

# Assessment of Non-Revenue Water in a Water Distribution System and Strategies to Manage the Water Supply

S. Sakthi Murugan<sup>1</sup>, S. Chandran<sup>2</sup>

<sup>1</sup>PG Student, Department of Civil Engineering, Thiagarajar College of Engineering, Madurai, Tamilnadu, India

<sup>2</sup>Associate professor, Department of Civil Engineering, Thiagarajar College of Engineering, Madurai, Tamilnadu, India

\*\*\*

**Abstract-** Water is the world's most critical natural resource. Rapid population growth and economic development have led to higher demand for water worldwide whereas on the supply side, natural sources of water have become less reliable. This demand-supply imbalance in the water sector calls for more innovative water management practices and suitable technologies, so as to provide sufficient quality water for present and future generations. The supply of drinking water to the people will be the primary goal for any water utility. When struggling to meet the demand for the provision of water, utilities cannot afford the water loss because of poor operation and maintenance of water distribution infrastructure facilities. This paper addresses the necessity of reducing the Non-Revenue Water (NRW) and assesses the volume of NRW in a distribution system. NRW is being used as the standard to establish the water balance and high levels of NRW typically indicate a poorly managed water utility. Revenue lost for an identified water supply scheme implemented in Madurai is estimated from the data collected from the utility. District Metered Area (DMA) is one of the most common practices used across the developed countries to monitor and reduce the level of NRW. A better pricing strategy has to be adopted for water consumption especially in the developing countries where flat rates are collected. By adopting such strategies and management policies water loss can be reduced which in turn helps in meeting the demand.

**Key Words** – water management, non-revenue water, water balance, district metered area, water pricing.

## I. INTRODUCTION

Water is one of the world's most critical natural resource and it is one of the basic needs not only for human but all the living things. Ever increasing population and drastic growth in service areas has made water utilities struggle to provide water for all their consumers. Among the various demand for water, the most crucial one is water for domestic purposes. Common water supply problems are related to the sources and use of raw water, intermittent supply, and the quality of water at the consumer's end.

The high level of water loss in distribution networks is found to be one of the major challenges that

need to be solved. Since this lost water yields no revenue, heavy losses also make it harder to keep water tariffs at a reasonable level. A World Bank study states that roughly 45 million cubic meters of water are lost daily with an economic value of over US\$3 billion per year. The water that is lost unbilled is referred as "Non-Revenue Water" (NRW). Poorly managed water utility would have a high level of NRW. Lack of comprehensive NRW management makes it difficult to provide continuous supply to the water users. Billions of cubic meters of treated water continue to be lost, and water utilities will continue to lose a substantial amount of revenues. Reducing NRW is important to overall efficiency and financial sustainability, since it provides additional revenues and reduces costs.

## II. LITERATURE REVIEW

The Issues and Challenges in Reducing Non-Revenue water in Asia were discussed. The estimated annual volume of NRW in urban water utilities in Asia is in the order of 29 billion cubic meters (m<sup>3</sup>). Assuming a value of water of \$0.30 per m<sup>3</sup>, Asia's water utilities are losing nearly \$9 billion per year (Rudolf Frauendorfer and R. Liemberger, 2010). The performance of the India's urban water sector is compared with other Asian Metropolitan regions and improvements were suggested. They have considered data like percentage of metered connections, percentage of piped connections, pricing strategies in different cities etc, and compared them with cities like Singapore, Bangkok etc. . The inclusion of private players in water sector has to be considered. (David McKenzie and Isha Ray, (2009))The methodology to assess each component present in IWA standard water balance (real loss, apparent loss) is discussed. Strategies to reduce NRW and improve the water supply were recommended (R.Liemberger and M.Farley, 2004& 2005). Smart meters have the capacity to provide more precise and frequent data on water consumption pattern thus helping the planners in designing the future plans. To make this smart metering system more reliable and transparent and effective the feature called Web Based Knowledge Management System (WBKMS) is suggested( Rodney A. Stewart. 2010).

### III. NON-REVENUE WATER

Until 1990s water losses were measured in terms of “unaccounted-for water”. International Water Association (IWA) developed a comprehensive range of performance indicators for water supply utilities. IWA established a Water Loss Task Force (WLTFF) and their recommendation is to use the term “non-revenue water” instead of “unaccounted-for water”. Non-Revenue Water is defined as the difference between the amount of water put into the distribution system and the amount of water billed to consumer. Following are the three components that contribute to NRW:

- Physical or real losses comprise leakage from all parts of the system and overflows at the utility’s reservoirs. The causes of this type of losses are poor operations and maintenance, the lack of active leakage control, and poor quality of underground assets.
- Commercial or apparent losses are caused by customer meter under registration, data handling errors, and theft of water in various forms.
- Unbilled authorized consumption includes water used by the utility for operational purposes, water used for firefighting, and water provided for free to certain consumer groups.

#### A. Non-Revenue Water in India

India is also a country which has the least attention on assessment and reduction of NRW and this is very unhealthy situation for country like India where population and Industrial growth is ever growing. It is estimated that the level of NRW in India is about 40%. In urban India, water scarcity is a problem because of poor infrastructure, inefficient use and rising demand. (Mona N Shah, 2011). A city level analysis was done for the important metropolitan cities such as Delhi, Hyderabad, Pune, Bangalore and it is found that expenses of the utilities are much greater than their revenues.

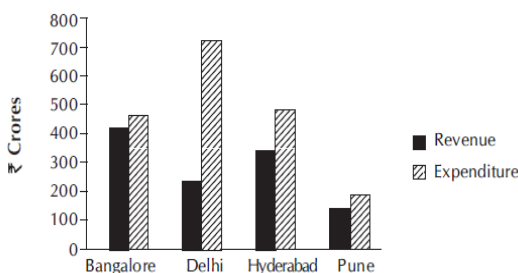


Fig 1. Comparison on Revenue and Expenditure of Utilities of Indian cities (Mona N.Shah,2011)

In this list, Delhi alone losses almost INR.115 lakhs per day which is mainly due to water theft and unbilled authorized consumption. There is no proper data

related to NRW, even if data are available they are not reliable.

### IV. NEED FOR MANAGEMENT OF NON-REVENUE WATER

According to India’s Water Budget prepared by Ministry of Water Resources (MoWR), the total utilizable water available in our country is 1123 BCM (billion cubic meters) whereas MoWR indicates that, by year 2050, India needs to increase by 5 times more water supplies to industries, and 16 times more for energy production, while its drinking water will demand double, and irrigation demand will raise by 50 percent. The main causes for this demand increase are ever growing population and extending Industrial sector. The National Water Policy had assigned the highest priority for drinking water supply needs followed by irrigation, hydro-power, navigation and industrial and other uses (GOI, 2002). The per capita water availability at national level has declined over the years. These demands lead to a need for very large and complex Utility infrastructures and added pressure on the utility managers and owners. In this Scenario it will be a crime to waste the water by means of illegal connections. We would need an improved Infrastructure and a strong Institutional frameworks and policies to manage water supply to all the consumers. Nowadays NRW (%) is used as an indicator to measure water utility performance. By taking NRW reduction measures we can boost revenue by increasing the amount of water that can be billed while reducing wastage of the product. However due to negligence of the utility owners and the complexity, we have failed in NRW management causing the utilities to enter a Vicious NRW cycle (R. Liemberger).

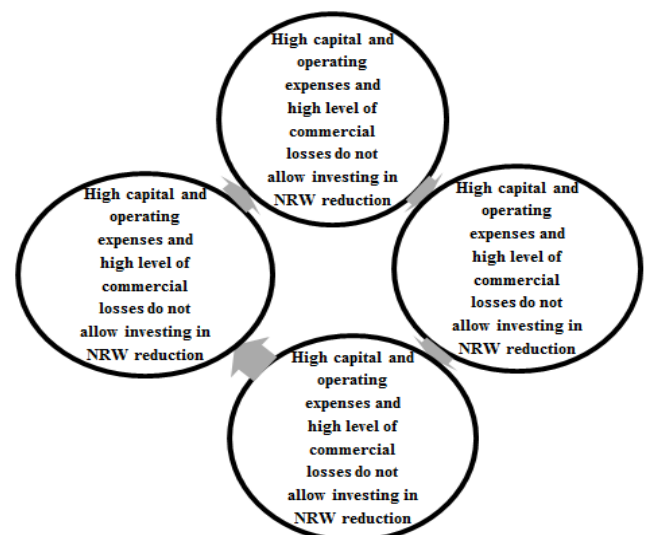


Fig. 2 Vicious NRW Cycle (ADB, 2010)

**V. METHODOLOGY**

The methodology that will be followed for the thesis is represented below in Fig 3.

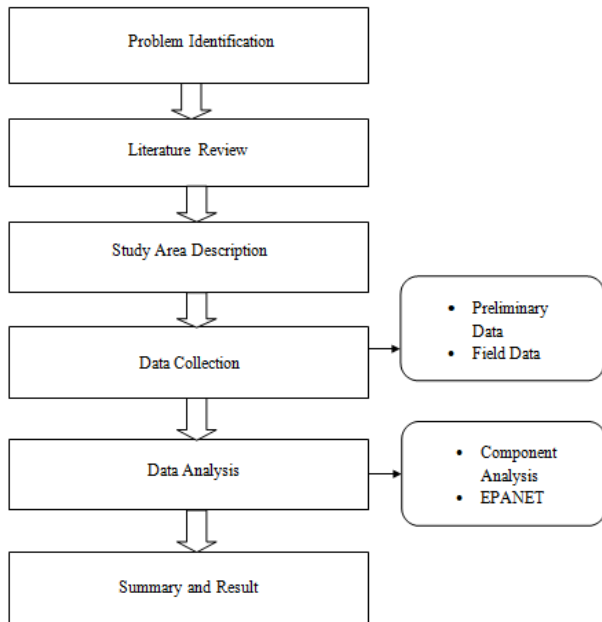


Fig. 3 Methodology

**VI. ASSESSMENT OF NON-REVENUE WATER**

For any Utilities to reduce Non Revenue water, it is important to prepare an estimation to know the volume of NRW in their utility. Because most of the utilities do not have data on NRW and even published NRW data are often problematic, suspicious, inaccurate, or provide only partial information.

The volume of water losses can be presented through a standard template which was developed by IWA called the Water Balance.

System Input Volume	Authorized Consumption	Billed Authorized Consumption	Billed Metered Consumption	Revenue Water	
		Unbilled Authorized Consumption	Billed Unmetered Consumption		
		Water Losses	Apparent Losses	Unauthorized Consumption	Non-Revenue Water
				Metering Inaccuracies and Data Handling Errors	
	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		

Fig. 4 The Standard Water Balance (IWA,2000)

To assess the volume of NRW either Top-down or Bottom-up approach shall be followed. The first step

in assessment is to calculate the Utility Input volume either by usage of Bulk meters or by portable discharge measuring devices. The difference between the measured input volume and volume of water consumed by the various users gives us the volume of NRW. And this assessment can be done by concentrating any of the PIs that are established by IWA. Based on PI's either a basic or Intermediate or detailed study can be done.

The physical losses can be calculated by component analysis method that is by measuring the following discharge rate at each distribution infrastructures like Sump, Water treatment plant, Overhead tanks; the average pressure maintained in the system; the length of the mains; Number of service connections; Number of repairs (R.Liemberger and M.Farley, 2004). The apparent losses are always difficult to assess and there is no exact data available. The apparent losses can be calculated by finding the difference between total NRW and the calculated real loss volume.

**VII. CASE STUDY**

We have planned to assess the level of NRW in an existing distribution system and have identified a water supply scheme which is under the control of TWAD board, Madurai. The total length of mains covered under the scheme is 5044 Km (includes both existing and new lines) and 17 primary sumps. From the recent survey by the Water Auditing team of Tamilnadu government it is found that normal leakage is around 15% of the input volume.

Cost of Supplied water = Rs.0.02 per litre

Average Price of water = Rs.0.0084 per litre

Quantity of water loss through leakages = 8.25MLD

Cost for supply of 55 MLD: Rs.11 lakhs per day

Revenue lost due to leakage alone :Rs.69,300 per day

**VIII. STRATEGIES**

To adopt strategies to overcome the challenge of water loss, a review can be carried out on the physical characteristics of the network and operational practices (R.Liemberger and M.Farley, 2005):

The review should assess;

- Particular country or regional characteristics, influencing factors, components of water loss.
- The condition of the network
- The level of technology available for monitoring and detecting leakage;

- Physical data (population, demands, topography, supply arrangements, mains length, number of service connections, customer meter location, average pressure)
- Drawings and records, billing data
- Measurements or estimates of system input volumes
- Techniques and equipment
- Economic data (cost of water, etc.)

#### A. District Metered Area (DMA)

DMA is found to be one of the effective strategies to both assess and reduce Non-Revenue water level in the water distribution system. The concept of DMA management was first introduced to the UK water industry in the early 1980's. DMA is defined as a discrete area of a distribution system usually created by the closure of valves or complete disconnection of pipe work in which the quantities of water entering and leaving the area are metered (IWA, 2007).

The factors that should be taken into account when designing a DMA are (IWA, 2007):

- The required economic level of leakage
- Size (geographical area and number customer connections)
- Housing type i.e. blocks of flats or single family occupancy housing
- Variation in ground level
- Water quality considerations
- Pressure requirements
- Fire fighting capacity
- Target final leakage level
- Number of valves to be closed
- Number of meters used to monitor flow ideally minimized
- Infrastructure condition

In general, hydraulic, practical and economic factors will ultimately determine the size of the DMAs. The size of DMAs has an impact on the cost of creating them: the smaller the DMAs, the higher the cost. DMAs in urban areas may vary between 500 and 3000 connections.

Following are the advantages of splitting the entire network into DMAs (ADB, 2010):

- The volume of NRW can be calculated on a monthly basis.
- The components of NRW can be quantified by analyzing flow and pressure data.
- Leak detection works can be prioritized.
- New pipe bursts can be identified immediately by monitoring the minimum night flow, and therefore

awareness time will be reduced from several months to several days (or even less).

- When leakage is eliminated, utilities can better gauge the existence of illegal connections or other forms of water theft and can take action.

#### B. Water Flow meters

In a developing country like India, loss of water in domestic sector on account of leakage is approximately 30 to 40% of the total flow in the distribution (Gopalakrishnan et al., 2107). Developed countries use acoustic devices which uses vibrations to identify leaks. In 2011, JICA has helped in reduction of NRW at Goa and they have used listening rods to identify the leaks (Water Conservation, 2014). Most of the developing countries are identifying the leakage only when they are visible on the surface and their water utilities are not metered and there is no record on the consumption of water by different users. In a survey conducted by NIUA (National Institute of Urban Affairs), India, of 260 urban centers, 17% of the cities used only metered connections (water charges), 45% used unmetered connections (water tax) and 38% used a combination of metered and unmetered connections (S Nagari, 2001). Installation of meters plays a vital role in reducing NRW, at least needed to provide data to manage NRW. The data obtained from meters also can be used to identify the leakages by finding the difference in discharge rates. There are different types of water meters such as: Displacement meters, Velocity meters, Turbine meters, Fire meters, Ultrasonic meters, Electromagnetic meters, Prepaid water meters etc., Developed countries have started to use Smart metering system (e.g. SCADA). In Smart metering system, flow rate meters are connected with certain valves which are in turn connected to GPRS modules or transmitters that helps in data logging(Gopalakrishnan et al., 2107).As an extension to the existing architecture of the smart water metering system, Web-based Knowledge Management System are included which is being used to find the end-uses such as toilet flushing, bathing etc., and the same can be prepared as report (Rodney A. Stewart et al., 2010).Prepaid water meters are installed at public stand posts and are actively adopted in many developing countries such as South Africa, Uganda, Brazil and Bangladesh (Maitreyee Mukherjee et al., 2015). Ultrasonic meters are potable meters can be used to find the flow rate where normal metering is not feasible.

#### C. Water Pricing System

Water pricing is a political process and obviously leads to controversies. This water tariff decides the revenue of the water utilities. A study concludes that on average it takes Rs.15 to operate and maintain the water supply system and on a contrast the typical price charged to residential consumers in India is



around Rs.1.5 per cubic meter (US\$ 0.03), only about a 10<sup>th</sup> of operating and maintenance costs. With average fixed charges of around Rs. 45 per month, these customers only contribute enough to pay for the operating and maintenance cost of providing three cubic meters per month (Usha p Ragupathi, 2002). There are different types of tariff structures are followed in India such as Uniform volumetric rate, fixed rate, Increasing Block Tariff (IBT) etc.,. Fixed rate per household is largely followed which is the worst scenario where charge is collected irrespective of the amount of water used by the consumer. In his paper, Maitreyee Mukherjee has suggested a tariff structure for study places in Bangalore. Though most of the utilities find IBT as the fruitful tariff structure some disagrees in that system too. Hence there is a need for an optimum tariff structure to be used to increase revenue as well as not affecting the consumers.

#### IX. CONCLUSION

As we all know that the demand for water among various water users will increase tremendously and it is very important to meet the primary goal of providing drinking water to all the people, especially urban people who mostly stay away from the source. NRW reduction is necessary action to be taken to meet the demand. To reduce NRW, we need to know the volume of it and the major contributor of the water loss. As suggested above, with the help of technologies like creation of DMAs with the proper water meters and good pricing strategies we can take the first step towards reduction of NRW. An institution for NRW management has to be created and maintained. A better pricing strategy that does not affect the poor people has to be established. Government should create policies that concentrates on increasing the revenue of these public utilities so that new investments can be made. And this revenue making by the utilities will encourage private players to enter into the water supply sector also similar to road sector. Even in India, there are certain utilities (Jamshedpur, Hubli) that have adopted NRW reduction strategies and became successful.

#### X. SUGGESTIONS

First and Foremost, usage of water meters should be encouraged not only at the sources and transmission line but also at the consumer ends also. By providing meters we can account for the input water and consumed water. Usage Smart meters can give much efficient output. With Technologies like GPRS modules, transmitters an automatic system shall be created (e.g. SCADA). Introduction of private players or Public-Private Partnership shall be considered. To make it successful, suitable contract structure should be created considering policies in India. Better pricing structure

considering the facility of subsidizing the poor consumers.

#### REFERENCES

1. David McKenzie and Isha Ray (2009), "Urban water supply in India: status, reform options and possible lessons", *Water Policy*, pp 442-460.
2. Farley. M and Liemberger. R (2004), "Developing a Non-Revenue Water Reduction Strategy, Part 1: Investigating and Assessing Water Losses", Anonymous.
3. Farley. M and Liemberger. R (2005), "Developing a non-revenue water reduction strategy: planning and implementing the strategy", *Water Science and Technology: Water Supply Vol .5, No 1*, pp 41-50.
4. Farley. M and Liemberger. R (2004), "Developing a Non-Revenue Water Reduction Strategy, Part 1: Investigating and Assessing Water Losses", Anonymous.
5. Gopalakrishnan.P, Abhishek. S, Ranjith. R, Venkatesh. R and Jai Suriya.V(2017), "Smart Pipeline Water Leakage Detection System", *International Journal of Applied Engineering Research ISSN 0973-4562, Volume 12*.
6. Maitreyee Mukherjee, Namrata Chindarkar and Jenny Grönwall (2015), "Non-revenue water and cost recovery in urban India: The case of Bangalore", *Water Policy*.
7. Mona N. Shah (2011), "Non-Revenue water Imperatives to improve water management of ULBs/WBs in Indian cities", *The IUP Journal of Infrastructure Vol.XI, No.4*.
8. Nagari (2001), "Tariffs and Subsidies", Twelfth meeting of Urban Think Tank.
9. Rodney A. Stewart, Rachelle Willisa, Damien Giurcob, Kriengsak Panuwatwanicha and Guillermo Capati (2010), "Web-based knowledge management system: linking metering to the future of urban water planning", *Routledge (Taylor and Francis Group)*, Vol. 47, No. 2, pp 66-74.
10. Rudolf Frauendorfer and R. Liemberger (2010), "The Issues and Challenges of Reducing Non-Revenue Water", *Asian Development Bank*.
11. Usha p. Ragupathi (2002), "Tariffs and Subsidies in South Asia", *Water and Sanitation Program*.