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WATER LOSS REDUCTION AS A TOOL TO PROTECT WATER RESOURCES

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Abstract

Water consumption is constantly increasing, mainly due to population growth, and resources are unfortunately shrinking. It becomes necessary to save water. There are many forms of saving water by protecting its resources, e.g. limiting leaks (generating water losses) both in the installation and on the water supply network, limiting unreasonable needs (e.g. multiple use of packaging or other objects), use of rainwater. The article presents the possibilities offered by the metering of the entire water supply network and water consumption at consumers. For the assumed zone supplying a housing estate inhabited by about 2,200 people, the coefficient of unavoidable losses was determined.

Keywords: water losses, supply zone, water meter, metering

REDUKCJA STRAT WODY JAKO NARZĘDZIE DO OCHRONY ZASOBÓW WODNYCH

Abstrakt

Zużycie wody stale się zwiększa, głównie z powodu wzrostu liczby ludności, a zasoby niestety się kurczą. Konieczne staje się oszczędzanie wody. Wiele jest form oszczędzania wody chroniąc jej zasoby, np. ograniczenie wycieków (generujących straty wody), zarówno w instalacji, jak i na sieci wodociągowej, ograniczenie nieracjonalnych potrzeb (np. wielokrotne wykorzystanie opakowań lub innych przedmiotów), wykorzystanie wód opadowych. W artykule przedstawiono możliwości, jakie daje opomiarowanie całej sieci wodociągowej oraz zużycia wody u odbiorców. Dla przyjętej strefy zasilającej osiedle mieszkaniowe, zamieszkiwane przez około 2 200 osób określono współczynnik strat nieuniknionych.

Słowa kluczowe: straty wody, strefa zasilania, wodomierz, opomiarowanie

1. INTRODUCTION

Water losses have become a very important issue in water supply systems since they affect both water costs and financial conditions of water supply plants. The topic becomes even more important when, apart from economic conditions, other aspects are involved such as environmental costs, comprising: lost resources, electricity consumption and carbon dioxide emission during water treatment processes. Current consumption of water in the world grows faster than water resources restoration. Nearly a quarter of the world's population lives in countries with a high water stress; by 2025, as many as 3.5 billion people may experience water scarcity [1, 2].

That is why it is so important to quickly locate and remove water leaks and reduce them to the minimum level, specific to the water distribution system.

Most frequently, water losses in water networks are caused by: water leaks from pipes and fittings, water pipes failures (real losses) and inaccurate measurements (apparent losses) [3].

Reduction of water losses involves a variety of activities, including: better control of an every-day operation of a city water distribution system, effective leakage control, upgrading of technical conditions of pipes and fittings operating within a water supply network, as well as more accurate measurements of water supply and sales. Each of them, if systematically implemented, can bring the expected results. Actions focused on reduction of water losses should follow the strategy that allows for optimization of costs incurred by the water supply company [4, 5].

2. ELEMENTS OF THE WATER LOSS REDUCTION STRATEGY

Although each water supply system encounters both the phenomenon of Non Revenue Water (NRW) and water losses, every water utility has or should have a strategy of actions intended to reduce water losses and high levels of NRW.

In the guidelines of the International Water Association (IWA), the following methods of reducing non-revenue water have been identified: effective leakage control, satisfactory quality of water network repairs and a quick service response time, infrastructure maintenance and pressure management [2, 6].

Generally, the devices used to diagnose the water supply network are divided into devices for initial failure detection and devices for precise location of the failure. The initial location of the leak can be based on flow and pressure measurements in the network. Sudden and intense leakage causes the water intake to increase and the water pressure to drop immediately. A thermal imaging camera using thermal radiation, loggers, correlators or a geophone (acoustic methods) is often used to precisely indicate the location of a leak. Georadar surveys are an innovative and effective approach to detecting leaks [7, 8].

Translating this approach into a daily practice of water supply companies that operate the water infrastructure, metering systems and technological metering of the water networks, it is possible to identify areas of successive activities and analyses, e.g. division of a water supply system into metered zones (District Metered Area - DMA) or use of acoustic loggers. According to the saying that "when we don't measure something, we can't manage it", most activities should focus on metering and monitoring of the water network, from the point of a water treatment plant discharge to the last consumer [9,10].

Monitoring provides information on basic parameters and technical conditions of a water supply network and water connections; it also may serve as the basic tool for a diagnostic work. On other hand, it improves a water network management by providing a real and constantly updated picture of operational conditions of its individual elements. The monitoring system comprises: instruments for pressure and water flow measurements (installed at measuring sites), a system of data transfer and storage and a software. The software helps to collect and interpret the data as well as visualize the network with all its measuring points. The SCADA monitoring systems use various communication methods to exchange data with measuring devices. Data obtained at measuring points are used to supervise and control a distribution system operation. This way a quick decisions can be made regarding inspections carried out by water emergency services (so-called "an expert diagnosis of network conditions"). Based on the measurement data, some control signals are also developed, which are then passed to the actuators, such as gate valves, dampers or inverters [11].

A precise measurement system working in real time is essential for functioning of the diagnostic system. For automatic successive control of both apparent and real water losses, companies more and more often use readings from remote water meters as well as a division of the network into DMA zones. Each zone has flow meters located at the "entrances" and "exits" from the zone, as well as a remote main water meter reader. This way the water balance can be monitored by comparing the volume of incoming and outgoing water as well as taking into account water sales in the zone. In addition, the system tracks night water flows, which are analyzed daily. The metering system uses water meters with a data recorder function (GSM/GPRS recorders) to track water distribution in a given period; while selecting the size and type of water/flow meter, the ratio of leakage to customer demand should be checked. Setting consumption point structures and grouping them into DMA zones is done using an IT tool. For each zone, the IT system can conduct successive analyzes of the water balance and individual consumption trends. In addition, the value of each incoming reading can be compared to the predicted value [12, 13].

Another area of analysis is sales metering, carried out by water meters installed at households; the meters have to comply with the provisions on legal metrological control and legalization. All water meters are replaced at least once every 5 years, and their maintenance is the responsibility of the water company. To reduce the volume of non-revenue water (NRW), water meters with a high metrological class should be used, i.e. class R160 for household water meters and class R315 for industrial water meters due to measurement accuracy tests at various operating states, e.g. accuracy of water leak measurements. As being responsible for water meter management, the company also has several sets of instruments which, if successively tested, will keep a proper accuracy throughout the water meters lifespan. These are the units left after metrological expertises performed at the request of the water recipients. The company has also water meters dismantled after a five-year period of operation, whose randomly selected batches can be examined in terms of accuracy of measurements. The authors have been conducting such research, to select the types of water meters with the highest reliability.

3. METHODS

The metered water supply network can be presented as a supply tree structure. This way it is possible to balance water based on the readings from individual databases, i.e. GIS, SCADA and billings, in both individual zones and the entire system [11, 14, 15, 16].

Balancing should be accomplished using the method of a power tree analysis and minimum night flows. The water flow balance should include:

- Analysis of daily flows from: water production monitoring (discharge from water treatment plants), key network points monitored within the SCADA system, as well as billing data (readings) collected from all water meters installed at water recipients.
- Daily successive analysis of a water balance in separate metered zones, regardless of how the zone has been created or metered.
- Setting alert thresholds for losses and comparing the daily water balance in a zone with unavoidable water losses, to adopt acceptable losses for each zone. Such approach requires integration of e.g. billing and GIS spatial information systems; this way it is possible to identify characteristic values of parameters affecting the level of unavoidable losses in a zone.

It is crucial to identify the flows entering each metered zone. The flows should be analyzed using both the daily balance method that takes into account characteristic fluctuations for individual week days and the night

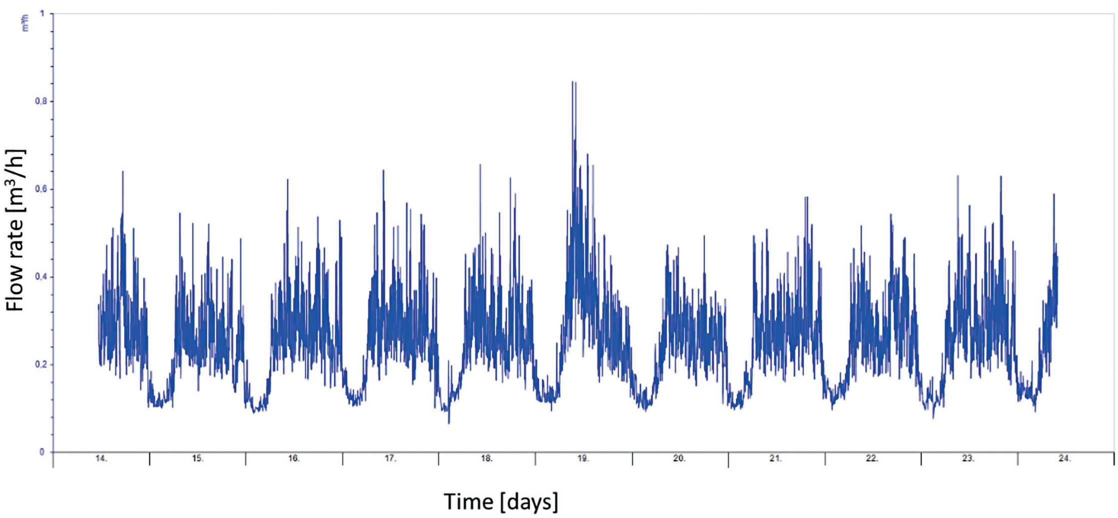

Fig. 1. Records of the instantaneous flows entering the zone
Ryc. 1. Wykres z rejestratora chwilowego natężenia przepływu w dopływie do strefy

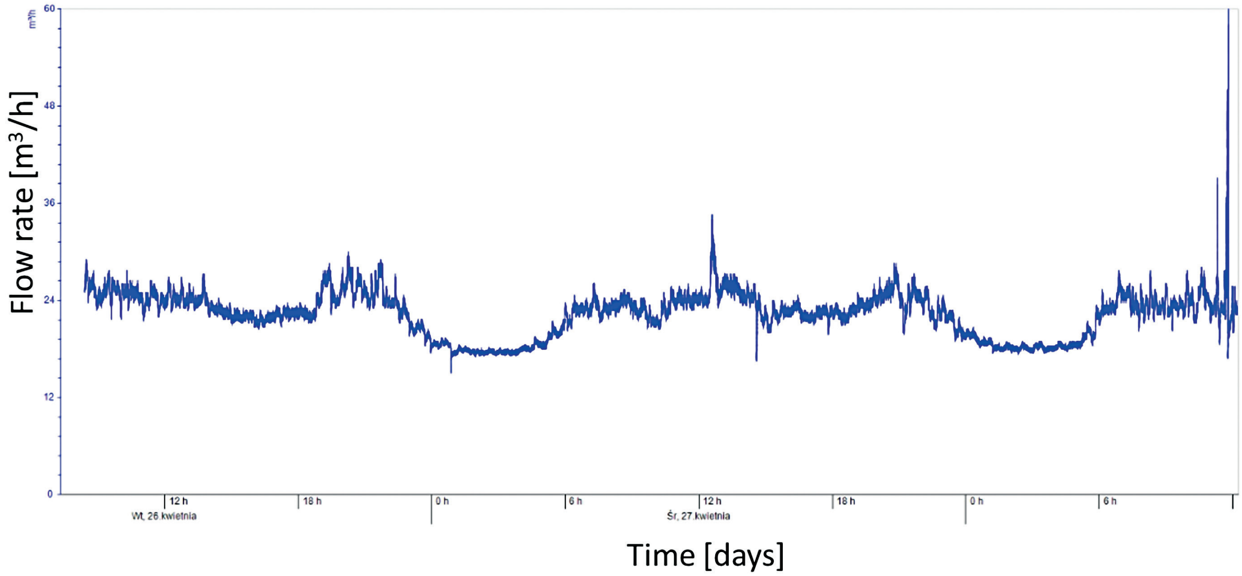

Fig. 2. Records of the instantaneous flows entering the zone
Ryc. 2. Wykres z rejestratora chwilowego natężenia przepływu w dopływie do strefy

flow method. In the big water distribution systems usually exist different metered zones. Different in terms of number of connections and customers, type of customers (like houses, services or industrial sites). Records showing the flows entering the zones are presented in Fig. 1 and Fig. 2. The figures come from different zones. First figure comes from the housing with block of flats. The second, includes shorter period and comes from the area with farms. The charts were taken directly from recorder, so the labels are small.

Unavoidable Annual Real Loss – UARL is calculated from the formula:

$$UARL = [18 \cdot (M + R) + 0,8 \cdot L_{PW} + 25 \cdot D_{PW}] \cdot P / 1000$$

where:
UARL – unavoidable water loss [m^3/day],
M – total length of water mains [km],
R – total length of water connections [km],
L_{PW} – number of service connections,
D_{PW} – average length of service lines [km],
P – average operating pressure in the zone [mH_2O].

4. RESEARCH AREA

The City of Krakow operates one of the largest water supply systems in Poland. It comprises four sources of surface water (Fig.3), with the largest one, Lake Dobczyckie. After treatment at four treatment plants (ZUW), the water is transported across over a 2,200 km long water supply network to individual recipients. The water consumption is metered by 59,000 main water meters, installed throughout the city. Usually, water supply systems are divided into zones in terms of network pressure and water sources.

Within the Krakow water supply system and its zones (Fig.4), several dozen measurement systems are installed at nodal points and their number is successively growing. In practice, flowmeters or water meters that measure water coming into zones or flowing between individual zones can be installed in existing facilities, such as pressure reduction chambers, hydrophore stations and valve chambers. Such installations, if only acceptable for such a purpose, usually do not require large investment costs and a time-consuming construction process.

In urban water systems, division of the network into metered zones that would enable an effective water flow balance pose usually a major challenge. The most common problem is a dense urban development and infrastructure, which makes it impossible to build measuring chambers for gauging instruments. In addition, many water supply systems work with multi-sided or ring feeds, that requires construction of multiple metering systems to balance the flows.

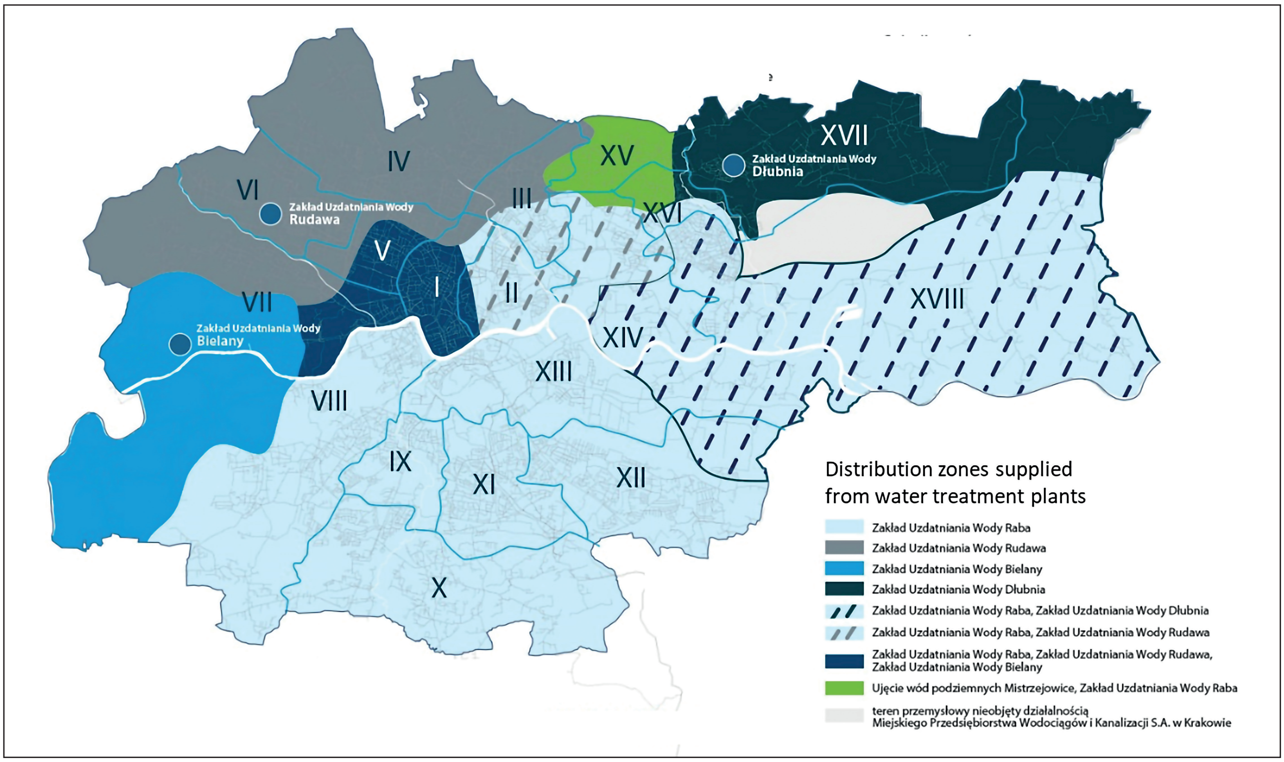

Fig. 3. Water supply zones at Krakow
Ryc. 3. Schemat stref zasilania w wodę sieci wodociągowej

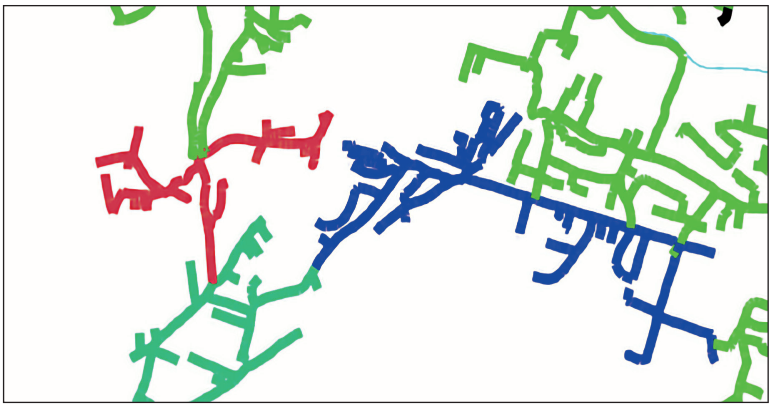

Fig. 4. A diagram of a water supply network at Krakow with color-coded division into zones. (green zones are supplied from the Rudawa treatment plant)
Ryc. 4. Schemat fragmentu sieci wodociągowej Krakowa z zaznaczonym kolorami podziałem na strefy (zielone strefy zasilane są z oczyszczalni Rudawa)

4. DISCUSSION OF RESULTS

The expected outcome of the water system metering is a supply tree structure, where individual branches represent the water flows. In such a structure, water flowing into the system will be obtained as the sum of flows discharged from the water treatment plant.

In the study, the authors selected the zone supplying water to the housing estate with approximately 2,200 inhabitants. The housing comprises blocks of flats of

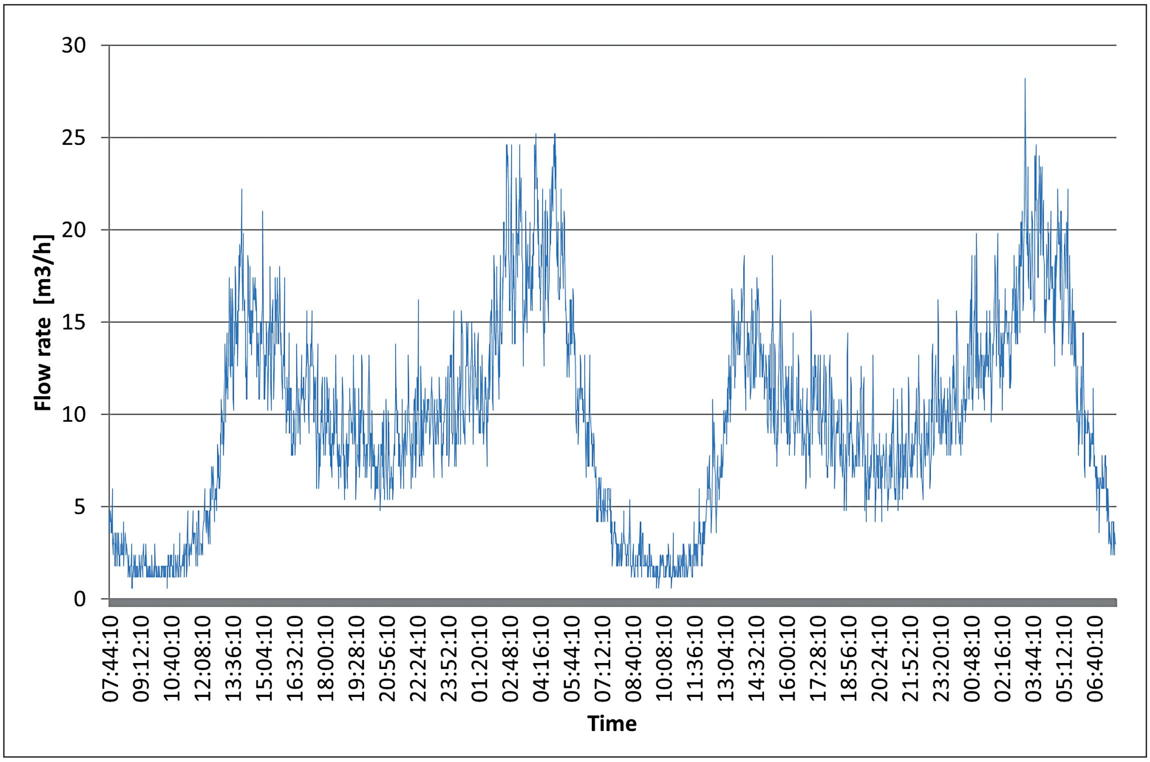

Fig. 5. Graph of instantaneous flow rates over a 2 days period
Ryc. 5. Wykres chwilowych natężeń przepływu z okresu 2 dób

various sizes. The zone is supplied through a reduction chamber metered by a water meter with a diameter of 100 mm. The water meter measures water flowing into the zone and records instantaneous flow rates. The graph of instantaneous flow rates over 2 days is shown in Fig. 5.

The records show that during normal operation, the minimum night flow to the zone is approx. 2 m^3/h, while the maximum evening peak flow is approx. 23–25 m^3/h.

Another extreme value will be the sum of readings from the main water meters installed at the consumers' sites. Such a structure will be even more effective if it comprises metered zones with up to several hundred water meters in individual zones. Due to such network operation, it is possible to calculate the balance difference in a given zone., i.e. the difference between the readings on the meter supplying water to a given zone and the sum of readings at household water meters in this zone.

The research conducted by the authors has shown that even in the well-operating network and the correctly metered zone show there may be differences in the water balance, i.e. between the readings at the water meters supplying water to the zone and the sum of readings at the household water meters. In the analyzed zone, such a difference ranged from 3.5 to 4% during normal operation and was caused by differences in the metrological parameters of the measuring instruments. The daily difference in the water balance [%] in the zone is shown in Fig. 6.

The balance difference was converted into the coefficient of unavoidable losses, and thus into the Infrastructural Leakage Index (ILI). The obtained graph presents the efficiency of the network zone with respect to water losses. During normal operation, the ILI is ≤ 2; a significant increase of the ILI above the acceptable value may indicate a system failure.

The graph showing the ILI values in the tested zone during the normal operation and during a failure is shown in Fig. 7. The indicator was calculated on the basis of the daily balance difference. A significant increase in the ILI values confirmed the need for detailed network diagnostics, which in turn helped to locate and remove the failure. The final results are presented on the graph as the indicator ILI.

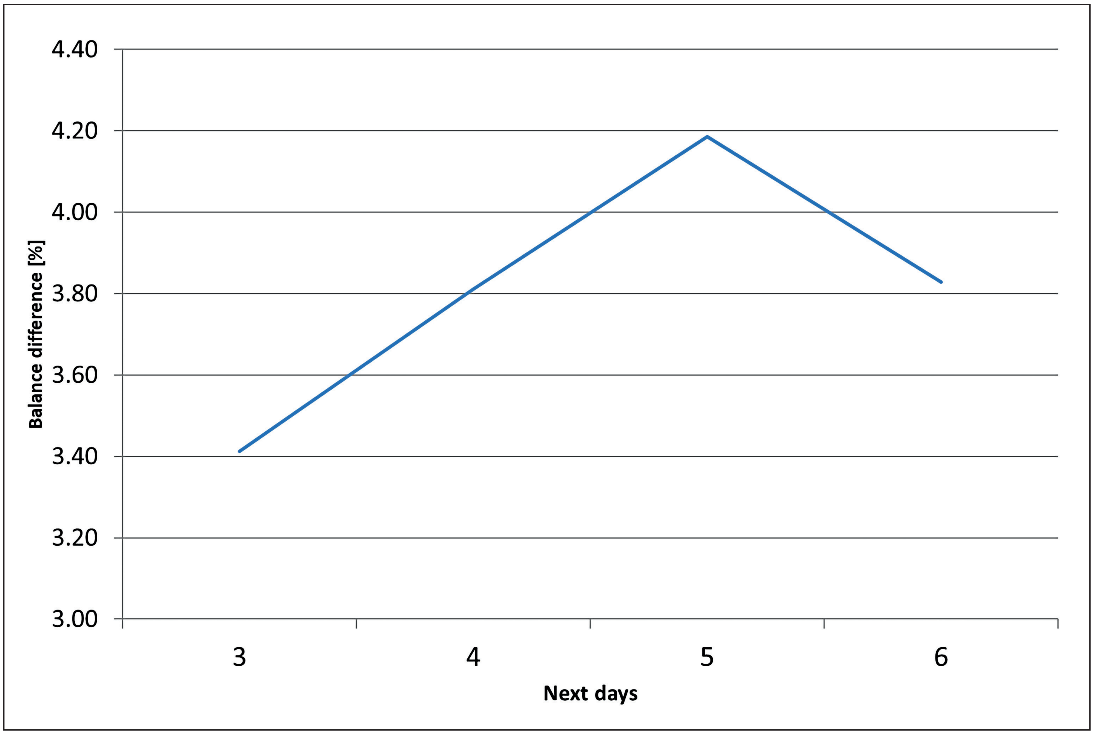

Fig. 6. Difference in water balance in the zone
Ryc. 6. Wykres różnicy w bilansie wody w strefie

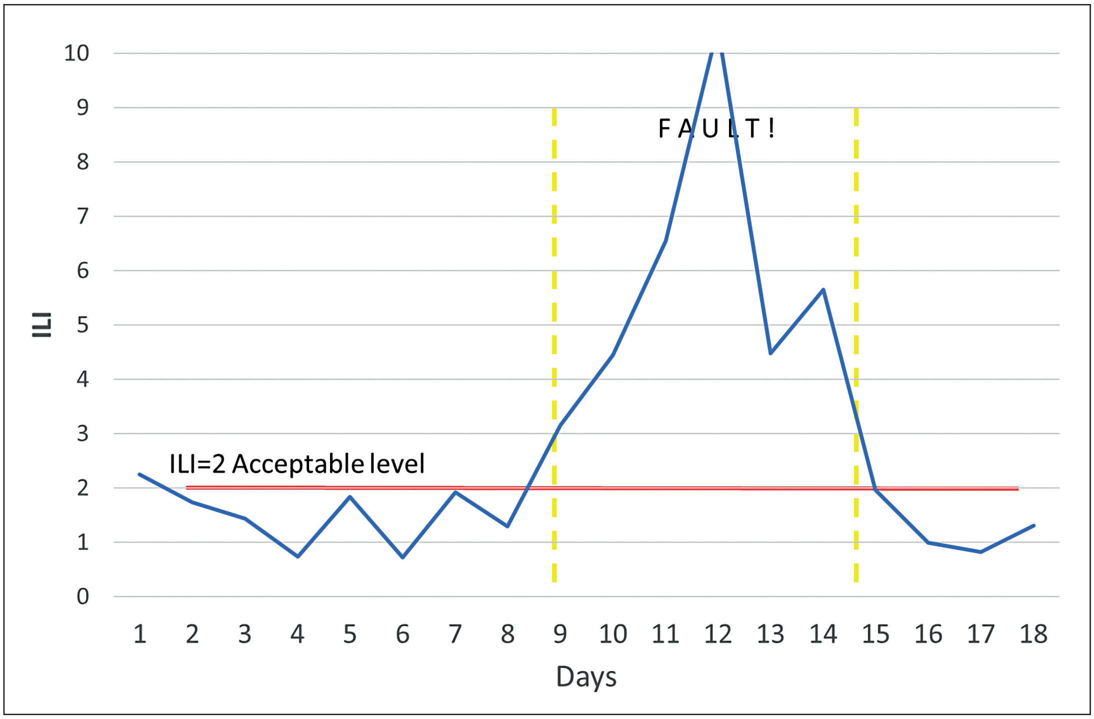

Fig. 7. Unavoidable losses in the tested zone during the normal operation and during the observed failure
Ryc. 7. Wykres strat nieuniknionych w badanej strefie w czasie prawidłowej pracy oraz podczas awarii

5. SUMMARY

Efficient management of water resources requires a strategic, sustainable approach. Reducing water consumption and minimizing water losses are activities that fit into this trend. A very important aspect of reasonable water management is proper metering of its consumption. The introduction of metering of water consumption and the resulting economic pressure were one of the main reasons for the reduction of water consumption as well as a lower failure rate of internal water supply systems and a significant reduction in leakage. An intelligent water supply metering system, which automatically collects water meter readings in appropriate databases and analyzes them, is a very good tool for minimizing water loss.

In order to reduce water losses, simultaneous activities involving organization, renovation and modernization of the water system as well as investment issues should be carried out. Without a proper flow and pressure monitoring as well as an accurate measurement data, water losses cannot be properly assessed.

To successively control and reduce water losses in the water supply system, it is necessary to establish supply zones and equip them with precise measuring instruments. This way algorithms and applications can successfully be used to balance and analyze the water flow.

The application that balances the supply tree combined together with billing tools for tracking water consumption trends at individual households can serve as a multi-faceted successive assessment of both actual and apparent water losses in the water supply system.

The combined use of technological monitoring of the water network as well as readings from water meters installed at individual households allows for successive monitoring of water losses in individual zones.

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