Dealing with the complex Interrelation of Intermittent Supply and Water Losses

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Abstract: In many world regions Intermittent Water Supply (IWS) systems are prevalent. It is evident from the results presented in this paper that although intermittent water supply may seem to be a solution to a water shortage situation in overall terms the water balance is adversely affected. Supplying less quantity in an intermittent manner causes such deterioration to the network that when continuous supply is re-established additional quantities are lost through increased leakage, which in fact places an added financial burden on the utility. It is therefore evident that no matter how good a network is, intermittent supply operation has definitely a detrimental effect on its integrity and in addition the amount of water 'saved' is later 'lost' and in greater quantities through increased levels of leakage. Such operational conditions should be avoided especially in pipeline networks that have been designed for continuous supply. In addition it has been shown that the domestic demand is in effect inelastic and in fact the quantities of water saved by the customers were very small. It is the authors' opinion that better results could be achieved through a structured conservation programme rather than intermittent supply. Of course such programmes are to be introduced as part of an overall strategy for water conservation both on the supply and demand side

Keywords: Intermittent water supply, water losses, continuous supply

General

IWS systems can be defined as piped water supply service that is available to consumers for less than 24 hours per day. In Latin America and the Caribbean, it is estimated that 60% of the population is served by household connections having intermittent service (PAHO & WHO 2001). In Africa and Asia, it is estimated that more than one-third and one-half of urban water supplies respectively, operate intermittently (WHO & UNICEF 2000).

In an IWS situation, the consumers usually secure their water supply through the use of ground and/or roof tanks or smaller capacity individual containers, where water is stored during the length of time that the supply is provided in order to be used during the period that the supply cut-off. It is worth noting that IWS is enforced not only in cases where there is water shortage but also where the hydraulic capacity of distribution networks is such that cannot satisfy demand as well as in cases where the network is severely deteriorated resulting in high leakage.

In many instances there is no indication how long intermittent supply will be in place. In many countries around the world IWS is the norm rather than the exception. The hydrological conditions in each case could impact adversely on water supply for years in which case conserving as much as possible the limited water resources may not be the long term solutions but it may be necessary to add to the water balance new non-conventional water resources. In many countries water shortage problems were overcome through the desalination of brackish or saline water. Of course exploring every potential water source available may be the only solution in many instances, but leakage reduction is always one of the least expensive and quickest solutions to ensure that water will be available when needed.

It is generally considered that IWS is not an ideal form of supply and should not constitute a permanent solution however it is applied by many water utilities with great ease mainly as a measure for dealing with water shortage or drought conditions without seriously looking into alternative solutions. It is also the authors' experience that some water utilities are applying IWS as a measure to reduce extremely high leakage from their networks which of course prevents them from maintaining a continuously pressurised network with all the adverse repercussions.

Even though in a number of instances it may not be possible to avoid IWS, the advantages of IWS if any, are very few and lack substance in order to convince that the use of intermittent supply is a sustainable modus operandi for water distribution networks. Intermittent supply is usually introduced either as an emergency measure, when the water availability is limited or in some cases it is introduced as a measure to control water use and to reduce leakage. In the first case when there is limited water availability, there may be no alternative to the rationing of water and an intermittent supply cannot be avoided once the supply resource has been depleted. In the second case, however, where the intermittent supply is introduced as a water saving measure there may well be alternative interventions that can provide savings without some of the problems that tend to accompany such pressurising and depressurising of the distribution network (Mckenzie, 2016).

In many systems IWS was not an element of initial system design but rather reflects a combination of deteriorating infrastructure and demand growing beyond design limits. A possible combination of factors, such as: water scarcity, prolonged drought periods, population growth, urbanisation and increasing demand, lack of awareness and forward planning may have been the root causes of IWS for many water utilities. Inevitably IWS is the cause of serious problems in the proper operation and management of a water distribution network.

The Vicious Cycle of IWS

Normally water reticulation networks are designed to provide piped water on a continuous basis without any discontinuity in this supply apart from extremely short intervals where the supply is cut-off for routine maintenance or fixing of pipe breaks. However, in some instances changing hydrological conditions may result in water shortage and the water utilities are unable to meet existing needs. In some geographical areas this situation may take the form of a cyclic phenomenon where periods of low rainfall are repeated every few years, resulting in water rationing and the temporary application of IWS (Charalambous, B. 2009) applied as a measure to deal with such circumstances.

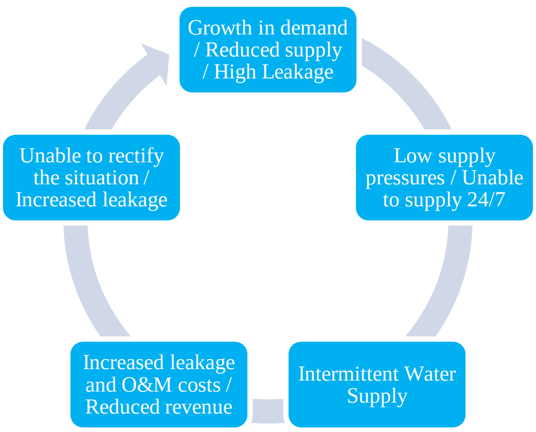

Figure 1 Vicious Cycle of IWS

Implications of IWS

Although intermittent supply is usually introduced either as an emergency measure or as a measure to control water use and to reduce leakage it is however a situation worthwhile avoiding through proactive planning and timely response to critical conditions. The adverse effects of intermittent supply on water quality, customer service and integrity of the distribution network as well as the financial repercussions to the utility are highly significant. Some of these are analysed below:

Water quality deterioration / Health hazard: - Intermittency entails a high risk of contamination, which creates substantial health hazards. The first route is the ingress of contamination through broken pipes or joints. Interruption of supply normally creates low pressures or even a vacuum condition in pipelines that last for a significant period of time. Consequently, potentially contaminated water, such as rainwater, sewage spills, latrine drainage, etc. may enter the system through the breaks in the pipe walls when supply is off.

It is difficult to keep proper chlorination level in the network since there are no constant hydraulic conditions with the repeated emptying and charging of the network. In order to deal with such situation it is normal to significantly increase chlorination which of course entails other dangers such as the potential creation of Trihalomethanes (THMs). Trihalomethanes are formed as a by-product predominantly when chlorine is used to disinfect water for drinking and result from the reaction of chlorine with organic matter present in the water being treated. The THMs produced have been associated through epidemiological studies with some adverse health effects and therefore limits are set on the amount permissible in drinking water. In addition excessive chlorination would not be acceptable to consumers as they would not be to deal with such high levels of contamination.

Inequitable distribution within a network: - In distribution systems designed on the concepts of 24-hour supply flow depends on pressure head. When the network is charged much higher peak flows than expected will occur in the pipelines thus increasing pressure losses in the network. Consequently, consumers furthest away from supply points will always receive less water than those nearer to the source (Gottipati et al, 2014). This will also be associated with low supply pressures, particularly in high ground areas and /or areas furthest away from the source.

Water Wastage: - Consumers exposed to IWS conditions are likely to keep their taps open to obtain as much water as possible whenever the service resumes. In addition consumers usually remove the control valves that are installed in the ground and/or roof tanks in order to increase to remove any flow restriction hoping to get larger volumes of water in a shorter period of time. Under these circumstances consumers experiencing IWS are likely to waste more water than those who receive a 24x7 supply from the fear of not having sufficient water they will tend to store as much as possible which is usually replaced by the fresh supply of the next day. Unfortunately for the less fortunate consumers who do not have the means of installing ground and/or elevated tanks are forced to manage with the small quantities that they have managed to store in their individual containers.

Inconvenience and high coping costs for consumers: - Inconvenient supply times mostly affect the poor, since consumers have to pay for storage and pumping. Alternatively, they will have to go to public taps, sometimes quite faraway and even during midnight, to collect water. Long distances and queues are typical problem of women and children from underprivileged areas, taking lots of productive time from them (Totsuka et al, 2004). Resulting from intermittent supply, the consumers have to pay the costs, so called coping costs, for additional facilities, such as storage tanks, pumps, alternative water supplies and household treatment facilities. The poor who cannot afford such facilities spend their time to fetch water from public taps or vendors at comparatively high total costs. Figure 2 (Chary,

2009) shows the direct costs that IWS inflicts on water consumers, rich people cope by spending money on water tanks, pumping systems and filters whereas middle-income groups spend less on capital equipment but more in terms of time and power. For the low-income group however the coping cost is primarily the opportunity cost of the time they must spend collecting water.

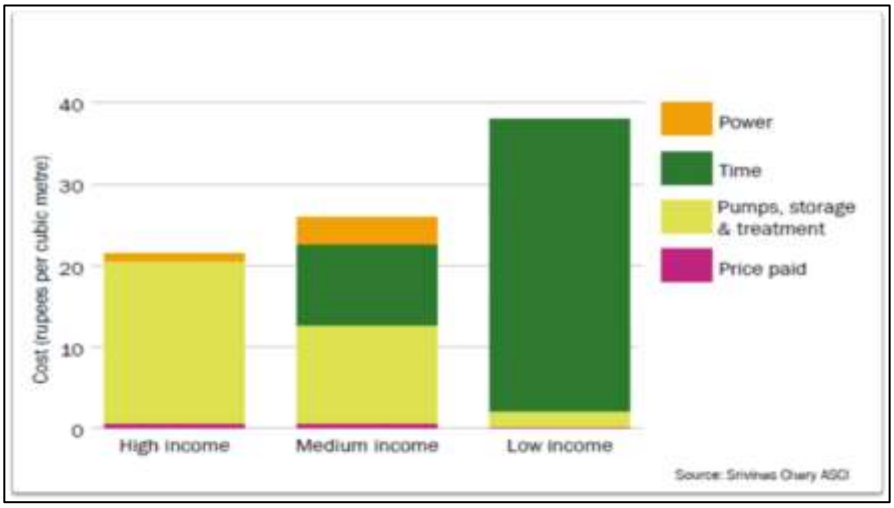

Figure 2 Coping Cost of IWS

Meter malfunctioning and accelerated wear and tear: - IWS would cause inaccuracies in meter registration. Meter registers might reverse due to vacuum conditions created during emptying of the network as supply is cut-off. Air expelled from the pipes during filling might drive meters at excessive speed during the charging stage after the supply has been resumed resulting in the accelerated wear and tear of the registration mechanism. Undesirable environment, such as repeated dry and wet conditions, would accelerate the performance deterioration of water meters. Meter malfunction brings difficulties for water providers to monitor the water use and collect accurate tariffs. Furthermore, it makes consumers sceptical to the accuracy of their water bills relating to the meter registration.

On the whole IWS has a detrimental effect on the network, results in ineffective supply and demand management, inefficient operations, increased difficulties in detecting and fixing leaks as well as greater number of illegal connections.

Myth Busters

Over the years a number of misconceptions have been linked to IWS, particularly relating to leakage and customer consumption. Based on their own experiences as well as data and information provided by colleagues, the authors' set out below evidence which clearly shows that the "myths" build around IWS are just not true, such as under an IWS regime the NRW is lower compared to 24x7 supply or the volume of water distributed under IWS is less compared to 24x7 regime. Analytically the "myth busters" are presented below:

Is distributed water less under IWS? It has been considered that under IWS conditions the volume of distributed water is less than the volume needed under a 24x7 supply regime. However, evidence from the Karnataka Demonstration Project (Jalakam, 2014) demonstrated that this is not the case as it can be seen from Figure 3.

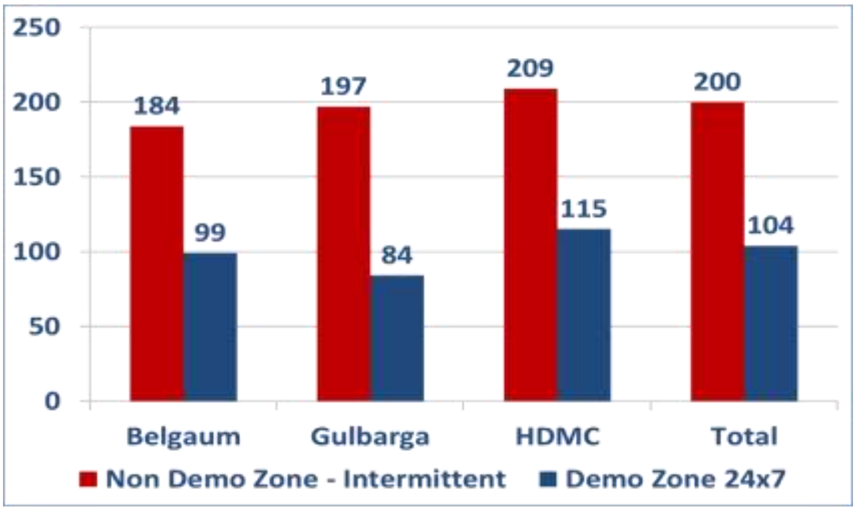

Figure 3 Water distributed in litres per capita per day (source: Anand Jalakam)

The volumes of water which were distributed to the demonstration zones in each city were far less compared to the volumes that were distributed to the areas of each city under IWS. In fact the numbers show that on average for the 3 cities the volume distributed to the network under IWS was the equivalent of 200 litres per capita per day compared to 104 litres per capita per day for the demonstration zones which were under 24x7 regime, that is 50% less water on average was distributed under the 24x7 regime in the demonstration zones.

Is IWS an effective leakage reduction measure? Data and information relating to leakage were collected and analysed for a distribution network which was operated over a 2 year period under an IWS regime (Charalambous, 2012). Figure 4 shows the total Minimum Night Flow before (blue colour) and after (red colour) the intermittent supply. It is evident that there has been a significant increase in the Minimum Night Flow which was attributed to the additional breaks which the network suffered during the 2 years of intermittent supply period.

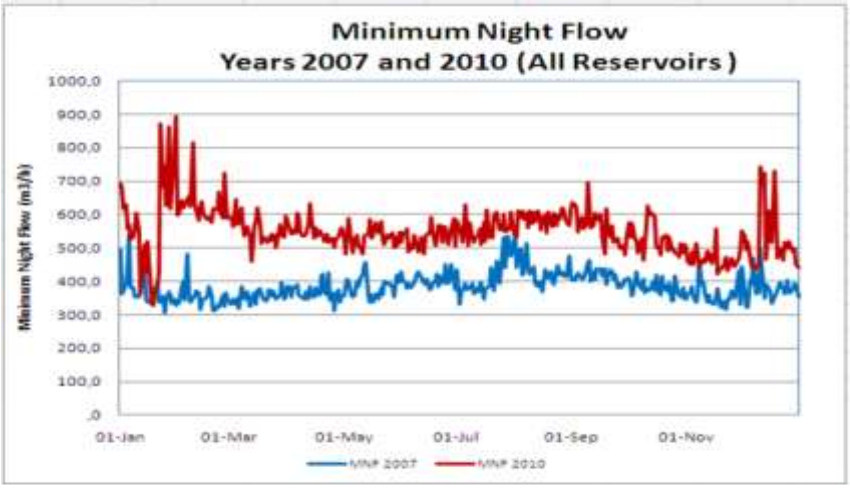

Figure 4 Minimum Night Flow before and after IWS

Further analysis of case study data showed that there was a large increase in the number of reported pipe breaks during the period of intermittent supply. In order to quantify these a comparison was made for a large number of District Metered Areas, covering a length of network of 373 km corresponding to 45% of the total length of the distribution network, between the breaks reported in 2007, before the intermittent supply was applied, and those reported in 2010, the first year immediately after the measures were lifted and a 24x7 continuous supply was in place. The results are shown in Table 1 covering both mains and service connections.

Table 1 Effect of intermittent supply on reported pipe bursts

Description	Number of Reported Breaks		
	Before (Year 2007)	After (Year 2010)	% Increase
Mains	14 per 100km	42 per 100km	200
Service Connections	15,5 per 1000	29,7 per 1000	100
20 DMAs: 373 km (45% of total length of the distribution network) IWS period 2008-09			

This comparison showed that the number of breaks on mains increased from an average of 14 per 100km of mains to 42 per 100km of mains, an increase of 200%. Similarly the number of reported service connection breaks increased from an average of 15,5 per1000 connections to an average of 29,7 per 1000 connections an increase of approximately 100%.

Of course, in addition to the number of reported breaks in 2010, there were still a significant number of breaks, which required being located through active leakage control.

Is IWS an effective drought / water conservation measure? Further evidence from the case study substantiating the increase in leakage due to the intermittent supply regime is given in Table 2 which provides data on System Input Volume and corresponding Customer Consumption. The Table shows that there was an increase of 12,8% in the System Input Volume in the year immediately after the lifting of the IWS regime compared to the base year immediately prior to IWS. This increase could in fact be attributed to either increase in customer consumption or increase in leakage or both. In fact from the data examined the customer consumption was slightly less (1,2%) compared to the year before the intermittent supply measures were applied which clearly indicates that the additional volume in System Input Volume is attributed to leakage . It is also evident from Table 2 that the System Input Volume in the first year of intermittent supply decreased by 17,5% whereas in the second year by 9,1% indicating that the number of breaks in the network increased during the second year resulting in less water being saved. This is substantiated by the fact that the reduction in the customer consumption remained effectively the same for the two years' of intermittent supply, -9.2% in 2008 and -8.9% in 2009.

Table 2 System Input Volume vs Customer Consumption

Year	System Input Volume	Customer Consumption
2007 Before Intermittent Supply	Base line 0%	Base line 0%
2008 Intermittent Supply	-17,5%	-9,2%
2009 Intermittent Supply	-9,1%	-8,9%
2010 After Intermittent Supply	+12,8%	-1,2%

The Challenge

While it is relatively easy to turn a 24x7 system to an intermittent supply, it is very hard to do the opposite. Water utilities that have fallen into the vicious cycle of IWS have major institutional, technical and financial issues and would definitely need to go through a reform process; moving to continuous supply requires often very difficult political and institutional choices that many water utilities / governments prove reluctant to make. A paradigm shift is therefore imperative to transition from IWS to 24x7 supply.

In order to improve operational, commercial and institutional efficiency the water utilities will need to strive towards reducing their water losses in the first instance coupled with an increase in the hours and days of supply until continuous supply conditions are achieved. A final step in this process once low water loss levels with continuous supply are achieved is to reduce and sustain the level of water losses to an economic level.

The Need for a Standardized Approach

Before the first edition the IWA manual of Performance Indicators (Alegre et al, 2000) was published, there was no international attempt to standardize the water balance and water loss performance indicators. The IWA water balance and water loss PIs have meanwhile become international standard and are promoted by many regional and national professional associations around the world (including AWWA).

It is well known that expressing water losses (or NRW) in percentage of system input is misleading in the best case and doesn't work at all in IWS situation (No wonder that % water loss can be low if a utility has only a few hours water supply per day).

Water loss performance indicators, for example physical losses in litres/connection/day, always need to be adjusted to continuous supply (the acronym used is "w.s.p." – when the "system is pressurized").

For example: When in a system with 10,000 service connections and IWS of 4h/day physical losses are 3,000 m3/d the correct performance indicator would be:

- 3,000 m3/d /10,000 connections = 0.3 m3/conn./d (300 l/conn./d)
- 300 l/conn./d / 4h x 24h = 1,800 l/conn./d (w.s.p.)

Only with this indicator (and the average operating pressure) the level of water loss can be understood and the transformation from IWS to 24x7 planned.

In summary, the IWA water balance methodology and the IWA water loss PIs can also be used in IWS systems – IF the supply time is properly taken into account.

Once the water loss situation is properly understood, forecasts can be made how much water will be required to supply the network in its present condition on a 24x7 basis and how much will be needed after network rehabilitation.

Transitioning from IWS to 24x7 will be different depending on the type of IWS:

- If the system was designed for IWS (like most in South Asia) one needs to start with pressurizing the system 24x7 on a zone by zone or DMA by DMA basis starting from the zone or DMA closer to the water source.
- In systems where IWS was not planned but became a reality in fringe areas of the system, water loss reduction (again, zone by zone) must be started in the part of the network with best supply and highest water losses and the water saved can then be pushed to the poorly supplied areas.

Details on the use of water loss PIs under IWS conditions and recommendations for transitioning to 24x7 will be published in the upcoming book on IWS to be available through IWA Publishing in the first half of 2017.

Conclusions / Key Learnings

From the data and information presented in this paper which is based on actual data from distribution networks worldwide the following conclusions / key learning can be drawn regarding the use of IWS:

- IWS can easily be adopted by the water utility but it is extremely difficult to revert to 24x7 supply due to the damage caused to the network.
- IWS may seem to be a water saving measure however in the long run greater quantities of water will be lost through increased leakage and wastage compared to the quantities that may initially be saved.
- IWS has a detrimental effect on the structural integrity of the distribution network thus leading to quicker asset deterioration.
- IWS results in a substantial increase in the number of pipe bursts in mains and service connections thus increased leakage.
- IWS could create water quality problems which may be detrimental to human health and wellbeing.
- IWS has an adverse financial effect on the water utility resulting in lower water sales and higher costs due to additional O&M activities needed to run IWS.
- IWS results in customer dissatisfaction and reluctance to pay due to poor quality of service provided.
- IWS is not considered an appropriate intervention to drought / water shortage.

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