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# Leakage in municipal water supply system: a case study in Nepal

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## INTRODUCTION

### Development of New Sources

A rising demand for potable water is exerted by rapid urban growth, population increase and an increasing per capita demand associated with affluence. Thus, municipal water agencies struggle to meet the increased demand while a large percentage of water is not accounted for; it is lost. So far, specially in developing countries, the tendency to overcome water shortage has been to opt for capital intensive new systems. It is hardly realized that the new systems too have their share of water losses and that the emphasis on new projects have led to a deterioration of water quality and an increase in losses due to negligence of operation and maintenance of the existing systems. Kuala Lumpur in Malaysia is an example in hand where losses increased from 18% in 1979 to 23% in 1982" (ref. 1)".

### Water Losses and Conservation

As pointed out, a part of the treated water supplied is lost in the system. The main causes of water losses have been enumerated as:

(i) losses at reservoirs and treatment plants due to evaporation, seepage and/or overflows,
(ii) inaccurate meters: over-and/or under-registration of master meters, domestic meters, industrial meters and commercial meters,
(iii) unknown water connections,
(iv) known but unmetered connections,
(v) underground leakage of mains and services including joints and
(vi) house wastage: wastage on the consumers' side including wastage at public standposts.

Therefore, another option for improving the useful supply is to control the losses. This becomes more attractive as enlarging the sources of supply and the plant capacity are increasingly more difficult and expensive. Studies in the developed countries show that conservation through a leak detection and repair programme brings about direct money savings, longer range savings from deferred capital investment and savings in production by reducing the cost of power and chemicals. Water conservation is often more cost effective than investment in additional capacity. Thus, a conservation programme could alleviate the poor condition of water supplies in Asia. The amount saved and the level of allowable losses is utility specific. Hence, after presenting the Asian water supply situation, this paper describes the pilot plant study carried out to quantify the losses and determine the economic level of allowable losses in the study area in Nepal.

## THE ASIAN SCENE

Most Asian water systems lack a well controlled distribution system with effective man-

Table 1 - Total Losses and Their Distribution in Asian Cities

| S.N. | City/Country | % of Total Losses | Distribution of Losses as a % of Total Losses | |
|---|---|---|---|---|
| 1 a. | Dhaka, Bangladesh | 45% of total capacity | open street hydrants | 50% |
| b. | Khulna, Bangladesh | 60%-40% | joint leaks | 30% |
| 2 | Hong Kong | 30% of law water input | illegal tapping of standposts | 5% |
| 3 a. | Delhi, India | 35% of production | public hydrants | 10 mgd |
| | | | treatment plants | 5-6% |
| | | | transmission main and service reservoir | 3-4% |
| | | | distribution pipes | 20-25% |
| b. | Bombay, India | 25-30% of total supply | consumers' connection of G.I. pipes | 60-70% of leakage |
| 4 | West Java, Indonesia | 40%-50% | leakage from pipes | 71.2% |
| | | | metering error | 27.8% |
| | | | other causes | 1.0% |
| 5 | Korea | 36.59% | service loss | 15.00% |
| | | | distribution pipe leakage | 9.00% |
| | | | loss through joints, valves etc. | 12.59% |
| 6 | Metro-Manila, Philippines | 51% (1982) | leakage | 25% |
| | | 49% (1981) | under-registration | 8% |
| | | 47% (1980) | illegal use | 6% |
| | | 28.5% (1954) | public use | 2% |
| | | | other causes | 1% |
| 7 | Greater Colombo, Srilanka | 30% | leakage | 20% |
| | | | squanderage | 10% |
| | | | 1/3 of the leakage occurs on the consumers' side while system leakage is very low. | |

agement. In general, the whole populace of a city is not served nor is the water demand of those served fully met. Despite rampant water shortages, heavy losses occur in the system. Table 1 presents the total losses and their distribution in some cities. The following addition gives a cursory review of the Asian scene.

Malaysia: The 15% or less unaccounted-for water in Malaysia increased to a shift to more development works which led to negligence of system maintenance. Now the overall losses in most districts range between 20-30%.

Kathmandu, Nepal: Binnie and Partners of London estimated that the gross leakage and wastage as 75% of the total supply. Engineering Science Inc. estimates a lower rate, 65% for 1980, assuming that metering has reduced the gross wastage.

Faisalabad, Pakistan: The existing system serves only 60% of the population. Experts estimate the unaccounted-for water at 50%.

Hyderabad, Pakistan: Hyderabad still faces 57% water scarcity. By repairing mains and reducing the length of service pipes, the 1975 estimate of 38% losses has been reduced to 30%.

Singapore: 99.5% of the main island is supplied with drinking water. As water consumption grows at 7% per annum, Singapore carries out a regular leak detection test on all mains 500 mm and below in order to conserve water to meet the future demand.

Bangkok, Thailand: By replacing old pipes and reducing the 60 types of meters used to 10 types Bangkok claims to have reduced its water losses from 65% (1972) to 49% (1975).

In addition, insufficient covering of buried pipes, use of sub-standard materials, pilferage, non-removal of old useless pipes which are replaced by new ones; inoperative and faulty valves, poor equipment like leaking pumps and poor workmanship all coupled with inadequate, intermittent supplies and a flat rate pricing policy has led to gross water losses in Asian countries. To control the losses, utilities encounter a lot of obstacles. There is a lack of good records, a lack of drawings, a lack of trained maintenance crew, a lack of incentives for employees, a lack of bye-laws, a lack of meters and necessary equipment and above all a limitation of funds. Still efforts to reduce losses are being made. Water agencies in Singapore, Manila and a few other affluent cities have seriously planned leak detection programmes. Through pilot plant studies a few cities have determined the quantity and distribution of losses; but the economic level of allowable losses have not been studied.

## 3. THE STUDY AREA

### Background

The study area lies in Lalitpur District in Kathmandu Valley in Nepal. Three schemes: Doodh Pokhari (1896), Sundarighat (1971) and Chapagaon (1976-77, a dual purpose scheme), serve the district. The water Supply and Sewerage Board through its Jawalakhel branch is responsible for the water supply of Lalitpur.

Complaints of contamination of the supplied water and the case of isolation of the network were the prime reasons for choosing Jwagal and Chakupat as the study area.

### Characteristics

Location, Population and Housing: A door to door survey revealed that 598 people live in 106 families in the study area located nearby Bagmati River (Fig. 1). The area is mainly residential with Chakupat representing relatively more affluent residences. Table 2 summarizes the detailed characteristics.

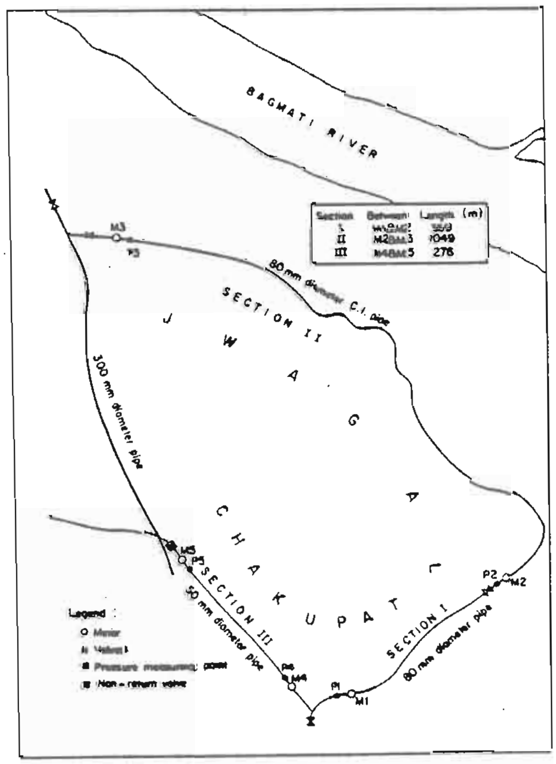


Fig. 1 - The Study Area - Pipes and Valves

Water Supply: The supply is intermittent with 2.5 hours of supply in the mornings and the evenings. Even when the valve 'X' (Fig. 1) is open Jwagal particularly, being a lowlying area, receives water for a few hours during the off-supply period. For the purpose of the study the five year old 80 mm diameter main was divided into sections I and II while the very old 50 mm main formed section III.

Table 2 - Characteristics of the Study Area

| | Description | Section I | Section II | Section III |
|---|---|---|---|---|
| 1 | Area | Chakupat Jwagal | Jwagal | Chakupat |
| 2 | Diameter of C.I. pipe (mm) | 80 | 80 | 50 |
| 3 | Age of pipes (year) | 5 | 5 | old |
| 4 | Length of pipe (m) | 359 | 1049 | 276 |
| 5 | No. of joints | 60 | 175 | 46 |
| 6 | Total No. of connections | 22 | 62 | 21 |
| 7 | No. of private connections | 22 | 60 | 21 |
| 8 | No. of public standposts | - | 2 | - |
| 9 | Population served | 138 | 370 | 90 |
| 10 | No. of metered connections | 19 | 48 | 20 |
| 11 | No. of functioning meters | 13 | 20 | 8 |
| 12 | No. of connections not metered | 3 | 12 | 1 |
| 13 | No. of underground tanks | 3 | 1 | 12 |
| 14 | No. of overhead tanks | 7 | 5 | 11 |
| 15 | No. of outside taps | 5 | 45 | 17 |
| 16 | No. of showers | 7 | 7 | 23 |
| 17 | No. of bath-tubs | 7 | 1 | 15 |
| 18 | No. of sinks | 9 | 6 | 11 |

## Objectives of the Study

The primary objective of the study was to quantify water losses and determine the economic level of allowable losses for the study area. A secondary objective was to assess the wastage while filling pitchers and that through dripping taps and to compare these with the losses in the distribution system.

## Methodology

Field Investigation: For the determination of losses in the distribution system, all the five installed integrating type master meters were read a maximum of six times a day: at the start and the end of the supply periods in the morning and the evening and twice between 2 a.m. and 4 a.m. at night when the area is supplied by the overflow of the reservoir. The corresponding residual heads at the meter points, P1, P2, P3, P4 and P5 (Fig. 1), were also noted for about three weeks in January unless interrupted by leakage or blockage of meters. To find out the metered consumption simultaneous readings of the domestic meters were taken during the supply periods.

The wastage while filling a pitcher for metered connections was assessed by noting the time and meter readings before filling, after the vessel is filled and after it is removed from under the tap. The difference among these readings gave the results. For unmetered connections, the overflow was trapped in a calibrated bucket.

The rate of leakage through dripping taps was measured in a measuring cylinder for a specified time.

Analysis: A mass balance of the flows and consumption gives the losses. The unmetered consumption is assumed to be 30% more than the measured metered consumption as the water use is primarily domestic "(ref. 3)".

As a complete leak detection and repair programme was beyond the time and resources allocated for the study, a preliminary estimate of the economic level of losses has been made. The analysis consists of finding the total cost: cost of the study plus the cost of repairing joints and replacing pipes and calculating the benefits obtained therefrom in terms of tariff. The cost of repairing joints are calculated by using the current costs for repairing joints by a passive leak control method. The savings obtained by controlling losses are computed using the prevalent tariff rates which cover the operational costs only. As far as possible, current rates have been used.

## Results and discussions

Quantification of Losses: Table 3 sums up the total losses as a percentage of the inflow in sections I, II, and III. During the supply hours the loss in the 80 mm pipe is 52.29% and that in the 50 mm pipe is 62.13%. This is as expected because the smaller pipe is much older. Heavy losses in the newer pipes could be due to poor workmanship in laying them. The 32.29% loss in section II as compared to the 19.08% loss in section I during the supply hours is reasonable as the pressure in section II is more because of its elevation.

The night time results give a different picture. The 81.05% losses in section I and II is much greater than the 13.81% losses in section III. This discrepancy may have crept in as the night consumption could not be measured due to practical difficulties. Further, the high usage in section III could be because underground storage tanks were being filled and allowed to overflow.

Table 3 - Percentage Water Losses (Intermittent Supply)

| Section | Description | Morning ℓ/h | Evening ℓ/h | Total ℓ/h | Night ℓ/h |
|---|---|---|---|---|---|
| I | Supply rate | 3,156.07 | 3,206.80 | 6,362.8 | 1,901.92 |
| | Consumption Rate | 1,835.76 | 1,113.43 | 2,949.1 | 332.95 |
| | Water Loss | 1,302.31 | 1,807.80 | 3,168.1 | 1,568.97 |
| | Total Supply in Line | 8,791.04 | 7,211.66 | 16,002.7 | 4,830.75 |
| | Loss (% of Total Supply) | 15.02 | 25.62 | 19.8 | 32.48 |
| II | Supply Rate in Section | 4,032.65 | 3,515.78 | 7,548.4 | 2,553.79 |
| | Consumption Rate | 1,709.43 | 639.51 | 2,348.9 | 207.33 |
| | Water Loss | 2,323.22 | 2,876.27 | 5,199.4 | 2,346.46 |
| | Total Supply in Line | 8,791.04 | 7,211.66 | 16,002.7 | 4,830.75 |
| | Loss (% of Total Supply) | 26.43 | 39.88 | 32.4 | 48.57 |
| I + II | Total Loss in 80 mm Main | | | 52.2 | 81.05 |
| III | Supply Rate in Section | 5,502.82 | 4,451.02 | 9,953.8 | 1,607.36 |
| | Consumption Rate | 1,571.32 | 1,522.96 | 3,094.2 | 1,052.78 |
| | Water Loss | 3,931.50 | 2,928.06 | 6,859.5 | 554.58 |
| | Total Supply in Line | 5,502.82 | 5,502.82 | 11,005.6 | 4,075.46 |
| | Loss (% of Total Supply) | 71.45 | 53.21 | 62.3 | 13.61 |

Table 4 presents the losses expressed in terms of per meter length and per capita. The 62.13 litre/meter loss in section III as opposed to the 14.83 litre/meter loss in the other pipe shows the effect of pipe age on losses. This is reaffirmed by the per capita losses. Judging from the excessively high, 190.54 lpcd (5h), loss in in section III, the pipeline requires replacement.

Table 5, comparing the losses in Asian countries, shows that the losses in the study area speak of Asian conditions.

Cost of Water Loss: By allowing 56.3% of water losses in the study area a tariff of

NRs 61400 (£1 = NRs 23.46, Jan. 1984) is lost per annum. Table 6 presents the percentage reduction of losses and the corresponding saving. It is found that by replacing old pipes and repairing joints both equivalent to 458 joints or 111 meter length of pipes, a trade-off is reached when the losses are reduced by 23.36% to 32.94%. The cost at this point is NRs 36000. Hence the study reaffirms the advantage of loss control measures. The benefits are suppressed in this case due to the low tariff rates.

Table 4 - Water Losses per Meter of Pipe and per Capita

| Section | Description | Morning | Evening | Total |
|---|---|---|---|---|
| I | Water loss (ℓ/h) | 1,320.31 | 1,847.80 | 3,150.11 |
| | Total loss (ℓ) | 3,255.78 | 4,619.50 | 7,875.28 |
| | Total pipe length (m) | 359.00 | 359.00 | 359.00 |
| | Loss/meter length | 9.07 | 12.87 | 21.94 |
| | Population Served | 138.00 | 138.00 | 138.00 |
| | Loss/capital (lpcd) | 23.59 | 33.47 | 57.07 |
| II | Water loss (ℓ/h) | 2,323.22 | 2,876.27 | 5,199.40 |
| | Total loss (ℓ) | 5,808.05 | 7,190.68 | 12,998.50 |
| | Total pipe length (m) | 1,049.00 | 1,049.00 | 1,049.00 |
| | Loss/meter length | 5.54 | 6.85 | 12.39 |
| | Population Served | 370.00 | 370.00 | 370.00 |
| | Loss/capita (lpcd) | 15.70 | 19.43 | 35.13 |
| Total: | Loss/meter length | 6.44 | 8.39 | 14.83 |
| | Loss/capita (lpcd) | 17.84 | 23.25 | 35.13 |
| III | Water loss (ℓ/h) | 3,931.50 | 2,928.06 | 6,859.56 |
| | Total loss (ℓ) | 9,828.75 | 7,320.15 | 17,148.90 |
| | Total pipe length (m) | 276.00 | 276.00 | 276.00 |
| | Loss/meter. length | 35.61 | 26.52 | 26.13 |
| | Population Served | 90.00 | 90.00 | 90.00 |
| | Loss/capital (lpcd) | 109.21 | 81.34 | 190.54 |

*In a day water is supplied for 5 hours.

Table 5 - Comparison of Water Losses in this Region

| No. | City/Country | % Losses |
|---|---|---|
| 1 | Dhaka/Bangladesh | 45 |
| 2 | Khulna/Bangladesh | 40 |
| 3 | Hong Kong | 30 |
| 4 | Indonesia | 40-50 |
| 5 | Korea | 36.59 |
| 6 | Malaysia | 20-30 |
| 7 | Delhi/India | 35 |
| 8 | Bombay/India | 25-30 |
| 9 | Pakistan | 50 |
| 10 | Metro Manila | 51 |
| 11 | Greater Colombo | 30 |
| 12 | Thailand | 49 |
| 13 | The Study Area | 56.3 |

Table 6 - Percentage Loss Reduction and Savings

| Sr. No. | % Losses | Cost NRs | % Reduction | Savings NRs | Cumulative % Reduction | Cumulative Savings |
|---|---|---|---|---|---|---|
| 1 | 56.3 | 61400 | - | - | - | - |
| 2 | 50.0 | 54500 | 6.3 | 6900 | 6.3 | 6900 |
| 3 | 45.0 | 49000 | 5.0 | 5500 | 11.3 | 12400 |
| 4 | 40.0 | 43600 | 5.0 | 5400 | 16.3 | 17800 |
| 5 | 85.0 | 38100 | 5.0 | 5500 | 21.3 | 23300 |
| 6 | 30.0 | 32700 | 5.0 | 5400 | 26.3 | 28700 |
| 7 | 25.0 | 27200 | 5.0 | 5500 | 31.3 | 34200 |
| 8 | 20.0 | 21800 | 5.0 | 5400 | 36.3 | 39600 |

*£ - 1 = NRs 23.46 January, 1984

Comparison of Wastage and Total Losses: The average value of wastage while filling pitchers for metered and unmetered connections are respectively 0.54 lps and 0.45 lps. The average wastage per tap in sections I and II was 7.04l/h while in section III it was 8.48 l/h. Table 7 compares these wastage and the total losses. Compared to the total losses in the study area (56.3%), the wastage while filling pitchers (1.48%) and that through dripping taps (1.11%) are neglible. However, a water conservation programme could begin by educating the people to control such wastages.

Table 7 - Comparison of Total Losses and Wastage (Intermittent Supply)

| Sr. No. | Description | Quantity ℓ/h | % of Supply |
|---|---|---|---|
| 1 | 80 mm dia. main | | |
| | Total supply | 16002.700 | - |
| | Total losses | 8367.600 | 52.29 |
| | Wastage thro' dripping taps | 190.914 | 1.19 |
| 2 | 50 mm dia. main | | |
| | Total supply | 11005.640 | - |
| | Total losses | 6859.560 | 62.33 |
| | Wastage thro' dripping taps | 110.190 | 1.00 |
| 3 | The Project Area (50 mm and 80 mm dia. mains) | | |
| | Total supply | 27008.340 | - |
| | Total losses | 15227.240 | 56.38 |
| | Wastage thro' dripping taps | 301.104 | 1.11 |
| | Wastage while filling pitchers | 339.720 | 1.48 |

## CONCLUSION

The study shows that a leakage control programme can be conducted by isolating an area into small zones. This is useful for developing countries with limited funds. To arrive at the feasibility of such a programme a rapid assessment of the economic level as presented here can be conducted. However, such an approach is recommended for extreme cases where a leak detection and repair programme cannot be executed and that too it must be used with extreme caution.

The study further shows that for conditions as encountered in the study area, the minimum night flow is not appropriate though it is used successfully for continuous supplies.

Cities faced with water shortages can start a conservation programme right at the consumer's tap as this costs the utility nothing.

In summary, it is concluded that a leakage control programme by isolating small areas and proceeding systematically will conserve water without calling for large finances.

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