Guidelines for Water Loss Reduction - A Focus on Pressure Management

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ABSTRACT

Customers worldwide expect from their water utility to be supplied with drinking water in sufficient quantity, quality and continuity. In many cases, leakage from water supply systems represents a major obstruction to achieve this aim. But in the light of scarce and further diminishing water resources, extensive water losses are incompatible with the principles of sustainable management.

Thus, in 2009, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (German Association for International Cooperation) and VAG-Armaturen GmbH (VAG) formed a public-private partnership (PPP) in order to introduce, promote and support Pressure Management (PM) as a state-of-the-art instrument for water loss reduction, particularly in developing countries and emerging economies. The primary objectives of this partnership are the development of guidelines for water loss reduction and the accompanying implementation of pilot projects and training measures in order to share knowledge with interested stakeholders worldwide.

The guidelines are addressed to decision makers and relevant stakeholders on national level, as well as to the management, the planning & design department and the operational level of local water utilities. Aims of the guidelines are to raise awareness and understanding on the different types, reasons and impacts of water losses. Methods and instruments for the assessment of the existing status and for the development of action plans are documented. Furthermore, basic requirements for a sustainable management of existing water supply networks and different strategies for water loss reduction are presented, with a special focus on pressure management.

KEYWORDS

Pressure management, guidelines, water loss reduction, technical cooperation, public-private partnership.

1 INTRODUCTION

Drinking water is a precious resource in many developing countries and emerging economies. However water loss is often high (40% or more of conveyed drinking water), caused by insufficient maintenance and leaking pipes. Pressure peaks increase leakage and provoke new pipe bursts, allowing sewage and other pollutants to infiltrate the pipe network which may cause the spread of various water-borne diseases. Economic losses for the water utility, increased technical difficulties, restricted equity of supply and numerous other negative impacts make it therefore important to protect water resources through future-oriented approaches in the operation and maintenance of existing water supply systems.

Despite of progress achieved in the past, water utilities are often not aware of innovative management methods for water supply networks. They often focus on the supply-side by developing new resources, and give only second priority to the efficient distribution of water to the users. Demand-oriented water distribution requires good management of water supply networks, including amongst other aspects the creation of network registers, hydraulic modelling, zoning of the network and the development of water demand scenarios. Based on this information, technologies and design of the networks can be adapted to the needs. Appropriate technologies for network adaptation and improvement have to be selected.

One solution is Pressure Management (PM), using the pressure management technology which allows setting the pressure in water distribution networks to the minimum necessary level. The goal is to reduce unnecessary pressure and to harmonise pressure variations in order to reduce leakage flow rate and to prevent new pipe bursts. Pressure management uses advanced valve technology with high demands of design, installation and management. However, PM shouldn't be understood solely as a technology, but as a holistic approach involving several elements as shown in Figure 1. Every supply area has its own characteristics and has to be studied individually for an optimal solution taking into account technical, financial, environmental and social aspects.

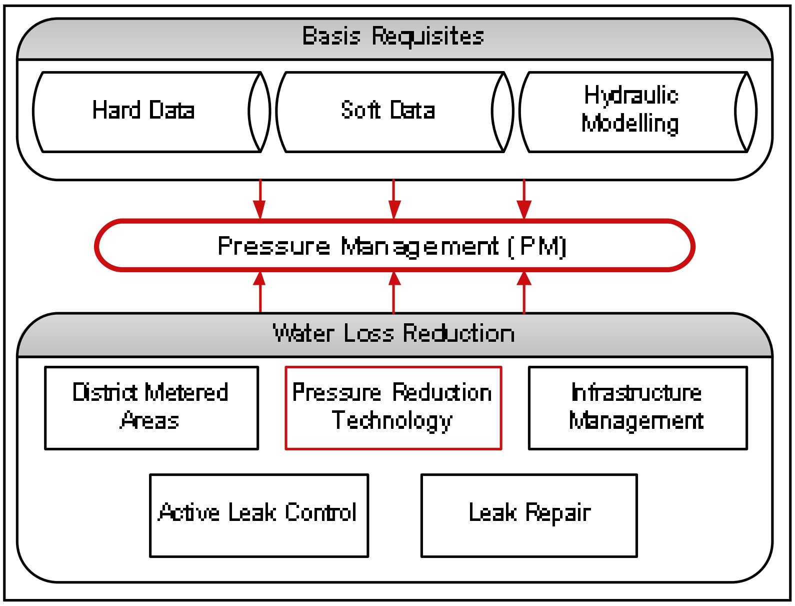

Figure 1: The different components involved in PM.

So far, GIZ and VAG have been cooperating in several integrated public-private partnerships in Jordan, Yemen, and in Peru. The successful cooperation increased the interest of further cooperation on water supply management and formed the basis for the elaboration of guidelines for water loss reduction, with a focus on pressure management. These guidelines will help to collect, consolidate and disseminate experiences from existing projects. Furthermore, running water programs of GIZ will be used to discuss the guidelines and to create pilot projects for implementing them. Case studies of completed projects are also integrated in the guidelines and selected ones are shortly described in the penultimate chapter of this paper.

2 GUIDELINES FOR WATER LOSS REDUCTION

2.1 THE GIZ-VAG PUBLIC PRIVATE PARTNERSHIP

Today the international community aims at a more sustainable society, sparing diminishing resources. In this perspective, there is an obvious need to reduce water losses and in order to tackle this challenge, GIZ and VAG decided to join forces in the frame of a public-private partnership. Additional partners of the project are the Karlsruhe Institute of Technology (KIT) and the University of Applied Sciences Northwestern Switzerland (FHNW). The project is financed by the German Ministry for Economic Cooperation (BMZ) and VAG, each bearing 50% of the costs. The main objective is the reduction of water losses through an improved management of existing water supply networks at different levels of intervention:

(a) Development of guidelines for water loss reduction - a focus on pressure management (January 2010 – August 2010)

These guidelines are meant to provide various target groups with relevant information on PM in order to understand the different types, reasons and impacts of water losses, to develop a strategy for water loss reduction in water supply systems and to understand prerequisites, methods and instruments for water loss reduction. This ambitious task is based on intensive dialogues, literature research, field experience and working sessions. The guidelines for water loss reduction are composed of three documents addressed to different target groups, as shown in Table 1.

Document		Target Group
1	Summary	Policy and management
2	Technical Manual	Planning and design
3	Working Materials	Implementation, operation and maintenance

***Table 1**: The three documents of the guidelines and their respective target groups.*

(b) Capacity development through dialogues, trainings and on-the-job instructions (March 2010 – June 2011)

To allow the implementation of the guidelines, target group oriented workshops and trainings are necessary. Based on a need assessment in three target groups (policy and management (1); planning and design (2); implementation, operation and maintenance (3)), tailor-made training plans and materials are developed on the design, installation and management of pressure management areas including valve design, maintenance and repair. The content of the guidelines provides the framework for a comprehensive training programme for technical directors and technicians of water utilities as well as potential trainers for local training institutions. Capacity building has a key importance within the PPP, as it can ensure education of the staff and sustainability of the technology implementation. It ensures an improved quality of the system and an understanding and commitment of the staff.

(c) Demonstration of improved management measures in pilot areas (March 2010 – June 2011)

The technical implementation of the guidelines will be examined together with the implementation of required technical installations for pressure management in selected pilot areas. The pilot projects will serve as practical examples for the discussion on best practices regarding design and management of water supply networks.

(d) The Pressure Management Homepage

In order to exchange information, facilitate contact and allow downloading the guidelines, the project homepage is available at the following URL: www.waterloss-reduction.com.

2.2 EXPECTED IMPACTS OF WATER SUPPLY SYSTEM OPERATED WITH PM

The use and implementation of the developed guidelines and the included recommendations on how to overcome existing problems will lead to more sustainable network management, reduction of water loss and improved access to constant and safe water supply. Additionally, the guidelines shall contribute to a more preventive operation and maintenance of the networks and the development measures shall contribute to the following direct and indirect impacts:

- Water supply increase (h/day)
- Increase in number of households having access to public water supply
- Reduction of pipe bursts
- Increased lifetime of network
- Equal and fair water supply distribution considering social constraints
- Reduced production costs and energy consumption
- Improved short-, mid- and long-term investment planning for sustainable management of water supply networks, instant savings opportunity, costs to reinvest into supply network.
- Improvement of the water quality (limitation of sewage and other pollutants infiltration into the pipe network)
- Consequent improvement of the situation regarding economic, technical, social and environmental impacts of leakages.

2.3 THE GUIDELINES FOR WATER LOSS REDUCTION

(a) Approach of guidelines

The **overall structure** of the guidelines for water loss reduction can be subdivided into three main categories: The technical manual, accompanying working materials as well as presentations for training measures. All materials follow the same modular structure as illustrated in Figure 2. The first two chapters of the guidelines contain the preface and the introduction and are addressed to decision makers and interested stakeholders of national water ministries and/or authorities, water utilities and professional associations. The following four chapters are addressed to engineers and technicians of water utilities. These chapters shall guide the reader step by step through the broad subject of water loss management and provide him with the necessary fundamentals for designing and implementing an efficient water loss reduction programme. Each chapter contains links to the accompanying working materials which present methodologies and instruments in more detail and provide an opportunity to the reader to practice the acquired knowledge. In the final chapter, case studies from selected international projects are presented which highlight particularly the capacities of pressure management for water loss reduction.

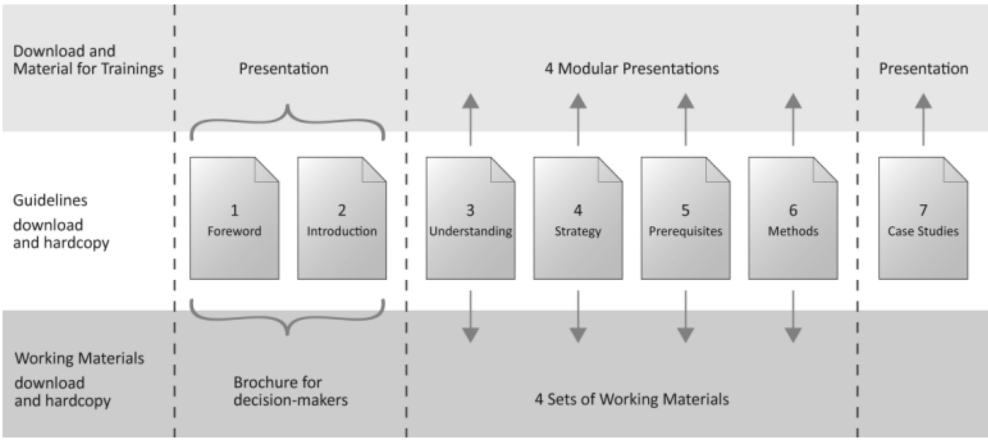

Figure 2*: Structure of the guidelines*

The explanations for the covered topics of the guidelines are written at a moderate level of detail in order to provide the reader with a fast insight into the specific field of water loss reduction. Necessary theoretical background is imparted, but it was intended to keep the contents of the manual closely related to practice. The presented methods and technologies are based on a broad literature research and state-of-the-art approaches from the International Water Association (IWA) as well as from the German Technical and Scientific Association for Gas and Water (DVGW: Deutsche Vereinigung des Gas- und Wasserfaches e. V.). The guidelines will be disseminated to interested stakeholders through water-related programmes of the GIZ in its partner countries and will furthermore be made available for download on the project's homepage.

(b) The contents of the technical manual

The introducing **chapters 1 and 2** of the manual shall arouse the reader's interest for the significance and importance of water loss reduction and shall emphasise the outstanding potential of pressure management as one of the central instruments for reducing losses from pipe bursts and leaks. The introducing chapters are also summarised in a short informative brochure which is available as hardcopy as well as for download from the project's homepage.

Because the comprehension of the problem is the cornerstone to successful water loss reduction in the long run, **chapter 3** is aimed solely at providing the basic knowledge about the different types of water loss, its causes and impacts. The terminology of the standardised IWA water balance is presented as a means of distinguishing and quantifying between different components of real and apparent losses (Lambert and Hirner, 2000) Basic leakage hydraulics are explained in order to focus the perception on the interrelation between system pressure and leakage flow rate. Furthermore, the various reasons for real and apparent losses are explained in brief, and the negative effects of leakage are categorised and described in four main groups: economic impacts, technical impacts, social impacts and environmental impacts.

In the next section of the manual in **chapter 4**, the reader shall be capacitated to assess the present status of water losses in its water supply system and draft the necessary and most appropriate steps of a custom-made action plan for water loss reduction. Different methods are explained for setting up a detailed water balance, which is indispensable for quantifying the actual level of Non-Revenue Water in a system. A method is described to review the reliability of these water balance calculations by means of 95 % confidence limits (Alegre et al., 2007). Because the water balance should never be based merely on desktop studies but should be backed up by measuring data from field research, various methods are presented for assessing and quantifying real water losses from transmission and distribution pipes and from storage tanks (Farley, 2001). Once having collected the key data about real and apparent losses, it is explained how relevant performance indicators can be calculated and how to use them for the evaluation of saving potentials and the setting of leakage reduction targets. At the final part of chapter 4, the major steps for setting up an action plan are outlined. It is the key message of chapter 4 that is essential to know properly the types and the dimension of water losses in a water supply system first before trying to implement countermeasures. If for example the largest amount of losses is due to inaccurate water metering, the procurement of expensive leak detection equipment will show no positive effects.

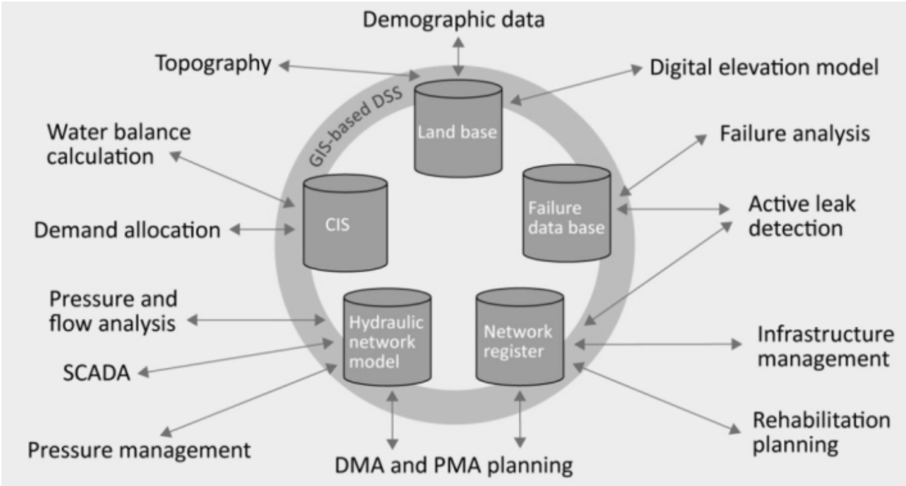

***Figure 3**: Interconnection between various GIS-based information systems and water loss reduction*

In **chapter 5** it is shown which modern, GIS-based information systems are considered as key prerequisites for efficient water loss management. Five central information systems and their relevance for water loss reduction in general and for pressure management in particular are described in detail. The land base is a seamless electronic map of the entire service area of a water utility and forms the basis for all other information systems. The network register is mandatory for maintaining overview about all facilities, transmission and distribution pipes, service connections and their respective accessories in a complex water distribution network. Hydraulic network models are valuable tools for the design and operation of water supply systems and are required for the optimum design of interventions as e.g. the installation of a pressure management scheme. The failure data base provides valuable information about the ageing behaviour and the condition of different pipe groups and is thus useful for the identification of vulnerable sections of the network (DVGW, 2009). The customer information system and the billing records are indispensable for the comparison between water input and water consumption into a zone and thus necessary for the calculation of the water balance. Figure 3 illustrates the interconnection between the above described information systems and their relevance for water loss reduction.

Finally, in **chapter 6**, the principal intervention methods for water loss reduction are recapitulated with a particular focus on the technical aspects of pressure management. The design and implementation of district metered areas and their importance for the continuous monitoring of the level of leakage and thus the reduction of awareness and location time for new leaks is explained. The next section is dedicated to pressure management: an overview about the fields of application and the potential benefits of pressure management is given. Different types of valves and pressure modulation and their respective advantages and disadvantages are explained in detail. Furthermore, the procedure for a typical pressure management project implementation and selection criteria for the most appropriate solution are specified (see Table 2 and Figure 4).

Use Case	Pressure Management Solution
1a	Local point modulation with single inlet, diaphragm valve with fixed outlet pressure
1b	Customized solution
2	Local point modulation with single inlet, diaphragm valve with time or flow modulation
3	Local point modulation with single inlet, plunger valve with time or flow modulation
4	Critical point modulation with single inlet and diaphragm valve
5	Critical point modulation with single inlet and plunger valve
6	Critical point modulation with multiple inlet and plunger valve
7	Dynamic DMA

***Table 2**: Explanation of the different use cases of Figure 4*

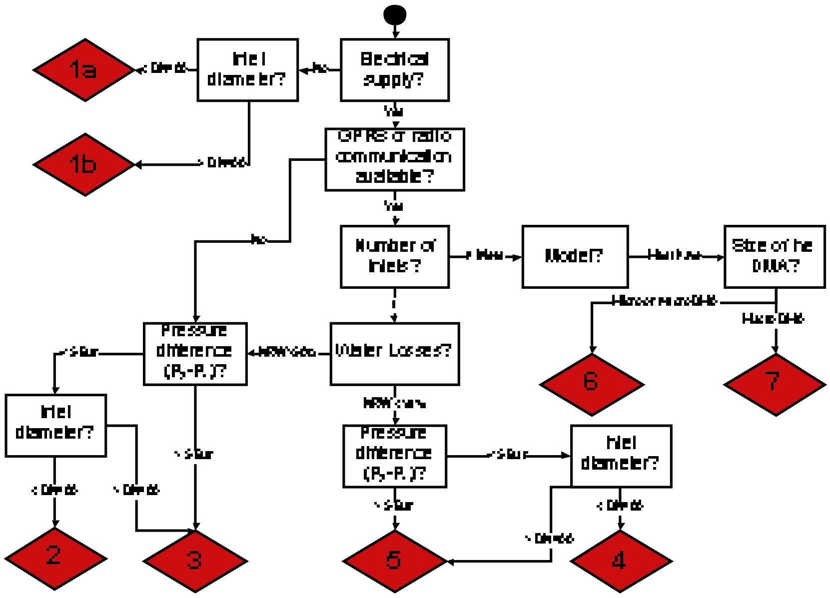

Figure 4*: Decision support diagram for the selection of the most appropriate pressure management solution*

In the second half of chapter 6, the three major steps of active leakage control (awareness, leak detection and leak location) are presented (Thornton et al., 2008). The importance of each step is explained, and for each step the state-of-the-art technologies are outlined in brief. Finally, in the last two sections of chapter 6, the purpose and key issues of leak repair works and infrastructure management are mentioned.

(c) Working materials

As mentioned already above, each chapter is accompanied with a series of working materials addressed to the staff of the planning and design department and the operational level. The working materials deliver practical descriptions to apply the content of the chapters of the technical manual. There are three types of working materials: working procedures, examples and theoretical background.

(d) Training materials

Along with the manual and the working materials, presentations for trainings will be made available. The presentations cover complete topics and may be combined as needed. For each presentation a short overview of the content, the objectives and suggestions for the set up of a complete training are provided for possible trainers. The training materials will follow the same modular structure as the technical manual.

2.4 CASE STUDIES

Furthermore, the technical manual contains several case studies reflecting several aspects involved when implementing PM. Among these, there is for example:

(a) The example of Santo Amaro, São Paulo, Brazil

In the metropolitan area of São Paulo, with a continuously increasing water consumption, it has become a challenge for the local water utility (namely the state-owned Companhia de Saneamento Básico do Estado de São Paulo, SABESP) to provide a constant supply of water to more than 17 million inhabitants. One reason for the difficulty of continuous water supply is the high volume of water losses that occur during operation due to leakage. If the pressure can be managed effectively, then water loss will be reduced. (Oppinger, 2009)

In the District of Santo Amaro, VAG and SABESP installed a pilot site consisting of a highly sophisticated water loss reduction system that included pressure regulating valves, control panels, telemetry installations and the supporting software. (Oppinger, 2009) Two technologies were implemented: in a first stage time based modulation and in a second stage remote node based modulation which led to the results shown in Table 3. Furthermore, new pipe breaks reduced by approximately 50% with a project pay back time of 4-5 months.

Technology	Period	Water losses [m^3/month]	Water savings [%]
Without PM	Jan. 2005 – Sept. 2005	301.7	
Time based modulation	Oct. 2005 – Jan. 2006	203.9	**-33%**
Remote node based modulation	Feb. 2006 – Jun. 2006	178.0	**-41%**

Table 3*: results obtained in the district of Santo Amaro in Brazil between January 2005 and June 2006.*

(b) The example of Lima, Peru

Drinking water is a scarce resource in Peru, particularly in its capital Lima, which is situated in a desert region at the Peruvian coast. Environmental pollution and insufficient water resources aggravate the situation in terms of adequate drinking water supply. Furthermore the water supply system records water losses up to 30 – 50% of the water fed into the network caused by leaking pipes and insufficient maintenance.

Besides the technical installation of PM technology, the aim of the Peruvian partnership project of SEDAPAL (GIZ and VAG) is to enhance the managerial and operative capacity of the respective utilities. To anchor knowledge on PM within the structures of SEDAPAL (a state-owned enterprise with the objective to provide the communal services, such as drinking water supply and sanitary sewerage), technical and educational materials have been provided and local trainers of the SEDAPAL training centre will be trained. The SEDAPAL training centre will allow utility staff throughout Peru to be trained in the management and technical operation of PM. The installations in the two pilot areas of Lima serve as best practice example for PM.

3 CONCLUSIONS

The technical manual has been finalised in March 2011 and is available for download on the project website www.waterlossreduction.com. To this day hundreds of professionals have registered and downloaded the manual and supplementary material. The guidelines have been presented and discussed with representatives of water associations, ministries, public authorities and water utilities at several regional workshops receiving a very positive feedback. Furthermore pilot projects for pressure management have been implemented on several continents and regional training centres have been established. For the future, the training modules will be available to individual organisations and further pressure management projects will be implemented.

Knowledge is an important precondition for reducing water losses and controlling them at a reasonable low level from a technical and economic point of view. The guidelines for water loss reduction are aimed at contributing to the dissemination of information about recent developments for efficient water loss management. Offering the guidelines with working materials in combination with training measures and pilot projects for pressure management implementation is seen as an effective approach for a long-term reduction of leakage from water distribution networks.

Figure 1: The different components involved in PM.
Figure 2: Structure of the guidelines
Figure 3: Interconnection between various GIS-based information systems and water loss reduction
Figure 4: Decision support diagram for the selection of the most appropriate pressure management solution

Table 1: The three documents of the guidelines and their respective target groups.
Table 2: Explanation of the different use cases of Figure 4
Table 3: results obtained in the district of Santo Amaro in Brazil between January 2005 and June 2006.

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