ORIGINAL ARTICLE

The strategic development for water loss prevention

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Abstract

The population growth and urbanization have gained importance in the Water Resource Management (WRM) works. The classic approach in relation to the development of the water resources has lost its sustainability. Water has, therefore, become an important, but also becoming a scarce natural source due to the global warming and its climate change impacts end results. The major aim of WRM is to increase the Water Distribution Network (WDN) to keep water supply sustenance by decreasing the water demand. The new approaches in relation to the WRM should take into consideration in a more refined manner the supply–demand balance with the improvements in the WDN. Recently, water resources performance improvements have become one of the significant investment topics in Turkey. However, data from the Turkish Statistical Institute and any academic research in this field have shown that there is a water loss of around 50% in the current water supply and distribution systems. In comparison to other developed countries, this loss is very high. It became, therefore, necessary that each Water Resources Administration should keep track on the costs, water leakage losses and the necessary technological investments. In the scope of this study, water loss levels reduction strategy possibilities are developed in the Sakarya City WDM system, Turkey. These strategies field applications have been presented in detail. Finally, the extent of accuracy in these strategies has been shown, which may provide guidance for other water administrations departments in the world.

Keywords Water Resource Management (WRM) · Water Distribution Network (WDN) · Domestic Water Supply and Distribution Network (DWSDN) · District Metered Areas (DMA) · Supervisor Control and Data Acquisition (SCADA) · Geographic Information System (GIS) · The Minimum Night Flow (MNF)

Introduction

As a result of urbanization, the local and central governments have made large investments for water supply in order to meet the demand in balance. The water loss within the Domestic Water Supply and Distribution Network (DWSDN) constitutes a huge problem in many countries around the globe. The huge investments and loss of domestic water, in the supply network, have brought drastic measures and investments in the water management system. Every Water Administration should, therefore, keep track on the economical consequences by keeping track on water losses, under the light of the recent technological developments and investments to reduce the costs of supply.

In Turkey, the proportion of water loss within the DWSDN is high, whereby it is strongly recommended to keep track on this matter by water administration departments.

Recently, the supply and distribution of domestic water gained significant importance in order to decrease and manage water losses, whereby in 2014 the Ministry of Forestry and Water Affairs has released a rules and regulations guidance named "The management and Control of Supply and Distribution of Domestic Water within the Network" and in 2015 "Technical Procedure Communication." These guidances aim to decrease the water loss on the average down to 25%.

Studies in water loss in relation to urbanization should be tracked and displayed in the Water Balance Table (Lambert et al. 1999; Farley and Liemberger 2005) by every Water Administration. This table will help to keep track on the water loss components whereby this table will at the same time help to choose the right direction in relation to those components.

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Even though the loss in water seems to be an issue of the local government, the details indicate that it is also affecting the central government expenditures economically. In Turkey, the local governments are accessing water by making use of water pumping sets and water supply stations. The loss of million cubic meters in domestic water within the DWSDN's causes to the pollution and to energy wastages. It is, therefore, necessary to pay attention to water losses, but also the energy wastage.

In the past view years, despite the effort for the water loss prevention, it was not possible to solve this issue, in general. Even though the necessary researches have been made in relation to the water loss, the necessary judgments have not been tackled sufficiently in the domestic government departments. In order to prevent the water loss, the Turkish Administration has kept statistics on the difference between the water input into the system and the billed consumption, which is necessary to decrease the difference significantly. In order to reach the former mentioned aim, the water supply into the DWSDN's have been measured and attention have been paid to the right water pressure. At the end, a comparison has been made between the water supply and the end bill for the consumption of the supplied water, which is necessary in order to take the right decision on the best suitable strategies development.

In order to decrease "real losses," the necessary attention should first be paid to the pressure management within the distribution network by means of the active leak control and the pipelines (if available) along with the speed in repair and the effort in quality improvements. In addition, the active decrease in water loss should be realized by stimulating an independent existence of large hydraulic Domestic Water Supply Networks within the 'District Meters Areas' (DMA) (Gomes et al. 2012a, b). The flow of water within the DMA should constantly be monitored, whereby the minimum flow should be measured every night. Apart from the measurements, the repair and renewal of the pipelines should also be considered. In addition, the DWSDN's should be transferred to the Geographic Information System (GIS). It is strongly recommended to make use of the Supervisor Control and Data Acquisition (SCADA) system in order to keep track on real-time control and on the necessary equipment.

The empirical estimates in the UARL formula are derived mostly from tests in district metered areas in England and Wales during the late 1990's. For example, the UARL of the main pipes is a combination of background leakage and leakage from reported and unreported breaks. All of these components are affected by network material and age. Further studies are needed to clarify whether the empirical parameters of the ILI formula are applicable to utilities with low connection densities and relatively young pipes.

It is clear that perceptual leakage targets are not very suitable, even when used internally at utilities, as the leakage percentage is a function of water use. Our results suggest that the ILI, even though it is theoretically more appropriate, is not a suitable indicator for setting leakage targets in Finland. Instead, in the absence of a suitable indicator, the utilities could be obligated to monitor leakage levels and formulate leakage management plans in the long term.

Decreasing the number in water loss by using the ILI and the Non-Revenue Water percentage, it is clear that a diversity in approach is needed. In the scope of this research, a method of calculation for the prevention of water loss has been developed within the DMA. As a result, a successful strategy has been created.

After the distribution network water loss levels are measured, apparent and real losses strategies must be initialized for the struggle. In order to fulfil the components successfully, the difficulties in the process should first be understood and then the necessary technical capacity should be developed. In order to realize the former, access to sufficient financial support should be realized for the renewal of the infrastructure, and strategical plan of each Water Administration for the decrease of water losses.

Literature review

Researches in this paper have taken into consideration the results of other related studies in the literature. In accordance with the mentioned studies, the following reasons have been presented briefly concerning the water loss problems.

- Leakage within the WDN (Samir et al. 2017)
- Leakage of water in the supply and reservoir network (Özdemir 2018)
- Leakage within the supply pipelines (Özdemir 2018)
- Illegal use of water by customer (Washali et al. 2020)
- Missing projects and the usage of unsuitable equipment
- Metering inaccuracies (Rıchards et al. 2010)
- The late repair of any breakdowns (Kanakoudis and Tolikas 2001)
- Unbilled water consumption by the fire station, in gardens, in parks, at religious facilities.

As a result of these reasons, water loss should be conducted by creating a strong team work and coordination within the water administration departments or centers. Subsequently, drastic savings can be achieved in the process from the water supply until the water consumption process (Karadirek 2016).

Administrations that have impacts and leading roles in the water management affairs should make use of the latest technologies (Muhammetoğlu and Muhammetoğlu 2017). The main factors in water management are productivity and the cost optimizations. It is unfortunately painful to

say that those administrations facing with water loss are not paying enough attention to productivity (Ferrari and Savic 2015). A productive administration management should consist of a system that pays attention to strategies to combat with water losses (Adedeji et al. 2018) and their reduction to an acceptable level (Ahopelto and Vahala 2020). This should be the right strategy, which should easily be followed up by every administrational system.

The administration system should first measure the current water loss levels (Adedeji et al. 2018) and sum up the aims in relation to the acceptable level to reach water loss reduction. For this purpose, it is recommended to pay attention to the water loss causing components (Kanakoudis et al. 2015) as mentioned on the Standard Water Balance Table (Lambert et al. 1999; Farley and Liemberger 2005) along with the strategies with a low budget (Adedeji et al. 2017). Among some of the components there are eight main reasons that might be less costly than the other components (Kanakoudis and Tsitsifli 2009; Tabesh et al. 2009).

In general, profits can be obtained when a real loss (Özdemir 2018; Tabesh et al. 2009; Fontana et al. 2016) is determined and the necessary measures are taken which can be reflected to the costs for supply and operating processes. The reflection is risible once the costs start to decrease. The administrations' general profits is expected to increase once the water losses are fixed (Tabesh et al. 2009; Xin et al. 2014; Rizzo et al. n.d.). Furthermore, the administrations' primary aim should be to increase the profits and decrease the losses.

Moreover, the aim to lower the water loss levels should be determined by setting up a plan and applying it in practice. Plan setting is beneficial, but also costly at the same time. Consequently, administration should consider whether it is, in general, financially sustainable to bear the costs in the long run (Muhammetoğlu et al. 2018). It is really attractive that the strategies should be on ready, but in the later stage the process may slow down as there might be some budget cuts resulting from the strategies in unfortunate situations (Ociepa et al. 2019). To avoid the former, it is strongly recommended to set up pilot projects to develop the mentioned strategies. The pilot project stimulates application and testing the necessary components for the water loss reduction strategies (Cinal 2009). If the pilot project seems to be successful, then it would be easier to apply in a larger project by keeping easier track on the financial balance.

After fulfilment of the said procedures, the accuracy of the tests should be compared with the standardized components. The former can be tackled by using the International Water Association's (IWA) Infrastructure Leakage Index, Current Annual Real Losses (CARL) and Unavoidable Annual Real Losses (UARL) Loss as a great performance example (Lambert and Hirner 2000).

$$CARL = SIV - UAC - BAC \qquad (1)$$

In the case the water System Input Volume (SIV) into the network in, Unbilled Authorized Consumption (UAC) for the administrations' own water consumption, and Billed Authorized Consumption (BAC) is the sold water; all in m^3/year. Hence, also m^3/year Inevitable Annual Real Loss (UARL) can be expressed as,

$$UARL = \left(18 \times L_m + 0.8 \times N_c + 25 \times L_p\right) \times p \qquad (2)$$

where L_m is for the main supply length (km), L_p is standing distance for the pipelines from the customers private land to the main meter in (km), N_c is for the number of service connections, p is for the average pressure (m). Finally, the Infrastructure Leakage Index can be expressed as follows.

$$ILI = \frac{CARL}{UARL} \qquad (3)$$

Invisible water leakage determination on surface

In general, the total water losses in the WDN are real losses (Washali et al. 2020). It takes time until the administration realizes the losses and repairs the leaks whereby the water loss volume increases (Hussein et al. 2017). It can take surprisingly weeks and years for underground leakages quantification, and therefore, water losses should be countered by water leakage strategies in addition to the water leakage areas determination (Yang et al. 2008) and the decrease in maintenance time.

In order for the administration to determine the different leakage types, the flow discharge, flow time, location determination and ALR procedures maintenance should be cared for along with the Real Volume Loss (Muhammetoğlu and Muhammetoğlu 2017). The kind of leakages within the WDN consists of notified and unnotified leakages in addition to the background leakages (those are small leakages, which are difficult to determine and expensive to maintain) (Adedeji et al. 2018; Xin et al. 2014).

The active leak control determination is a cost-effective, important and effective lifesaving method (Yang et al. 2008). In order to use this method effectively, the network hydraulics should be separated from each other in the District Metered Areas (DMA) (Farley and Liemberger 2005; Xin et al. 2014). As the DMA flow at the entrance is very sensitive, the measurements should be made with sensitive flow meters (Rıchards et al. 2010; Kara et al. 2015). Any leakages of the pipelines within the network could be determined earlier during the measurements as the flow starts to increase and exceeds pre-determined limits. The

former should be done along with the minimum night flow measurements (Tabesh et al. 2009; García et al. 2006) and the net night flows (leakages). The increase in night flow shows the increase in leakages. It is strongly recommended to use acoustic methods in order to trace the right leaking pipeline(s).

System entrance measurement

The flow measurement within a WDN should start at the system's entrance (Washali et al. 2020; Kanakoudis et al. 2015; Kara et al. 2015), which stimulates the possibility to understand the features much better. The following hierarchy shows the way and procedure of the measurements:

- First of all, spring water is being measured until the entrance and exit of the water from reservoir, the entrance and exit of the treatment facility and the backwash flush (Kara et al. 2015).
- Water demineralization, at the entrance and exit of the water reservoir (Washali et al. 2020).
- At the entrance–exit of the water pump stations.
- At the geographic and hydraulic borders by measuring the region.
- Measurements in district metered areas (Washali et al. 2020; Kanakoudis et al. 2015; Kara et al. 2015).
- The placement of customers or commercial places.

The measurements within the scope of this study have started at the Sapanca Leak in the Province of Sakarya (Turkey). Here, the untreated water has been measured by attaching a flow meter at the exit of the pump station. At the first stage (Year 2009), flow meters have been mounted in areas, where the capacity of the water reservoir were above the level of 4000 m^3 or areas where the water capacity of the water reservoir was below the level of 4000 m^3 with a population density. In the scope of this stage, 7 (seven) flow meters have been mounted at the locations. Some of the mounted flow meters are currently in use.

Distribution lines and digitation of the network

As one can imagine, it is impossible to remember the WDN lines, locations and depths of the pipelines. As a result of fast urbanization and the density in substructure make it hard and almost impossible to keep track on the lines if the necessary information are not saved somewhere (Alıcı and Özaslan 2018). In the past, former workers have tried to transfer the necessary knowledge and experience regarding the substructure to the new starters. This should be avoided and digitized in order to keep fast track on any issue and to improve the performance of administration.

In such works, the importance of the Geographic Information Systems (GIS) has grown and the need has grown for digitation of the substructure (Keskin and Yılmaz 2005). Formerly, the necessary determinations have been made by keeping track on the investments in addition to a track on the economic lifetime and maintenance has been kept. From this information, it is obvious that digitation is an effective method to decrease the number of water losses (Alıcı and Özaslan 2018).

From this view, the WDN measurements should be digitized into the GIS, the water loss should be inspected via the system and the life time of the pipelines should be taken into consideration before the necessary decisions are being taken. Within GIS, every DMA area should have its own archive whereby the necessary information should be saved from field research until the measurements of pipelines, connection points, coordination, and length etc. Every detail like the brand, type, height, age and numbers of the networks should be saved as well (Alıcı and Özaslan 2018). This information is off importance to counter the water loss.

The necessary information form 2009 until today in relation to the district areas of Adapazarı, Erenler and Serdivan in Sakarya region are available. The network in these areas have been planned, coordinated and digitized. The necessary auction information and the recent constructions (renewals excluded) are included in Table 1 with the necessary studies.

Flow measurement and evaluation

The track on the flow capacity within DWSDN, through the measurement of the water pressure, the water level within the reservoir (Creaco et al. 2019), the track on energy consumption and the preparation of the IWA table are of important for the reduction of water loss (Fontana et al. 2018). The DWSDN shows variation in the water demand on an hourly, daily, seasonal and yearly bases.

The necessary technical infrastructure is being maintained to keep track on the water supply into the districts. SCADA has started from 2008 onward to keep track on the water input into the districts and the water levels. The following year, SCADA has started to measure the water flow through the flow meters that have been mounted to the Network. By means of SCADA, the track on the system and the prevention of overflow has been stimulated (Fig. 1).

Pressure management and the realization of the district metered area

The water pressure within the DWSDN depends on the pipeline codes, reservoir and all other pipeline levels along with the maximum water supply level and water consumptions (Choi et al. 2014). Pressure management (Adedeji et al. 2018; Fontana et al. 2018) depends on the water pressure

Table 1 Digitization studies

Order No	Years	Water breakdowns (numbers)	Authorized consumption (numbers)	Network valves (numbers)	New lines (m)	Network renewals (m)	Current network measurements (m)
1	2013	704	566	376	63.956	34.032	152.830
2	2014	422	297	270	31.971	19.470	257.729
3	2015	335	468	144	31.545	17.247	11.936
4	2016	427	672	167	32.321	5.323	10.511
5	2017	618	771	198	34.325	6.288	195
6	2018	542	439	219	33.254	9.321	2.480
7	2019	425	549	83	24.413	6.780	0
Total		3.473	3.762	1.457	251.785	98.461	435.681

Fig. 1 Traced works on a yearly basis
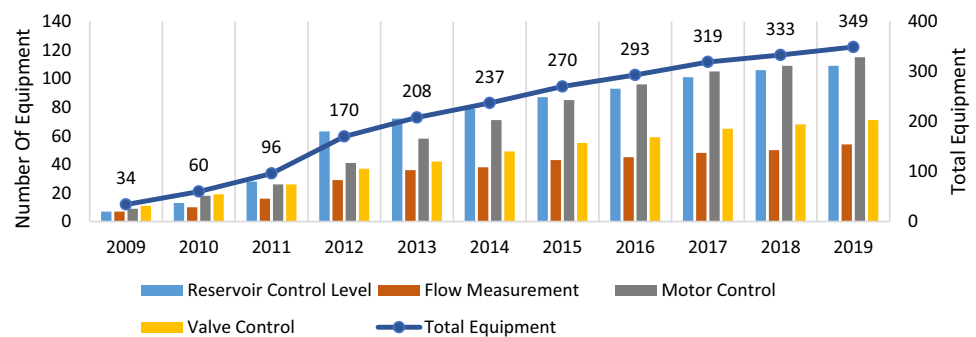
measurements in those indicated areas (Samir et al. 2017; Rizzo et al. n.d.). The water loss reduction within the DWSDN is the most (cost) effective method for the prevention of water loss (Güngör et al. 2019). In order to manage the pressure, a good analysis and controllable DMA should be separated and the necessary pressure should be controlled (Fontana et al. 2018). Pressure management means the control or pressure through check valves (Cinal 2009).

The Numbers in water loss within a large distribution network is an average of the total number (Babel et al. 2009). This approach makes it hard to reduce and have control over the water loss (Farley and Liemberger 2005). Large water networks' hydraulics have been separated from DMA in order to keep effective track on the water loss control and the small changes in the main parameters (Xin et al. 2014; Fontana et al. 2018). Generally, water pressure is being measured at the DMA entrance along with the minimum and maximum pressures (Adedeji et al. 2018). As a result, every water loss within the DMA is being measured and controlled (Lambert et al. 1999; Babel et al. 2009).

Every district that receives water should constantly be tracked and measured so that any increments in water going to that district area might have a water leak within its pipelines (Karadirek 2016). Attention to the minimum night pressure should be paid at the moment real losses within the network are being measured (Tabesh et al. 2009).

Tracing water leak through acoustic leak detection

Water leak within the network consists of three different kinds, namely inherent, visible and non-visible (Borges de Abreu and Ram'irez 2010). Inherent leakage is a small one, which is not visible and easy to determine. Non-visible leakage is not visible on the surface, but can be traced through the available technologies. It is traced through acoustic leak detection, which is being used to trace water losses that are not visible on surface and when the right equipment is not available. By using this method, water loss is being traced through a listening method, which is realized through placing acoustic leak detections on both sides of the leaked pipelines (Khulief et al. 2012). This is in order to trace the right the leaked pipeline that is under pressure. The listening performance depends on the size, figure, pipe measures and materials. The most used acoustic equipment are acoustic recorders, leakage correlators, floor microphone and sound sticks (Muhammetoğlu and Muhammetoğlu 2017).

This method has been applied to all separated DMA. The results of this method are mentioned in the section below.

Findings

Depending on the kind of pipeline, domestic water networks are sending certain acoustic emission waves when there is a breakdown. By using the acoustic leak detection (Yang et al. 2008) it is easier to trace those emission waves. The kind of breakdown and water leak depend on the size of the pipelines, their form, the size of the breakdown, the base whereunder the breakdown occurs, the way of how the pipelines are connected and the kind of materials that have been used (valves, network etc.). Tracing breakdowns by only acoustic leak detection method will not be sufficient. Apart from the abovementioned method, it is also important to apply the pressure management and the minimum night flow (MNF) analyses.

By taking the former mentioned method into consideration, the district in the scope of this study has been divided into 132 areas. There have been build pressure chambers in the areas in order to measure the pressure more accurate. Taking these pressure chambers into hand, 19 DMA have been evaluated. Figure 2 shows the details in these areas.

The application of this method indicates that it is important to pay attention to which areas should be analyzed first and which strategies should be applied once the MNF analyses are being evaluated.

The following calculation is for determination of the relation between the percentage of water loss and the MNF.

$$\text{Prior percentage} = \frac{\%\text{Loss in percentage} \times \text{MGD}}{100} = \text{Leakage number} \tag{4}$$

Apart from the percentage in loss and the peak in DMA, it is strongly recommended to prioritize the determination of hit peaking DMA and the number of leakage (Table 2).

As displayed in Table 2, to interpret that the numbers of water leakages are high is rather wrong when the numbers

in one area are high. This along with the fact that consumption in one area might be much higher. The MNF is in this case a determined factor, which should be used along with the water loss reduction strategies to counter the numbers in leakages in those areas, where the number of water loss hits the ceiling.

In the study, an order has been made in accordance with the water leakage numbers. From the results in these numbers it is noticeable that DMA 7 should be taken on the first place. However, it is wrong to argue that the order should be made by only looking at the percentage of water loss or MNF. It should be considered to determine the leaking numbers along with all the DMA. By taking the former and the numbers in Table 2 into consideration, the ranking order will be as follows; DMA 7, DMA 9 and DMA 3. If the numbers are being determined from the water leaking numbers point of view, then the ranking order should be as follows; DMA 7, DMA 16 and DMA 13. The water leakage determination from this point of view will be a wrong starting point.

The MNF results are close to each other and by taking this occasion into consideration, DMA 7 should be determined first following DMA 9 and DMA 13. At the moment, these numbers are being used to calculate the percentage of water losses, then it can be said that DMA 9 with 62% should be determined prior to DMA 13 with a percentage of 68% water loss.

By comparing DMA 1, DMA 3 and DMA 6 among each other, it is clear that the night flow and water loss percentage in DMA 3 is bound to be the highest. From this calculation, it is clear that by using acoustic leak detection among the mentioned three districts, DMA 3 district should be prioritized. DMA 1 and DMA 6 should thereafter be taken into consideration.

Along with this determination, the ILI of every district should be calculated. From the ILI results it is clear that DMA 17 with its priority order 16 is the highest in its ILI
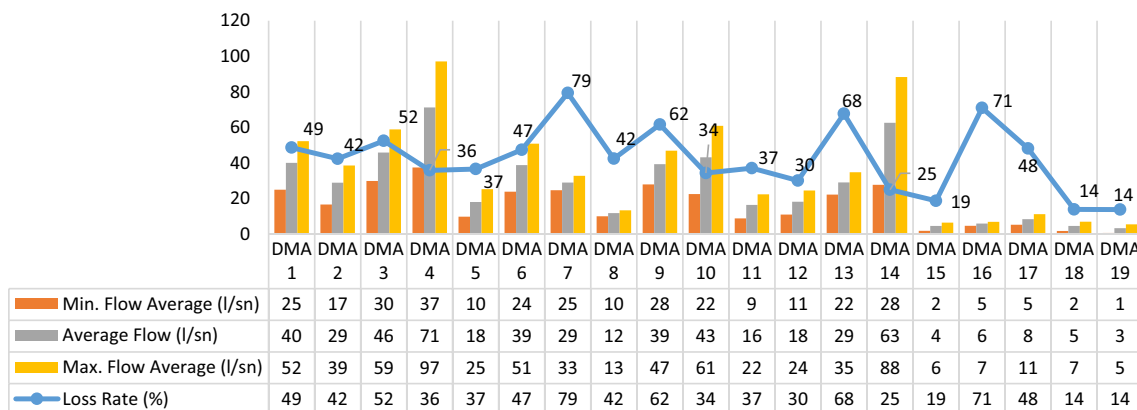

	DMA 1	DMA 2	DMA 3	DMA 4	DMA 5	DMA 6	DMA 7	DMA 8	DMA 9	DMA 10	DMA 11	DMA 12	DMA 13	DMA 14	DMA 15	DMA 16	DMA 17	DMA 18	DMA 19
Min. Flow Average (l/sn)	25	17	30	37	10	24	25	10	28	22	9	11	22	28	2	5	5	2	1
Average Flow (l/sn)	40	29	46	71	18	39	29	12	39	43	16	18	29	63	4	6	8	5	3
Max. Flow Average (l/sn)	52	39	59	97	25	51	33	13	47	61	22	24	35	88	6	7	11	7	5
Loss Rate (%)	49	42	52	36	37	47	79	42	62	34	37	30	68	25	19	71	48	14	14

Fig. 2 DMA water loss in percentage, minimum flow rate in percentage, average of minimum flow rate, average of maximum flow rate and the average flow rate

Table 2 The leakage determination order	DMA name	Water loss (%)	Min. flow rate (l/s)	Average flow (l/s)	Number of leaks	Order of priority	ILI
	DMA 1	49	25	40	12.10	6	5.09
	DMA 2	42	17	29	7.02	9	3.11
	DMA 3	52	30	46	15.62	3	7.01
	DMA 4	36	37	71	13.37	5	2.87
	DMA 5	37	10	18	3.54	12	3.31
	DMA 6	47	24	39	11.25	7	4.78
	DMA 7	79	25	29	19.50	1	12.82
	DMA 8	42	10	12	4.21	11	4.13
	DMA 9	62	28	39	17.16	2	8.80
	DMA 10	34	22	43	7.70	8	4.80
	DMA 11	37	9	16	3.25	13	4.40
	DMA 12	30	11	18	3.27	15	1.30
	DMA 13	68	22	29	14.97	4	20.27
	DMA 14	25	28	63	6.88	10	4.61
	DMA 15	19	2	4	0.33	17	2.09
	DMA 16	71	5	6	3.24	14	15.33
	DMA 17	48	5	8	2.49	16	21.46
	DMA 18	14	2	5	0.23	18	1.05
	DMA 19	14	1	3	0.07	19	1.10

with 20.27 and DMA 13 is in the second line with an ILI of 20.27. The determination of the remaining DMAs should not only be considered with the ILI numbers, but also with the other components.

The number of leaks in the scope of this study have been tackled as follows; the non-visible leaks number has been determined first through acoustic leak method. As explained before, this method is the most effective one to trace the most non-visible leakages.

Secondly, the leaks in the remaining DMA have been determined through the same method. During the determinations in the scope of this study a lot of leakages have been tackled.

Through the acoustic leak detection, the MNF pressure management has been determined and a breakdown around 12 l/s has been tackled by preventing the leaked water from seeping further underground (Fig. 3). The former has been applied in many cases and has taken into care for water decrease within the network.

Night flow determinations in relation to the DMA have taken place and as a result, the aforementioned methods
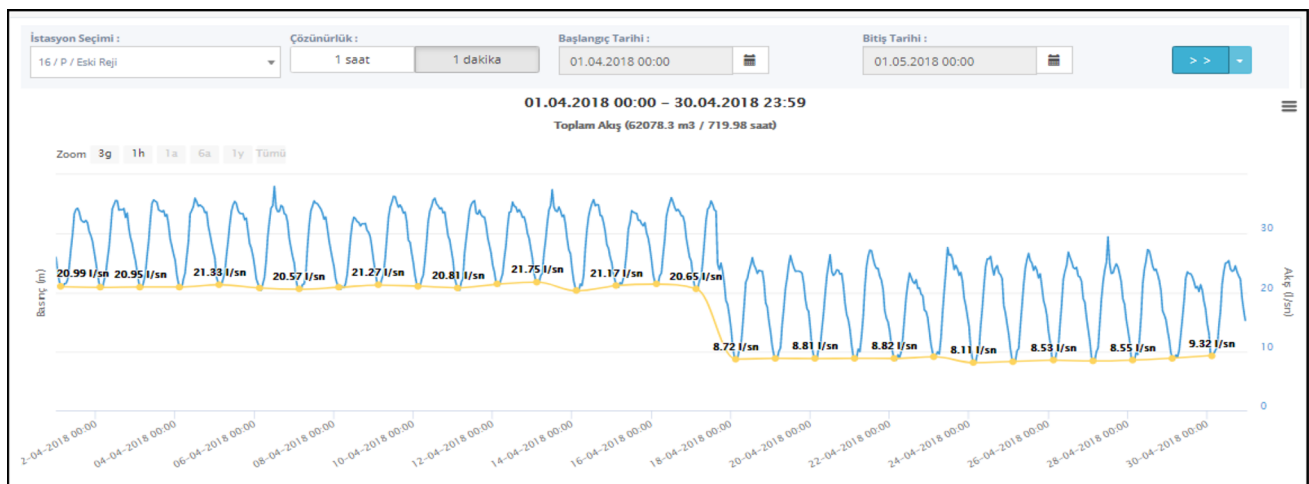

Fig. 3 Breakdown determination through Acoustic Leak Detection and the decrease of water within the Network

have been applied and the DMA with the most leakages have been tackled (Fig. 4).

Breakdowns traced through acoustic lead detection are displayed in Fig. 3. However, Fig. 4 shows the beneficial result of traced breakdowns in the early stage. The numbers show that the water has been inserted into the network in the years 2017, 2018 and 2019 along with the percentages 5%, 7% and 12% and costs around 12%, 16% and 22%, respectively (Tables 3 and 4).

Table 5 shows the numbers in percentages for non-revenue water, where the non-revenue water is above 60%. The same table reveals the numbers as a result of the applied methods. Figure 5 shows a decrease in non-revenue water from 71% to 45% and a decrease in real loss from 66% to 40% between the years 2009 and 2019.

Those methods that have been applied in the scope of the study have taken care of drastic decrease in water loss around 26% in the districts of Adapazarı, Erenler and Serdivan (Fig. 6).

Recommendations

In accordance with the European accession negotiations, Turkey must make an investment around 50 billion Euros. This investment is needed to supply clean and safe water. In order to meet the investment purposes, it is important to decide on the right strategies and take care of the necessary studies. Although, meeting this aim should contain studies, wherein the water loss must be tackled and this must be done by each water administration individually.

Meeting the aim to tackle the water loss to a minimum level should start by making sure that the whole organization within administration (from management until the lowest level of workers) understands the importance of the water loss reduction and the results thereof. The former responsibility should especially be transferred to the following groups.
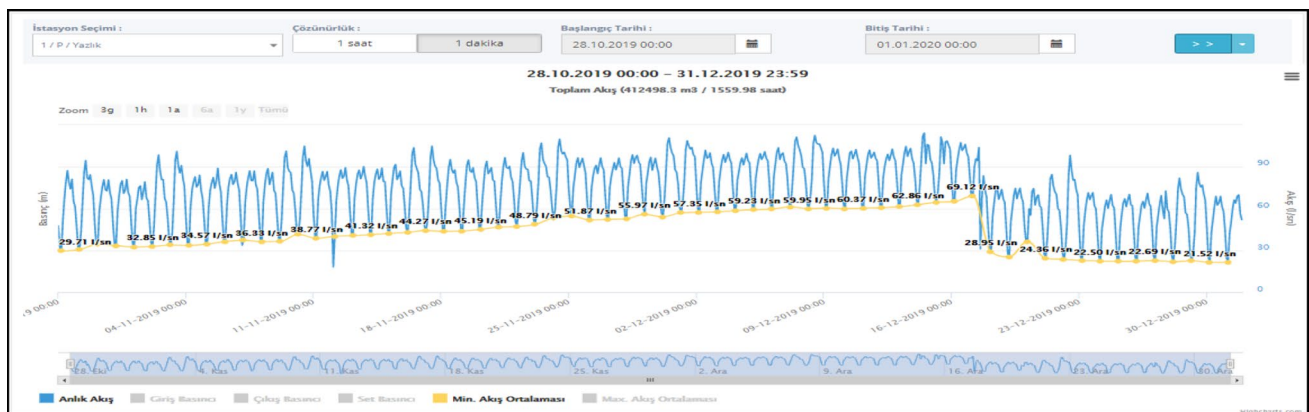

Fig. 4 Increment in MGD and the daily graphic after determination of a breakdown

Table 3 Acoustic Lead Detection numbers in years (Source: results SASKİ leaking detection system)

Districts	Years								Total
	2012	2013	2014	2015	2016	2017	2018	2019	
Adapazarı	350	332	470	443	360	390	450	583	3378
Erenler	128	128	189	177	148	129	127	274	1300
Serdivan	240	198	282	266	252	192	225	260	1915
Total	718	658	941	886	760	711	802	1117	6593

Table 4 The benefits deriving from the traced breakdowns (Source: results SASKİ SCADA system)

DMA	2017		2018		2019	
Measured district areas	Gained water	Gain of water on a yearly bases	Gained water	Gained water on a yearly bases	Gained water	Gained water on a yearly bases
13	298 m^3/h	2617.488 m^3/year	410.4 m^3/h	3595.104 m^3/year	586.4m^3/h	5136.840 m^3/year

Table 5 The water supplied to the Network, the costs and the number of non-revenue water for the years between 2009 and 2019

| Years	Supply of water (m^3/year)	Costs (m^3/year)	Non-revenue water (m^3/year)	Non-revenue water (%)	Water leaks (%)
2009	51,253.235	14,745.610	36,301.86	71	66
2010	54,855.301	17,392.253	37,219.556	68	63
2011	54,495.230	18,199.792	36,040.641	66	61
2012	53,151.579	18,957.219	33,928.959	64	59
2013	52,924.374	20,076.479	32,566.825	62	57
2014	49,024.036	19,952.911	28,791.784	59	54
2015	49,400.911	21,326.355	27,775.987	56	51
2016	49,760.976	22,601.572	26,842.982	54	49
2017	45,329.666	21,004.396	24,031.208	53	48
2018	44,793.101	21,968.221	22,517.325	50	45
2019	41,910.483	22,670.747	18,922.345	45	40

Fig. 5 The water supplied to the Network, the costs and the number of non-revenue water for the years between 2009 and 2019 (Source: results SASKİ SCADA systems)
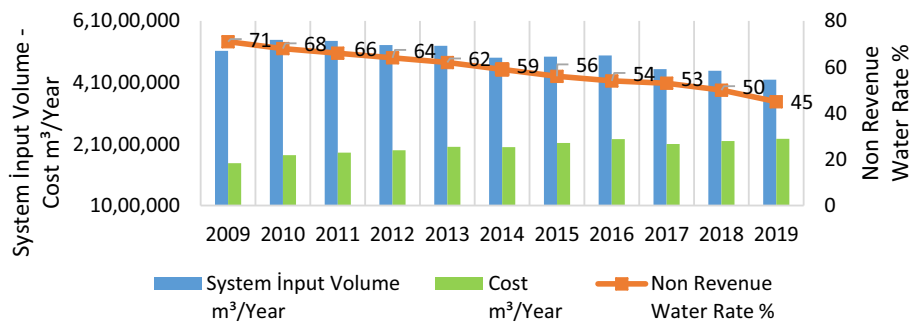
Fig. 6 Non-revenue water in three districts between 2009 and 2019 (Source: results SASKİ SCADA systems)
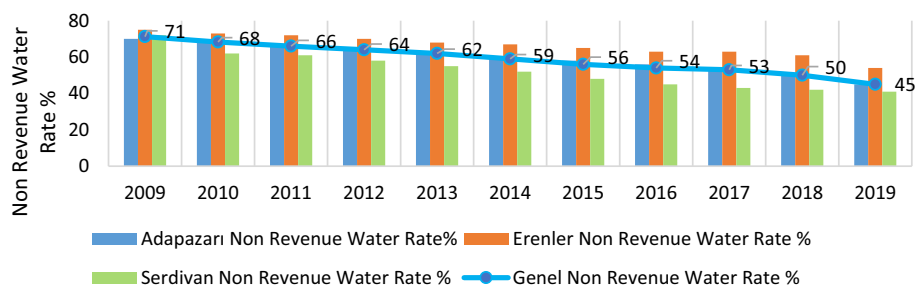
- The upper management of the water management department
- Each level of workers within the water management department
- The consumers

From this study, it has been revealed that the missing consent from the upper management and the lack of setting an appropriate budget aside results in unsuccessful strategies. If the upper management takes the risk and effort to take the necessary measurements to meet the necessary strategies then the employees on the lower level of the same department will build trust in chasing the aims. Moreover, the trust will pursue the employees to understand the breakdowns and importance in water loss, the need in tackling the breakdowns, etc.

Sakarya has developed a strategy named "Sakarya Water Loss Reduction". SASKİ has started to apply this strategy by making the necessary investments and purchasing the necessary equipment to complete the DMA. In addition, the districts should be divided into several areas, the water levels within the reservoirs should be chased, all the measurements (including the night flow) should be made in real time, the input and output of the pressure reduction valves mounted to the DMAs should be measured in real time, the factors in relation to the pressure reduction must be followed and

not only should the water leaks be estimated, but also the billed and consumed amount of water should be taken into consideration.

Above all, it is strongly recommended to pursue this aim to complete the strategy successfully.

Compliance with ethical standards

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