Non-Revenue Water Management in Palestine

Samah Jawad Jabari

Abstract—Water is the most important and valuable resource not only for human life but also for all living things on the planet. The water supply utilities should fulfill the water requirement quantitatively and qualitatively. Drinking water systems are exposed to both natural (hurricanes and flood) and manmade hazards (risks) that are common in Palestine. Non-Revenue Water (NRW) is a manmade risk which remains a major concern in Palestine, as the NRW levels are estimated to be at a high level. In this research, Hebron city water distribution network was taken as a case study to estimate and audit the NRW levels. The research also investigated the state of the existing water distribution system in the study area by investigating the water losses and obtained more information on NRW prevention and management practices. Data and information have been collected from the Palestinian Water Authority (PWA) and Hebron Municipality (HM) archive. In addition to that, a questionnaire has been designed and administered by the researcher in order to collect the necessary data for water auditing. The questionnaire also assessed the views of stakeholder in PWA and HM (staff) on the current status of the NRW in the Hebron water distribution system. The important result obtained by this research shows that NRW in Hebron city was high and in excess of 30%. The main factors that contribute to NRW were the inaccuracies in billing volumes, unauthorized consumption, and the method of estimating consumptions through faulty meters. Policy for NRW reduction is available in Palestine; however, it is clear that the number of qualified staff available to carry out the activities related to leak detection is low, and that there is a lack of appropriate technologies to reduce water losses and undertake sufficient system maintenance, which needs to be improved to enhance the performance of the network and decrease the level of NRW losses.

Keywords—Non-revenue water, water auditing, leak detection, water meters.

I. INTRODUCTION

EFFICIENT distribution of water is a key element for any water authority or company both in terms of cost and maximizing the availability of water for customers. This is particularly true in countries like Palestine where water is very scarce. High levels of NRW reflect huge amounts of water being lost through leaks, non-invoicing to customers, or both. In fact, it is affects the financial viability of water utilities through lost revenues and increased operational costs. Poorly run water utilities result in high NRW levels, and are characterized by the lack governance, absence of autonomy and accountability, weakness in the technical and managerial skills necessary to provide reliable service to their communities [4]. In Palestine, high NRW levels result in the waste of resources which is a considerable challenge.

There is an increasing awareness around the world that water is becoming the critical issue of the 21st century [5].

Samah Jawad Jabari is with the Palestine Polytechnic University Hebron-West Bank, Palestine (e-mail: samahj@ppu.edu).

Water loss, which is the major component of NRW, has been one of the major challenges in managing water utilities around the world; this situation is even more challenging and serious in Palestine. This is aggravated by the fact that there is a lack of technological expertise and equipment to deal with water loss in most water utilities. Therefore, taking all these challenges into account, better management of the water resources in the country is extremely important and research is required by studying and understanding these losses and the proper management of distribution systems [1].

Literature and studies about NRW in Palestine and on ongoing efforts to assess the water systems and needs to repair and reconstruct damaged systems are lacking. The available data obtained from PWA indicate that the level of water loss is above 30%, but the strategy for metering improvements and NRW reduction is not clear, nor has this topic been deeply studied before. The emergency response to water leakage should be to an acceptable level. The philosophy of the PWA and HM in regard to the current emergency response practice shows it is focused principally on resolving the cause of the problem as quickly as possible. The other important elements of providing public information, alternative water supplies and examining the contingency options for further reconfiguring the network and speeding up the repair during long duration events are not given the same level of focus.

According to the data and literature provided by the Interior Department of PWA, the water systems in the study area (South of West Bank of Palestine) face a number of problems [6], among which are; low coverage, low service levels, some problems with hydraulic designs, high NRW, frequent pipeline bursts, problems with billing and collection of revenue, and stopped or faulty water meters. The purpose of the present study is to identify the problem of NRW that affects the operating of water systems in Palestine and to suggest how these problems may be reduced through effective mitigation measures. The study investigates the state of the public water system in south West Bank to first determine the current water loss accounting practices and resulting loss estimates, gain more information on current water loss prevention and management practices, and then to make recommendations for more consistent water use accounting and water loss management. The Hebron city water system is taken as a case study for this water losses study.

II. METHODOLOGY

A. Collection of Data

The basic data and information such as the characteristics of the distributed pipes including pipe diameters, lengths and materials along with some maps were collected from the HM archive. For the purpose of the present study and in order to

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estimate and audit the water losses in the water distribution network of the study area (Hebron city), the data sheet presented in Table I was prepared in order to collect data from the engineers in charge of the water leakage detection program [3]. The data and information necessary for water auditing were analyzed using the American Water Works Association (AWWA) free Water Audit Software.

Within the framework of the present research work and in order to achieve the main objective of this study, the researcher has prepared a questionnaire for PWA and HM staff. The aim of this questionnaire is to assess the views of stakeholder in PWA (staff) on the current status of water losses in Palestine from technical and strategic aspects. It seeks to discover from PWA and HM staff who are concerned with water losses, what their perceptions are about the stated NRW figure, their understanding of the impact and main causes of water loss, and their opinions on PWA's procedures and policy related to water loss reduction.

The questionnaire was developed based on the objectives of the study and by looking to similar questionnaires given in the literature. The researcher conducted pilot tests of the questionnaire prior to its final use. Thirty staff from the PWA and HM were interviewed face-to-face and completed the questionnaires. The staff members consist mainly of engineers, who are concerned with the water losses, and some managers.

The questionnaire consists of primary and secondary questions and is sub-divided into two main sections.

TABLE I
DATA SHEET FOR WATER LOSS INFORMATION [7]

A- Basic Information						
Name of City or Utility:			Country:			
Reporting Year:	Start Date (MM/YYYY):		Start Date (MM/YYYY):			
Name of Contact Person:			E-mail:			
Telephone:	Fax:		Mobile:			
Reporting Units for Water Volume:						
B- Reporting Work Sheet	2010	2011	2012	2013	2014	
1. Water supplies						
1.1 Volume from Own Sources						
1.2 Master Meter Error Adjustment						
1.3 Water Imported						
1.4 Water Exported						
2. Authorized Consumption						
2.1 Billed Metered						
2.2 Billed Unmetered						
2.3 Unbilled Metered						
2.4 Unbilled Unmetered						
3. Apparent Losses						
3.1 Unauthorized Consumption						
3.2 Customer Metering Inaccuracies						
3.3 Systematic Data Handling Errors						
4. System Data						
4.1 Length of Mains						
4.2 Number of Active and Inactive Service Connections						
4.3 Average Length of Costumer Service Line						
4.4 Average Operating Pressure						
5. Cost Data						
5.1 Total Annual Cost of Operating Water System						
5.2 Costumer Retail Unit Cost (Applied to Apparent Losses)						
5.3 Variable Production Cost (Applied to Real Losses						

The first section addresses the basic information, while the second section deals specifically with water losses in the Hebron water network. The questionnaire is given in Table II. The data analysis was performed by first tabulating the collected data after taking the percentage values for each answer, and then discussing the results. For some questions, the researcher calculated the average values and the standard deviations for the data to check the consensus between the answers.

B. AWWA Water Audit Software

The level of water losses can be determined by conducting a Water Audit with the results shown in a Water Balance consistent with international terminology. Estimation of water production, water imported - exported, water used and lost are the key elements of the Water Balance [2]. The American Water Works Association (AWWA) developed the Water Audit Software based on the standard water balance.

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TABLE II
QUESTIONNAIRE FOR PWA AND HM STAFF [6]

A- Basic Information					
Name of Contact Person:					
Position			**Depart.**		
Job Related to Water Loss					
Tel.		**Fax**		**Mob.**	
E-mail:					

B- Water Loss in the Hebron Network

1. General Information

	What is your estimated percentage for the water losses (UFW) in the Hebron Network?
1.1	o 10-20% o 20-30% o 30-40% o 40-50% o More than 50% o Don't know
	What do you think are the main factors that contribute to water losses? Please prioritize the factors according to their contribution (1 = very high, 6 = very low)
1.2	o Meter Inaccuracies o Losses during repair o Age of pipes o Illegal Connection o Service reservoir overflow o Water pressure Your opinion based on your experiences:
	What do you consider to be the best solution to reduce water losses in the Hebron water system? Please prioritize the measures according to their efficiency (1 = very high, 6 = very low)
1.3	o Improve pipe maintenance o Clampdown on illegal connections o Pipe replacement o Active leak detection o Increase public Awareness o Improve metering Your opinion based on your experiences:
	Which method of PWA strategy focuses of deriving the water loss figure:
1.4	o Leakage Level (%) o Leakage level (%) and UFW o UFW o NRW o UFW and NRW o Don't know
	What do you think are the possible impacts of the high water loss figures? Please prioritize the impacts according to their effect (1 = very high, 6 = very low)
1.5	o Reduction in pressure o Increase expenditure on development o Water contamination o High cost of O&M o Short lifespan of existing resources o Property damage

2.	Procedures and Policy	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
2.1	A National Water Policy exists which aims at reducing water losses.					
2.2	A Water loss reduction program is implemented.					
2.3	Pressure management is used to reduce water losses.					
2.4	A Network Maintenance/ Rehabilitation Program is implemented.					
2.5	Measures to fight illegal connections are applied					

3.	Obstacles for Fighting Water Losses	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
3.1	Institutional situation					
3.2	Lack of financial means from PWA					
3.3	Lack of appropriate technologies for water loss reduction.					
3.4	Maintenance system					
3.5	Personnel capacities (technicians)					
3.6	Personnel awareness					
3.7	Public acceptance / awareness					

B- Staff Opinion: Please state your opinion on the issue of water losses in Palestine

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The software has capable of analyzing losses in its different categories and calculating the revenue and NRW, as well as other parameters. The program runs under excel Microsoft office with a number of working sheets. Once data entries are accomplished, the program calculates losses, revenue and NRW and the detail water balance. The analysis of water losses was carried out using the water loss and auditing software developed by American Water Works Association (AWWA) version 4.2.

III. ANALYSIS OF THE RESULTS

A. Water Losses in Hebron Water Supply System

The data of water supplies, authorized consumption and system data for the last five years (2010-2014) for the Hebron water distribution network were collected and the predicted values of water losses and NRW were obtained using AWWA version 4.2. For the first time for Hebron city, the percentage values of apparent losses, real losses and total water losses were predicted from the software analysis, ad along with NRW water for Hebron city, are presented in Table III.

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Apparent losses, which are known as commercial losses, relate to the water that is consumed, but not correctly measured and/or billed; it includes all types of inaccuracies associated with production metering and customer metering. Theft or illegal use of water utilties also results in lost revenues.

TABLE III
THE VALUES OF WATER LOSSES AND NRW AS A PERCENTAGE OF WATER SUPPLIED

Year	Water Losses			NRW (%)
	Apparent (%)	Real (%)	Total (%)	
2010	15.9	28.4	44.3	45.2
2011	15.0	20.9	35.9	36.8
2012	15.6	18.5	34.1	35.3
2013	15.9	17.4	33.3	34.0
2014	16.1	15.8	31.9	32.5

The results indicate that the values of apparent losses are very high (around 16%). The high values are attributed to the following reasons:

- Unauthorized consumption (theft or illegal use).
- The performance of the billing system and the delay in issuing water consumption bills.
- Non-registration of the monthly readings of meters.
- Trading and transfer of the data are inaccurate and disorganized.
- High water pressure in some parts of the network.
- The inaccuracy of the water meters. The meters are not change periodically, and many of them are 15 years old.

The values of real losses are comparatively high; however, the data also show that the value of real losses has decreased from about 28.4% in 2010 to about 15.8% in 2014. This reduction may be the result of the improved management of the water network, and the intensification of maintenance works, as wells as in the speed of repair of faults and breaks in the pipe network. The values of NRW are comparatively high resulting from the problem of high values of apparent losses as explained above. The values of unbilled authorized consumption are low (less than 2%).

TABLE IV
HEBRON WATER BALANCE FOR YEAR 2014

AWWA Water Audit Software: Water Balance			Report For: Hebron	Report Year: 2014
Own Source (Adjusted for known errors) 100%	Authorized Consumption 68.1%	Billed Authorized Consumption 67.5%	Billed Water Exported 0%	Revenue Water 67.5%
			Billed Metered Consumption 67.5%	
			Billed Unmetered Consumption 0%	
Water Export 0%				
		Unbilled Authorized Consumption 0.6%	Unbilled Metered Consumption 0%	
			Unbilled Unmetered Consumption 0.6%	
Water Supplied 100%		Apparent Losses 16.1%	Unauthorized Consumption 8.2%	NRW 32.5%
			Customer Metering Inaccuracies 3.4%	
	Water Losses 31.9%		Systematic Data Handling Errors 4.5%	
		Real Losses 15.8%	Leakage on Transmission and/or Distribution mains Not broken down	
Water Imported 0%			Leakage and Overflow at Utility's Storage Tank Not broken down	
			Leakage on Service Connections Not broken down	

B. System Water Balance

The water balance for the years of study for the Hebron water network were obtained from the results of the software analysis. Table IV summarizes the software water balance results for 2014 based on the data reported for the same year from the reporting sheet of the software. The percentage values are given in the final output table.

The water balance for Hebron city indicates that the NRW in 2010 was more than 40 %, this value decreased in the last two years and is now about 32.5%. At the same time, the data of the water balance shows that billed unmetered water consumption and unbilled metered water consumption is zero for all the years studied, which means that authorized water consumption includes all billed metered and unbilled unmetered water consumption.

The value of apparent losses is almost constant in the last five years (around 16%). The results reveal that apparent losses are mainly due to unauthorized consumption-theft or illegal use (8.2%), and because of data handling errors (4.5%) related to the performance of the billing and collection system, while the customer metering inaccuracies in the Hebron city area are low (less than 4%).

Unbilled authorized consumption are components that do not produce revenue, they are legal but not billed and include activities such as watering of municipal gardens, public fountains, flushing of sewers, street cleaning, etc. The results of the water audit show that the percentage value of this unbilled authorized consumption is less than 1.0%.

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C. Existing Situation and Management Strategy

The aim of the first question in the questionnaire was to review the causes of water losses, the impacts and suggested solutions from the standpoint of PWA and HM staff. The answers of the question (What do you think the main factors that contribute to water losses?) is listed in Table V. The data show that the main factors that contribute to water losses in Hebron city is unauthorized consumption, inaccuracies in billing volumes, and the method of estimating consumptions through faulty meters, which calls for improved meter

accuracy and identifying meters that require maintenance.

Water pressure in the pipes also contributes to water losses, while the age of the pipe contributes to a lesser degree. Water pressure in the network is increased in some areas where the pipes are old, which also results in a water leakage problem, and therefore, where necessary pressure management should be implemented.

The answers to the question (What do you think are the possible impacts of the high water loss figures?) are presented in Table VI.

TABLE V
THE MAIN FACTORS THAT CONTRIBUTE TO WATER LOSSES

Answers		Prioritize According to Contribution (1 = very high, 6 = very low)					
		1	2	3	4	5	6
Meter Inaccuracies		30	15	10	20	20	5
Losses during repair		0	10	10	30	20	30
Age of pipes	Percentage Values (%)	10	30	20	30	10	0
Illegal Connection		40	20	30	10	0	0
Service reservoir overflow		0	10	10	0	40	40
Water pressure		20	15	20	10	10	25

TABLE VI
THE POSSIBLE IMPACTS OF HIGH WATER LOSS FIGURES

Answers		Prioritize According to Contribution (1 = very high, 6 = very low)					
		1	2	3	4	5	6
Reduction in pressure		10	10	20	50	0	10
Increase expenditure on development		30	20	20	20	10	0
Water contamination	Percentage Values (%)	0	10	10	0	30	50
High cost of O&M		50	30	10	0	10	0
Short lifespan of existing resources		30	20	30	10	10	0
Property damage		0	0	0	0	30	70

TABLE VII
THE BEST SOLUTION TO REDUCE WATER LOSSES IN THE HEBRON WATER SYSTEM

Answers		Prioritize According to Contribution (1 = very high, 6 = very low)					
		1	2	3	4	5	6
Improve pipe maintenance		0	20	20	20	30	10
Clampdown on illegal connection		30	20	10	10	10	20
Pipe replacement	Percentage Values (%)	0	20	10	20	20	30
Active leak detection		50	30	10	0	0	10
Increase public Awareness		0	0	40	10	30	20
Improve metering		20	10	10	40	10	10

TABLE VIII
PROCEDURES AND POLICY FOR WATER LOSSES

Procedures and Policy	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
	Percentage Value (%)				
A National Water Policy exists which aims at reducing water losses.	10	70	10	10	0
A Water loss reduction program is implemented.	70	0	20	10	0
Pressure management is used to reduce water losses.	30	50	20	0	0
A Network Maintenance/ Rehabilitation Program is Implemented.	0	80	20	0	0
Measures to fight illegal connections are applied	50	10	10	30	0

Grades: Strongly agree = 5, Agree = 4, Neutral = 3, Disagree = 2, Strongly disagree = 1

The findings emphasize that high water loss figures result in the high cost of Operation and Maintenance (O&M), short lifespan of existing resources and increased expenditure on

development, while the high water losses did not cause damage to water infrastructure.

Table VII presents a summary of the best solutions that

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could be utilized to reduce water losses in the Hebron water system according to answers of PWA and HM staff to the question (What do you consider to be the best solution to the reduce water losses in Hebron water system?). Half of the staff surveyed (50%) think that the first priority should be active leak detection, 30% think there is a need to clamp down on illegal connections, and 40% think that improving metering is the first priority. Other responses show that improvement of pipe maintenance and replacement of old pipes is also important.

The second part of the questions presented to staff members is related to the current procedures and policies. Five options are given for each policy (strongly agree, agree, neutral, disagree, and strongly disagree). The summary of the responses are presented in Table VIII. Most of staff members

agree that a national water policy exists which aims at reducing water losses and that a water loss reduction program is being implemented. The government has tried to apply this policy for different areas through a water loss reduction program. In Hebron city, pressure management and control is used to reduce water losses, and in addition, pipe repair and line maintenance programs were implemented, all of which has resulted in a reduction of water losses and NRW in the last two years.

The last set of questions are related to the obstacles for fighting water losses, and in the same way, five options are given for each question (strongly agree, agree, neutral, disagree, and strongly disagree). The responses of the PWA and HM staff are given in Table IX.

TABLE IX
OBSTACLES FOR FIGHTING WATER LOSSES

Obstacles	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
	Percentage Value (%)				
Institutional situation	0	0	20	50	30
Lack of financial means from PAW	0	70	20	10	0
Lack of appropriate technologies for water loss reductionzz.	30	70	0	0	0
Maintenance system	10	50	0	20	10
Personnel capacities(technicians)	60	40	0	0	0
Personnel awareness	20	30	10	0	40
Public acceptance / awareness	10	30	0	20	40

Grades: Strongly agree = 5, Agree = 4, Neutral = 3, Disagree = 2, Strongly disagree = 1

It is clear that the main obstacle is with the leak detection staff. It seems there are insufficient qualified staffs available to carry out the activities related to leak detection. Also, there are no formal or refresher training programs in the use of leakage detection equipment, and it is clear that training is given a very low priority. The other important factor is the lack of appropriate technologies for water loss reduction. It seems classic techniques are used, and there is necessity to move to new technology.

Due to a lack of finances, limited efforts are employed to promote programs for fighting water losses. According to the findings of the questionnaire, 60% of staff agree that there is a problem in the maintenance system and that it should be improved to reduce and limit water losses. Other factors such as personnel awareness and public acceptance/awareness are not considered as major obstacles for fighting water losses.

D. Strategy for Reducing Water Losses

According to the field survey, analysis of the results, and the comments and opinion of interviewed staff, the strategy for reducing water losses should include the following:

- Proper organization: including the recruitment of field supervisors for Customer Services in order to reduce the incidence of fraud and to update the customer database, as well as the recruitment of leak detection teams throughout the whole country.
- Adequate and tailored training: Water leak detection training programs must organized for water sector employees, new tools and methodology must be provided

through training prpgrams so as to improve practices in Palestine in order to reach the best international standards.
- Purchase of appropriate equipment and technologies: Modernization and availability of leak detection equipment such as gas techniques, tanker filling stations monitoring equipment, etc.
- Meter accuracy: Improvement in meter reading accuracy and identification of meters that require maintenance. At the same time, the standards and specifications should contain a metering specification designed to improve the accuracy of meters and prolong their working life.
- Pressure management: Reinstate existing pressure management schemes and identify scope for extension of pressure management throughout PWA.
- Leakage teams: It is essential that sufficient leakage teams are created and that they are provided with the necessary equipment to enable them to carry out their allotted tasks efficiently.
- Contractual tools: The development of appropriate contractual tools to closely manage our contractors (penalties, framework contracts, etc.).

IV. CONCLUSIONS

The results indicate that the level of NRW in Palestine districts is above 30%. This is due mainly to inaccuracies in billing volumes, high unauthorized consumption, and the method used for estimating consumptions, as well faulty meters.

The results indicate that the values of apparent losses are

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very high (around 16%). The high values are attributed mainly to unauthorized consumption (theft or illegal use), performance of the billing and collection system, the delay in issuing water consumption bills, the non-registration of the monthly readings of meters, and the inaccuracy of water meters.

The values of real losses are shown to have decreased in the last two years when the PWA began rehabilitated and upgrading many of the pipelines in the network, and replaced many of main and service water meter. The management of the water network has also improved.

The results of the field survey emphasize that high water loss figures result in the higher cost of operation and maintenance, shorter lifespan of existing resources and an increase in expenditure on development. The best solutions that could be utilized to reduce water losses, according to PWA and HM staff, are applying an active leak detection program, improvement in metering, as well as pipe maintenance and the replacement of old pipes.

In Palestine, a water losses reduction policy is already in place and the government is trying to apply this policy through a water loss reduction program. However, it is clear that the main obstacle for fighting water losses is the lack of qualified leak detection staff available to carry out the activities related to leak detection.

According to the field survey, analysis of the results, and comments and opinion of interviewed staff, the strategy for reducing water losses should include: proper organization; adequate and tailored training; purchase of appropriate equipment and technologies; metering accuracy; pressure management; leakage teams and contractual tools.

REFERENCES

[1] Adu Yeboah, P., 2008, "Management of Non-Revenue Water: A Case Study of the Water Supply in Accra, Ghana", M.Sc. Thesis, Water, Engineering and Development Centre, Department of Civil and Building Engineering, Loughborough University, Accra, Ghana.

[2] International Water Association (IWA), 2003, "Assessing Non-Revenue Water and its Components: A Practical Approach", A Special Series for Water21 by the IWA Water Loss Task Force.

[3] International Water Association (IWA), 2000, "Losses from Water Supply System: Standard Terminology and Recommended Performance Measures".

[4] Kingdom, B., Liemberger, R., and Marin, P., 2006, "The Challenge of Reducing Non-Revenue Water (NRW) in Developing Countries", Water Supply and Sanitation Sector Board Discussion Paper Series, Paper No. 8. The World Bank, Washington, DC, USA.

[5] McKenzie, R. and Seago, C., 2005, "Assessment of Real Losses in Potable Water Distribution Systems: Some Recent Developments", Water Science and Technology: Water Supply Vol 5 No 1 pp 33-40, IWA Publishing.

[6] Palestine Water Authority (PWA).

[7] http://wstagcc.org/en/wp content/uploads/sites/2/2015/02/5_AbuSharkh-and-AlAbri_NRW-in-water-distribution-network-Oman.pdf.