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OVERVIEW OF WATER LOSSES FROM NON-REVENUE WATER (NRW) IN OMAN

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ABSTRACT

Water is the most vital and crucial resource for all living things, including humans. Public health, economic prosperity, and the well-being of the country are all impacted by both the availability and the quality of drinking water. Non-Revenue Water (NRW) occurs in many water supply systems around the world that cause the losses of priceless clean water before it reaches consumers. In Oman, the information on water audit, NRW, or water losses are scarce. According to the PAEW, the average of water losses in Oman between 2013 and 2016 is estimated to be around 37%, which exceeds the global benchmark that the Leak Detection and Water Accountability Committee of the American Water Works Association recommends. This paper presents a critical review of the magnitude of non-revenue water (NRW) in Oman and evaluates the effectiveness of mitigation strategies. Previous studies indicate that Oman experiences significant water losses, with NRW reaching approximately 40%, a level considered high by global standards. A critical assessment of the contributing factors reveals that excessive water pressure in certain network segments and inaccuracies in water consumption estimation, primarily due to meter deficiencies, play a significant role in these losses. Moreover, the financial impact of NRW is substantial, accounting for 32% of the total revenue budget. Despite these challenges, the Public Authority for Water (DIAM) reported notable progress in reducing NRW in 2017. While the reported success is attributed to the implementation of advanced strategies, procedures, and technologies, a deeper analysis is required to assess the long-term sustainability and scalability of these measures. This review highlights the gaps in current mitigation efforts and underscores the need for continuous improvements in NRW management to enhance water conservation and economic efficiency in Oman.

Keywords:
Water, NRW, water losses, water distribution system, mitigation plans

INTRODUCTION

The world's water condition has evolved over the last few decades, going from one of relative abundance to one of relative scarcity. This is a result of urbanization, population expansion, food and energy security policies, macroeconomic factors like trade globalization, shifting consumption patterns, and population increase. Particularly, the availability of freshwater resources is put under intensely localized pressure by growing urbanization. One of the major issues for water utilities in underdeveloped countries is managing the notable discrepancy between the amount of water billed to consumers and the amount discharged into the distribution system, sometimes referred to as non-revenue water (Kingdom et al., 2006; Al-Bulushi et al., 2018). The average level of NRW around the globe is 35% of the water that is delivered, or 48.6 billion m^3, annually, with an estimated global cost of US$14 billion (Al-Washali et al., 2019). Non-Revenue Water (NRW) occurs in many water supply systems around the world that cause the losses of priceless clean water before it reaches consumers. Generally, NRW relates to the water wasted from physical accidents including pipe leakage which cause by burst during the transmission from water treatment plant to the consumer, private water-related damages arising from meter error, unmetered public usage and illegal connections (Choi et al., 2006). According to Cassidy et al. (2021), one-third of the water abstracted from metropolitan water distribution systems can be lost through leaks, which could result in substantial financial loss. The lack of information on the sources of NRW in Salalah has resulted in large amount of clean water wastage. Implementing a successful water loss reduction program requires an understanding of the elements influencing water loss and what makes its reduction so challenging. Hence, this research is being conducted to investigate the NRW sources in Salalah area. The data obtained will be a valuable information to the Salalah water utilities provider to mitigate the problems and increase the water transmission efficiency for long-term water supply reliability and sustainable water management.

LITERATURE REVIEW

Urban water supply systems frequently can't keep up with demand and aren't accessible to everyone. The Commercial Utilities' (CU) inability to develop and expand its water delivery infrastructure is reported to be caused by both technical and economic issues. Failure to control and minimize water losses is one of the delivery bottlenecks, among other problems. Therefore, it is vital to analyse the available literature on the subject in order to have a better knowledge of the problem of Non-Revenue Water (NRW) in Salalah. Cassidy et al. (2021), stated that one-third of the water abstracted from metropolitan water distribution systems can be lost through leaks, which could result in substantial financial loss. Urban regions, where more than 50% of the world's population reside, will experience a worsening water shortage. Over 95% of the projected urban population growth between 2000 and 2030 is predicted to occur in low-income nations, adding 2.12 billion people to the urban population (Jang, 2018). The demand for drinking water has been rising quickly in metropolitan areas of developing countries in tandem with this population expansion.

Water distribution system

Water distribution refers to the procedures by which water is moved or conveyed across a network of interconnected pipes, and it serves as an auxiliary while being continuously pumped and stored to fulfil needs and keep the system's pressures stable (Awe et al., 2019). Water distribution systems, or WDSs, involve an interconnection or network of pipes that deliver water for end use. Pumping stations, reservoirs, water towers, as well as other parts of the system like hydrants, valves, measuring devices, etc., are typically connected together for the system to operate as efficiently as possible. A water supply distribution system's objective is to provide each customer with safe drinking water that is both suitably diluted and has a tolerable odor, flavor and appearance. For ages, communal drinking water distribution has been a major global concern (Geldreich, 2020). Water distribution system (WDS) design has historically relied on experience and trial-and-error to achieve requirements. According to Guo et al. (2021), the optimization of WDS design, operation, etc. has since received a lot of attention due to the numerous design combinations that are available and the necessity to maximize the efficacy of the investments made in water supply infrastructure. Numerous scholars and practitioners have looked into the issue of the best least-cost design of WDSs in the past. In developing nations, government organizations run numerous utilities, including water supply utilities, which must meet both the quantitative and qualitative needs for water (Jabri, 2018). Natural catastrophes can have a significant impact on infrastructure, especially water supply systems. In addition to natural disasters, operational practices that result in the loss of a water service are a key worry because of the potential losses.

Oman's water distribution system

The water supply sector is predicted to face significant problems in the years to come, including maintaining a net increase in population, bridging the coverage and service gap, guaranteeing the sustainability of existing and future services, and enhancing service quality (Naamani et al., 2021). The sustainability of the system to adapt to variations in the amount and quality of water flow in the system owing to population increase, as well as water losses or Non-Revenue Water (NRW) that negatively impact the water utilities, are the two main difficulties facing the water sector in Oman. Figure 1 shows conventional water resources, which comprise both surface and groundwater, make up 87% of the total amount of water resources in Oman. Non-conventional water resources, on the other hand, make up the remaining 13% (Al-Qurashi, 2019). While groundwater is Oman's most significant source of available water, representing over 94% of that country's conventional water resources and delivering about 1,295 Mm3/year of water, surface water is extremely scarce, accounting for only about 16% of those resources. non-conventional water resources, on the other hand levels decreased and sea water intrusion rose as a result of over use of traditional water resources, notably in coastal regions like Al Batinah and Salalah.

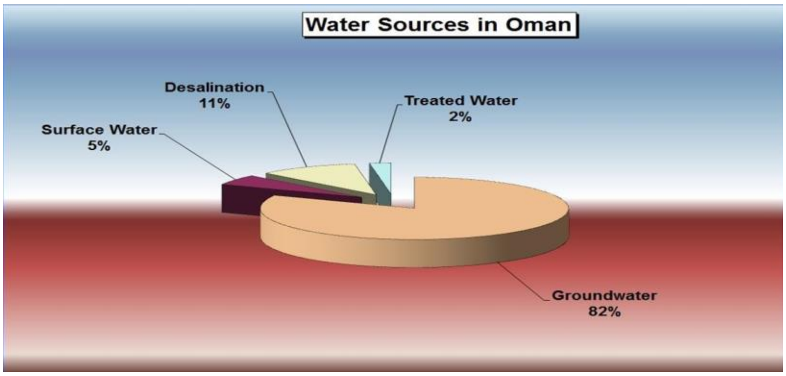

Figure 1: Water sources in Oman (Al-Qurashi, 2019)

According to Al-Siyabi & Expert, (2019) to supplement the residential water supply in the Greater Muscat Area and some other municipalities and villages, desalination facilities were built. The estimated reserve of water is thought to be 5,000 MCM, according on recent findings of fossil water aquifers in the Al-Najd area. According to the Ministry of Water Resources (MWR), an area of about 2,500 feddans can be irrigated with an annual outflow of 100 MCM. Naamani et al., (2021) added that millions of Omanis receive drinkable water from desalination operations, which are essential components of the country's utility infrastructure. In the next seven years, it is anticipated that the Main Interconnected System's (MIS) water consumption will rise from 281 MCM in 2015 to between 390 MCM and 440 MCM in 2022, an increase of 5% to 7% every year. The pumping station, tanker filling stations, transmission lines, networks and reservoirs make up Oman's water supply system. Production sites from desalination plants or wells also form part of it. The creation of 250 district metering areas (DMA) is one of PAW's greatest accomplishments. The SCADA systems continuously monitor the DMAs, so if there is any anomalous water usage in any region, the system will warn the operators and they may take the necessary steps to investigate the problem.

Non-revenue water

The phrase "Non-Revenue Water" (NRW) was initially used as a performance indicator to calculate the amount and percentage of water that is not billed annually (including unreported authorized usage and water loss) compared to the annual system input volume of a water delivery network as shown by the Figure 2. The term "unaccounted-for water" was discontinued because to its inconsistent definition, and it was suggested that "non- revenue water" be used as the major indicator of water loss control. NRW is described as the differential in water volume between the amount that is placed into a water distribution system and the amount that consumers are charged for. The water sector uses a number of indicators to measure NRW in practice (Güngör-Demirci, 2018). An effective water supply system that can sustainably serve customers and make profit for water utilities is one with a low rate of NRW. In contrast, high NRW raises the possibility of water scarcity and has detrimental effects on people's, economies', and the environment's well-being (Lai, 2020).

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorised Consumption</td><td rowspan="2">Billed Authorised Consumption</td><td>Billed Metered Consumption (including water exported)</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent* Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real* Losses</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to the measurement point</td></tr>
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Figure 2: IWA Standard water balance (Gupta & Kulat, 2018)

Managing pressure, replacing pipes, and developing educational initiatives that focus on various NRW causes are just a few of the difficult and complicated tasks involved in reducing NRW (Lai et al., 2020). In light of this, it necessitates modifications to institutional, cultural, and governance frameworks in addition to the participation of numerous departments from various water utilities. For instance, minimizing water theft entails eradicating institutional corruption as well as altering consumer habits. Countries must adapt their water regimes to an integrated framework that can address the complicated human-technology-environment system in order to handle the complex water challenge. Al-Bulushi et al. (2018), investigated the water balance, water losses, uncounted water NRW amounts, and the operational and economic implications to study the performance of the water distribution systems in Muscat. The findings revealed that Oman often has water losses and NRW of around 40%, which is quite high by worldwide standards. Additionally, the findings indicate that excessive water pressure in some network segments and the estimation method of water consumption due to meter inaccuracies were the main contributors to water losses. On the other side, it was discovered that the NRW's financial impact represented 32% of the overall revenue budget.

Non-revenue water in Oman

Water misfortune, which is the true cause of NRW, has been one of the major challenges in managing water utilities around the world, and it is especially challenging and serious in developing countries like Oman (Al-Bulushi et al., 2018). This is made worse by the fact that most water utilities lack the mechanical know-how and equipment necessary to handle water disasters. As a result, it is crucial to improve the management of the water distribution system since it is necessary to evaluate the effectiveness of the nation's urban water supply systems. Prior studies on Oman's water audit, NRW, and water losses is very scarce. Nonetheless, according to the PAEW, Oman's average water losses between 2013 and 2016 are estimated to be around 37%, which is higher than the global standard advised by the American Water Works Association (AWWA) Leak Detection and Water Accountability Committee, which specifies that anything less than 10% is acceptable. Figure 3 summarizes non-revenue water rates in various nations, including Oman. It should be noted that while NRW rates are high in Oman, they are also high in a number of other nations and locations. Public Authority for Water (DIAM) has made excellent progress in lowering NRW in 2017. Water losses decreased by 33.6 Mm^3, going from 118.2 to

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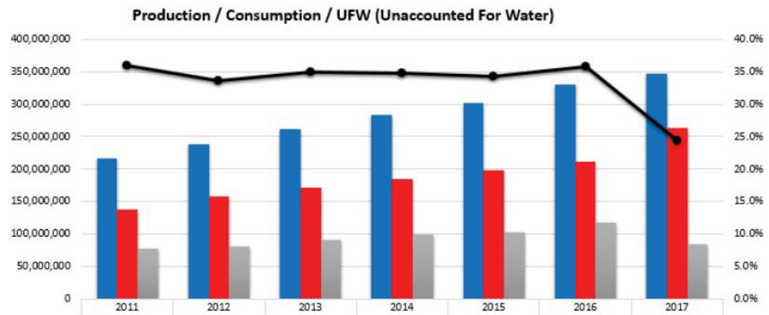
84.6 million cubic meters. The drop was 11.5%, taking the percentage from 35.86% to 24%.34. Additionally, despite the yearly growth in the number of customers, there was a decrease in output percentage in 2017 when compared to the years before, indicating that water losses were effectively controlled. These remarkable outcomes were attained by utilizing incredibly efficient strategies, procedures, and tools.



	2011	2012	2013	2014	2015	2016	2017
Production	215,900,000	238,200,000	262,199,120	283,135,760	301,008,112	329,787,928	347,684,307
Accounted Consumption	138,290,000	158,010,000	170,609,120	184,625,760	197,668,112	211,522,119	263,051,772
UFW	77,610,000	80,190,000	91,590,000	98,510,000	103,340,000	118,265,809	84,632,536
UFW%	35.9%	33.7%	34.9%	34.8%	34.3%	35.86%	24.34%

Figure 3: Production, consumption and UFW/NRW in Public Authority of water (DIAM) in Oman (Al-Siyabi & Expert, 2019)

One aspect of demand management is the reduction and control of non-revenue water, where the goal is to reduce user demand for water services and the impact of ongoing water loss on demand reduction initiatives. This translates to more effectively using the resources already available, which becomes a more affordable option to supply augmentation and management (Mubvaruri et al., 2022). As the public sees the results of the efforts, a program for NRW reduction and control should considerably benefit the Authority financially and operationally. The benefits of decreasing NRW include better service, fewer leaks, and expansion of the distribution system. But for such a project to be effective and have long-term benefits, it needs to be adequately conveyed.

CONCLUSION

In Oman, there is a noticeable lack of studies addressing Non-Revenue Water (NRW), water audits, and water losses. Most existing research has focused on water distribution system performance in cities such as Muscat, Alexandria, and Sana'a, primarily examining water losses and unaccounted-for water (NRW). To develop effective strategies for reducing water losses, improving the efficiency of the water supply system, and ensuring sustainable long-term water management in Oman, it is essential to investigate both the sources and the magnitude of NRW in the region. The gap can be address by providing critical insights into Oman water distribution system.

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