Water Practice & Technology

IWA PUBLISHING

Water Practice & Technology Vol 17 No 10, 2023 doi: 10.2166/wpt.2022.110

A case study on integrated management of water losses in Antalya, Turkey

Tugba Akdeniz
General Directorate of Antalya Water and Wastewater Authorities (ASAT), Fabrikalar Mh., Dumlupınar Blv. No:3, Antalya, Turkey
E-mail: tugbaakdeniz@asat.gov.tr

TA, 0000-0003-4013-2457

ABSTRACT

In this study, effects of the combination of meter replacement and active leakage control on real and apparent losses are investigated. Generally, water meter replacement campaigns, SCADA system operation, data analysis studies and physical leak detection activities are carried out by different units in water utilities. Within the scope of this study, the studies carried out by different units of the water utility were carried out in an integrated manner in the same period and the obtained data sets were analysed together. Thus, water losses, which were at the level of 52% in the pilot study area (PSA), were reduced to 35%. When the volumes of water supplied to the system before and after the study are compared, the volumes after the study were decreased. Also, water losses in the PSA have been reduced by 17%.

Key words: active leakage management, apparent losses, drinking water networks, economic analyses, real losses

HIGHLIGHTS

- Reducing water losses is not only a revenue problem, it also results in wasting sources.
- Effects of integrated management techniques on water losses are investigated.
- The application in this study by different water utilities will contribute to the management of water losses in WDS.
- The importance of regular active leakage control studies has been proved.
- As a result of the study, water losses were reduced by 17%.

1. INTRODUCTION

Recently, sustainable management of drinking water resources has become more crucial due to climate change, population increase and industrialization. Therefore, sustainable management of urban water systems, which are vital for management of water resources, has become more important. A large volume of water, around 35% of the water supplied to the distribution systems, is lost in water distribution systems (Farley *et al.* 2010; Karadirek *et al.* 2012, Al-Washali *et al.* 2016).

A standard water balance table which is presented in Table 1 has been developed by IWA in order to accurately assess water losses in different countries. Water losses, which are classified as real and apparent losses, are the difference between the system input volume and volume of authorized consumption. Real losses are due to pipe bursts, pipe cracks and overflows from storage tanks whereas apparent losses are associated with measurement errors of water meters, data handling errors and unauthorized consumption (Alegre *et al.* 2000; Lambert & Hirner 2000; McKenzie & Seago 2005; Tabesh *et al.* 2009; Karadirek 2019, 2020). The problem of excessive water losses is common in many countries such as Turkey, where the country average of total water losses is around 50% and apparent losses are estimated to be 20% (Karadirek 2020).

Strategies and control techniques for water losses have been developed in many parts of the world (Lambert *et al.* 2002; Kanakoudis *et al.* 2011). There are four basic intervention tools to control real losses in water distribution systems, which are pressure management, active leakage management, speed and quality of repairs, and pipeline and asset management (Lambert *et al.* 2002). Dividing water distribution systems into district metered areas (DMAs) and pressure management are helpful tools to control real losses in water distribution systems (Karadirek *et al.* 2012). DMAs are isolated sub systems, where the amount of water supplied and consumed can be measured (Thornton 2002; Gomes *et al.* 2013). Thus, monitoring night flows by the help of DMAs can be facilitated to manage real losses (Alkasseh *et al.* 2013).

Table 1 | Standard IWA water balance (Lambert & Hirner 2000)

System input volume (SIV)	Authorized consumption (AC)	Billed authorized consumption	Billed metered consumption	Revenue water
			Billed unmetered consumption	
		Unbilled authorized consumption (UAC)	Unbilled metered consumption	Non-revenue water (NRW)
			Unbilled unmetered consumption	
	Water losses	Apparent losses (AL)	Unauthorized consumption	
			Metering inaccuracies	
		Real losses (RL)	Leakage on transmission and/or distribution mains	
			Leakage and overflows at utility's storage tanks	
			Leakage on service connections up to point of customer metering	

There are also four basic methods to control apparent losses in water distribution systems. These are controlling metering inaccuracies and unauthorized consumption, reducing data transfer and analysis errors (Rizzo *et al.* 2007). In well managed water distribution systems, a vast majority of apparent losses is resulted from water meter inaccuracies (Arregui *et al.* 2016).

This study is aimed at providing an evaluation for control of water losses by integrating intervention tools of real and apparent losses. For this purpose, a study area was chosen to control water losses by implementing active leakage control and water meter replacement campaign.

2. MATERIALS AND METHODS

2.1. Study area

Antalya, which is one of Turkey's largest tourism destinations, is located in a karstic region, where most of the pipe failures in the drinking water network cannot be detected from the surface. Groundwater is the only source to supply water to the Antalya city and approximately 43% of Antalya City's drinking water is supplied from Duraliler facilities (53 wells). Abstracted water from Duraliler wells is pumped to the distribution system after chlorination as there is no need for treatment. Total average daily water production of the Duraliler facility is approximately 270,000 m^3/day. In Antalya city, the distribution system has been divided into nine pressure zones to provide water services for the settlements located at varying elevations. Sedir water distribution network, operated independently from the rest of the distribution network of Antalya city, was chosen as the pilot study area (PSA) (Figure 1). The study area is a dense residential area and mainly consists of domestic customers.

The PSA lies in the P6 pressure zone and water abstracted from Duraliler facility is supplied to the region after chlorination. The PSA has a total pipe length of 8019 m and includes different types of pipes such as PVC, HDPE, and steel. Detailed information about the study area is given in Table 2.

The PSA, which was previously divided into a DMA, was tested by implementing zero-pressure test on October 2019 to determine whether the PSA is an isolated sub system. For this purpose, the inlet valve of the PSA was closed, then water pressure and flow rates of the PSA was monitored through the SCADA system, which is available in the region. It was observed that the water pressure and the flow rate dropped to zero (Figure 2).

Furthermore, the selected buildings within the boundaries of the PSA were visited one by one to check whether the water was cut off. During the zero-pressure test, it was determined that the connections were faulty in eight buildings located within the borders of the PSA, and the data were updated in the GIS system. In addition, a manual pressure measurement was carried out in a hospital in the region, and it was observed that the pressure value decreased rapidly. Thus, it was determined that the PSA was an isolated DMA from the rest of the network.

2.2. Reactive and proactive leakage management

Detection of water losses in water distribution systems can be carried out by implementing active and passive leakage detection methods. Passive (reactive) leakage control is based on repairing water leaks reported by customers and/or visible on the surface (Shammas & Al-Dhowalia 1993). Active (proactive) leakage control includes the studies carried out by water organizations in order to detect and repair leaks that do not come to the surface (Shammas & Al-Dhowalia 1993; Thornton *et al.* 2008; Aboelnga *et al.* 2018). Active leakage control often relies on the detection of leaks, including unreported and background leaks. Active leakage control helps reducing the

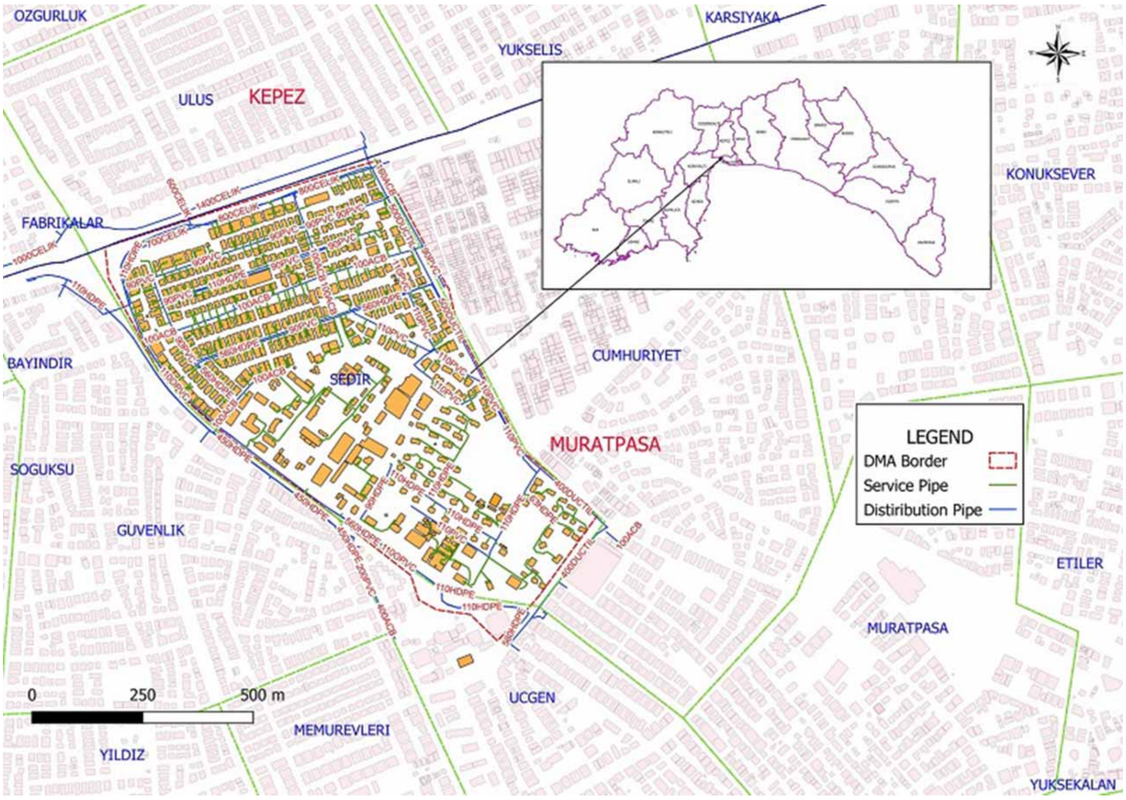

Figure 1 | Map showing the details of the PSA and Antalya in Turkey.

Table 2 | Detailed characteristics of the PSA

Total length of distribution pipes	8019 m
Average age of pipes	11 years
Total number of service connections	395
Total number of customers	4260
Maximum and minimum water pressure during operation	4.43 bar–3.20 bar
Average pressure	3.71 bar
Maximum and minimum elevation	63 m–52 m
Number of valves	59
Total length of service pipes	12,379 m

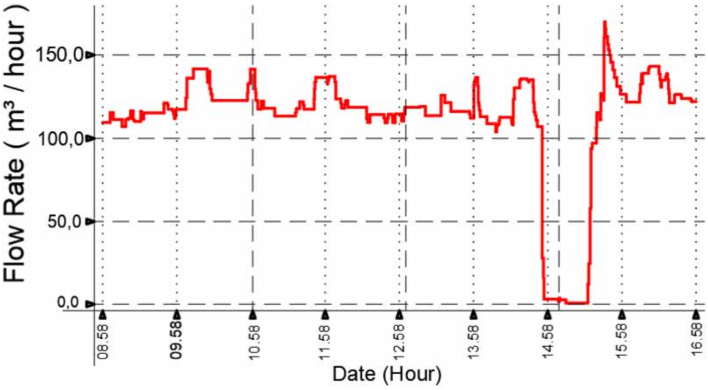

Figure 2 | Flow rates at the entrance of the PSA.

time required for repairment and is a helpful response tool to control real losses. It is crucial in karstic regions where pipe failures cannot be determined from the surface due to the ground structure. Active leakage control studies were carried out intermittently throughout 2020 in the Sedir DMA. Standard acoustic listening methods have been applied for active leakage control. Severin AQUAPHON A-100 (1 Hz 9950 Hz) device was used for acoustic listening studies. In the same period, reactive water loss management was also carried out with notifications from customers.

2.3. Water meter replacement campaign

The total number of customers in the PSA in 2020 was 4260. The approximate age of the customer meters was determined according to the meter brand and type. The customer meter data used in the study were prepared based on the billing data of November 2020. Figure 3 shows the age percentage of existing water meters in the PSA. There are many different brands, models, and ages of meters in the PSA. Evaluation of the data showed that apparent losses in the PSA were predominantly due to meter inaccuracies. In this context, all customer meters in the pilot study area were replaced with multijet-wet chamber (R160) water meters in November 2020.

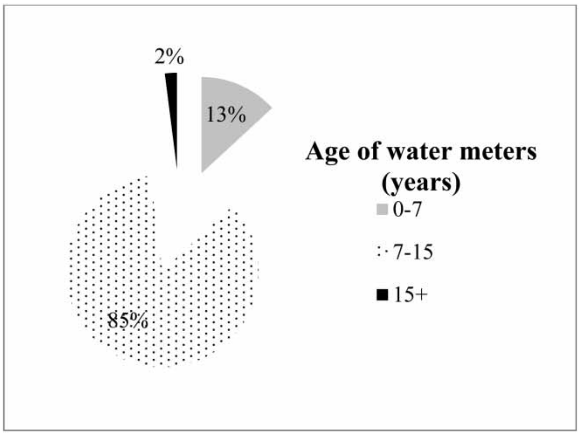

Figure 3 | Age classification of existing water meters in the PSA.

3. RESULTS AND DISCUSSION

Pipe bursts may occasionally occur, especially in water distribution networks with high pressure and relatively older pipe ages. These bursts result in interruptions in water supply, required additional costs for repair and damage to nearby properties and infrastructure. Therefore, water utilities try to minimize the occurrences of pipe bursts and search for techniques for detection and localization of bursts. Active and passive leakage control techniques have been utilized to control water losses in distribution networks. In this study, a total of 68 pipe failures was detected by proactive and reactive leakage management techniques carried out in the PSA in the year of 2020. A total of 26 failures was detected in distribution pipes whereas 42 of total failures were detected in service connections up to water meters. Locations of pipe failures detected and repaired in 2020 are given in Figure 4.

Furthermore, existing water meters have been replaced to control apparent losses in the PSA.

As a result of the integrated water loss management strategies carried out in the PSA, flow rates and water pressures at the entrance of the PSA were analysed (Figure 5).

Minimum night flow (MNF) analysis was carried out in the PSA. The MNF of the PSA was around 87 m^3/h before water loss control studies started. As active leakage control studies were implemented in June 2020, the MNF value started to decrease down to 76 m^3/h. Then an increase was observed in MNF rates as new bursts occurred. In the meantime, active and passive leakage control studies were carried out and a water meter replacement campaign was started. As water distribution systems are dynamic systems, active and passive leakage control studies should be carried out regularly. At the end of the study period, MNF rates of the PSA were observed around 65 m^3/h. Average MNF rates before the studies started were around 87 m^3/h whereas average MNF rates were reduced up to 65 m^3/h. An average water saving of 22 m^3/h was achieved by implementing

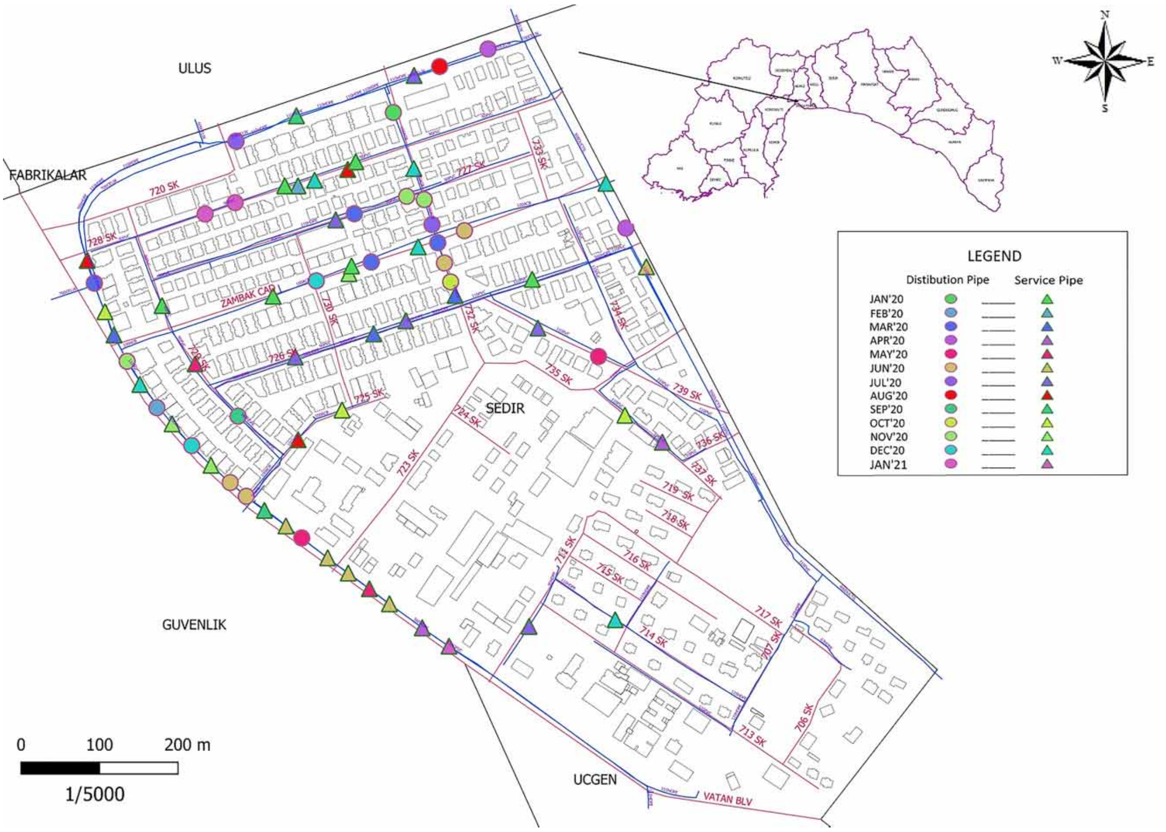

Figure 4 | Locations and types of pipe failures in the PSA.

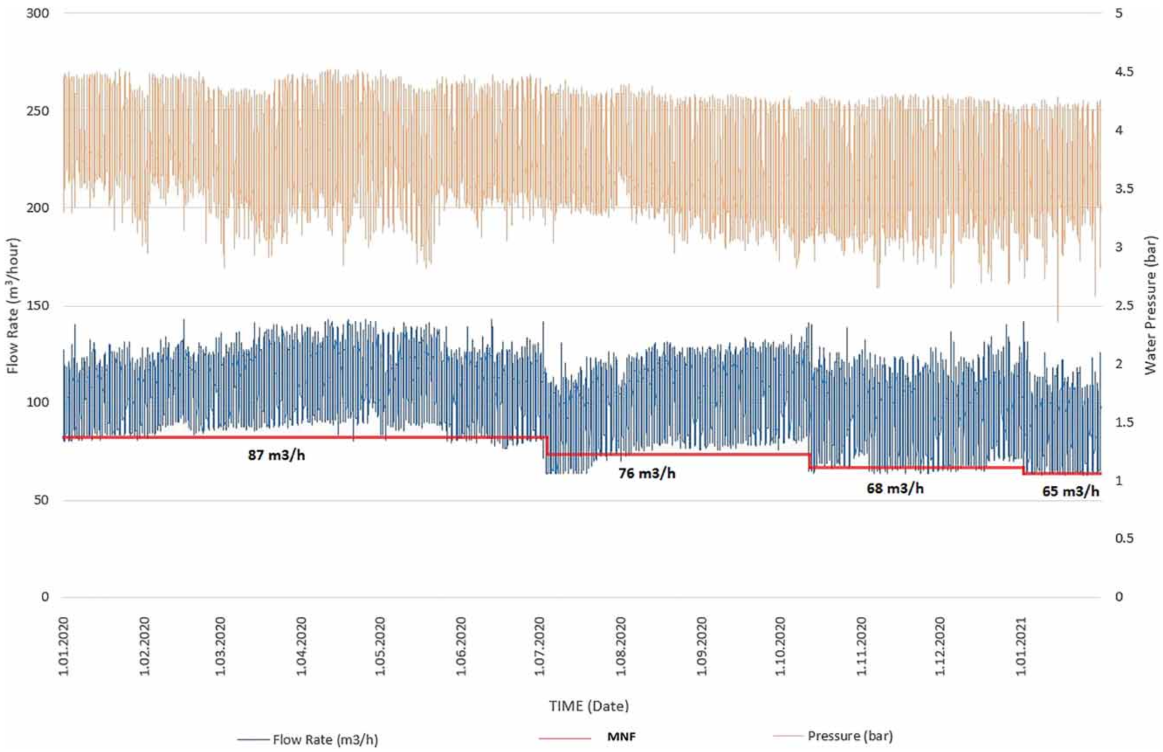

Figure 5 | Flow rates and water pressure levels at the entrance of the PSA.

active and passive leakage control and the water meter replacement campaign. The rate of water losses has been reduced from 52% down to 35% by implementing integrated water loss management strategies. Standard water balance tables of the PSA are presented in Tables 3 and 4. Unbilled unmetered consumption is the water that is connected to the network by the water administration but is not metered and therefore not billed within the knowledge of the administration. It basically consists of the amount of water used from parks, fire hydrants, water discharged during the maintenance of pipelines and armatures etc.

Table 3 | Standard water balance of the PSA before study (for 11 months)

System input volume (SIV) 139,734 m^3/year 100%	Authorized consumption (AC) 412,648 m^3/year 48.47%	Billed authorized consumption 404,063 m^3/year 47.46%	Billed metered consumption 404,063 m^3/year 47.46%	Revenue water 404,063 m^3/year 47.46%
			Billed unmetered consumption 0 m^3/year 0.00%	
		Unbilled authorized consumption (UAC) 8585 m^3/year 1.01%	Unbilled metered consumption 220 m^3/year 0.03%	Non-revenue water (NRW) 447,347 m^3/year 52.54%
			Unbilled unmetered consumption 8365 m^3/year 0.98%	
	Water losses 438,762 m^3/year 51.53%	Apparent losses (AL) 145,080 m^3/year 17.04%	Unauthorized consumption 21,285 m^3/year 2.50%	
			Metering inaccuracies 123,794 m^3/year 14.54%	
		Real losses (RL) 293,682 m^3/year 34.49%	Leakage on transmission and/or distribution mains 289,295 m^3/year 33.98%	
			Leakage and overflows at utility's storage tanks 4388 m^3/year 0.52%	

While physical water losses refer to the water that is physically lost before the water reaches the user, apparent water losses are the sum of the losses in which the water is actually used but cannot be compensated by the municipalities/water organizations (Al-Washali *et al.* 2016). Reducing apparent water losses provides short-term increases in water services/municipal revenues, and these increases allow users to receive better service in the long run (Karadirek 2020). Metering inaccuracies refers to all types of errors associated with the manufacture of meters, and the water consumption due to errors caused by the age, model, type of meters, as well as data processing errors (meter reading and billing). Metering inaccuracies can be determined for administrations that have meter repair and control stations, based on their general calibration experience and data records, while administrations without repair stations use measurement and adjustment legislation, manufacturer information etc. The recommended value for metering inaccuracies in Turkey is between 3 and 20% of the sum of billed metered and unbilled metered consumption (Muhammetoğlu & Muhammetoğlu 2017). This value is estimated by technical personnel familiar with the system. Metering inaccuracies value was estimated as 30% of the Authorized Consumption (AC) for 11 months before the replacement customer meter and 10% of the AC for two months after the replacement of customer meters in this study. Apparent losses resulting from meter inaccuracies are the main reason of apparent losses in well-managed water distribution systems (Arregui *et al.* 2018). A study showed that inaccuracies of water meters corresponded to 22% while apparent losses were calculated as 37% of system input volume (Mutikanga *et al.* 2011).

4. CONCLUSIONS

Water meter replacement campaigns, SCADA system operation and data analysis studies and physical leak detection activities are usually carried out by different departments in water utilities. Within the scope of this study, the

Table 4 | Standard water balance of the PSA after study (for two months)

System input volume (SIV) 139,734 m^3/year 100%	Authorized consumption (AC) 90,295 m^3/year 64.62%	Billed authorized consumption 88,734 m^3/year 63.50%	Billed metered consumption 88,734 m^3/year 63.50%	Revenue water 88,734 m^3/year 63.50%
			Billed unmetered consumption 0 m^3/year 0.00%	
		Unbilled authorized consumption (UAC) 1561 m^3/year 1.12%	Unbilled metered consumption 40 m^3/year 0.03%	Non-revenue water (NRW) 51,000 m^3/year 36.50%
			Unbilled unmetered consumption 1521 m^3/year 1.09%	
	Water losses 49,439 m^3/year 35.38%	Apparent losses (AL) 12,523 m^3/year 8.96%	Unauthorized consumption 3493 m^3/year 2.50%	
			Metering inaccuracies 9029 m^3/year 6.46%	
		Real losses (RL) 39,919 m^3/year 26.42%	Leakage on transmission and/or distribution mains 36,422 m^3/year 26.07%	
			Leakage and overflows at utility's storage tanks 494 m^3/year 0.35%	

studies carried out by different departments of the water utility were carried out in an integrated manner in the same period and the obtained data sets were analysed together. Thus, water losses, which were at the level of 52% in the pilot study area, were reduced to 35%. When the amount of water supplied to the system before and after the study are compared, the amount of water supplied to the system decreased by 11,058 m^3/month and the authorized consumption increased by 7686 m^3/month. Also, water losses in the PSA were reduced by 17%. In addition, the NRW level, which was 53% before the study, was reduced to 37%. Thus, the revenue of the water company increased by 16%.

The integrated water loss management actions mentioned in this study show us that the integration of different water departments in developing countries will reduce the levels of water losses and increase the revenues of the administration.

Pipe bursts in drinking water networks are mainly due to plastic and old pipes. Within the scope of this study, 62% of the failures in the PSA occurred in service pipes and polyethylene pipes. The findings of the study can be concluded as follows:

- In addition to the decrease in the rate of water losses, the decrease in the amount of water supplied to the system and the increase in the amount of revenue water are important for water utilities.
- Special attention should be paid to the pipe selection and storage criteria (standby in the sun, etc.) used in the drinking water network.
- The study reveals the importance of ensuring integration between units in water utilities to carry out the required studies and to analyse the findings.
- Due to the porous and permeable ground structure in karstic areas, not all the leaks in the drinking water network are visible on the surface. Therefore, physical leak detection studies should be carried out at regular intervals as it becomes difficult to detect the faults of water pipes, especially in karstic regions.

ACKNOWLEDGEMENT

This research study was supported by the General Directorate of Antalya Water and Wastewater Administration (ASAT) of Antalya Metropolitan Municipality.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Aboelnga, H., Saidan, M., Al-Weshah, R., Sturm, M., Ribbe, L. & Frechen, F. B. 2018 Component analysis for optimal leakage management in Madaba, Jordan. *Journal of Water Supply Research and Technology-Aqua* **67**(4), 384–396.

Alegre, H., Hirner, W., Baptista, J. M. & Parena, R. 2000 *Performance Indicators for Water Supply Services*, 1st edn. IWA Publishing, London.

Alkasseh, J., Adlan, M. N., Abustan, I., Aziz, H. A. & Hanif, A. M. 2013 Applying minimum night flow to estimate water loss using statistical modeling: a case study in Kinta Valley, Malaysia. *Water Resources Management* **27**(5), 1439–1455.

Al-Washali, T., Sharma, S. & Kennedy, M. 2016 Methods of assessment of water losses in water supply systems: a review. *Water Resources Management* **30**(14), 4985–5001.

Arregui, F. J., Balaguer, M., Soriano, J. & Garcia-Serra, J. 2016 Quantifying measuring errors of new residential water meters considering different customer consumption patterns. *Urban Water Journal* **13**(5), 463–475.

Arregui, F. J., Gavara, F. J., Soriano, J. & Pastor-Jabaloyes, L. 2018 Performance analysis of ageing single-jet water meters for measuring residential water consumption. *Water* **10**(5), 18.

Farley, B., Mounce, S. R. & Boxall, J. B. 2010 Field testing of an optimal sensor placement methodology for event detection in an urban water distribution network. *Urban Water Journal* **7**(6), 345–356.

Gomes, R., Marques, A. S. A. & Sousa, J. 2013 District metered areas design under different decision makers' options: cost analysis. *Water Resources Management* **27**(13), 4527–4543.

Kanakoudis, V., Gonelas, K. & Tolikas, D. 2011 Basic principles for urban water value assessment and price setting towards its full cost recovery – pinpointing the role of the water losses. *Journal of Water Supply Research and Technology-Aqua* **60**(1), 27–39.

Karadirek, I. E. 2019 Non revenue water management: current trends and future prospects. *Fresenius Environmental Bulletin* **28**(7), 5226–5233.

Karadirek, I. E. 2020 An experimental analysis on accuracy of customer water meters under various flow rates and water pressures. *Journal of Water Supply Research and Technology-Aqua* **69**(1), 18–27.

Karadirek, I. E., Kara, S., Yilmaz, G., Muhammetoglu, A. & Muhammetoglu, H. 2012 Implementation of hydraulic modelling for water-loss reduction through pressure management. *Water Resources Management* **26**(9), 2555–2568.

Lambert, A. & Hirner, W. 2000 *Losses From Water Supply Systems: Standard Terminology and Recommended Performance Measures*. IWA's Blue Pages, pp. 1–13.

Lambert, A. O. M. F., Tveit, O. A., Abdin, N. A. Z., Lazzari, L., Lorenze, H., Lee, H., Farley, M., Masakat, E., Suphani, R., Esko, H., Johnson, K., Rapinat, M., Dohnal, P., McKenzie, R., Manesc, A., Weimer, D., Lai, S. K. S., Somos, E., Monteir, A., Davis, S., Martinez, F., Lo, S. L., , Onep 2002 In: *2nd World Water Congress: Water Distribution and Water Services Management* (Wilderer, P. A. G., Arvin, E., Blackwell, L., Hamoda, M. F., Mikkelsen, P. S., Mino, T., Morgenroth, E., Otterpohl, R., Pons, M. N., Rauch, W., Stephenson, T., Ujang, Z. & Jianrong, Z., eds). IWA Publishing, London, pp. 1–20.

McKenzie, R. & Seago, C., 2005 In: *4th World Water Congress: Innovation in Water Supply – Reuse and Efficiency* (Wilderer, P., ed.). IWA Publishing, London, pp. 33–40.

Muhammetoğlu, H. & Muhammetoğlu, A. 2017 *Control of Water Loss in Drinking Water Supply and Distribution Systems – Handbook Ministry of Forestry and Water Affairs*. General Directorate of Water Management, Ankara.

Mutikanga, H. E., Sharma, S. K. & Vairavamoorthy, K. 2011 Investigating water meter performance in developing countries: a case study of Kampala, Uganda. *Water SA* **37**(4), 567–574.

Rizzo, A., Vermersch, M., John, S. G., Micallef, G., Riolo, S. & Pace, R. 2007 Apparent water loss control: the way forward. *Water* **21**(9), 45–47.

Shammas, N. K. & Al-Dhowalia, K. H. 1993 Effect of pressure on leakage rate in water distribution networks. *Journal of King Saud University – Engineering Sciences* **5**(2), 213–226.

Tabesh, M., Yekta, A. H. A. & Burrows, R. 2009 An integrated model to evaluate losses in water distribution systems. *Water Resources Management* **23**(3), 477–492.

Thornton, J. 2002 *Water Loss Control Manual*. McGraw-Hill, Estados Unidos.

Thornton, J., Sturm, R. & Kunkel, G. 2008 *Water Loss Control*. McGraw-Hill Education, New York.

First received 25 April 2022; accepted in revised form 8 September 2022. Available online 16 September 2022