Minimization of inflow and infiltration in separate sanitary sewer systems

Réduction des apports des eaux de surface et de l'infiltration dans les systèmes d'assainissement urbain

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RESUME

Les apports non désirables d'eaux de surface et d'infiltration aux réseaux d'assainissement urbain sont souvent responsables de problèmes fonctionnels sévères. Donc, l'adoption de mécanismes pour réduire à un niveaux acceptable les débits excessifs est nécessaire, afin d'assurer la conformité aux directives européennes, minimiser les impacts dans les milieux récepteurs et diminuer les coûts d'opération. Dans cette communication on présente une méthodologie pour minimiser ces apports excessifs et l'application au système géré par Águas do Ave, soulignant les contraintes et difficultés rencontrées. Cette approche, innovante au Portugal, peut contribuer à l'amélioration significative de la performance et de l'efficacité des réseaux et à la connaissance du fonctionnement actuel.

ABSTRACT

Sanitary sewer systems often show functional problems as a result of significant proportion of the total flow originating from infiltration, storm water inflows and industrial effluents. Mechanisms aiming at the detection and reduction of excessive flows are particularly important when compliance with discharge directives is to be achieved, and impacts on receiving water bodies and operation costs are significant. In this paper a methodology for addressing this problem, and the practical application to systems managed by Águas do Ave, is presented, emphasising constrains and difficulties encountered. This approach, innovative in Portugal, is believed to allow sound improvements in the performance and efficiency of wastewater systems as a whole, contributing to a better knowledge of the current situation.

KEYWORDS

Infiltration, inflow, performance, sanitary sewer.

1 INTRODUCTION

Extraneous flows into the separate sanitary sewer systems can result in significant performance decrease, both on sewer systems and in treatment plants, and consequently causing negative impacts on receiving water bodies. Despite the large investments made on wastewater systems, in many cases the present performance is far from satisfactory, extraneous flows being perceived as one important cause. Sources of extraneous flows into separate sanitary sewer systems include rain induced flows (illicit connection of drains from private proprieties; misconnection of drains from gullies; misconnection of storm sewers; entry of surface water through manhole covers), infiltration (groundwater entering through pipe and manhole walls; cross leakage from water supply mains and storm sewers) and unauthorised industrial connections. This problem has been reported in different countries as seriously reducing functional performance of the systems as well as significantly increasing operation costs (White *et al.*, 1997; Ainger *et al.*, 1998; Heaney *et al.*, 1999; Weiss *et al.*, 2002). Problems derived from these extraneous flows include:

- Reduction of the sewer system hydraulic capacity, eventually leading to overcharge, overflows and flooding.
- Hydraulic surcharge, overflow and efficiency reduction at treatment facilities.
- Increased pollution of receiving waters.
- Operational costs and structural condition deterioration.

As consequence, failure to meet established basic performance requirements often occurs, leading to unwanted impacts on the overall performance of water utilities.

The water sector in Portugal incorporates two general types of utility services: those focused on wastewater collection at municipal areas; and those responsible for the main wastewater interceptor and treatment systems. The former are mainly managed by local administrations bodies, while the latter are mostly managed by multimunicipal and municipal concessions.

To achieve the economic, operational and environmental sustainability of wastewater systems it is essential to act on the efficiency of both types of systems. One of the major challenges is to promote the necessary cooperation between those utility services, especially on extraneous flows control.

Data on the magnitude of this problem in the country is unavailable but consequences are well known, having severe impacts on the conformity with applicable directives and regulations, e.g. the wastewater treatment directive and the Portuguese general regulation for public and private water supply and wastewater systems (Decree-law 23/95). While these obligations are to be met by all systems, given that problems are more acute at upstream municipal networks, major consequences arise at the downstream wastewater interceptor and treatment systems. Furthermore, since management is often made by different utilities, those responsible by the downstream systems are limited in their ability to implement corrective measures.

Thus, mechanisms to promote the gradual reduction extraneous flows into sanitary sewer systems are needed to increase economic and environmental efficiency as well as to improve operational levels of service.

Within this scope the Águas de Portugal (AdP), a publicly-owned company that presently covers about 70% of Portuguese territory and about 50% of Portuguese population (in total about 5 million inhabitants) aims at developing partnerships with utilities managing the municipal collection systems to implement strategies for overall reduction of rain induced and infiltration flows.

In order to establish a conceptual framework, to be applied in all systems managed by the AdP group, a methodology was developed and implemented together with one of the subsidiary companies, the Águas do Ave (AdAve), in close collaboration with utilities responsible for the wastewater systems.

The practical application is essential for refining the methodology before generalised application to other subsidiary companies.

2 METHODOLOGY

While the overall goal is the gradual reduction of extraneous flows in the municipal systems, the main objective of the conceptual framework proposed is to develop a plan for each Municipality incorporating appropriate measures adapted to the specific situation, in terms of local problems, constraints, and organisational and physical characteristics. Additionally, these plans should include implementation schedule, costs associated to each measure, resources allocation and recommendation on organizational issues.

Reports on similar programs highlight the major factors for successful control programs as being the good quality flow monitoring (before and after remedial works), the careful investigation of local conditions and the adoption of a structured approach to locate the worst problem areas that are major contributors to the problem (DCC, 2005).

Given the constraints in resources and limited information, the approach selected consists of a two level analysis: a macro analysis of the main catchments inflowing to the interceptor systems and a micro analysis, more detailed, to be carried out at small pilot catchments. The micro analysis is essential to identify the contributing causes and its relevance per system, to allow quantification of the problem and estimate costs of rehabilitation.

Development of a plan for each municipality includes the following phases:

1. **Characterization of present situation (reference)**. This phase includes:

- Gathering available system information, carrying out consistency analysis of data and identification of gaps, and establishment of a program for missing data collection;
- Compilation of operation and maintenance information including functional problems identification (e. g. failures, complains);
- Execution of the data collection program, including the required field work.
- Characterization of sanitary wastewater flows, per sub-catchment connecting to the main trunk sewers.
- Selection of pilot catchments (target size around 2 to 4 ha; network length approximately 1 km); choice of measurement locations, both to flow and rain gauges. The pilot catchments are intended to be representative of the wider municipal system characteristics, allowing for detailed investigations to be carried out. Measurements locations required include the downstream connection sewers to the main interceptor systems and outlet of the pilot catchments.
- Comprehensive characterisation of the pilot catchments infrastructures, namely, sewers, manholes, household connections, storm water inlet connections, and other deficiencies observed by detailed field work. When necessary tracer testing or CCTV inspections can be carry out.

- Short term flow and rain survey at the previously selected locations. Minimum requirements of data are fifteen dry weather days and five rainfall events.
- Mathematical modelling of the sewer systems, using SWMM, for detailed characterization of the hydraulic behaviour under different scenarios, both of existing situation and of rehabilitation scenarios. Collected data (flow and rain data) is to be used in model calibration and verification.
- Selection of an appropriate set of performance indicators to be applied both for the pilot catchments and for the catchments inflowing the main interceptor system.
- Calculation of the performance indicators and critical analysis considering the knowledge obtained in the previous tasks.
- Diagnosis of the systems, including the identification of extraneous flows sources and main contributing causes.

2. **Definition of specific objectives and goals, and establishment of a program of measures.** This phase includes:

- Definition of the objectives to the served area, on the short and medium term, taking into account intervention priorities derived from the diagnostics phase.
- Selection of a set of tailored measures (structural and operational) for each sub-system. Different scenarios should be considered in the program to incorporate the potential levels of implementation that might be achieved depending on the particular conditions of each municipality. For each scenario, required resources and expected benefits are estimated.
- Set up of a program for each municipality and system establishing the priority measures, detailing schedule, associated resources and costs of implementation.

3. **Mechanisms for implementation**. This phase includes:

- Establishment of the plan for each municipality, based on the program of measures developed for each sub-system. Selection of the appropriate mechanisms for implementation of the plan.
- Identification of the necessary means for plan implementation, both in terms of technical team and required resources.
- Recommendations on the required training for personnel involved in plan implementation.
- Set up of an auditing program for the evaluation of the plan throughout implementation and procedures for control and adjustment.

The application presented herein allows for refining the methodology before generalisation to other subsidiary companies.

3 APPLICATION TO THE AGUAS DO AVE SERVICE AREA

3.1 General system description

The AdAve wastewater interceptor and treatment systems presently provides service to eight municipalities, namely, Fafe, Guimarães, Póvoa de Lanhoso, Santo Tirso, Trofa, Vieira do Minho, Vila Nova de Famalicão and Vizela, corresponding to a total of 510 000 inhabitants. The region is mostly rural with industrial clusters and some small urban areas, thus having a large proportion of dispersed agglomerations, and consequently a large number of individual collection sub-systems.

Urban areas networks are comparatively old and have relatively low maintenance. In recent years, considerable investments have been made in order to increase connected population to treatment systems, with associated benefits of protection of public health and pollution control, resulting in the expansion of the wastewater interceptor systems managed by AdAve. The main characteristics for the connected municipal systems are presented in Table 1.

Municipality	**Total population** (inhabitants)	**Connected population** (%)	**Geographic area** (km^2)	**Number of systems**	**Interceptor system** (km)
Fafe	52 757	30	219,1	6	28
Guimarães	159 576	52	241,3	44	341
Póvoa de Lanhoso	22 772	27	132,5	4	27
Santo Tirso	72 396	31	136,5	31	113
Trofa	37 581	26	71,9	5	25
Vieira do Minho	14 724	28	218,5	11	48
Vila Nova de Famalicão	127 567	31	201,7	35	257
Vizela	22 595	31	24,7	1	20

Table 1 – Characteristics of served municipalities (current situation)

Given the constraints of this application, two pilot catchments were selected per municipality for the micro analysis. Although the initial aim was to study all catchments inflowing to the interceptor sewers (macro analysis), due to the high number of catchments, it was decided to limit to only the larger areas. To illustrate the application of the methodology, herein the case of Trofa municipality is presented.

Overall, the number of rain gauges and flow gauges installed in the AdAve serviced area was 24 and 119, respectively. In average, the rain gauges were installed during 64 days (minimum 40 days; maximum 79 days) and flow gauges were installed for 32 days (minimum 20 days; maximum 64 days).

3.2 Trofa case study

Trofa interceptor system serves presently circa 9 800 inhabitants, within an area of 72 km^2, where approximately 25 km of sewers intercept the sanitary flows from seventeen main catchments and direct them to two wastewater treatment plants. The estimated collection sewer network length is 65 km. Today, only four of the eight boroughs are connected to the interceptor system, being the future situation of service to 90% of the population estimated in 37 connected main catchments, in a 6 years horizon. Territorial occupation is characterised by predominant rural areas, one main urban area and dispersed industrial units.

According to the methodology, available information was compiled, pilot catchments selected and monitoring locations identified. Due to limited resources, not all catchments inflowing to the interceptor systems are monitored. In total, sixteen flow gauges and two rain gauges were installed. Additionally, problematic areas were identified with the help of maintenance technicians.

Selected pilot catchments are intended to be as representative as possible of spectrum in the municipality, the main criteria being age, structural condition and density of connections. Newer sewer networks still have a low number of existing properties connected, thus pilot catchments had to be located in older areas, typically with more than ten years. The main characteristics of the selected pilot catchments are presented in Table 2.

Catchment	**Population** (inhabitants)	**Area** (m^2)	**Network length** (m)	**Pipe materials**	**Slope range** (m/m)	**Diameter** (mm)
TRF_BP1	129	42 000	781	PVC and vitrified clay	0.012 - 0.12	200
TRF_BP2	705	54 000	796	PVC and vitrified clay	0.025 – 0.63	200

Table 2 – Characteristics of selected pilot catchments (Trofa)

The application of the methodology was carried out in the similar way in all eight municipalities.

4 RESULTS AND DISCUSSION

4.1 Available systems information

The initial phase of the implementation revealed important gaps on available information, this having considerable impact on the results of this application. The main aspects to consider include:

- network mapping is generally incomplete and inaccurate;
- register of connections, both households and industries, to public sewers is not available in an appropriate format for the present purpose;
- systematic recording of operation and maintenance information is virtually inexistent;
- mechanisms for construction quality control and supervision are insufficient;
- for historic reasons and availability of water sources, water consumption is not directly related to wastewater production;
- limited information exists on wastewater flows since very few gauges are installed permanently and, for these, records are not continuous.

Therefore these aspects are a priority in the plans for all municipalities.

Problems arising during the detailed characterisation of the pilot catchments include incomplete or inaccurate network mapping, non-compliance with design regulations (e.g. minimum slopes, level of outlet pipes in manholes higher than inlet pipes), deficient condition of manholes (e.g. broken and leaking manhole covers), cross connections from storm sewers to sanitary sewers, solids accumulation in pipes and manholes, evidence of surcharge in manholes, connection of basements drainage into the sanitary sewers.

4.2 Rainfall and flows survey

The option for a short term rainfall and flow survey, resulting from resources available, proved to be limited for the assessment of the magnitude of the problem since the range of hydrologic conditions was not monitored. In fact, the period during which the survey took place did not allow characterization of effective dry weather periods. This implies some limitations on the estimation of the infiltration flows.

Thus, a recommendation for other applications is to extend the measurement period, achieving a hydrologic year would be desirable.

Regarding flows monitoring, the main problems result from the predominance of small sewer diameters, low flows, high flow velocities, irregularities in the construction of sewers and manholes, type of equipment used, accumulation of solids in the sensors and deficient gauge installation. Illustration of some problems is given in Figure 1.

Figure 1 – Problematic flow gauge installation (Trofa)

These problems resulted in loss of a considerable amount of reliable data as illustrated in Figure 2, after accumulation of solids in the sensor.

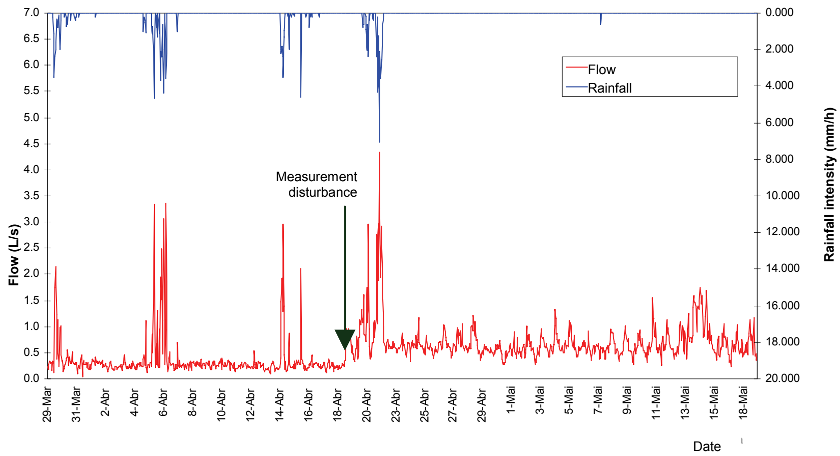

Figure 2 – Measurement results (Trofa)

Recommendations for a minimum flow measurement network, in order to follow up results of rehabilitation actions or influence of new connected areas, are included in the plan. Suggestions to other applications include previous selection of more adequate measurement devices and, whenever possible, consider a number of permanent installations from the beginning. Additionally, verification and maintenance of temporary flow gauges should be carried out more frequently.

4.3 Performance assessment

Whilst performance measures are essential for diagnosing the systems and establishing intervention priorities, the selection of the appropriate technical indicators resulted to be difficult. Existing indicators, such as those presented in Cardoso *et al.* (2005), require information not available in the short term or unreliable (e.g. total sewer length or number of house connections). The quantification of some variables required a longer period of measurements to be representative of the real problem (e.g. minimum flow to be used to calculate infiltration flows).

Hence, use of performance indicators should be always complemented with a comprehensive analysis of results of the measurements, and evaluated throughout the time.

Given the limited experience, the usage of the assessment results based on performance indicators, to support rehabilitation options is not straightforward. Knowledge of reference ranges is of value for the definition of thresholds to support decisions. Building up experience will allow definition of these values according to the standard of practice in the water utility.

5 CONCLUSIONS

Reduction of extraneous flows into sanitary systems is recognised as a difficult and expensive task and the best strategy is to invest in good quality construction and supervision. However, in existing systems with low performance, actions should be carefully planned to allow for sound results that might be only achieved in the medium or long term.

Despite the constrains and difficulties encountered to implement a predefined methodology for addressing this problem, the practical application to systems managed by Águas do Ave, important opportunities for improvement were identified.

This approach, innovative in Portugal, of collaboration between different stakeholders is believed to allow for future sound improvements in the performance and efficiency of wastewater systems as a whole, contributing to a better knowledge of the current situation.

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