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Water loss in distribution system of Zone-V and Korail slum as a sub system

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Abstract– Demand of water supply for rapidly growing urban population in developing countries is increasing dramatically. As a result demand for additional water sources and infrastructure is growing. Moreover, nearly 40% of the water produced is lost at different levels of the distribution system before reaching the consumers. Korail is one of the slums in Dhaka city suffering a high shortage of water as well as high water loss. In this study, an attempt is made to evaluate the water loss with the available secondary data for Korail slum and Zone-V of DWASA. Water production data that is only available for the entire city and the water consumption as collected from individual customer meter readings was used to evaluate the total water loss of Korail slum and Zone-V, were compared using different performance indicators. Water loss as percentage (UFW) for Zone-V and Korail slum is 14% and 5% respectively. Loss per length of Zone-V is 51.93 m^3/km/day whereas loss is only 10 m^3/km/day for Korail slum. Loss per connection is about 1118.478 lit/connection/day for Zone-V and 147.09 lit/connection/day for Korail Slum.

Keywords: Water loss, Real losses, Apparent losses, Distribution system, UFW.

1. Introduction:

Problems in providing satisfactory water supply to the rapidly growing especially that of the developing countries is increasing from time to time. Urban settlements in developing countries are at present, growing five times as fast as those in the developed countries [4]. The developing cities have great difficulty both financial and technical to develop and expand water

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supply projects and one of the difficulties among the others is managing and reducing losses of water at all levels of distribution system. As a result of the overall shortage of water, many cities are faced a problem in distributing the available water impartially among the residents.

Water requirement (e.g. drinking, removing or diluting waste materials, producing manufactured goods, growing food, producing and using energy) varies with weather, lifestyle, culture, tradition, diet, technology, and wealth. Water supply in Bangladesh relies mainly on ground water and 87.72% of the Dhaka city's water supply is depends on groundwater resources. Even though Dhaka city is surrounded by the four rivers namely Buriganga, Balu, Turag and Tongi Khal but only 12.28 % of supplied water is obtained from these rivers. Dhaka city faces two major problems in supplying water to its residents: i) gradual decrease of raw water sources and ii) discharge of large quantities of polluted water. Surface water sources from surrounding rivers and lakes have ready exceeded the standard limits of many water quality parameters because of the discharge of huge amount of untreated and municipal waste materials. Other than these four over-polluted rivers, the nearest water body is the Padma and the Meghna that have acceptable water quality and ability to fulfill the demand. However, those rivers are located within a distance of 17 km and 50 km respectively from Dhaka.

1.1. Water Distribution System

A water distribution system is a hydraulic infrastructure that conveys water from the source to the consumers; it consists of elements such as pipes, valves, pumps, tanks and reservoirs. The most important consideration in designing and operating a water distribution system is to satisfy consumer demands under a range of quantity and quality considerations during the entire lifetime for the expected loading conditions [11]. Also a water distribution system must be able to accommodate abnormal conditions such as breaks in pipes, mechanical failure of pipes, valves, and control systems, power outages, malfunction of storage facilities and inaccurate demand projections. The possibility of occurrence of each of these deficiencies should be examined to determine the overall performance and thereby the reliability of the system. In general, reliability is defined as the probability that the system performs successfully within specified limits for a given period of time in a specified environment .

1.2. *Importance of Water loss analysis*

Water loss is the difference between the water entering the supply system (through wells, surface intakes, and/or wholesale purchases) and water used (sold to customers or used for free). All systems experience some water loss as an ordinary part of operation. Water loss is also called 'unaccounted for water' to distinguish it from losses that occur for known reasons, such as for water treatment processes or hydrant flushing [5], [6]. Amounts of unaccounted for water are typically expressed as a percentage of the total amount pumped and/or purchased. In Fig.1 shows the component of different water losses.

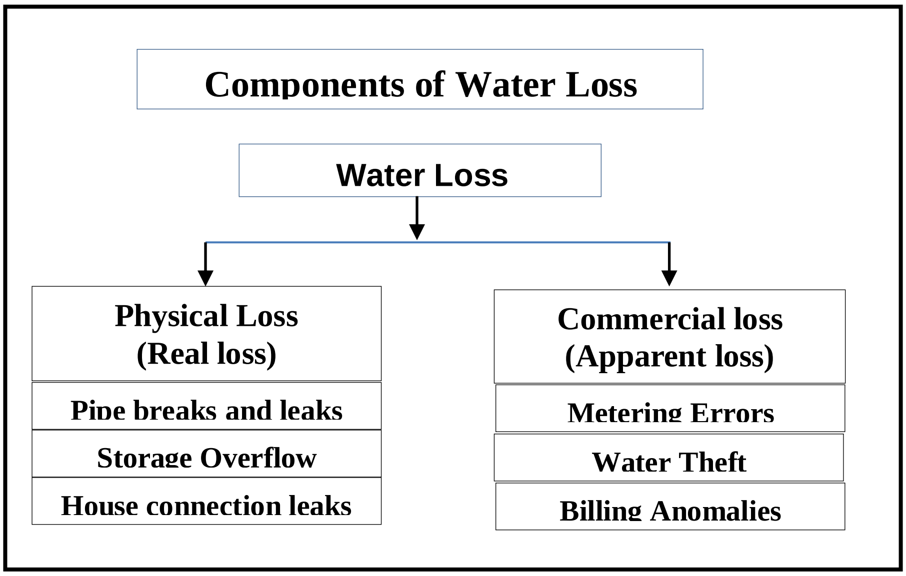


Fig-1: Components of Water Loss

Lost water is lost money. If losses are due to under registering customer meters, than lose revenue on water that paid to deliver. If losses are caused by leaks, than lost the money it cost to produce or purchase that water. In some cases, curbing large water losses from leaks can save a town or district the cost of finding additional water sources [10].

Water loss percentages indicate to others how efficient the system is [9]. This may be an issue applying for additional water rights, contracting to purchase or sell water, seeking a grant or loan for system improvements, or trying to stay within established conservation goals.

To avoid for the wide diversity of formats and definitions related to water loss, many practioners have identified and urgent need for a common international terminology that among them task forces from the international water association (IWA) recently produced a standard approach for water balance calculation by the IWA WLTF [1], [7] with a definition of all terms involved as indicated in Table 1:

Table - 1: IWA Water balance (Lambert, A., 2003)

<table>
<tr><td rowspan="9">System input Volume</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Meter Consumption (Including water exported)</td><td rowspan="2">Revenue water</td></tr>
<tr><td>Billed Un-meter Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>unbilled Meter Consumption</td><td rowspan="7">Non-Revenue Water (NRW)</td></tr>
<tr><td>unbilled un-meter Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized 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 Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer Metering</td></tr>
</table>

2. *Water Supply System in Dhaka City:*

Dhaka is the capital city of Bangladesh. It is one of the major cities of South Asia, located in the heart of the Bengal delta. Dhaka has an estimated population of around 15 million, making it the ninth largest city in the world, with forecasts of 29 million by 2035. Dhaka Water Supply and Sewerage Authority (DWASA) is responsible for construction, operation, improvement, and maintenance of necessary infrastructure for providing potable water supply, sewerage, and storm water drainage services in its services areas. DWASA was established in the year 1963 as an independent organization, under the East Pakistan ordinance XIX. It covers more than 400 sq. km service area with 15 million people with a production of almost 2110 million liters per day.

For better operation, maintenance, and customer care, the total service area of Dhaka WASA is divided into 11 geographic zones, which includes 10 in Dhaka City and 1 in Narayanganj. There is an office for each zone, and this office carries out the responsibilities of engineering, maintenance, and operation as well as revenue activities. So that the respected consumers can obtain all possible services and counseling from one place. In Fig.-2 shows the jurisdiction map of DWASA and Table-2 represents the zone wise pump no. of DWASA.

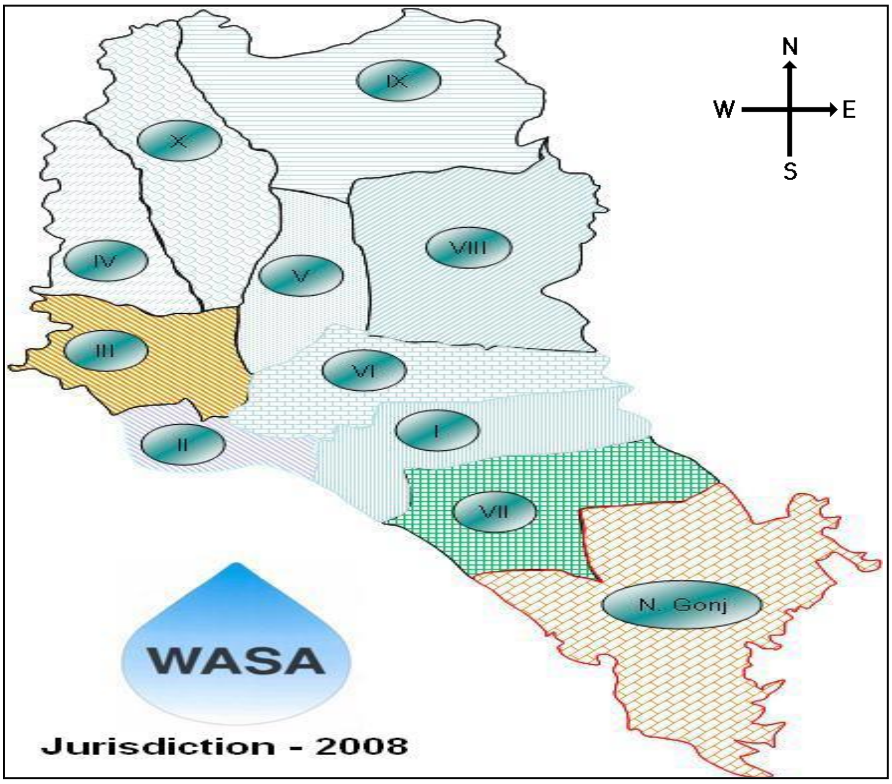


Figure-2: Jurisdiction of DWASA

Table-2: Zone wise pump number and pipe length

Sl #	Name of Zone	Pump No.	Length of Pipe (km)
1.	Zone – I	65	509.00
2.	Zone-II	50	180.00
3.	Zone-III	89	299.45
4.	Zone - IV	83	501.00
5.	Zone- V	54	280.00
6.	Zone- VI	93	480.52
7.	Zone – VII	36	192.23
8.	Zone – VIII	46	187.22
9.	Zone – IX	45	301.50
10.	Zone- X	60	229.64
11.	Zone- XI	24	301.00
	Total	645	3,461.56

Source: MIS Report, December-2013

Consumption Management of DWASA

One of the difficulties faced by the water authority is determining the accurate water demand of the slum as the consumption during the past years that should have been used as a base is far below the actual demand due to shortage of water. Consumption of water for Dhaka is therefore estimated based on the amount supplied rather than the actual demand. DWASA projects total water demand considering per person per day water demand as 150 liter. Total water demand in Dhaka city varies from 2100 to 2300 Million Liter per Day (MLD) with seasonal variation. However, total production capacity of DWASA is 2247.47 MLD (both groundwater and surface water). Apparently, DWASA is able to fulfill current water demand through their capacity. However, DWASA has never reached its production target and actual production for groundwater and surface water is 1831.20 MLD and 256.30 MLD respectively with a demand-supply gap of 160 MLD. Moreover, if we account 31.68 percent Unaccounted for Water (UFW) or system loss between production and end-user level then real supply would be 1426.18 MLD. The statistics imply that almost half of the population in Dhaka city are deprived of getting DWASA projected standard water requirement (150 l/p/d).

Water loss in distribution system of Zone-V and Korail slum as a sub system

2.1. Description of the Study Area

Korail is one of the largest slums in Bangladesh and is located under ward No. 19 and 20 of Dhaka City Corporation, adjacent to Gulshan-Banani Lake which satellite view is showing in Fig.-3. The slum can be accessed by several roads or by water across Gulshan Lake. The main two units of Karail are known as Jamaibazar (unit-1) and Boubazar (unit-2). Within Boubazar, there are four sub-sections known as Ka, Kha, Ga and Gha. In addition to the main Korail slum area, BeltoliBosti, T&T Bosti, BaidarBosti, Ershadnagar and GodownBosti are also part of greater Korail. The slums are gradually expanding across the lake by land reclamation and through the dumping of waste and soil.

Figure-3: Satellite View of Korail Slum

More than 20,000 families now reside in Korail, comprising a significant element of Dhaka's work force in the garment, transportation, construction, land development, domestic help, waste management, small industry and informal sectors. Despite their significant contribution to the economy, slum dwellers from Korail and elsewhere remain excluded from basic services principally because slums are considered to be "illegal settlements".

2.2. Water Supply condition of Korail Slum:

Korail is under the Jurisdiction of Dhaka WASA, Zone-V. Length of water distribution pipe of Zone-V is altogether 280 km. and that of Korail slum is about 7km. Korail is mainly established on Govt. land where people have brought land to reside and rent. Though Korail is under WASA jurisdiction, but as per present Government of Bangladesh (Gob)policy, no basic service is provided in slums. Illegal system has grown up in the slum to provide it's dwellers with water supply. Namely water isarranged by making illegal connection with WASA main line and any householderhaveto pay tk.100 for each kind of utilitywhich is much higher compared to normalbilling system. Some Govt. officials, middle manand muscle man are collecting the moneyand Govt. is not getting any kind of revenue from this illegal setup. Recently water supply connections are provided legally in many householdsby WASA and many landlordshave bored tube wells for their residents. Presently many landlords are moving intoelectricity driven pump for collecting andproviding water.

Recently the state-run agency gave connections to 504 households for meeting water demand of 20,000 families. But the slum dwellers said that the connections were not enough to meet the demands of about 2, 82,000 people. The residents of the slum have been using water, through connecting illegal pipelines with WASA's pipelines which is installed at Gulshan and Banani, depriving WASA from huge amount of revenue in every year. Consequently, the government-owned agency has taken steps to cut illegal lines for reducing system loss. If the WASA disconnects all illegal lines without ensuring required water for all the slum dwellers, 70% people of the slum will face acute water crisis.The WASA has built 504 reserve tanks at the slum and capacity of each tank are 5,600 liters, 3,600 liters or 2,100 liters. WASA has installed a pump, which is able to pump 30,000 liters of water per hour. Capacity and the number of each tank are given in the following Table -3.

Table -3: Capacity Wise Reserve Tank

Sl #	Capacity of Reserve Tank	Number of Tank
1.	5,600 liters	44
2.	3,600 liters	242
3.	2,100 liters	218

3. Methodology :

Water loss was analyzed into two levels, the entire Zone-V and Korail slum as a sub-system. The total water produced and the actual water consumption as aggregated from data that has been previously recorded by DWASA for monitoring purpose was used in the study. After calculating the loss at all levels, comparison has been made using different methods of measurement in order to choose a suitable method fit for the condition. After evaluating totalwater losses at two different levels, the possible causes of water losses were tried to be identified by comparing the losses in conjunction with some factors having an effect to the water loss. The research methodology is shown in the Figure- 4.

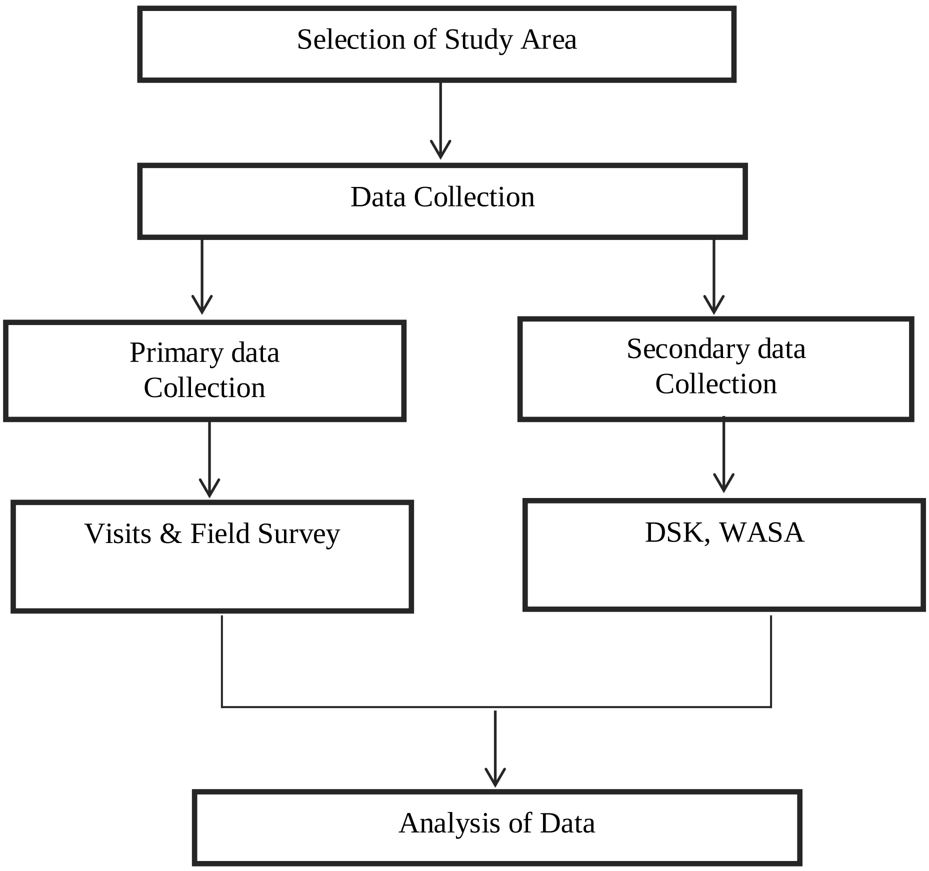


Figure-4: Research Methodology (Process Diagram)

3.1. Data Collection

Primary data have been collected by direct field survey of Korail slum. Interview has been taken to 40 house hold owner to collect information about size of family, water supply, daily water consumption, purpose of using water, sources of water etc. Secondary data were collected from MIS report of DWASA, revenue office of DWASA and Zone-V office. Some data were collected from the Pump Office of Korail slum.

3.2. Different Methods of Water Loss Calculation

Water loss can be calculated in different methods. Depending on the availability of data we calculate loss of water by the following three methods:

- Water loss as percentage(UFW) of net water production (delivered to the distribution system)
- Water loss as length of pipe. (m^3/day/km)
- Water loss as number of connection. (m^3/day/connection)

Unaccounted-for-water (UFW) – represents the difference between the net production(the volume of water delivered into a network) and consumption (the volume of water that can be accounted for by legitimate consumption, weather metered or not).

UFW= Net production – Legitimate consumption

$$Total\ water\ loss\ = \frac{Total\ water\ production - Total\ water\ billed}{Total\ water\ production} \times 100$$

4. Water Loss Analysis:

The total annual water produced and distributed to the distribution system and the water billed that was collected from the individual customer meter readings were used to quantify the total water loss for the entire Zone-V and Korail slum as a sub-system. All the water consumptions in the city were metered except very few like for firefighting use and water used by the water authority itself. As the authorized non-metered consumption are insignificant while compared with the total water production, the unaccounted for water (UFW) has been used as a synonymy of the total water loss in this analysis. Data records of 12 months water production and consumption (from Nov.2013 to Oct.2014), [3] for entire Zone-V and Korail slum are used in the water loss calculation is shown in Table-4 and Table-5 respectively, while the corresponding curve of the total water loss is shown below in Figure 5 and Figure 6 respectively.

Table-4: Total monthly water production, consumption and loss (Zone-V)

Months	Production (M^3)	Consumption (M^3)	Monthly Loss (%)	Cum. Production (M^3)	Cum. Consumption (M^3)	Cumulative Loss (%)
Nov-	3263318	2749712	15.74	3263318	2749712	15.74
Dec-	3184321	2857123	10.28	6447639	5606835	13.04
Jan-14	3049482	2698535	11.51	9497121	8305370	12.55
Feb-	2769350	2314578	16.42	1226647	10619948	13.42
Mar-	3317795	2833781	14.59	1558426	13453729	13.67
Apr-	3372056	2776621	17.66	1895632	16230350	14.38
May-	3465987	3147984	9.17	2242230	19378334	13.58
Jun-	4007309	3494538	12.80	2642961	22872872	13.46
Jul-14	3552523	2958735	16.71	2998214	25831607	13.84
Aug-	2685261	2135866	20.46	3266740	27967473	14.39
Sep-	3349159	3094327	7.61	3601656	31061800	13.76
Oct-	3206936	2854518	10.99	3922349	33916318	13.53

Fig.5: Monthly total water loss distribution curve based on cumulative values (Zone-V)

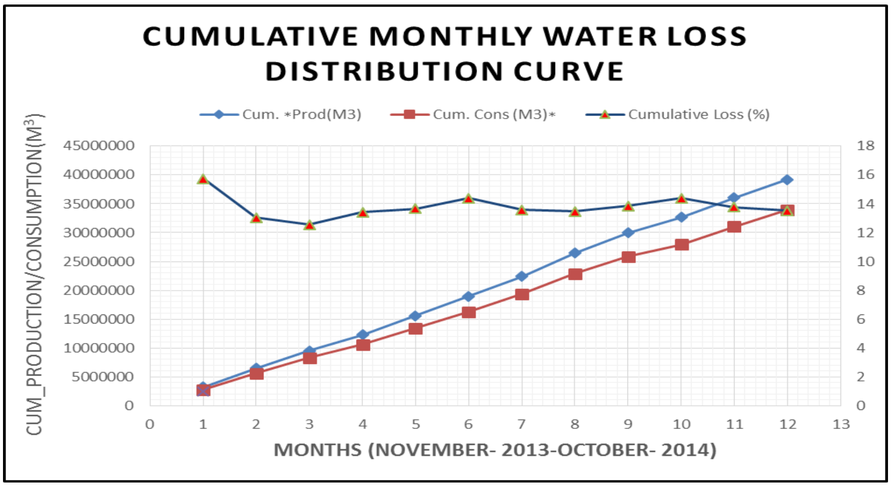
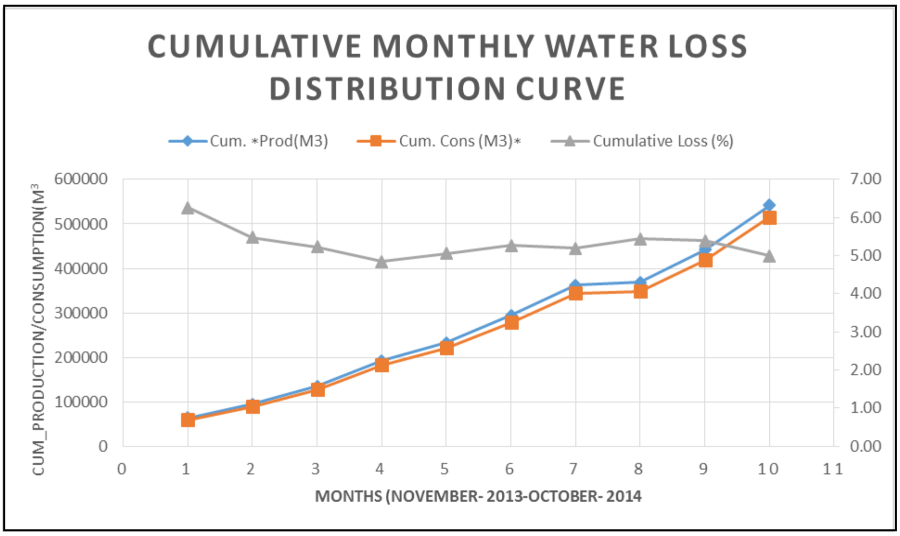


Table-5: Total monthly water distributed, consumed and loss (Korail Slum)

Months	Production (M^3)	Consumption (M^3)	Monthly Loss (%)	Cum. Production (M^3)	Cum. Consumption (M^3)	Cumulative Loss (%)
Nov-13	19872	18820	5.29	19872	18820	5.29
Dec-13	20683	19254	6.91	40555	38074	6.12
Jan-14	23260	21750	6.49	63815	59824	6.25
Feb-14	31180	29970	3.88	94995	89794	5.48
Mar-14	39600	37766	4.63	134595	127560	5.23
Apr-14	57570	55296	3.95	192165	182856	4.84
May-14	40479	38008	6.10	232644	220864	5.06
Jun-14	61608	57895	6.03	294252	278759	5.27
Jul-14	68350	65021	4.87	362602	343780	5.19
Aug-14	6460	5208	19.38	369062	348988	5.44
Sep-14	73210	69457	5.13	442272	418445	5.39
Oct-14	99620	96388	3.24	541892	514833	4.99

Fig.6: Monthly total water loss distribution curve based on cumulative values (Korail)



4.1 Comparison of the loss between Korail and Zone-V:

Network place	Percent of loss(%) (UFW)	Total pipe length (km)	Loss per length (M^3/km/da	No. of connection	Loss per connection (lit/connection/day
Entire	14	280	51.93	13,000	1118.478
Korail	5	7	10.59	504	147.09

Guideline for water Loss Level:

For system with per capita consumption of less than 150 l/day the general rule for water loss level is

Good condition of system < 250 Litter/connection/day
Average condition of system < 250-450 Litter/connection/day
Bad condition of system > 450 Litter/connection/day

Another guideline for water loss level is the "Benchmark" Litter/km mains/day

Good condition of system < 10,000 Litter/km main/day
Average condition of system < 10,000 – 18,000 Litter/km main/day
Bad condition of system > 18,000 Litter/km main/day

Source: Gerhard Zimmer (Experiences from Kfw funded programs)

5. Conclusion:

- The average water supply coverage was evaluated based on the daily per capita consumption and level of connection using the population data of the city and Korail slum as a sub-system. The average water supply coverage of the Korail slum is found to be 5.26 liter/person/day. This average per capita consumption is found much lower than other developing cities. Per capita consumption is even lower than the 150 lit/person/day set by DWASA. Even the basic need of water set by Un-Habitat is 20 lit/person/day. But at the case of Korail slum most of the dwellers belong to the low earning group. However there is huge amount of consumed water which have no records.

- Water loss as percentage (UFW) for Zone-V and Korail slum is 14% and 5% respectively. There is only 504 DWASA connections available for 2, 82,000 populations at Korail slum which is very insufficient in terms of connection. So there are huge number of illegal connections which have taken from the main service line, which was observed by field survey.
- Loss per unit length of delivery pipe of Zone-V is 51.93 m^3/km/day whereas loss is only 10 m^3/km/day for Korail slum. Length of pipe and leakage, corrosion, breaks of pipe lineof Zone-V are more compared to Korail slum. From the water loss guideline for length of pipe, it can be said that Korail slum condition is good whereas Zone-V condition is bad.
- Loss per connection is about 1118.478 lit/connection/day for Zone-V and 147.09 lit/connection/day for Korail slum. Connection number in Zone-V is 13000 which is higher than Korail slum. In Korail, only 504 connections are available. Density of connection in Korail is lower than Zone-V that is why loss is relatively low. From the water loss guideline for number of connection, it can be said that Korail Slum condition is good whereas Zone-V condition is bad.
- Total water loss expressed as percentage is an important tool to know the extent of the loss within a given environment. Comparison of losses from one location to another using the percentage has limitations as the percentage of loss highly depends on the amount of water produced. Both the loss per kilometer length of main pipes (m^3/km/day) and loss per connection (liter/connection/day) may be appropriate to measure the loss in the Korail context.
- After surveying at Korail slum, some possible causes of water loss are found, which are given below:

A. Meter Error

Customer Metering inaccuracies and systematic data handling error, losses can be thought of as accounting losses. This quantity of water flows through the water distribution systems and reaches the customer endpoint, with under-stated or no revenue generated. The mechanical water meters typically decline in accuracy with usage over the period of time, causing revenue losses to the utility and giving rise to unequal billing policy [8].

B. Huge Illegal Connection

Water supply coverage is not sufficient in Korail slum. There is only 504 DWASA connections available for 2, 82,000 populations which is very insufficient in terms of connection. So there are huge number of illegal connections which have taken from the main service line.

C. Leakage and Break of Pipes

Distribution and transmission main leaks, which represent the quantity of water that is lost from the system, generates no revenue, can severely damage system reliability if not corrected [2]. Storage leaks and overflows from water storage tanks, which consist of the quantity of water that is lost from the storage facilities within the system. Service connection piping leaks, which consist of the quantity of water that is lost from leaks from the main to the customer's point of use.

D. Poor record keeping:

The necessity for good maintenance records is often overlooked. System maps, designs of the network and reservoirs, historic records or the equipment installed in the system are often not available, whereas minimum information is required to operate and maintain the system efficiently.

E. Community Behavior:

Water loss is not just an engineering problem but also reflects a socio cultural situation that requires changes in community behavior and attitudes toward water usage. Most of the dwellers of Korail slum are belong to low income group and their education level is very minimum. They don't have enough knowledge of using water properly. That is why large amount of water is wastage due to awareness of the dwellers.

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