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A WATER AUDIT ANALYSIS TOOL FOR URBAN WATER UTILITY

Ruchika Sharma[1], Mahender Choudhary[2*] and Sudhir Kumar[3]

[1] *Research Scholar, Department of Civil Engineering, MNIT Jaipur, India*
[2] *Professor, Department of Civil Engineering, MNIT Jaipur, India*
[3] *Professor, Department of Civil Engineering, MNIT Jaipur, India*

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Abstract: This paper introduces a procedure for calculating non revenue water (NRW) based on IWA terminology. A water audit analysis tool is developed to determine the components of water balance i.e.; apparent and real losses for Jaipur water utility, India. Identification of these parameters is important especially in developing countries with critical water resource situation in water scare urban area. Water audit analysis tool also evaluates the leakage performance indicators i.e. Unavoidable Real Losses (UARL) and Infrastructure Leakage Index (ILI). Results reveals that Jaipur water utility suffers with a technical and managerial constraints and reporting high level of non revenue water (50% of the total water produced). The Real losses (37% of total water supplied) is the major component of NRW due to old deteriorating water supply asset with poor operation and management (O&M). Apparent losses (8% of the total water supplies) are significant component of NRW due to meter under registration, illegal connections and thefts and also indicated by value of Infrastructure Leakage Index (2.311). There is need of proper NRW reduction strategy which addresses all these three issues of real losses, unauthorized consumption and management practices along with change management strategy.

Keywords: Non-Revenue Water (NRW), Infrastructure Leakage Index (ILI), Apparent losses and Real losses, Unavoidable Real Losses (UARL), Operation and Maintenance

* Correspondence to: Mahender Choudhary, Email: mah_thory@yahoo.co.in

INTRODUCTION

The world faces a huge challenge to provide improved water supply and sanitation services especially in urban areas of developing countries. The statistic figures from the World Health Organization (WHO)/UNICEF Joint Monitoring Program (JMP) indicates that in 2008, nearly 900 million people lacked drinking water supplies (WHO/UNICEF, 2010). Non-Revenue Water is one of the major reasons for inadequate water supply in developing countries. The World Bank estimates that in developing countries leakage is about 45 million cubic meter per day (m^3/day) (Kingdom *et al.*, 2006). The developing countries face a financial and technical constraint to develop and expand water supply projects (McIntosh, 2003). Leakage is often a large source of unaccounted for water (UFW). It is a result of either lack of maintenance or failure to renew ageing system. Leakage may also be caused by poor management of pressure zones, which results in pipe or pipe-join failure. As a result of the overall shortage of water many cities are facing problems of distributing the available water impartially among the residents (Asadiani, 2004; Hirner and Lambert, 2000).

UFW is one of the commonly used methods for evaluating the water losses (Liemberger and McKenzie, 2003). International Task Force constituted by of International Water Association (IWA) recommends the use of Non Revenue Water (NRW) in place of UFW (Farley and Trow, 2003). It is defined as the difference between total inflow to the system and total metered and authorized un-metered consumption. NRW is divided into parts; apparent and real losses as shown in **Table 1** (Tabesh & Brown, 1995).

Literature Review

A few methodologies have been developed to assess the Unaccounted for Water (UFW) and NRW in water distribution systems. However most of them just concentrate on the real losses concept, and have no emphasis on the apparent losses, which is important in most underdeveloped and developing countries (Lambert, 1994). May (1994) presented the concept of Bursts and Background losses Estimation (BABE) and Fixed and Variable Area Discharge (FAVAD) concept. These two concepts were applied in many countries to resolve the problem, regarding real losses and leakage management. Several models have been developed to evaluate real losses and leakage management schemes, which mostly investigate the leakage calculation, pressure management and optimal leakage level etc. A study of these models has been done by Asadiani (2004). Recently few software for leakage modeling have been developed which are described as follows.

SANFLOW model (Mackenzie, 1999) uses the Minimum Night Flow (MNF) method based on the inflow measurement at the MNF time. This model suffers from two major shortcomings. First one is use of estimated values for reported and unreported bursts and second one is calculation of the total daily leakage by multiplying the leakage rate at the MNF time by 24. PRESMAC model (Mackenzie, 2001) is applied for pressure management purposes. As a disadvantage, this model does not use a hydraulic model and pressure is calculated with some simplifications which lead to high uncertainty especially in complex networks.

ECONOLEAK model (Mackenzie and Lambert, 2002) calculates real losses using the annual water balance method in which, apparent losses are considered as a percentage of NRW. Then using bursts and background losses estimation (BABE) concept, the leakage components are evaluated. Therefore it just uses estimated values to calculate the NRW components. Finally, BECHLEAK model (Mackenzie *et al.,* 2002) was written in an excel environment to calculate the NRW components using the water balance.

This paper introduces a procedure for water audit tool to calculate the water balance components and leakage performance indicators based on IWWA terminology. To evaluate and verify the software results, a case study was carried out in one of the metropolitan city (Jaipur city) of developing country (India) facing the water security issue due to inadequate water resource, insufficient infrastructure, poor management and high apparent and real losses as shown in **Fig. 1**. This procedure was also used to evaluate the Leakage performance indicators i.e. financial indicators, operational efficiency indicators, Unavoidable Real Losses (UARL) and Infrastructure Leakage Index (ILI).

Table 1. Descriptions of the Water losses and its Components

No.	Item	Descriptions
1	Volume from own source	The volume of treated water input to system from own production facilities
2	Water Imported	Bulk water purchased to become part of the water supplied. Typically this is water purchased from a neighboring water utility or regional water authority. Be sure to account for any import meter inaccuracy in reporting this volume.
3	Water exported	Bulk water sold and conveyed out of the water distribution system. Typically this is water sold to a neighboring water utility. Be sure to account for any export meter inaccuracy in reporting this volume.
4	Authorized Consumption	This is a sum of Billed metered+ billed un-metered+ unbilled metered+ unbilled un-metered volume of water. The volume of metered and/or un-metered water taken by registered customers, the water supplier and others who are implicitly authorized to do so for residential, commercial and industrial purposes It include water that is exported
5	Billed Authorized Consumption	All consumption that is billed and authorized by the utility. This may include both metered un-metered consumption.
6	Billed metered consumption	All metered consumption which is billed. This includes all groups of customers such as domestic, commercial, industrial or institutional. It doesn't include water sold to neighboring utilities (water exported) which is metered and billed.
7	Billed un-metered consumption	All billed consumption which is calculated based on estimates or norms but is not metered. This might be a very small component in fully metered systems (for example billing based on estimates for the period a customer meter is out of order) but can be the key consumption component in system without universal metering. It doesn't include water sold to neighboring utilities (water exported) which is un-metered but billed.
8	Unbilled metered consumption	Metered consumption which is for any reason unbilled. This might for example include metered consumption of the utility itself or water provided to institution free of charge.
9	Unbilled un-metered consumption	Any kind of authorized consumption which is neither billed nor metered. This component typically includes items such as fire fighting, flushing of mains and sewers, street cleaning, frost protection etc. In a well run utility, it is a small component which is very often substantially overestimated.
10	Qa(m3/month)	Mean monthly consumption of each connection
11	Nu	the number of unauthorized connections
12	No	the number of all active properties which the water company records show zero consumption for them
13	Nm	the number of connections which have not been illustrated in computer records of utility
14	Eu(Unauthorized consumption)	Unauthorized connections*mean monthly consumption of each connection. Includes water illegally withdraw from hydrants, , illegal connections, bypasses to consumption meter or meter/ meter reading equipment
15	Data Handling error	Apparent water losses caused by data handling error in meter reading and billing system .It is a sum of operation and management error
16	Customer metering inaccuracies	apparent losses caused by customer meter inaccuracies
17	Water Losses or UFW	UFW can be identified by calculating the difference between system input volume and authorized consumption. They consist of apparent losses and real losses.
18	Real losses	It results from losses at mains, service reservoirs, and service connections (up to the point of customer metering). The annual volume lost through all types of leaks, bursts, and overflows depends on their individual frequencies, flow rates and duration.
19	NRW	Non Revenue after is the difference between system input volume and billed authorized consumption , and it consists of the following: 1). Unbilled authorized consumption(usually a minor component of water balance) 2). Apparent losses(Commercial losses) and 3). Real Losses (technical losses)

No.	Item	Descriptions
20	Apparent losses	It results from unauthorized consumption and all type of inaccuracies associated with metering.
21	Length of mains	Length of all pipelines(except service connections) in the system starting from the system input metering (for example at the outlet of the treatment plant)
22	Number of active and in-active service connections	No. of service connections main to curb stop. Please note that this includes the actual number of distinct piping connections whether active or inactive. This may differ substantially from the number of customers
23	Connection density	no. of active and inactive service connections/length of main
24	Average length of private pipes	This is the distance between the curb stop and the customer meter, or from curb stop to the building line (first point of customer consumption) if customers are un-metered.
25	Average operating pressure	The average pressure may be approximated when compiling the preliminary water audit.
26	Operation and maintenance cost	These costs include those for operation, maintenance and any annually incurred costs for long-term upkeep of the system, such as repayment of capital bonds for infrastructure expansion or improvement. It includes employee salaries and benefits, material equipment, insurance, fees,, administrative costs and all other costs that exist to sustain the drinking water supply.
27	Customer retail unit cost (applied to apparent losses)	The customer retail unit cost represents the charge that customers pay for water service. This unit cost is applied to the components of apparent loss, since these losses represent water reaching customer but not fully paid for. Since most water utilities have a rate structure that includes a variety of different costs based upon (class of customer, a weighted average of individual costs and number of customer accounts in each class can be calculated to determine a single composite cost that should be entered into this cell)
28	Variable production cost (applied to real losses)	The cost to produce and supply the next unit of water. This cost is determined by calculating the summed costs for ground and surface water treatment and all power used for pumping from the surface to the customer. It also includes the unit cost of bulk water purchased as an import if applicable.
29	NRW as percent by volume	This is a percentage of non Revenue water to total water supplied
30	NRW as percent by cost	(unbilled metered +unbilled un-metered +apparent loss)*variable cost applied+(apparent loss*customer retail unit cost)
31	Annual cost of apparent losses	apparent losses*customer retail unit cost
32	annual cost of real losses	real losses*variable cost applied to real losses
33	UARL (Unavoidable real losses)	UARL(gallons /day)=(5.41 Lm+0.51Nc+7.5Lp)*P; or UARL (liter/day)=(18.0Lm+0.8Nc+25.0Lp)*P Where Lm(Length of mains in miles or kms), Nc(no of service connections), Lp(total length of private pipe in miles or km). The UARL is a theoretical reference value representing the technical low limit of leakage that cold be achieved if all of today's best technology could be successfully applied.
34	ILI(Infrastructure Leakage Index)	CARL/UARL

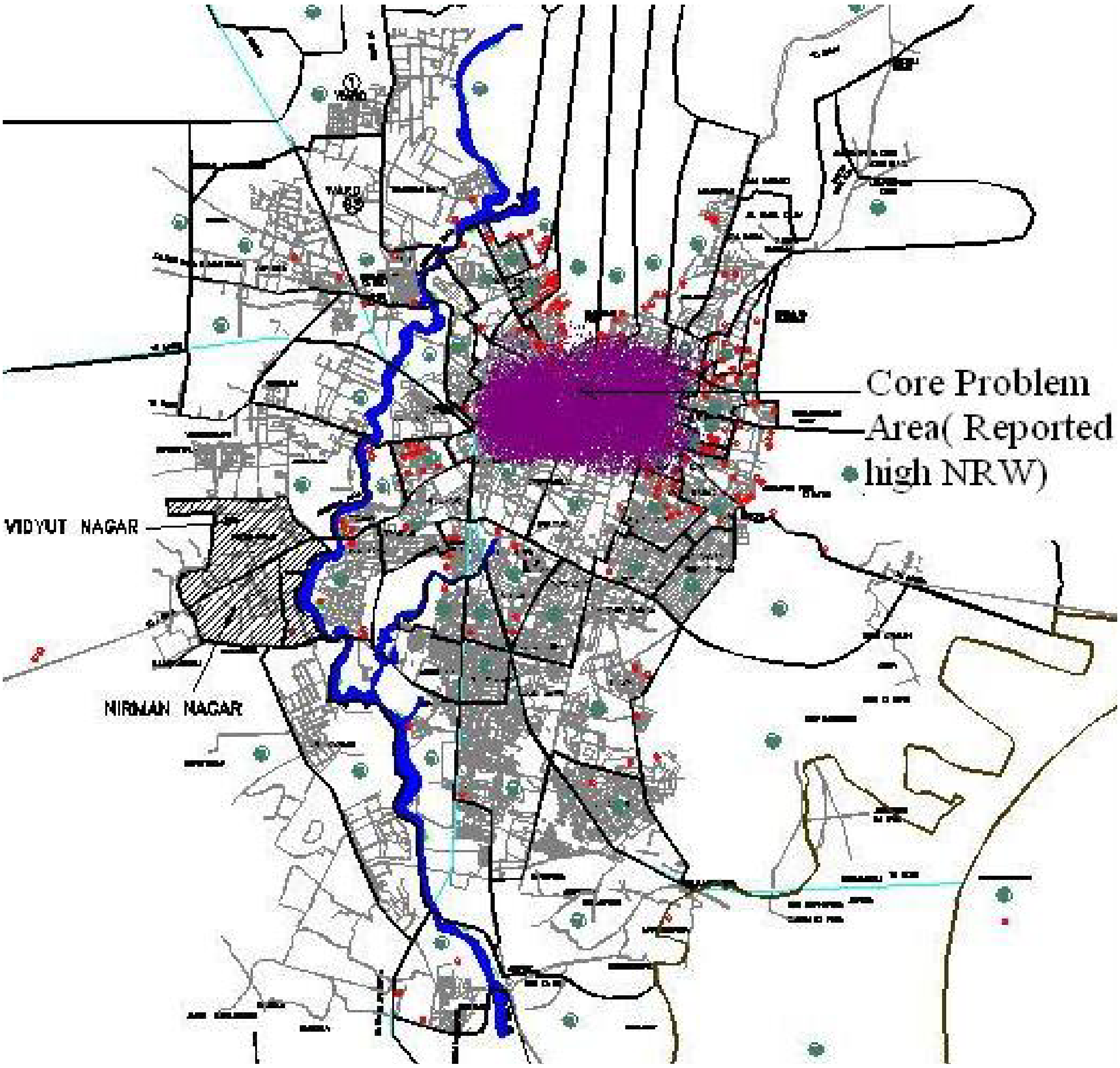

Fig. 1 Showing the Core Problem Area of Jaipur City

Need of the Study

The functional population of the Jaipur water supply department service area has increased tremendously with an annual growth rate 26.91% (2001-2011 census data) (GOI, 2011). As a consequence, demand for potable water in the area has increased significantly over the past several decades. Present water demand is 419.7 MLD considering 40 % transmission and distribution losses as shown in **Table 2**.

Per capita water availability of 146.32 L has been considered in above estimation (JMC, 2012). The city water supply is solely the responsibility of state level department, Public Health Engineering Department (PHED). PHED is responsible for providing water supply and sanitation services in the state. North zone of the service area reported a high level of NRW (51%-45%). This is due to old deteriorating infrastructure asset with poor operation and management practices as shown in **Table 3** (SAFEGE, 2000). In addition to consumers are accustomed to removing the meters or making taps at lower places to secure water due to low water pressure as shown in **Fig. 2 (a, b)**. In view of the growing needs for water on one side and dismissing water resources on the other, it has become imperative to conserve available water and replenish natural water resources to the maximum extent possible through demand management and water conservation strategy through appropriate NRW reduction strategy.

Methodology and Data Collection

The level of water losses can be determined by conducting a water audit analysis based on the concept of International Water Association (IWA's) Water Loss Control Committee methodology for the case study of Jaipur city. A water balance is based on measurements or estimations of water produced, imported, exported, used and lost. The initial step was to complete a comprehensive water audit. The audit resulted in quality data on authorized consumption, apparent losses, real losses and leakage performance indicators. Further it

Table 2. Salient Features of Jaipur Water Supply System

No.	Particular	Unit	
1	Population of the city as per 2011	lac	23.14
2	Present Population	lac	31.12
3	Population connected with water supply	lac	27.98
4	Water Demand	lac lt	4197
5	Water Production		
i	From TWs (1897 nos)	lac lt	2900
ii	From Bisalpur System	lac lt	720
iii	From Single Point TWs (117 Nos)	lac lt	15
iv	Total	lac lt	3620
6	Description of Water Connections		
i	Total Connections	no	363468
ii	Working Connections	no	332435
iii	Metered Connections	no	327704
iv	Flat Rate Connections	no	4731
v	Domestic Connections	no	285297
vi	Non Domestic Connections	no	40376
vii	Industrial Connection	no	2031
viii	Public Stand Post	no	1170
7	Demand Supply Deficit		
i	Demand	lac lt	4197
ii	Supply	lac lt	3400
iii	Deficit	lac lt	797

Table 3 NRW Status for North and South Zone of City

No.	Production(m3/day)	Consumption(m3/day)	NRW
Fiscal Year 2009			
North	228,489	138,884	56.33%
South	236,548	159,554	46.07%
Total	395,595	228,996	51.08%
Fiscal year 2010			
North	216,274	144,158	33.34%
South	234,246	162,434	30.65%
Total	378,441	234,524	38.02%

(a) (b)

Fig. 2 (a) Low Water Supply Pressure and (b) Leakage due to accident vandalism

was also used to analysis the computation of Unavoidable Real Loss (UARL), infrastructure Leakage Index (ILI), and an analysis of lost revenues from apparent losses & NRW.

Data used for the preset study were collected from the Public Health Engineering Department (PHED) records and interviewed from the concerned officers, technicians & operators at the pump house through a well-designed questionnaire. The quantity of water produced was estimated based on the capacity & operation period of pumps at the Tube-wells while consumption data were taken from billing records.

Consumption was billed based on meter reading and estimation based on consumption during other billing period. Quantity of water sold to the category of consumers to whom bills were raised was estimated based on assumed average consumption in that category and number of consumers in that category. Jaipur water supply system is mainly dependent on groundwater resources (97%) and rest part on nearby surface water as depicted in **Table 2**. System input value was calculated by aggregating the quantity of water produced from all these sources. Although the study predominately was planned to conduct using secondary data, in order to support it qualitatively a discussion with local experts of PHED has also been made through questionnaire survey.

Theoretical Consideration

The American Water Works Association (AWWA)-approved methods and tools for such projects were developed through the AWWA Water Loss Control Committee and published in a peer-reviewed committee report in August 2003 AWWA Journal. This article adopts the International Water Association's Water Loss Committee methodology. The detailed description of water balance and its components are given in **Table 4.**

Apparent losses are the summation of unauthorized consumption (E_u), customer metering inaccuracies, and data handling errors as shown in **Eq. (1).** Unauthorized consumption (E_u) is given by **Eq. (2).** Where N_u and Q_A are the number of unauthorized connections and mean monthly consumption of each connection respectively. Data handling error is calculated by summing the operational (E_o) and management error (E_M) as given in **Eq. (3).** It is caused by data handling error in meter reading and billing system. Customer meter inaccuracies (E_{FM2}) are determined by the **Eq. (4)**, where ER_{FM2} is the average meter error in the range of transient to maximum discharge and N_A is total connection.

$$\text{Apparent Losses} = \text{Unauthorized consumption } (E_u) + \text{Customer metering inaccuracies} + \text{Data handling errors} \quad (1)$$

$$E_u = N_u * Q_A \quad (2)$$

$$\text{Data Handling Errors} = \text{Operational Error } (E_o) + \text{Management Error } (E_M) \quad (3)$$

$$E_{FM2} = ER_{FM2} * N_A * Q_A \quad (4)$$

Real loss is carried out through the field study, it includes investigation of all the reported bursts that occur in the period of study, measurement of reservoir leakage and overflow, leakage from pumps & valves and network flow & pressure rate. It is also calculated by subtracting the volume of apparent loss from the total volume of water loss as shown in **Eq. 5**. Unaccounted for water (UFW) is commonly used terminology for evaluating the water loss. It is usually defined as the difference between water supplied to a distribution system and the water that leaves the system through its intended uses. It is calculated by using the **Eq. 6**. NRW is calculated by summing the volume of un-metered authorized consumption, apparent losses and real losses. It is the difference between system input volumes and billed authorized consumption as given by the **Eq. 7**. UARL is a theoretical reference value representing the technical low limit of leakage that could be achieved if all of today's best technology could be successfully applied. It can be assessed by formula using a formula developed by IWA Water Losses Task Force (Lambert *et al.*, 1999) as shown in **Eqs. 8–9**. Data required for this assessment are the Number of service connections (N_c), is the length of mains (L_m) and total length of private pipe in miles or km (L_p) . Total length of private pipe is calculated by multiplying the average distance of private pipe with the N_c. The general equations for UARL are given as follows in **Eqs. 8–9**. UARL is used in the calculation of a new and important performance indicator, the Infrastructure Leakage Index (ILI), which is the ratio of UARL to real losses as depicted in **Eq. 10**.

$$\text{Real Loss} = \text{Total Loss} - \text{Apparent Loss} \quad (5)$$

$$\text{UFW} = \text{System Input Volume} - \text{Authorized Consumption} \quad (6)$$

$$\text{NRW} = \text{Un-metered authorized consumption} + \text{Apparent losses} + \text{Real losses}$$
$$\text{NRW} = \text{System Input Volume} - \text{Billed Authorized Consumption} \quad (7)$$

$$\text{UARL (liter/day)} = (18.0L_m + 0.8N_c + 25.0L_p)*P \quad (8)$$

$$\text{UARL (gallons/day)} = (5.41L_m + 0.51N_c + 7.5\,L_p)*P \quad (9)$$

$$\text{ILI} = \text{CARL}/\text{UARL} \quad (10)$$

where ILI=Infrastructure Leakage Index, CARL= Real Losses and UARL= Unavoidable Real Losses.

Table 4. Summarization of the Water Losses Components for Jaipur Water Supply System

<table>
<tr><td colspan="5">Water Balance</td></tr>
<tr><td colspan="2" rowspan="2">Water Audit Report for Report Year</td><td colspan="3">Jaipur Water Supply System</td></tr>
<tr><td colspan="3">2006</td></tr>
<tr><td colspan="5">Components of Apparent and Real Losses Based on IWA terminology</td></tr>
<tr><td rowspan="6">System Input Volume
10037500</td><td rowspan="3">Authorized Consumption
5520625</td><td rowspan="2">Billed Authorized consumption
5018750</td><td>Billed Metered Consumption
4852083.33</td><td rowspan="2">Revenue Water
5018750</td></tr>
<tr><td>Billed Non-metered consumption
166666.67</td></tr>
<tr><td>Unbilled Authorized Consumption
501875</td><td>Unbilled Metered Consumption
(water used for fire-fighting, etc)
335750
Unbilled Non-metered consumption
(free water distribution at standpipes)
166125</td><td rowspan="4">Non Revenue Water (NRW)
5018750
50%</td></tr>
<tr><td rowspan="3">Water Losses
(Unaccounted for Water, UFW)

4516875
45 %</td><td rowspan="3">Apparent Losses
(commercial losses)
803002.5
8.0%

Real Losses
(Technical Losses)
3713872.5
367%</td><td>unauthorized consumption
(illegal use and connections)
200752.5</td></tr>
<tr><td>Customer Metering Inaccuracy
501875</td></tr>
<tr><td>Data Handling Errors
100375
Leakage on Transmission and/or Distribution mains
Not Broken Down
Leakage and overflows at utility's storage tanks
Not Broken Down
Leakage on service connections up to customer's meters
(Not Broke Down)</td></tr>
</table>

RESULTS AND DISCUSSIONS

This paper presents a spread sheet version of mathematical framework based on IWA water balance methodology for real world water utility. To evaluate the introduced procedure and verify the software results, a case study was carried out in one of the metropolitan city of developing country, India. In Jaipur city water supply department (PHED) is unable to meet out the burgeoning water demand of growing population with account of 79.7 MLD supply demand deficit (**Table 1**) The city is grappling with issues like inadequate and intermittent water supply, poor water quality due to high concentrations of nitrate, low cost recovery and high level of NRW as shown in **Table 2**. In this context, it is necessary to study the water balance components for Jaipur city. The detailed analysis of water balance components assist policy makers in designing program for NRW reduction through a concrete efforts.

Some key results of the initial water audit analysis are: non-revenue water for fiscal year 2010 was 50% of the total water supply is given in **Fig. 3** (CPHEO 1999). Real water losses (37%) are the dominant component by volume as given in **Fig. 3**.

This is due to the old , deteriorating and corrode pipe line (>50 years old) ,lack of a proper scheme for active leakage control, use of improper Asbestos Cement Pipes materials, improper pipe installation, poor workmanship in repair, accidents due to heavy traffic congestion, poor accountability and delay in repair. Apparent losses (8% of the total water produced) are also significant component of NRW due to meter under registration, and faulty non-functional meters. It require a proper corrective action through mapping of distribution

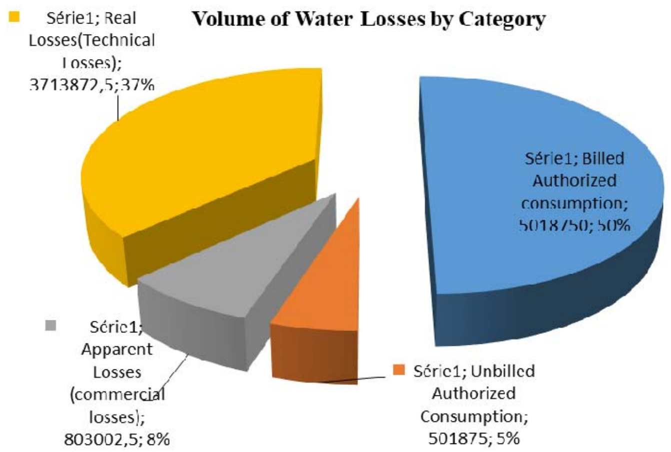

Fig. 3 Volume of Water Losses by Category

network, replacement of old and faulty meters with the new one, staff moral and incentives etc. Good record and public scrutiny with the help of neighbors will help to eliminate illegal connection.

High NRW also put a great financial burden on the water utility as shown in **Fig. 4**. Jaipur water supply department spend 3079.06 million Rs annually due to apparent and real losses. So there is an urgent need for reducing real losses and apparent losses through an appropriate NRW reduction strategy. Key operation performance indicators for the Financial Year 2010 water balance are shown in Figure. Unavoidable real loss (UARL) for Jaipur Water Supply Department is 286.16 million litre per day. UARL represents the technical low level of leakage in a system that could exist if the best management practices for leakage management were applied. Value of ILI (5) indicates a deteriorating old aged water supply asset with poor operational management and workmanship practices. These require following financial, operational and water resource considerations.

Financial considerations: Water resources are costly to develop or purchase; ability to increase revenue via water rates is greatly limited because of regulation or low rate payer affordability.

Operational Considerations: Operating with system leakage above this level would require expansion of existing infrastructure and/ or development of additional water resource to meet the demand.

Performance Indicators		
Leakage Performance Indicator		
NRW as percentage by volume	50	%
apparent losses as percentage by volume	8.000024907	%
UFW as percentage by volume	45	%
Financial Indicators		
NRW as percent by volume	50	%
NRW as percent by cost	278206510.4	Rs
Annual cost of real losses	2663998207	Rs
Annual cost of apparent losses	415065062.1	Rs
Operation efficiency indicators		
Apparet losses per service connections per day	0.38022572	3/conns/day
Real losses per service connections per day	1.758537296	m3/conns/day
Real losses per length of main per day	0.044212768	m3/m/day
Real losses per service connection per day per m (head pressure)	0.586179099	m3/conn/day/m
Pipe Breaks(breads/km/yr)	5.892857143	breads/km/yr
UARL(lt/day)	286158577.8	lt/day
UARL(m3/month)	8584757.334	m3/month
ILI(Infrastructure Leakage Index)	2.311537979	

Fig. 4 Performance indicators calculation

Water Resource Considerations

Available resources are greatly limited and are very difficult and environmentally unsound to develop. One core principle in the AWWA-IWA methodology is that water loss management is a continual improvement process. The initial top-down water balance using the AWWA-IWA methodology provide a starting point for completing an initial analysis but the methodology calls for continued refinement of data and periodic water audits to track progress. The key contribution of the water audit analysis tool is that it enables the calculation of NRW and its components using empirical data. Such information can be used, for example to assist water utility policy makers in devising programs, that balance reducing leakage, increasing collections, adjusting tariff and investing in new infrastructures. In the present study there complete absence of functionally effective metering regimen, data taken from utility record with lower and acceptable level of reliability. There is need for some type of data base or information system such as Geographic Information System (GIS) to enable analysis of flows in the networks and provide early warning or indication of leakage.

The tool can determine optimal values for physical losses, commercial losses, and total NRW depending on site conditions and basic engineering parameters. The Manual on Water and Treatment provides that loss of water above 10% in case of 24 hours water supply and above 20% in case of intermittent water supply would require remedial measures. Results reveal that Jaipur water supply department reported a high level of NRW (50% of the total water supplied) so there is a need of proper remedial measures through installation of proper leak detection program. To understand the reasons for leakage, the data regarding, and most common causes of failures which had been obtained from the repair sites was analyzed. The analysis revealed that the most common causes of failures due to decayed rubber ring (19.4% of the total failures) and the second most common category is pipe and joint failure due to heavy loads(14.3% of the total failures) as shown in **Fig 5**. Approximately 30% of the total failures which was collected at the opportunistic repair sites were due to service connections failures.

Since these activities are very limited (mainly for riser mains and house connections only), most of the information is obtained when consumers complain about low pressure or contamination. PHED does not carry out any special leakage inspections for distribution pipes. Activities for discovering or detecting leakages are obviously insufficient. It would be difficult to directly identify and characterize the causes of the losses from the results of the total loss. There is need of comparing the total losses with the other possible affecting causes like pipe age, ground elevation differences and comparison of meter record etc.

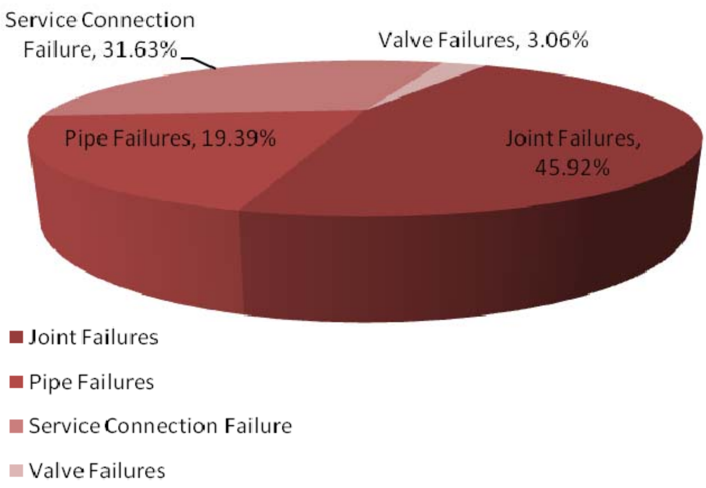

Fig. 5 Different type of Failures

Water Loss Implementation Plan

Subsequent steps towards developing a Jaipur Water Supply Department (PHED) comprehensive water management program include a comparison of the department's practices for reducing NRW and developing a comprehensive NRW reduction implementation plan. The above water audit analysis was focusing to the total water loss at the city level. Nevertheless identification is not by itself an end in reducing loss. Identifying the causes of the losses might help where to focus with probably limited resources that the city is having. This study indicates that the predominant cause of the water loss in the city is leakage and loss due to faulty meter and vandalism. Therefore, an appropriate long and short term strategy is necessary. Some of the remedial measures suggested to reduce water loss and leakage in a distribution system are; setting and leakage index and target, improving organization management and provision of training, establishing pressure management, proper maintenance and renewal, regular inspection of water network as shown in **Table 6**.

CONCLUSIONS

Calculating and evaluating the water audit analysis for the city in developing country is important as it can support for development and establishing a water loss strategy. Water

Balance is the measurement of distribution input and water consumed that can be measured using different techniques. In this paper water balance has been computed using the case study of Jaipur city. This water audit analysis tool determined all the components of non-revenue water (50%) including physical losses (36.99%), commercial losses (8.03%), unbilled

Table 6. NRW Reduction Activities for Jaipur Water Supply Department

Problems	Solutions
Insufficient Leak Detection due to low frequency of patrolling and absence of leak detection equipment.	Regular Inspection of the water network • Regular inspection supports to find the problematic areas and take action immediately before much water is wasted through the care-taker approach.
Aging and Corrode Pipes (> 50 years) Galvanized pipes were used for installations which are more than 50 years old. Use of improper material i.e Asbestos Cement Pipes (ACP). This is not a proper pipe material and susceptible for damage by excavation works	Proper Maintenance and Renewal of this old and deterioration water supply assets One of the main cause of lo Establishing Pressure Management Need for Up-to-date record Keeping
Insufficient Data Collection/Mapping Insufficient leakage record and meter reading data.	There is need to maintained a proper records for water-demand, condition of tube wells, pumps, supply hours etc.
Absence of bulk meters and more than 50% of the customer meters are out of orders or unreadable	So there is need for installation of bulk meters and replacement of faulty-non functional consumer meters for proper water billing
Poor workmanship in repair	Training, motivation and provision of incentives to staff

authorized consumption (5%), customer metering inaccuracy (5%) and data handling error (1%). Results shows that Jaipur water Supply utility suffers from a technical and managerial constraints and reporting high level of real losses (37% of total water supplied) and apparent losses (8% of the total water produced). This is due to old deteriorating water supply asset, poor governance, low level of accountability at all level, illegal connection, poor operation and management practices, lack of proper scheme for active leakage control, vandalism, thefts, faulty meters, meter under registration and accidents etc. Hence there is an urgent need for NRW reduction strategy through improved organization management and provision of training, establishing pressure management, proper maintenance, regular inspection of water network and renewal.

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