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Contribution of Major Factors Affecting Non-Revenue Water to Water Supply Network in Gaza Strip, Palestine

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***Abstract**: Water losses occurring in water distribution systems (WDSs) are now considered as a serious problem, necessitating a robust and effective management strategy. Non-revenue water (NRW) data indicate that most cities in Gaza Strip, Palestine experience high NRW. In 2015, the average percentage of NRW in Gaza Strip was 39%. This figure resulted in major financial, supply, and pressure losses, as well as excessive energy consumption. The estimated annual volume of NRW in 2015 was in the order of 34 million m3 which is equivalent to American $ 16 million. Furthermore, NRW is a good indicative of water utility performance; high levels of NRW usually indicate a poorly managed water utility. This paper investigates the reasons why NRW is so high in many cities in Gaza Strip. Results of the study revealed that the lack of incentives for management units, the lack of awareness of citizens-users of the water service, apparent losses, the blockade on Gaza Strip, the wars on Gaza are the main causes.*

***Keywords:** non-revenue water, IWA standard water balance, water service providers, key performance indicators*

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1. INTRODUCTION

Water is the world's most valuable elements and one of the main sources for life (Ku-Mahamud, Abu-Bakar and Wan-Ishak, 2005). The growing pressure on water has led this resource to be considered scarce and therefore, the efficient management of water resources is a growing necessity (Mutikanga and Sharma, 2012). With increasing global changes such as climate change, urbanization and population growth, there is a high probability of an additional reduction in the available water resources in the future (Tan, Huang and Cai, 2013). This could be combined by the high rate of water infrastructure deterioration which would cause greater loss of treated and pressurized drinking water. Besides, the impact of poorly managed urban WDSs associated with the global change could result in extreme scarcity scenarios (Mutikanga, Sharma and Vairavamoorthy, 2012). Nowadays, many international organizations such as International Water Management Institute (IWMI), The International Water Association (IWA) and World Water Council (WWC) are set up to organise and monitor global water management (Ku-Mahamud, *et al.*, 2005). One of the most important issues affecting water utilities, especially in urban areas in the developing countries, is the considerable difference between the volume of water flow into the distribution system and the volume of water billed to consumers which is called "non-revenue water" (Kingdom, Liemberger and Marin, 2006). In the year 2000, the IWA and American Water Works Association (AWWA) recommended water utilities and drinking water stakeholders to use the term NRW (AWWA, 2009). The expression "water loss" and "non-revenue water" are now internationally accepted, and have replaced expression such as "Unaccounted-For Water" (UFW) (Frauendorfer, Liemberger and Bank, 2010).

Furthermore, the most widely accepted framework for describing NRW and determination of water loss is the IWA Water Balance, as shown in Table 1. The IWA defines NRW as the difference between the system input volume and billed authorized consumption. NRW comprises real or physical losses, apparent or commercial losses, and unbilled authorized consumption (AWWA, 2009, Wyatt, 2010). Water losses in a WDS comprise apparent losses and real losses (Kanakoudis and Tsitsifli, 2012).

Apparent losses relate to water that is being consumed but not being paid for. Apparent losses consist of four primary components, namely customer meter inaccuracy, meter reading error, unauthorized consumption (theft, meter bypass, illegal connections, misuse of fire hydrants, etc.), and data handling and billing errors (Karadirek, Kara, Yilmaz, Muhammetoglu and Muhammetoglu, 2012). Apparent losses, or non-physical losses, are in many cases the most expensive water losses to occur from a system since they represent a direct loss of revenue to the water supplier (Seago, Bhagwan and McKenzie, 2007). Apparent losses component of a normal well-managed system constitute between 10% and 20% of the total water losses (Seago, *et al.*, 2007).

Real losses are leakage from joints in water pipes, service connections, pipe bursts, pipe cracks and overflows from storage tanks (Karadirek, *et al.*, 2012). Real losses can be categorised to pipe system leakage, reservoir leakage and overflow and finally leakage from valves and pumps (Tabesh, Yekta and Burrows, 2009). High levels of real losses normally indicate a poorly managed water utility system (Thornton, Sturm and Kunkel, 2008); sometimes make up more than 70 % of the total water losses (Greyvenstein and Van Zyl, 2007).

Expressing NRW and its components as % of system input volume can be very misleading. Thus, IWA now recommends several key indicators such as NRW, physical losses, and commercial losses, all measured in L/connection/day; as for physical losses alone, IWA recommends the use of m^3/km of pipeline/day (Wyatt, 2010). IWA has neglected using the indicator NRW as a percentage of system input to compare locations or look at trends over time because it is accurate only if the consumption is unchanged, which is rarely the case (Wyatt, 2010).

Table 1. IWA standard water balance and terminology (Farley and Trow, 2003)

System input volume	Authorized consumption	Billed authorized consumption	Billed metered consumption (including water exported)	Revenue water
			Billed unmetered consumption	
		Unbilled authorized consumption	Unbilled metered consumption	Non-revenue water (NRW)
			Unbilled unmetered consumption	
	Water losses	Apparent losses	Unauthorized consumption	
			Customer metering Inaccuracies	
		Real losses	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	

Water losses are occurring in both developed and developing countries (Gonzalez-Gomez, García-Rubio and Guardiola, 2011) with an estimated NRW levels of 15% and 35% of the annual system input volume, respectively (Al-Omari, 2013).

The Global Water Supply and Sanitation Assessment 2000 Report pointed out that NRW levels in Africa, Asia, Latin America and the Caribbean, and North America are 39%, 42%, 42%, and 15%, respectively (Alkasseh, Adlan, Abustan, Aziz and Hanif, 2013, WHO-UNICEF-WSSCC, 2000). Moreover, the average water loss in European Union (EU) countries is about 20%, whereas several countries have water loss levels lower than 10% such as Germany and Denmark (Puust, Kapelan, Savic and Koppel, 2010). A pipe network with NRW less than 15% is supposed to be in good condition. If the value of NRW is greater than 30% the network needs immediate inspection (Alkasseh, Adlan and Abustan, 2016). The Word Bank estimates the world wide NRW volume to be 48.6 billion m^3/year and the real losses volume (40%) occurring in the developing countries is sufficient to supply approximately 200 million people. Furthermore, the Word Bank estimates the monetary value of the global annual NRW volume to be US $ 14.6 billion per year (Kanakoudis and Tsitsifli, 2012).

In the context of WDS operation and management, the sectorisation of large networks (division in district metered areas or DMAs) can evaluate leakage level in each DMA, allowing leakage location activities to be directed to the worst parts of the system, thus increasing their efficiency (Alkasseh, Adlan, Abustan and Hanif, 2015). The DMA technique is first applied in the United Kingdom in the early 1980s (Jankovic-Nisoic, Maksimovico, Butler and Graham, 2004) and has been employed by many water utility companies worldwide (Gomes, Marques and Sousa, 2012). A DMA is defined as a discrete area of distribution caused by the closure of valves, in which the quantity of water entering and leaving the area is metered (Mounce, Boxall and Machell, 2010). It is supplied via a single source, having approximately equal pressure levels across its population of pipes, and with night flows regularly monitored (Fragiadakis, Christodoulou and Vamvatsikos, 2013). A permanently monitored DMA is considered to be the most effective tool for reducing the duration of unreported leakage (Strum and Thorton, 2005). The introduction of DMAs and pressure management areas (PMAs) can achieve significant reduction in real losses and frequency of bursts (Fantozzi, Calza and Lambert, 2009).

To estimate real losses, minimum night flow (MNF) can be an indicator of distribution leakage and consumer wastage (Johnson, Ratnayaka and Brandt, 2009). MNF is the measured flow into a controlled district metered area (DMA) of a network during the period with minimum demand, i.e., between 1:00 am and 4:00 am (Johnson, *et al.*, 2009). MNF is a commonly used method in evaluating leakage levels in a water network (Loureiro, Alegre, Coelho and Borba, 2012). Generally, MNF occurs during the early morning hours, from midnight to 4:00 am. During these hours, most users are not consuming water; thus, water demands can be easily estimated (Cheung, Girol, Abe and Propato, 2010). During MNF period, which usually occurs between 2:00 am and 4:00 am, legitimate customer use is normally at a minimum, network pressures are high, and leakage is at its maximum percentage of the total inflow into the DMA (Adlan, Alkasseh, Abustan and Hanif, 2013). Therefore, a significant increase in MNF (usually between 1:00 am and 5:00 am) can be a reliable indicator of a system anomaly, often produced by a burst in the network (Garcia, Cabrera, Garcia-Serra, Arregui, Almandoz, Maksimović, Butler and Memon, 2003).

A large proportion of water loss in distribution networks is common in many Asian cities, averaging 35% in the region's cities and even reaching much higher levels (Frauendorfer, *et al.*, 2010). In Gaza Strip, NRW is excessive in many cities. According to the Water Sector Regulatory Council (WSRC), the NRW in 2015 was 39% (WSRC, 2017). High levels of NRW usually indicate a poorly managed water utility and growing pressure on water has led this resource to be considered scarce and must therefore be managed efficiently. Considering this gap, the present study attempted to determine the contributions of major factors that affect NRW to a water supply network in Gaza Strip, Palestine,

2. The Study Area

The study area is situated in Gaza Strip, Palestine which is consisted of 25 cities (Figure 1). In Gaza Strip, the groundwater is considered to be the main water source that supplies the residents for different purposes and Gaza coastal aquifer is limited. Gaza Strip is a part of the Palestinian coastal plain located in arid and semi-arid regions which is bordered by Egypt from the south, the Green Line from the North, Nagev desert from the East and the Mediterranean Sea from the West (Mayla and Amr, 2010). It is one of the most densely populated areas in the world (4138 people per km^2) based on the Municipal Development and Lending Fund (MDLF, 2009). According to Palestinian Central Bureau of Statistics (PCBS), the estimated population in Gaza Strip at the end of 2016 is 1.91 million (Murrar, Tamim and Samhan, 2017). Because of the high population growth rate (~4%) (Weinthal, Vengosh, Marei, Gutierrez and Kloppmann, 2005), the population is expected to reach more than 2.6 Million inhabitants by year 2025 according to the Coastal Municipalities Water Utility (CMWU) and PCBS (CMWU, 2011). CMWU is the service provider for all water and wastewater services in the Gaza strip. CMWU coordinates its activities with Palestinian Water Authority (PWA) as a regulator for the water and wastewater sector (CMWU, 2014).

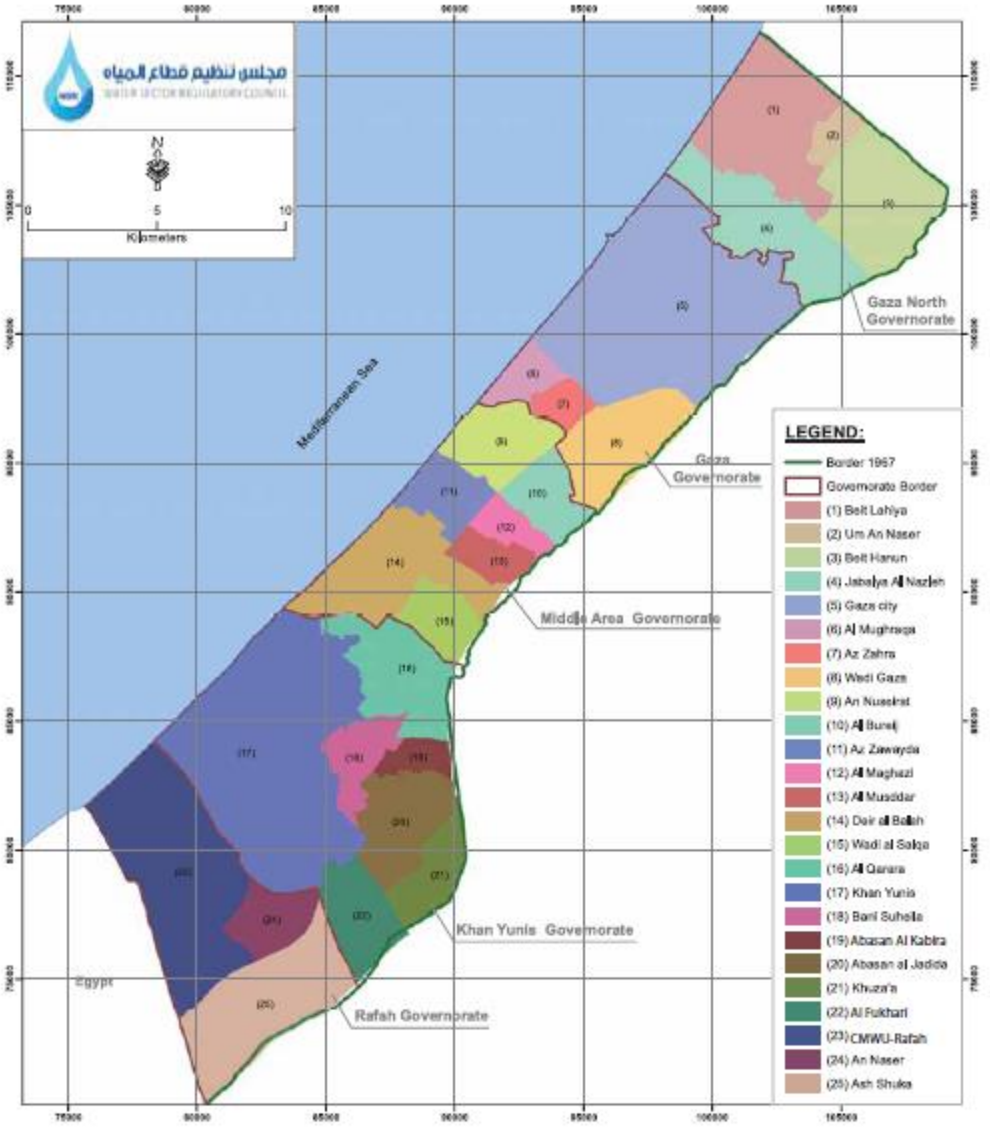

Figure 1. Gaza Strip Service Providers (WSRC, 2017)

The situation of the water quality and quantity in Gaza is already grim (Amr and Yassin, 2008, UNDP, 2010). The quantities of water abstracted to meet the demand of an increased population have put the aquifer under stress already since the late nineties (Nembrini, 2010). After Kuwait, the Gaza Strip is the next most‘‘water-poor’’ region in the world, with 52 m^3 available per person each year (Weinthal, *et al.*, 2005). Domestic consumption per capita was between 70 to 85 liter per capita/ day (CMWU, 2011, UN, 2012). In addition, the aquifer has been depleted and contaminated by over extraction and by sewage and seawater infiltration (Aiash and Mogheir, 2017, CMWU, 2011). As a consequence, , more than 90% of the water is unfit for drinking as stated by an Amnesty International Report of 2009 (Amnesty International, 2009, CMWU, 2015) and due to high levels of salinity, most of the ground water is not suitable for both domestic and agricultural consumptions (Mayla and Amr, 2010). The concentration of chemical pollutants, including the chloride ion Cl^- and nitrate ion NO_3^- has exceeded the recommended WHO standards (CMWU, 2011, Mayla and Amr, 2010). For example, the Cl^- concentration varies from less than 250mg/L in the sand dune areas as the northern and south-western area of the Gaza Strip to about more than 10,000mg/L where the seawater intrusion has occurred (CMWU, 2011, Mayla and Amr, 2010). The NO_3- concentration reaches a very high range in different areas of the Gaza Strip, while the WHO standard recommended nitrate concentration less than 50mg/L (CMWU, 2011, Mayla and Amr, 2010).

3. METHODOLOGY

In Gaza Strip, there are 25 water and wastewater service providers (SPs), 24 of them are departments in the municipalities and one is considered a semi-independent utility- the Coastal Municipal Water Utility (CMWU) providing its services to Rafah Municipality (WSRC, 2016). The general operational information and available water resources for SPs for the year 2015 are presented in Table 1.

Based on the International Water Association Performance Indicator (PI) system, a set of key performance indicators (KPIs) was adopted for Palestinian water service providers. The KPIs used were adapted to account for local conditions (WSRC, 2016). In this study, a list of technical indicators was introduced to analyze the performance of SPs. Hence, the technical indicators were NRW by Volume, NRW per km of Network per Year and NRW per Connection per day.

NRW by volume, as a percentage, shows the difference between the amount of water supplied through the water distribution system and that billed to customers based on the international water balance. It is worth noting that the water balance was used in 2015 to calculate the percentage of NRW. The water balance is a logical analysis based on international standards in classifying the components of NRW and provides an excellent tool for service providers to define priorities of their action plan to reduce NRW (WSRC, 2017).

The importance of this indicator is that NRW is an indicator of the service providers' efforts in maintaining the assets of the utility in general, and the network in specific, in good working conditions. Also, it helps the utility plan for investment in the rehabilitation or replacement of the network and in budget preparation. Moreover, it is a tool that it is used by the regulator to assess the performance of the individual service provider upon a request of tariff change. It is also a good monitoring tool for the regulator to set performance levels for operators to achieve in order to safeguard the interest of customers, reduce operation costs, and preserve limited water resources (WSRC, 2017).

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NRW can be Calculated as: 100% - (Total billed quantity (m^3) during the assessment period / (Total supplied water during assessment period ± difference in stored quantities in utility reservoirs) * 100%).

Table 1. The general operational information and available water resources for SPs for the year 2015 (WSRC, 2017).

Municipality Water Data 2015	Served Population (NO.)	Active Connections (NO.)	Available Water Resources (MCM)	Network Length (Km)	Average daily per capita water consumption (l/c/d)
Abasan al Jadida	6.114	1.279	0.39	36	131
Abasan al Kabira	23.198	3.322	1.22	55	104
Al Bureij	41.382	3.740	1.71	50	75
Al Fukhkhari	6.420	1.008	0.24	52	82
Al Maghazi	28.221	2.650	1.48	48	86
Al Mughraqa	8.241	1.412	0.67	25	94
Al Musaddar	2.410	330	0.16	19	120
Al Qarara	20.000	2.400	1.21	120	121
An Naser	8.206	1.275	0.42	37	115
An Nuseirat	75.000	8.300	4.28	93	88
Ash Shuka	11.867	1.578	0.5	82	73
Az Zahra	3.889	1.100	0.45	19	96
Az Zawayda	15.257	2.323	1.00	87	140
Bani Suheila	39.941	4.638	1.6		
Beit Hanun	50.051	4.163	3.38	120	82
Beit Lahiya	73.547	7.658	4.5	170	95
CMWU – Rafah	195,570	18,34	7.95	375	73
Deir Al Balah	78.329	7.258	3.9	139	80
Gaza	591.712	48.13	31.23	600	91
Jabalia AL.Nazlh	160.157	13.67	12.24	190	162
Khan Yunis	193.123	17.37	8.45	371	72
Khuza'a	11.524	1.266	0.52	50	84
Umm an Naser	3.773	457	0.25	10	125
Wadi as Salqa	5.300	402	0.18	44	56
Wadi Gaza	3.570	318	0.12	33	39

The relying entirely on NRW by volume as an indicator to benchmark NRW between water utilities or even to monitor changes in performance over time can be misleading, if factors such as network length and the number of connections are not taken into consideration (WSRC, 2016).

Therefore, IWA and other international organizations recommend the use of the key indicators: NRW, physical losses, and commercial losses, all measured in L/connection/day; as for physical losses alone, IWA recommends the use of m^3/km of pipeline/day (Wyatt, 2010). NRW per km of Network per Year allows comparing service providers of different sizes and reflects the efficiency of the network and main conveyance pipes. Moreover, it provides more accurate, reliable and comparable results compared to NRW percentage since it eliminates the effect of the difference in length between networks. Also, its results will assist the water service provider to improve plans for future investments and repair or replace the network (WSRC, 2016, WSRC, 2017).

It can be calculated as: total NRW during the year (m^3) / network length (km).

Furthermore, to eliminate the impact of density of connections in the system, NRW per connection is used along with the NRW percentage when benchmarking the performance of water utilities (WSRC, 2016).

NRW per Connection per day can be calculated as: total NRW (m^3) during the assessment period * 1000 / number of days * total number of served connections.

3. RESULTS AND DISCUSSIONS

According to the report of PWA about the water resources status summary in 2014 in Gaza Strip, the total water supplied for domestic use was about 88.466 million cubic meters (mcm) and the total water consumption was 52.1 mcm. The network distribution system efficiency was 58.9%. The NRW was 41% (PWA, 2015). The water resources available to service providers for the year 2015 were about 88.1 mcm. The amount of water purchased from Mekorot Company in 2015 was 6.9 mcm. The total cost of consumption of Mekorot Water in the Gaza Strip in 2015 was to be US $3.4 million. The NRW was 39% (WSRC, 2017). The estimated annual volume of NRW in 2015 was to be 34 million m^3. Furthermore, the estimated monetary value of the NRW volume was to be US $ 16 million per year (WSRC, 2017). Figure 2 provides the percentages of NRW by volume of service providers in Gaza Strip for the year 2015.

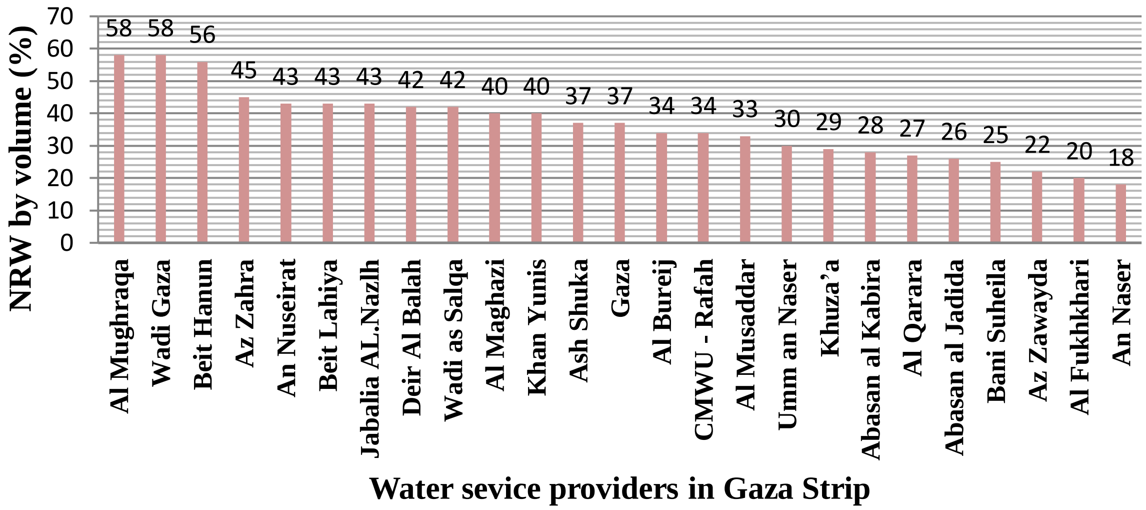

Figure 2. The average percentages of NRW of water SPs in Gaza Strip for the year 2015

Figure 2 confirms that most municipalities in Gaza strip experienced high NRW. Hence, the municipalities of Al Mughraqa, Wadi Gaza and Beit Hanun still registered the highest rates of NRW (58%, 58%, and 56% respectively). This may be due to that the majority of the municipalities in Gaza strip were suffered from different levels of destruction in their networks during the war 2014, which caused major losses in water (WSRC, 2016).

On 6th July 2014 the Israeli offensive on Gaza Strip has started (PWA, 2014, UNDP, 2014a) Which resulted in a severe humanitarian crisis. According to United Nations Education, Scientific and Cultural Organisation (UNESCO, 2014), the scale of destruction and devastation after 50 days of conflict in July-August 2014 is unprecedented in Gaza. Consequently, water and sanitation infrastructures were massive damaged. Based on the field survey, the main damages in the water infrastructure revealed are as follows: (a) 15 wells were partially damaged and 11 wells were totally damaged; (b) 11 water reservoirs were partially damaged and 5 tanks were completely damaged; (c) a total of 20,000 metres of water network pipes of PE, UPVC and steel ranging in size from 50 mm to 315 mm, were damaged (UNDP, 2014a, UNDP, 2014b). Based on the preliminary assessment, the value of damages to the water and sanitation infrastructure was estimated at USD $ 34,434,100 (CMWU, 2014, UNDP, 2014a).

In the aftermath of the Gaza war 2014, the water distribution networks are highly deteriorated due to Israeli aggressions and limited maintenance programs. Almost all municipalities in Gaza strip had to pump water from municipal wells and distribute water through tankers (private and public) to people who had fled from their homes during and after the war. These quantities were not billed and were distributed free of charge (WSRC, 2016).

In addition, a marked improvement has been noted among service providers in the rate of NRW in 2016 compared to 2015. The WSRC (2018) reported that the percentage of NRW in 2016 was 36%. For example, the rate went down from 58% to 41% in Wadi Gaza and from 58% to 19% in Al Mughraqa, and from 56% to 35% in Beit Hanun. Also, a large municipality like Khan Yunis achieved a noticeable improvement in the rate of NRW which went down from 40% in 2015 to 26% only in 2016. The considerable improvement in rates of NRW can be due to the following: (i) the improvement in the conditions of distribution networks in terms of maintenance, follow up, and completion of repairs of sections of the network that were damaged due to the 2014 war and its aftermath. This is clearly the case for Beit Hanun municipality, (ii) Some municipalities improved the meter readings and treatment of illegal connections on a wide scale, as is the case of Al Mughraqa municipality, (iii) Khan Younis municipality installed meters and billed the residential apartments which were not billed before or the consumption readings were largely based on estimates (WSRC, 2018) .

Water losses vary among systems and can be attributed to a number of different factors. These factors include network length, number of service connections, pressure fluctuation over the day, pipe material, leaks, bursts, and age of the system (Gomes, Marques and Sousa, 2011). Figure 3 provides the amount of NRW during the year (m3) for every km in length of the network of service providers in Gaza Strip for the year 2015.Consequently, the figure showed a rise in the NRW per km in the network for many SPs starting from the highest as Jabalya Al Nazla (27,466 m3/Km/year), An Nuseirat (19,982 m3/Km/year), Gaza (19,330 m3/Km/year), Beit Hanun (15,722 m3/Km/year) and others, due to the high population density and the war 2014 at the Gaza Strip, as well as part of it is due the non-functioning administration of distribution and network wearing (WSRC, 2017).

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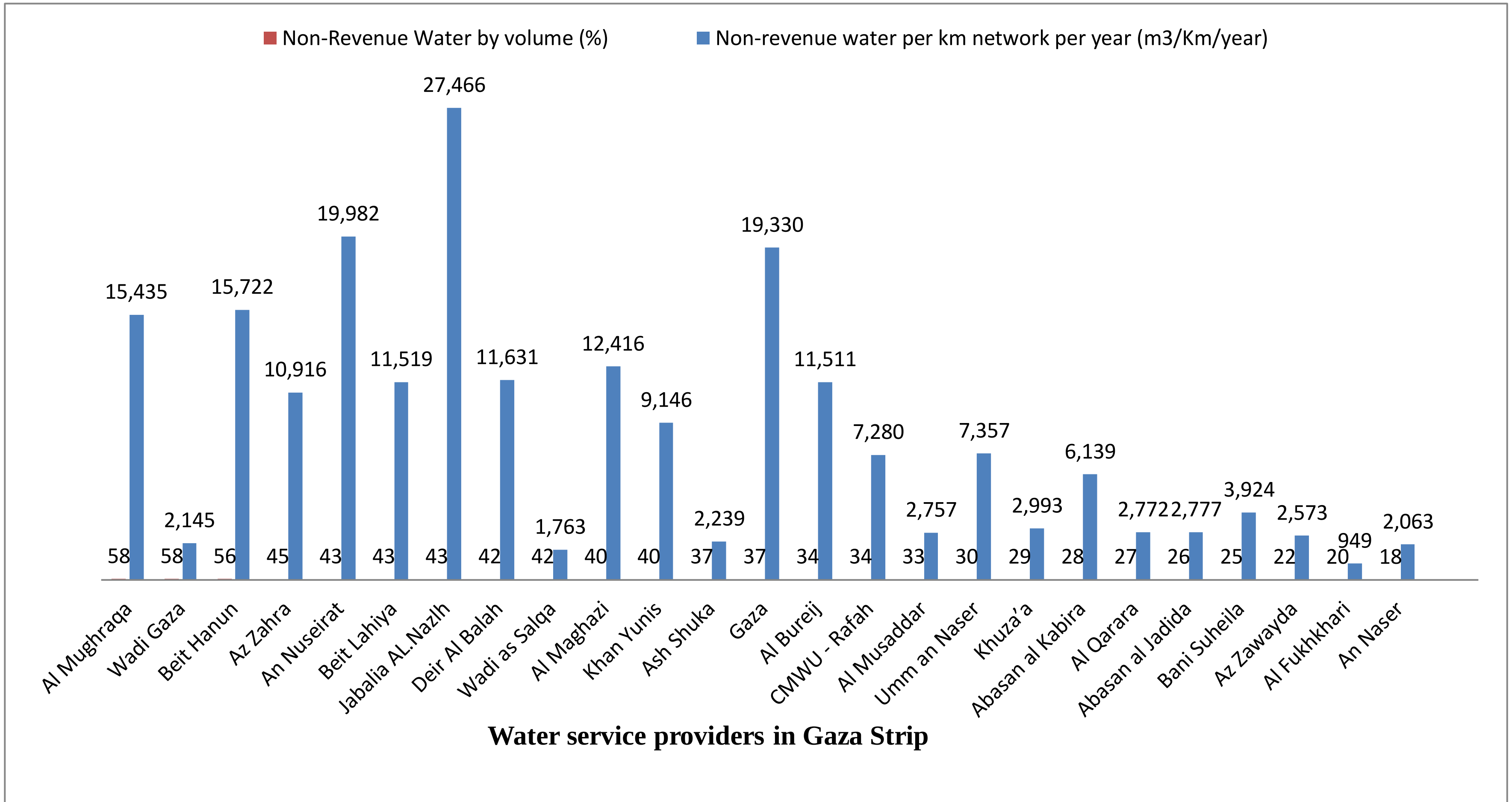

Figure 3. NRW during the year (m3)/ network length (km) of SPs in Gaza Strip for the year 2015

Additionally, water loss also depends on the number of service connections. Water losses increase significantly when house connections are not done properly (Çakmakcı, Uyak, Öztürk, Aydın, Soyer and Akça, 2007). The international studies show that the greatest proportion of losses occurs in service connections rather than in mains, except in networks characterized by a low density of connections (Thornton, et al., 2008). Figure 4 provides the NRW per Connection per day (l/c/d) of service providers in Gaza Strip for the year 2015. The municipalities of Beit Hanun (1,242 l/c/d), Jabalya Al Nazla (1,046 l/c/d) and AlMughraqa (749 l/c/d) still registered the highest rates of NRW.

Infrastructure and services throughout Gaza's municipalities are in need of a major overhaul as it has suffered from years of under investment and poor maintenance due to the blockade on Gaza (United Nations, 2008). As stated by United Nations Development Programme (UNDP) (2010), the blockade on the Gaza Strip was imposed in June 2007. The blockade on Gaza has led to that municipal infrastructure was nearing collapse (MDLF, 2009). For instance, the power outages, coupled with the severe shortage of fuel and spare parts for back-up generators, have disabled part of the water and sanitation system. Water, sanitation networks could not be rehabilitated or maintained for lack of spare parts and materials. As a result, about 80% of Gaza's water wells were functioning only partially and the remaining were non-functional. In addition, over half of the population of Gaza City was having access to water only several hours once a week (United Nations, 2008).

Furthermore, the electricity problem and unreliable sources are still the reason behind the negative impacts on the operational schemes of most of the water facilities including water wells and pumping facilities, and create a lot of damages and loss of services at various sites (CMWU, 2017). In addition, the system efficiency of water distribution networks in the case of Gaza strip is subject to the seasonal water demand requirements and temperature conditions. Consequently, system efficiency increases during winter months and starts to decrease when it comes hotter where illegal connections especially used for irrigation. It forms about 15% of NRW which consumes a lot of water during hot weather and negatively affects the whole system efficiency (CMWU, 2017).

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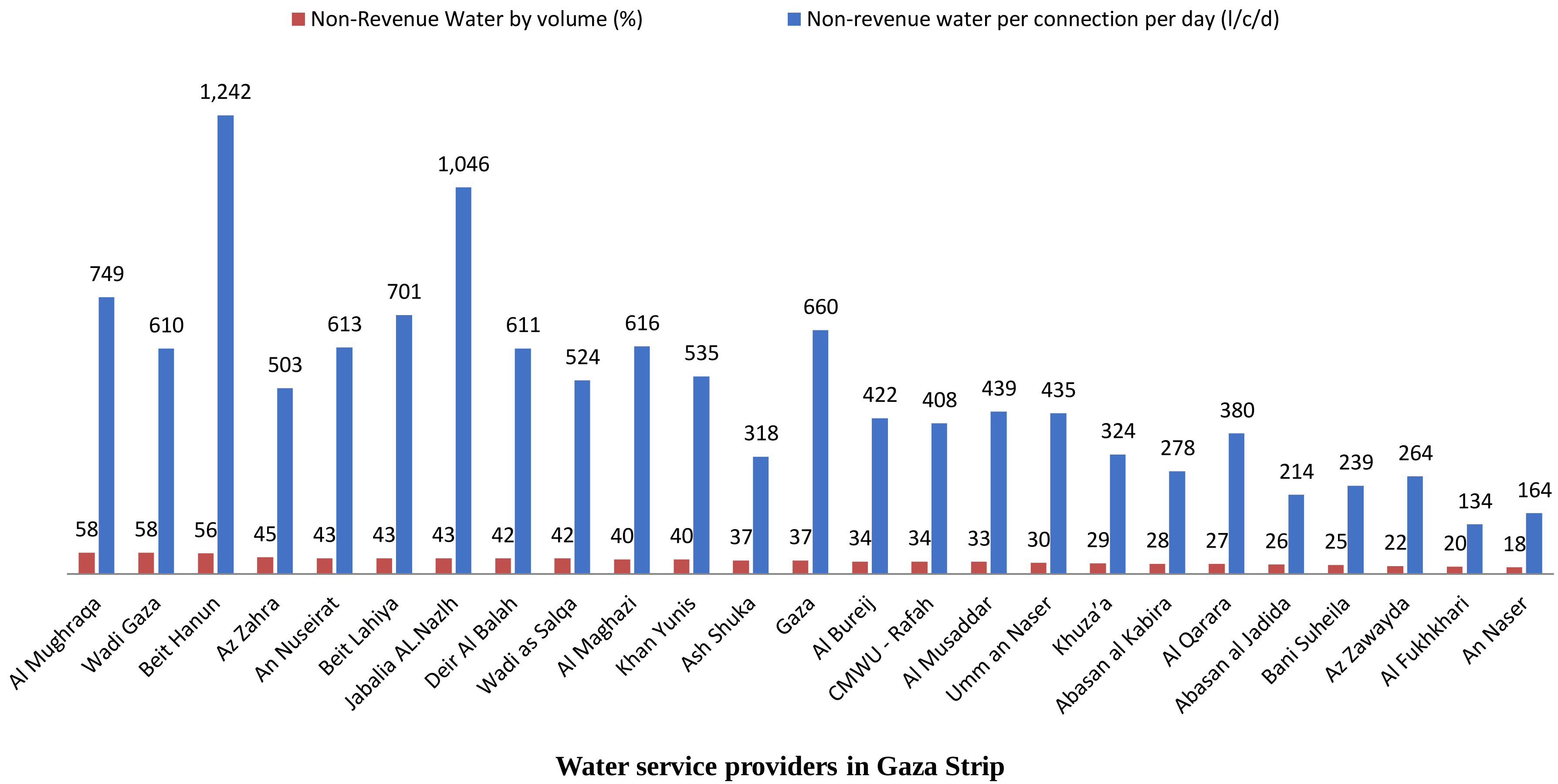

Figure 4. NRW per Connection per day of SPs in Gaza Strip for the year 2015

On average, the causes of NRW are varies between developed and developing countries. In developed countries, leakage is usually the major component, while in developing countries apparent losses and unbilled but authorized consumption are more important. In these countries there are a large number of illegal connections, untrue meter readings or meter damaging. Moreover, lack of incentive for utilities management to decrease the non-revenue, corruption among utilities management, carelessness of political level and also lack of awareness campaigns for customers are main reasons for high non-revenue water (Murrar, et al., 2017).

The high level of NRW in Gaza and West Bank is unacceptable and the PWA has a policy to drastically reduce NRW by 2020. In 2012, PWA proposed a strategy to reduce NRW to water service providers. Consequently, it was designed to target the reduction of NRW in the most cost efficient manner. The PWA has a policy to reduce NRW from 38% to 35% by 2020. However initial estimates indicate, when examining the investment required, a reduction in 10% of total estimates of the existing NRW represents in excess of $5M/yr increased revenues, or a net present saving of over $40M compounded over 10 years. (PWA, 2012). The effort to reduce the NRW is to be continued in the “Strategic Plan and Action Plan for the Palestinian Water Sector (2017 – 2022)” of PWA in order to improve the efficiency of water supply. The 31% NRW target can be achieved way before 2022 (WSRC, 2017). The 20% NRW target can be achieved way before 2032 (WSRC, 2016).

4. CONCLUSİON AND RECOMMENDATİONS

High levels of NRW represent huge volumes of water being lost and affect the financial capability of water utilities through lost revenues and increased operational costs. Furthermore, NRW is a good indicative of water utility performance; high levels of NRW usually indicate a poorly managed water utility. Significant amounts of water loss are being lost because of leakage in WDSs. The large volume of water leakage can also cause contaminant intrusion under low- or negative-pressure conditions within pipes, which may lead to harmful or even serious water quality incidents. On the other hand, financial, environmental, and social benefits can be derived from controlling and improving management of water losses caused by leakage. Hence, minimising water lost through leakage from water supply systems is one of the main challenges that faced water network managers. Significant amounts of money must be invested every year for leak detection and repairs. This investment will be balanced by the benefits resulting from the use of recovered water from repaired leaks. Definitely, politicians have a great responsibility where NRW are concerned. However, Policy-makers could contribute by helping to make the general public aware of how important it is to reduce NRW. Finally, policy-makers could also create independent organizations to control the activity of water utilities and these control organisms should have the power to establish and monitor the accomplishment of NRW objectives.

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