y.; Guo, T.; Cai, Y.; Sun, X. Pipeline Leakage Detection and Localization Using a Reliable Pipeline-Mechanism Model Incorporating a Bayesian Model Updating Approach. *Water* **2022**, *14*, 1255. [CrossRef]
10. Gheibi, M.; Eftekhari, M.; Akrami, M.; Emrani, N.; Hajiaghaei-Keshteli, M.; Fathollahi-Fard, A.M.; Yazdani, M. A Sustainable Decision Support System for Drinking Water Systems: Resiliency Improvement against Cyanide Contamination. *Infrastructures* **2022**, *7*, 88. [CrossRef]
11. Ramos, H.M.; McNabola, A.; López-Jiménez, P.A.; Pérez-Sánchez, M. Smart Water Management towards Future Water Sustainable Networks. *Water* **2020**, *12*, 58. [CrossRef]
12. Bakker, M.; Rajewicz, T.; Kien, H.; Vreeburg, J.H.G.; Rietveld, L.C. Advanced control of a water supply system: A case study. *Water Pract. Technol.* **2014**, *9*, 264–276. [CrossRef]
13. Ramos, H.M.; Morani, M.C.; Carravetta, A.; Fecarrotta, O.; Adeyeye, K.; López-Jiménez, P.A.; Pérez-Sánchez, M. New Challenges towards Smart Systems' Efficiency by Digital Twin in Water Distribution Networks. *Water* **2022**, *14*, 1304. [CrossRef]
14. Mabrok, M.A.; Saad, A.; Ahmed, T.; Alsayab, H. Modeling and simulations of Water Network Distribution to Assess Water Quality: Kuwait as a case study. *Alex. Eng. J.* **2022**, *61*, 11859–11877. [CrossRef]
15. Dini, M.; Hemmati, M.; Hashemi, S. Optimal Operational Scheduling of Pumps to Improve the Performance of Water Distribution Networks. *Water Resour. Manag.* **2022**, *36*, 417–432. [CrossRef]
16. García-Ávila, F.; Avilés-Añazco, A.; Ordoñez-Jara, J.; Guanuchi-Quezada, C.; Flores del Pino, L.; Ramos-Fernández, L. Pressure management for leakage reduction using pressure reducing valves. case study in an andean city. *Alex. Eng. J.* **2019**, *58*, 1313–1326. [CrossRef]
17. Puleo, V.; Sambito, M.; Freni, G. An Environmental Analysis of the Effect of Energy Saving, Production and Recovery Measures on Water Supply Systems under Scarcity Conditions. *Energies* **2015**, *8*, 5937–5951. [CrossRef]

18. De Marchis, M.; Milici, B.; Volpe, R.; Messineo, A. Energy Saving in Water Distribution Network through Pump as Turbine Generators: Economic and Environmental Analysis. *Energies* **2016**, *9*, 877. [CrossRef]
19. Fagiani, M.; Squartini, S.; Gabrielli, L.; Severini, M.; Piazza, F. A Statistical Framework for Automatic Leakage Detection in Smart Water and Gas Grids. *Energies* **2016**, *9*, 665. [CrossRef]
20. Shao, Y.; Yu, Y.; Yu, T.; Chu, S.; Liu, X. Leakage Control and Energy Consumption Optimization in the Water Distribution Network Based on Joint Scheduling of Pumps and Valves. *Energies* **2019**, *12*, 2969. [CrossRef]
21. Gupta, A.; Bokde, N.; Kulat, K.; Yaseen, Z.M. Nodal Matrix Analysis for Optimal Pressure-Reducing Valve Localization in a Water Distribution System. *Energies* **2020**, *13*, 1878. [CrossRef]
22. Pietrucha-Urbanik, K.; Tchórzewska-Cieślak, B.; Eid, M. Water Network-Failure Data Assessment. *Energies* **2020**, *13*, 2990. [CrossRef]
23. Macharia, P.; Kitaka, N.; Yillia, P.; Kreuzinger, N. Assessing Future Water Demand and Associated Energy Input with Plausible Scenarios for Water Service Providers (WSPs) in Sub-Saharan Africa. *Energies* **2021**, *14*, 2169. [CrossRef]
24. Morani, M.C.; Simão, M.; Gazur, I.; Santos, R.S.; Carravetta, A.; Fecarotta, O.; Ramos, H.M. Pressure Drop and Energy Recovery with a New Centrifugal Micro-Turbine: Fundamentals and Application in a Real WDN. *Energies* **2022**, *15*, 1528. [CrossRef]