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A Study on Non-Revenue Water in Intermittent and Continuous Water Service in Hubli City, India

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Abstract
The Cities in developing countries generally have high levels of non-revenue water (NRW), which requires high attention. In parts of Hubli-Dharwad in India, a study was conducted to assess NRW in one of the intermittent water service (IWS) pilot area and also in newly constructed continuous water service (CWS) demonstration zone. The study revealed that the NRW in IWS is as high as 37%, whereas in CWS, it is limited to about 15%. The outcome of this study will be helpful in CWS scaling up projects in India and developing countries.
Keywords: Intermittent water service, Continuous water service, Non-revenue water, Physical losses, Commercial losses

1. Introduction

Most of the urban water utilities in developing countries are incurring huge water losses in water service management. The scenario is not different in Indian cities as well. Too many formats, definitions were followed by different utilities with regard to assessment of water losses. International Water Association (IWA) Task Forces recommended for discontinuity of the term 'unaccounted for water' (UFW) (Alegre et al., 2000). Because of varied interpretations of the term and published an international best practice concept for water balance calculations, as a first step in water losses management Non-Revenue Water (NRW) is defined as the difference between system input volume and billed authorized consumption. NRW consists of unbilled authorized consumption and water losses, which is divided into apparent losses and real losses. Apparent or commercial losses consist of un-authorized consumption and metering inaccuracies and the Real or Physical losses comprised of the annual volumes lost through all types on mains, service reservoirs and service connections, up to the point of customer metering(Hirner and Lambert, 2000; Alegre et al, 2000).

The calculation of components, unbilled authorized consumption, apparent losses and real losses is the essential step for the beginners (Lambert, 2003). Frauendorfer and Liemberger (2010) defined NRW as a good indicator for water utility performance. Practical measurement of leakage is obtained from minimum night flow minus the recorded metered consumption (Tabesh et al., 2008). Gomez et al. (2011) identified the main causes of NRW as the no incentives for managing staff, corruption, lack of customer knowledge about water service and political reasons. Ramirez (2008), in an analysis for Columbia showed that the behavior of NRW index was highly sensitive to efficiency variations and no considerable effect to penalizing actions. Kingdom et al., (2006) reported that reduction of half of the current losses in developing countries could be a realistic target. Wyatt (2010) developed a financial model to assess accurate, steady-state NRW without requiring large data, applicable for developing countries. This model allows decision makers to establish NRW targets and to optimally allocate funding to NRW management. In Asian water utilities, the estimated NRW volume per year is about 29000 million liters, the cost of which is about $9 billion per year (Frauendorfer and Liemberger, 2010).

In India, the Central Public Health and Environmental Engineering Organization (CPHEEO) Manual (2001) recommends a limit of 15 % for UFW. Recently, the service level benchmark for NRW in urban water sector in India is fixed at 20% (GOI, 2012). In a study by Andey and Kelkar (2007), in four cities across India, to evaluate the influence of intermittent and continuous water service on NRW, it was showed that NRW increased from 19.5% to 35.8% under IWS, whereas it increased from 31 to 47.8% under continuous supply system. Mathur and Vijay (2013), after a study by Seureca Consulting Engineers in two district metering areas of Jaipur city, India, reported NRW varying from 23% to 63%.

This study was done in Hubli city of Hubli-Dharwad Municipal Corporation (HDMC), Karnataka state, India. Hubli-Dharwad a prospective city in North Karnataka, India has a population of about 1 million as on 2013. The water supply service provision was a responsibility of the HDMC until March 2003. To improve the operational efficiency, the Government of Karnataka (GoK) issued an order in Feb 2003 for managing water service in HDMC by the Karnataka Urban Water Supply and Drainage Board (KUWS&DB) with effect from April 2003. The water service has been gradually improved by KUWS&DB over last ten years through augmentation of bulk water supply, replacement of old pipes and better management. Now, the city is provided with IWS at a periodicity of once in 2 to 3 days for an average duration of 3 hours. Under the assistance of the World Bank, Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC) implemented 24 x 7 water supply projects in three cities in the State of Karnataka: Hubli-Dharwad, Belgaum and Gulbarga on a pilot basis, covering about 10% of the total population in each city. The CWS pilot project (called as demonstration zone) in a selected area of Hubli was implemented from April 2006 to December 2007 with an operation and maintenance (O & M) period of two years through a private operator under a management contract (KUIDFC, 2005). The O & M in the Demo Zone has been continued from January 2008 through the same operator. Planning and scaling-up the CWS to the remaining areas of the city is currently under progress. The purpose of the study is to assess NRW and identify opportunities to improve service levels. This paper elaborates assessment of NRW in IWS and CWS areas of Hubli city. The outcome of this study will be a great help to the water supply engineers in planning CWS in Indian cities. The Government of India is also allocating major funds towards urban water sector. The water supply, sewerage and storm water drainage investments amount to about 24% of all urban sector requirements for capital and 41% for O&M respectively. In this situation, enhancing capital efficiency is clearly a priority to use funds efficiently and effectively to deliver maximum benefit from investment" (GOI 2012).

2. Study Area

Before the year 2003, under the maintenance of water supply by HDMC, no metering was prevailed in Hubli-Dharwad twin cities. KUWS&DB took over the maintenance of water supply in the year 2003, resulting in considerable improvements in water service and commenced metering for customers in the year 2005. So far, about 70% customer metering has been achieved in the twin cities. Two study areas for assessment of NRW were selected; one zone in intermittent water service area and another is CWS demonstration zone in Hubli city.

The study zone selected in IWS area is Lingaraj Nagar located on north side of Hubli city comprising of 334 water connections. This area was selected because of the high prevalence of customer meters in the area. The area boundaries were mapped with the assistance of the valve men and local engineers. This area was provided with water on a 3-day cycle.

The CWS demonstration zone is located in the North-East part of Hubli city (Figure 1). It comprised of a total road length of 86 kilometers and an area of 328.9 hectares. This zone has predominately a high income urban residential area with some rural and slum areas mixed in. There are four wards, 27, 28, 29 (Part) and 32 (Part) located around Nrupathunga Betta ground level service reservoir (GLSR), which facilitates more than 99% gravity supply, were selected for CWS demonstration. With a total base population of 43,877 in the year 2005 by including unconnected properties also, the population of demo zone for the years 2020 and 2035 was projected as 59,049 and 79,476 respectively. (KUIDFC 2005).

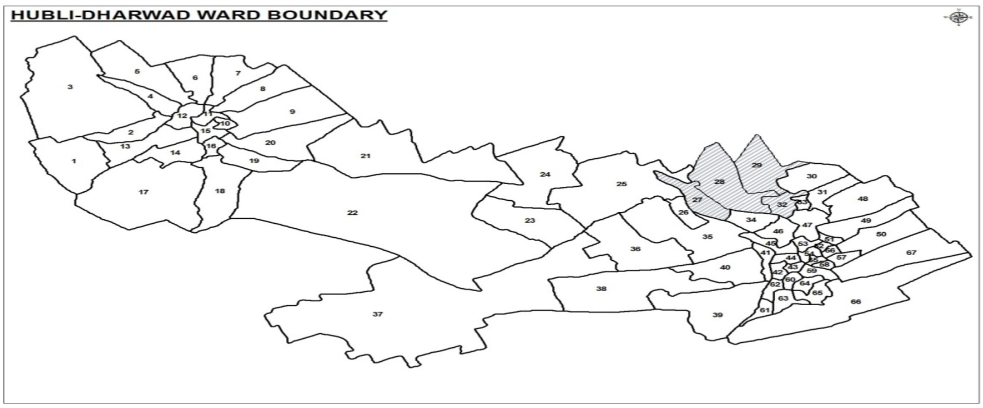

Figure 1. Location CWS demonstration zone, Hubli

There were 48 existing public taps connected to piped water supply system especially in urban poor areas. Apart from this bore wells with hand pumps and bore wells with power pump sets connected to mini tanks (2500 liters capacity) were provided to meet the shortage in water. Because of high hardness, the customers used bore well water only for non-potable purposes and for drinking purpose they depended on public taps or bottled water (paid private service). The customers close to public taps (about 20 meters) were drawing sufficient water through half or one inch sized hose pipes free of cost and the distant customers were not getting enough quantity of water from public taps. As per target, 100% houses in CWS service areas were connected to the piped water supply and metered because of pro-poor policies. The main performance targets of CWS water service are as follows (GOK 2005): (a) Continuous Pressured water supply to every customer in each Demonstration Zone. The strategy was to ensure a minimum day time pressure of 6 m (from 6 am to 10 pm) and minimum night time pressure of 2 m (from 10 pm to 6 am) near four critical zonal points using data loggers. (b) Metering of minimum of 90% property connections (individual and shared), public stand posts and feeds to storage tanks on volumetric basis. (c) Maintenance of computerized records of meter readings. (d) Reduction of the losses to 30 Liters per connection per day per meter pressure in each Demonstration Zone for a continuous period. These performance targets are the key elements in reducing the NRW in CWS demonstration zone.

3. Methodology

3.1 Intermittent water service area

Intermittent water service areas in Hubli city do not have arrangements for regular water audit. The authors selected the pilot study area in Lingarajanagar area in Hubli, which could be isolated easily and existence of a single inlet main to fix bulk flow meter. The NRW study was conducted by KUWS&DB through NextDrop Co. from March 15th to June 15th 2012. After mapping the area, the addresses of the households were confirmed, and the sample meter readings were taken using a team of enumerators. The area consisted of a total of 334 households, in the neighborhood of Lingaraj Nagar, where water was provided via a 150 mm pipe fitted with a bulk flow meter on a 3-day cycle. The Bulk Flow meter readings (Figure 3) were also collected to estimate the total quantity of water supplied to the area. Of the total sample of 334 households, 258 numbers had working meters (Figure 4), 52 numbers had broken meters and in case of another 24 households, access could not be secured to their household meters due to door locks. Hence, the household consumption was extrapolated from meter readings from a smaller sample of 258 households with working meters.

In order to calculate household consumption of water, a team of enumerators were trained to take meter readings before and after the water supply. Because of challenges associated with getting access to household meters—due to door locks and lack of trust by residents, the results in the study are based on the last readings

Figure 2. Bulk Flow Meter at Lingarajnagar, Hubli

Figure 3. Customer Meters at Lingarajnagar, Hubli

taken on June 1st and June 4th 2012. By using the above data, input volume into study zone and billed water volume were calculated. The NRW is calculated by using a simple formula as below:

NRW % = [1 – (Billed Water Volume) / (Input Volume)] * 100 (1)

Estimation of commercial losses involves determining customer meter accuracy, theft of water and assessing quantum of meter reading, data handling and billing errors through detailed process and billing data verification (Liemberger 2010). The volume of physical losses can be easily calculated by deducting authorised consumption and commercial losses from NRW (Figure 1), which is a scope of work for future study. But in this study, the scope of work is limited to assessment of NRW only.

3.2 CWS Area

3.2.1 Bulk water supply and Water pressure

The monthly water consumption data sets were collected for four years from July 2008 to March 2013 from KUWS&DB. Averages for each year were calculated to study the physical losses and NRW in the CWS demonstration zone. There was a dedicated tank called as Nrupathunga Betta tank for CWS demonstration zone. The outlet of the Nrupathunga Betta was provided with an Electromagnetic Flow meter along with a data logger in a Control Room near Nrupathunga Betta tank, Hubli (Figure 4). Bulk flow readings were logged continuously (every 10 minutes) at the outlet of Nrupathunga Betta tank.

Figure 4. Bulk water Meter and Valve Control Room near Nrupathunga Betta Tank, Hubli

In CWS area, there are four critical pressure monitoring points. Pressures were logged continuously on day to day basis at four critical zonal points and daily average pressure for each location was determined. An average of 15 days of daily average pressures for each of the location was recorded at each of these points. Finally, an overall average of these four averages was calculated (GOK, 2005).

3.2.2 Calculation of Non-Revenue Water, Physical Losses and Commercial Losses

Calculation of the main NRW components, physical and commercial losses is of much importance in initiating specific actions to reduce NRW and also in decision making on investment planning in NRW reduction program. The calculation of NRW is done simply by taking the difference in input volume and billed volume. NRW is expressed generally in percentage and specifically in liters per connection per meter pressure. The commercial losses were calculated by deducting physical losses from NRW. The Minimum Night Flow (MNF) was obtained from logged data. The Net Night Flow (NNF) which is nothing but physical losses is calculated by deducting night customer usage from MNF. But, not much study has been in India on night usage because of intermittent supply for a few hours in day time. At the International level, the UK Water Industry established a national average figure of 1.7 liters per connection per hour as Legitimate Night Use (UK Water Industry, 1994). The same value is considered in calculating the NNF from MNF.

4. Results and Discussions

4.1 Intermittent water service area

With the limited availability of data it was possible to assess NRW only. NRW in the study area was calculated as follows. Firstly, input water volume and billed water volume in the study area was accounted. The input volume to the study area in the study period of one supply cycle was 1.17 Million Liters (Ml). Using meter reading data from June 1st and June 4th, it was calculated that for 258 households, average consumption was 2,213 Liters. For 24 households with door locks or other problems and 52 households with faulty meters, for which readings were excluded. However, 52 households out of 334 (15.6% of households), had meters that appeared not to work properly. In general, meter readings from these households indicated zero consumption, or in some cases, negative consumption. Extrapolating from the average across the 334 households, the total Consumption was 0.74 Ml (Table 1).

Table 1. Input Volume and Billed Volume in IWS Area

Parameter	Number of houses	Average 3 days Consumption per house in Liters	Total Volume in Ml
1. Input Volume	-	-	1.17
2. Billed Water Volume			
2.1 Houses with working water meters	258	2213	0.74
2.2 Houses with door Locks	24		
2.3 Houses with faulty water meters	52		
Total	334		0.74

Source: KUWS&DB

By using formula (1) in paragraph 3.1 above,

$$NRW = [1 – (0.74)/ (1.17)] * 100 = 37 \%$$

The NRW of 37% is very high when compared with the standard of 15% (CPHEEO, 2001). There were several possible causes of the high rates of NRW which include leakages, illegal connections and improper meter placement i.e. meters placed such that not all household consumption is captured.

4.2 CWS Area

4.2.1 Design Values

Table 2 shows the projected water demand at the tap in the Demo Zone based on the unit consumption rates of 135 Liters per Capita per day (LPCD) for domestic usage, 45 LPCD for institutional / commercial usage and 40 LPCD for public taps (CPHEEO, 2001). The water demand at tap for the years 2008, 2020 and 2035 ranged between 4.74 Million liters/day (Ml/d) to 10.28 Ml/d. In this case, the losses considered in calculation of bulk water demand range from 40% to 44%.

Table 2. Water Demand Calculation for CWS area

Year	Population	Number of Connections	Water Demand at Tap in Ml/d	Leakages Included Ml/d	Bulk Water Demand in Ml/d
2005 Base Year	43877	5346	4.74	2.08	6.82
2008	47500	6650	5.14	2.24	7.38
2020	59000	9419	7.61	3.06	10.67
2035	72000	13402	10.28	4.35	14.63

In the hydraulic design of distribution system, the recommended minimum residual pressures are 7 M, 12 M and 17 M at ferrule points of single-storey buildings, two storey buildings and three storey buildings respectively with residual pressures not to exceed 22 M (CPHEEO, 2001). In this CWS demonstration project, the pipe network design was made with a minimum pressure of 6 M maintained in the Demonstration zone with no upper limit (KUIDFC 2005).

4.2.2 Non-Revenue Water

The NRW is calculated as the difference between input volume and billed volume, which varies from 100 to 150 Liters per connection per day (L/con/d). If expressed in percentage, it varies from 13% to 17% (Table 4). The public taps in CWS area was eliminated by providing individual water connections to urban poor through Government subsidies. As per Pro-poor policy, for urban poor (with houses having plinth area of 600 square ft.) the one time connection fee was waived off except water meter cost, which was collected in monthly installments of Rs 30 only. Further, the monthly minimum water charge is a meager amount of Rs 48 per month. This policy of covering 100% metered customers also helped in minimizing NRW. During the last two years the NRW has been increased to 17%, which needs to be managed within 15%. This can be achieved by reducing the high pressures in the system using pressure reducing valves (PRV) and leakage reduction can be initially be assumed as direct proportional to pressure reduction (Farley et. al. 2008).

Table 3. Calculation of NRW in CWS area

Year	Total Connections	Average Daily Input Volume in Ml/d	Average Daily Billed Water in Ml/d	NRW in Ml/d	NRW in L/con/d	NRW in %
2008-09	7234	5.49	4.54	0.95	131	17
2009-10	7520	5.79	5.02	0.76	101	13
2010-11	7787	6.29	5.44	0.85	109	13
2011-12	8070	6.97	5.86	1.11	138	16
2012-13	8402	7.50	6.23	1.26	150	17

4.2.3 Physical Losses

The physical losses in the Demo zone vary from 102 to 114 L/con/d with the average pressure varying from 21 to 28 m (Table 3). A simple physical loss assessment matrix was published by Liemberger and McKenzie (2005), which classifies the leakage levels for utilities to four technical performance categories A, B, C and D. The category B is with the average pressure is 20 m and the physical losses of 100-200 L/con/d. Accordingly the CWS demonstration zone in Hubli falls in technical performance category B, which means that there is potential for marked improvements through pressure management, better active leakage control practices and better network maintenance.

Table 4. Calculation of Physical Losses in CWS area, Hubli

Period	Number of Connections	Average Zone Pressure in M	Minimum Night Flow in L/s	Legitimate Night Use in L/s	Net night Flow (Physical Losses) in L/s	Physical Losses in L/con/d
2008-09	7234	23	11.9	3.4	8.5	102
2009-10	7520	22	13.1	3.6	9.5	109
2010-11	7787	21	13.7	3.7	10.0	110
2011-12	8070	27	17.5	3.8	13.7	112
2012-13	8402	28	18.5	4.0	14.6	114

4.2.4 Commercial Losses

After calculating NRW and physical losses separately, the commercial losses were calculated by deducting physical losses from NRW. It shows that the commercial losses were gradually reduced from 4 to 1% of input volume over a period of three years in the beginning, whereas, it started increasing and reaching 4% within two years (Table 5). It is necessary to initiate action plan to reduce the commercial losses.

Table 5. Calculation of Commercial Losses

Year	NRW		Physical Losses		Commercial Losses	
	L/con/d	%	L/con/d	%	L/con/d	%
2008-09	131	17	102	13	29	4
2009-10	121	15	109	14	12	2
2010-11	121	15	110	13	11	1
2011-12	138	16	112	13	26	3
2012-13	150	17	114	13	36	4

4.3 Revenue Potential

The CWS area in Hubli and Dharwad cities account for about 12% of total connections. The revenue potential in case of balance 88% of total connections has been assessed in Table 6. If the NRW in IWS area of entire Hubli-Dharwad is assumed as the same as that in Lingarajanagar study area, the annual revenue potential is about Rs 152 Million (Table 6).

Table 6. Revenue Potential in IWS area of Hubli-Dharwad

Sl. No	Details	Values
1	Annual System Input Volume in Ml	63875
2	NRW in IWS area	37%
3	Target NRW as in CWS area	15%
4	Enhanced Revenue Water in Ml	14053
5	Average Tariff in Rupees/Cum	10.83
6	Annual Revenue Potential in Rupees Million	152

5. Conclusion

In this paper, water audit study has been made both in intermittent and CWS areas. In IWS area, the NRW was estimated as 37 %, which is very high compared to local standards of 15% as per CPHEEO manual. In the CWS demonstration zone the physical losses vary from 102 to 114 L/con/d at an average pressure varying from 21 to 28 m. The NRW was estimated at 13 to 17%, which is normal when compared to local standards of 15%. The demonstration zone has a mix of different income category consumers. Full rehabilitation of network, non-provision of public taps, authorization of illegal connections and 100% metering have resulted in managing NRW nearer to the standard limits. The revenue potential in the intermittent service area of entire Hubli-Dharwad, the annual revenue potential is about Rs 152 Million. It is recommended to scale up CWS in entire Hubli-Dharwad, India and developing countries as well.

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