Rocznik Ochrona Środowiska

Volume 23 Year 2021 ISSN 1506-218X pp. 883-890

https://doi.org/10.54740/ros.2021.060 open access

Received: 11 November 2021 Accepted: 04 December 2021 Published: 06 December 2021

Remote Reading of Water Meters as an Element of a Smart City Concept

Tomasz Cichoń
The City of Krakow Waterworks, Poland

*Jadwiga Królikowska**
Faculty of Environmental and Power Engineering,
Cracow University of Technology, Poland
https://orcid.org/0000-0003-1043-7807

**corresponding author's e-mail: j.kapcia@upcpoczta.pl*

Abstract: The provisions of the European law have defined "Smart Metering" as a tool for remote meter readings and management of energy networks. Currently, after years of research and many real-life applications, it is one of the most popular solutions that defines friendly and modern cities. Similarly to automatic street lights, traffic signals or waste management systems, monitoring and control of water supply and sewage systems significantly improves the quality and comfort of life of city residents. The city infrastructure managers may use it as a tool that primarily allows for some cost savings and better resource management. The paper describes a remote transfer of water meters data through the Internet of Things technology. Also additional options have been presented, which are available once the data on water demand has been acquired. They can be communicated to other clients, e.g. other municipal services, as an element of Smart City, and to the customers. Thanks to this technology, the customers may analyze and better manage their actual water consumption trying to optimize it. Over time, it seems that saving water has become not only a fashionable whim but a trend to stay.

Kaywords: smart city, water meter, reading

1. Introduction

Metering of water supplies (as a part of metrology) has been developing since only municipal water systems have been organized, so over a hundred years. First information about water meters appeared in publications in the late 19th century. At the beginning, water meter was used for correct billing for water supply services. Measuring and counting mechanisms used in water meters undergo continuous upgrading to increase their efficiency and reliability. What has remained unchanged is their purpose; water meters measure the volume of water consumed by the customer. In the 21st century, global digitization creates a new dimension for the use of water meters. It is a remote transfer of water meter readings, together with current water consumption analysis and early notification about possible emergency alarms. A possibility to record the data in short intervals throughout the day and then report them regularly to the supplier has created completely new options for data management. The water consumption data are also made available for the consumers, at their premises. (Billewicz 2011, Cichoń & Królikowska 2019).

The amount of water consumed by a statistical resident has been changing over the last several decades. First of all, it depends on the standard of household appliances as well as available services, e.g. sewage system. In Poland, until the late 1980s, the economic factor in water consumption was of a rather minor importance; water consumption increased as new properties were connected to water supply networks. Once a market economy was introduced and a water price followed real production and distribution costs, water consumption started to decrease. Actually, the City of Kraków Waterworks observed this trend until the second decade of the 21st century. The annual water production since the very beginning of the City of Krakow Waterworks operation is shown in Figure 1.

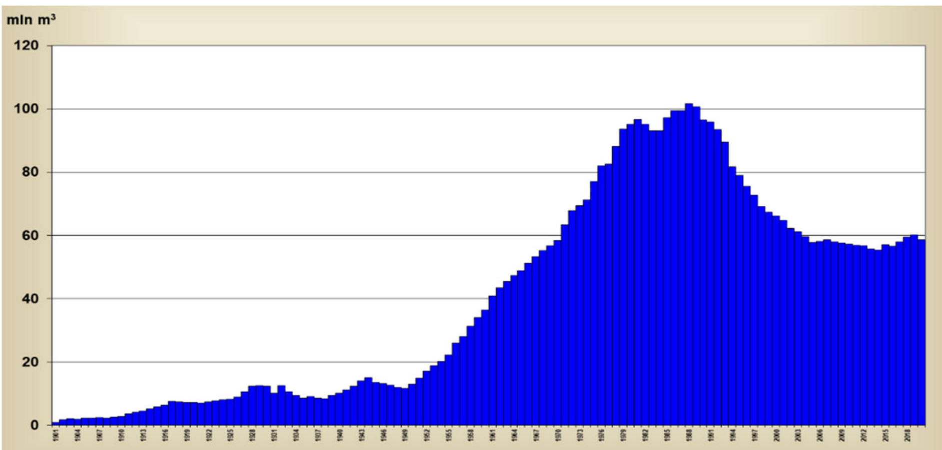

Fig. 1. Annual production of water at the City of Krakow Waterworks in years 1901-2020

However, not only economy has an impact on a lower water consumption. The new decisive factor is environmental awareness. The popular household appliances are not only more energy- efficient, they also consume less and less water, e.g. in washing or dishwashing cycles. All this means that even though the actual real number of residents served by the system becomes higher, the water demand remains constant, or only slightly increases (A).

The analysis of the water production at the City of Krakow Waterworks have exposed completely new relationships and trends that emerged during the COVID-19 coronavirus pandemic. Imposed restrictions and a shutdown of many industries resulted in a clear revision of consumers habits concerning a water demand. The largest drop in consumption was observed in services related to tourism and education, which remained closed for some time. It is a large group of consumers that includes hotels, restaurants, public utility facilities and schools of all levels, universities and dormitories. Also many corporations working mainly in large office buildings sent their employees back home to work remotely. This in turn, resulted in a higher water consumption in households while in office buildings a water demand dropped down. One should also notice a substantial migration outside the cities. As a result, a water demand in neighboring communes, located around large cities, has increased significantly. Pandemic-related changes observed in a water demand are difficult to accurately analyze since water consumption readings, in case of multiple consumers, have been collected only once per the accounting cycle.

2. Water consumption readings vs billing for services and reduction of water losses

Water consumption readings are carried out by residents, as specified in the contract; usually, the readings are done in monthly or longer periods of time. The billing systems convert consumption into daily average values, however, these are just approximate and not actual values. Such data is sufficient for selection of a water meter or for monitoring of consumption trends during the period of normal water consumption. However, such a system is obviously insufficient if more accurate metering of water consumption is required as well as more precise analysis of its different aspects. Management of municipal infrastructure, which primarily means savings and better management of resources, is undoubtedly one of such aspects.

Water resources protection has become increasingly important in recent years and as such it demands reduction of water losses. Poland, similar to other European Union countries, is obliged to rationally use and protect water resources following the principles of sustainable development, i.e. while improving the quality of life, one should not intrude upon the natural environment, in particular water resources (Jakuta 2015). Approximately 40% of population have a limited access to drinking water while about 20% of the world's population do not have access to clean drinking water at all. The countries of northern and central Africa, South America and Central Asia are most severely affected by the water deficit. Also, water resources of Poland are not sufficient; their average size is about 62 km^3 while the more difficult renewable groundwater resources are estimated at about 16 km^3. According to the European Commission, the annual volume of water per person in Poland was 1580 m^3 (year 2009); such value is three times lower than the European average (4580 m3) and 4.5 times lower than the world's average (Skwarzyńska et al. 2014).

Combination of the diagnostic system and a well-tuned model of the water supply system (working in real time) enables a precise detection, localization and determination of the size of the leak, thus reducing water losses. Hence, a careful monitoring and measurements of water consumption will also contribute to protection of water resources (Cichoń & Królikowska 2018).

A precise measurement system, operating in real time, is essential for operation of the diagnostic system. To obtain sufficient number of data on water consumption and balance the flow in the network divided into zones, it is necessary to collect readings from consumers' water meters at least in daily intervals. Daily water consumption and daily readings from water meters are have to be compared with a water volume pumped into the distribution system in order to get the system balanced. The balance should be made at the beginning of each day on the basis of data collected at midnight. Then, it is possible to compare the volume of water that has flowed to individual network nodes with the volume showed on the main water meters, at the customer's premises. Once the threshold values for individual zones are determined, the water balance should not be altered by fluctuations observed at the individual water meters. On the other hand, a higher water flow into a given zone that is not balanced with water meter readings points to the failure risk in the zone. As the automatic reading of water meters at the customers premises is implemented, the system will bring more accurate and real data on current water losses in individual zones on a daily basis.

Remote readings of water meters not only resulted in a faster and better access to meter readings at the customer premises, but also provided other valuable information (Kubiak & Urbaniak 2013, Kubiak & Urbaniak 2015). The system, comprising electronic modules (overlays) installed on water meters, allows to monitor an instantaneous water consumption; it also detects and stores emergency alerts or any abnormal situations that are observed in the system. The information on alerts (failures) is valuable not only for the water company, but also for the consumer, who this way can be aware of a failure at a very early stage and may limits its potential effects. The effects could be either financial (for the client or the company) or can be related to the water resources management. Modules furnished with a memory function may store both measurements and time of their occurrence, i.e. to record measurement data. Such registration can be a helpful option in situations when the consumer questions readings from the measuring devices. The meters supported by data transmission modules are also more resistant to unauthorized interference and to errors and distortions in the reading process. All of these features allow for implementation of advanced technologies to reduce the volume of water that does not create profit as well as water losses; it applies to both hardware and software technologies, based on data analysis.

3. Water consumption as an input parameter for city life modeling

When only mechanical devices were used as popular meters, reading of instantaneous flows required professional tools or it was impossible. Information about the actual instantaneous water demand is necessary for a successive monitoring of guidelines for selecting a water meter, sizing of connections, but also for calculating an actual capacity of the existing pipes. It applies to both the current real-life situation and forecasts for the future designs. New algorithms for modeling water supply networks offer much better results when they work on real measurement data; that is why there is a huge demand for more and more frequent readings from the water meters.

On the other hand, the read-out data is available only once per accounting period and that is the main limitation in verification of network models. It turns out that data on daily water consumption, developed for balancing water consumption and water losses, is insufficient and using hourly readings would be better option. Such approach is not impossible, but it requires a more advanced reading databases and tools for their management (Kubiak et al. 2016).

Water meter readings are needed not only for the water utilities (billing for the services), but they also may help to more accurately synchronize functions of the city, as a whole. In the era of development of cities and their advanced services, management of the city's organism as a system of intelligent connections becomes more and more important (Billewicz 2011). Such phenomenon is the widely known as the idea of Smart City.

Water consumption is related more to the presence of people than other utilities. While in the case of electricity or gas, their consumption may be related to operation of automatically controlled systems (e.g. heating) not always directly related to the presence of residents at home, water consumption almost always results from operation of man-operated water intake points. This means that tracking down a water consumption can be correlated with tracking of people's movement, e.g. between home and workplace. This cannot be said for electricity, especially because of the widespread use of renewable electricity sources, which make households prosumers of energy. Thus, the demand for water verifies the actual number of people staying at a given property or in agiven area of the city. Currently, more and more cities ties charges for waste disposal with the amount of water used. For example, Łódź estimated that tens of thousands of residents have disappeared from the of waste collection system. In 2016, the system recorded 675,000 residents while in 2020 only 615,000. In recent years, water consumption in the city remained at a similar level, which

means that the population in Łódź has not decreased – contrary to declarations submitted to the City of Łódź Office (https://www.teraz-srodowisko.pl/aktualnosci/oplata-opdady-dla-inhabitants-zuzycie-water-Warsaw-Lodz-9628.htm).
Each water company may collects such data about customers, but there is a formal limitation related to the privacy issues and solutions complying with the provisions on the protection of personal data (GDPR) have to be respected.

Another more advance example is the use of water consumption data for modeling of resident migration within the city. Various institutions have showed interest in such an issue and it is becoming more and more popular with time. Companies and organizations that deal with specific public services, e.g., modeling of a public transport system where intelligent solutions are often used, turn to water utilities. Such systems may help to improve both a traffic flow and a travel comfort, as well as a comfort of living in the entire city (e.g. when limited traffic zones are created). As part of this task, special maps with grids of settlements or areas characteristic for the people relocations are prepared.

There are three main constraint factors in applying the water consumption data. The first one are the GDPR requirements, which severely limit the rights of water and sewage companies to share knowledge about water consumption. To do so, they have to inform residents and obtain their consent to share the data and also they have to protect the data against unauthorized use e.g. giving away information about the absence of residents at home.

The second limitation is a difference in a spatial distribution of the water supply network and road and communication system. Due to this limitation, data on water intake from nodal points of the water supply network (e.g. entire housing estates) is usually insufficient and data from individual properties has to be collected and then analyze in particular sub-classes, characteristic for the area served by individual stops.

The third limitation involves frequency of data collection. Daily data collections were defined as a target frequency for the water supply system. For migration modeling purposes, such frequency is completely insufficient and data collection at least on an hourly basis is required. Such limitation may be of crucial importance if there is no access to stationary data transfer technologies, i.e. the Internet of Things (IoT) technology. The technology allows for a frequent transmission of small packages of data and this way one can process data collected even more often than every hour. To achieve such a goal it is necessary to build large databases and create efficient tools for data managing.

Another very valuable feature of using the IoT technology for transmission of data from water meters is the fact that consumers may analyze their water consumption; This way an environmental consciousness and a pro-environmental behavior related to a climatic footprint can be promoted in the households.

4. Conclusions

The use of the Internet of Things technology to collect water meters readings opens new, much wider possibilities of their application. While the daily data transfer has expanded possibilities of using the data for balancing water flows in the network, and thus for a successive monitoring of water losses, the IoT technology enables transfer in the hourly consumption data for modeling of the city, as a flexible but resistant structure. The SMART CITY is an expertise and interconnection that are driven by the use of technology and communication to solve urban issues. It combines many elements related to the economic, social and spatial zones and allows the city authorities for a systemic approach to the decision-making process. Currently, the idea of SMART CITY is based on IoT and intelligent computing methods used in the design and operation of water supply systems (Czapczuk et al. 2015, Dawidowicz 2012). Learning algorithms allow you to adapt in the process of operation on an ongoing basis to changing conditions.

Readings of water meters at consumers sites, at the smart city, not only help to protect water resources, but also provide information necessary for urban services, such as: transport or traffic management. By monitoring water consumption, residents save not only water but also energy.

References

Billewicz, K. (2011). *Smart metering – Inteligentny system pomiarowy*, Wydawnictwo Naukowe PWN, Warszawa.

Cichoń, T., Królikowska, J. (2016). Ewolucja procesu odczytu wodomierzy na podstawie doświadczeń Wodociągów Krakowskich, *Instal, 12*, 45-48.

Cichoń, T., Królikowska, J. (2018). Protection of water resources for sustainable development. *Desalination and Water Treatment, 128*, 442-449.

Cichoń, T., Królikowska, J. (2019). W jakim kierunku zmierza gospodarka wodomierzowa – szanse i zagrożenia wynikające z zastosowania elektronicznych liczników. *Instal, 11*, 51-54.

Czapczuk, A., Dawidowicz, J., & Piekarski, J. (2015). Artificial Intelligence Methods in the Design and Operation of Water Supply Systems. *Rocznik Ochrona Srodowiska, 17*, 1527-1544.

Dawidowicz, J. (2012). Expert System for Evaluation of Water Distribution System Created with an Inductive Inference. *Rocznik Ochrona Srodowiska, 14*, 650-659.

Jakuta, D. (2015). Woda surowcem bezcennym. *Wodociągi Kanalizacja, 5*, 6.

Koral, W. (2019). Wodomierze – nowoczesne rozwiązania. *Wodociągi-Kanalizacja, 4*, 42-44.

Kubiak, Z., Urbaniak, A. (2013). Inteligentny system pomiarowy – rozwój standardu, przykładowe rozwiązania. *Rynek Energii*, 43-49.

Kubiak, Z, Urbaniak, A. (2019). Smart Metering a woda. Mat. VIII Ogólnopolskiej KNT. Politechnika Śląska, Instytut Technologii Wody i Ścieków, Szczyrk 2015, *Instal, 5*, 23-27.

Kubiak, Z. et al. (2016). *Technologia Lora w kontekście sieci bezprzewodowych oraz Internetu przedmiotów w systemach pomiarowych przedsiębiorstw wodociągowych i kanalizacyjnych.* Mat. Konferencyjne Zaopatrzenie w Wodę, Jakość I Ochrona Wód, 605-622.

Skwarzyńska, A., Jóźwiakowski, K., Sosnowska, B., Pytka, A., Marzec, M., Gizińska, M., Szyszlak-Bargłowicz, J., Słowik, T. & Zając G. (2014). Jakość wód opadowych i ocena możliwości ich wykorzystania w indywidualnych gospodarstwach domowych. *Technologia Wody, 6*, 20-23.

https://www.teraz-srodowisko.pl/aktualnosci/oplata-opdady-dla-mieszkancow-zuzycie-wody-Warszawa-Lodz-9628.htm