Uniform registration of failures in wastewater systems (SUF-SAS)

Archivage homogène des défaillances dans les systèmes d'assainissement (SUF-SAS)

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RESUME

Nombreux sont les composants des systèmes d'assainissement qui peuvent tomber en panne et affecter les procédés primaires de collecte et de transport des eaux usées et de ruissellement ainsi que leur traitement. La plupart des gestionnaires ont institué des systèmes de détection automatique des défaillances. Cependant, les rapports ne sont pas uniformisés et contiennent aussi bien des données réelles d'incidents qui des données d'exploitation ayant localement fait l'objet d'une interprétation. De plus, le données d'exploitation sont généralement archivées à des intervalles insuffisants afin d'économiser les capacités de stockage. Par conséquent, même si un relevé des données opérationnelles et des incidents existe, la pratique actuelle ne permet pas d'effectuer une analyse systématique de la performance des systèmes, ni de l'impact des défaillances. Afin de permettre une analyse systématique des procédés s'appuyant sur des données réelles, la fondation RIONED et STOWA ont lancé un modèle d'enregistrement qui définit de manière uniforme les défaillances ainsi que les données opérationnelles concomitantes.

ABSTRACT

Many components of wastewater systems may be subject to operational failure, thus affecting the primary processes of collection and transport of wastewater and stormwater and subsequent treatment. The majority of management authorities has automatic systems for failure reporting. However, current failure reports are not uniform, as they consist of a combination of real failure data and locally interpreted operational data. Moreover, operational data are generally registered at a low frequency in order to save storage capacity. Consequently, even though operational data and failure data are measured, current practice hampers systematic analysis of wastewater system performance, including the impact of failures. In order to enhance systematic process analysis based on real data, the RIONED foundation and STOWA have launched a uniform registration format, which uniformly defines failures and underlying operational data.

KEYWORDS/MOTS CLES

Failure registration, operational data, process analysis, standard format, wastewater.

INTRODUCTION

Wastewater systems comprise numerous components that may suffer from operational failures. Many of these components are critical with respect to the primary processes of collection and transport of wastewater and stormwater and subsequent treatment.

Failing pumps in sewer systems may result in unintended combined sewer overflows (CSOs), sanitary sewer overflows (SSOs) or flooding. Pump failures are estimated to be responsible for an increase of the annual CSO volumes by 15% in the Netherlands (Korving, 2004). At the wastewater treatment plant (WWTP) failure of components may reduce performance in terms of effluent quality and hydraulic capacity. In addition, failure of components in the sewer system may affect WWTP performance and vice versa (Langeveld, 2004). As a result, exchange of operational data between sewerage and wastewater treatment departments is necessary in order optimise the performance of the total wastewater system.

Systematic analysis of wastewater system performance in order to improve the overall performance of wastewater systems by addressing the weakest and most critical components requires a uniform registration of failures and a clear definition of failure. Such an analysis should provide answers to the following questions: What level of performance is required for a specific component? What level of performance is reached?

The majority of management authorities have automatic systems for failure reporting. However, most of these systems are especially intended for warning, informing and directing the fault-clearing service. This causes problems for systematic failure data analysis. First, reported failures are a mixture of real failures (i.e. component does not function) and interpreted operational data (such as water level and power). As a result, current failure registrations are not uniform and not clearly defined. Second, operational data are generally registered at a low frequency in order to save storage capacity of SCADA systems. The frequency required for process analysis based on operational data depends on the characteristic time scale of the process.

Summarising, although sewer system and WWTP managers collect a huge amount of operational data, this data is unsuitable for process analysis because standard formats for failure data as well as a clear definition of failure are missing.

This paper describes a standard format for failure data of wastewater systems. First, the information needed for management of wastewater systems is discussed. Second, the selection procedure for failure data is presented. Based on identified failure mechanisms and alarm filters of management authorities the components have been determined of which operational and failure data need to be collected. Finally, the required data for each component of the wastewater system are listed including the required registration format.

1 INFORMATION FOR WASTEWATER SYSTEM MANAGEMENT

1.1 Information needs

Wastewater system management takes place at several levels, ranging from long term strategy to daily operation and maintenance. Each level is associated with specific information needs. Irrespective of the organisational embedding, three levels of wastewater system management can be distinguished:

- At a strategic level (i.e. management level in many organisations), middle and long term objectives are formulated and assessed, typically based on performance indicators, such as number of failures related to year of installation or type of sewer district. The assessment of wastewater system performance requires testable performance indicators. These indicators should express the probability of a potentially dangerous or adverse consequence and its impacts. The performance of the wastewater system largely depends on the performance of individual components. Examples of indicators are presented in e.g. Ashley and Hopkinson (2002), Geerse and Lobbrecht (2002), Bennis et al. (2003), Matos et al. (2003) and Saegrov (2006). However, most indicators are only used for benchmarking without a clear definition of operational data and failures. As a result, their applicability for evaluation of wastewater system performance is limited.

- At a tactical level, middle management issues are addressed, such as planning of inspections and replacement, and maintenance and repair schemes. This requires typical information on life expectancy, and costs of repair and replacement.
- At the operational level, emphasis is on dealing with failures and carrying out urgent repairs. This requires detailed failure reports.

With respect to failures in wastewater systems, higher levels of wastewater system management may benefit from information obtained at a lower level. This requires that the information on failures obtained in daily operation to be uniform and uniquely defined and systematically registered. Recent research (Korving, 2004) showed that sewer system management could be improved by exchanging available information between the strategic and operational level.

The focus is on the information needed at the strategic level: what type of information is necessary to be able to assess the impact of failures on wastewater system performance and to improve daily operation based on this knowledge. Nonetheless, this information could also be used to improve maintenance schemes or to instruct fault-clearing services.

1.2 Data types

Wastewater system management involves a large number of different types of data, which can be divided into the three main groups, see figure 1:

- Basic data, comprising system data and set points and control data
- Complementary data, comprising data on observed wastewater system behaviour which include inspections, observations and complaints.
- Operational data, comprising data related to process control and operation which include measurements and failure registrations.

The 7 types of data distinguished in figure 1 are:

- System data. This data describes the wastewater system characteristics and dimensions, such as weir levels and widths, location and capacity of pumping stations, and surface area, depth and shape of secondary clarifiers.
- Set points and control data. The set points determine the control of components of wastewater systems and tell whether wastewater system components such as pumps should be active. The switch on and off levels of sewer pumps and set points of aeration in activated sludge systems are examples of this type of data. The set points can be adjusted frequently in case of RTC (real time control), normally the set points are seldom adjusted.
- Failures. Failures of wastewater system components are normally registered automatically by SCADA systems.

- Measurements of process parameters. This type of data describes the data derived from measurements of the primary process. In sewer systems, the primary process is transport and storage with flow and water level measurements as typical process parameters. At a WWTP, typical process parameters are concentrations of e.g. pollutants and oxygen. General process parameters are electricity consumption, operational hours of components, such as pumps, and number of on-off switches.
- Inspections. Data derived from inspections give information on the condition of objects within the wastewater system. An example of inspections are CCTV inspections of sewers, providing information on the condition of the sewer pipes .
- Observations. Observations are a very valuable source of information. This type of information is obtained during daily operational management, other than inspections. Observations comprise a wide range of data, typically registered in logs or only known to the operator.
- Complaints. Complaints from consumers can give valuable information on the performance of wastewater systems, especially on sewer and wastewater transport systems as they are not continuously supervised by an operator, whereas WWTP's normally are.

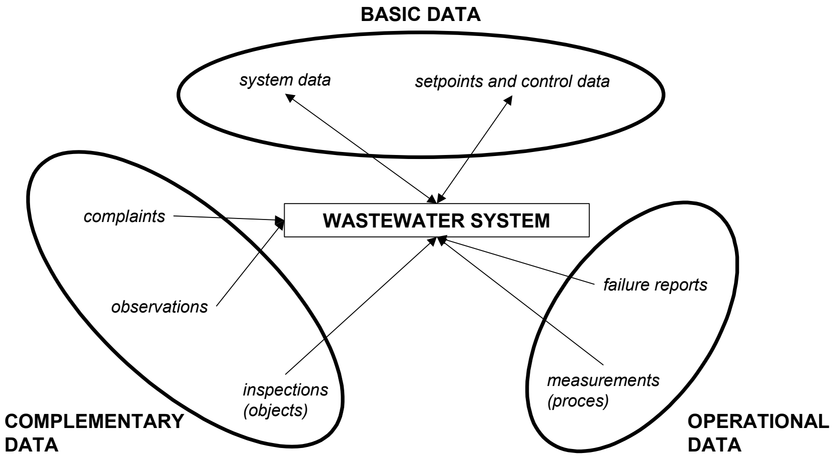

Figure 1. Operation and maintenance data wastewater system

2 MATERIALS AND METHODS

Qualitative risk analysis has been applied in order to select the necessary data. The analysis is based on a combination of failure mechanisms and alarm filters:

- Failure mechanisms describe the actual physical process leading to failure of a system or component. Failure is defined as the inability of a system or a component of a system to fulfil its task relative to a given standard. This standard is defined by the user, e.g. for sewage pumps in terms of design capacity and head. As a consequence, failure may include partial failure, where the system still functions but at an unacceptable level of performance.

- Alarm filters are defined by management authorities in order to discriminate urgent from non-urgent failures. It determines the repair priority of a component. In general, after office hours only urgent failures are reported to the fault-clearing service.

For an effective analysis the wastewater system is divided into the following subsystems: sewer system, transport system and WWTP. Each subsystem is subdivided in different components, including pumping station, pressure main, sedimentation/storage tank, orifice/valve, vortex regulator, grit removal, sand trap, primary clarifier, aeration tank and secondary clarifier.

Event trees are applied to systematically and effectively identify the different possible sequences of events leading to all potentially dangerous or adverse consequences following an initiating event. Potentially dangerous consequences include contact with faecally contaminated wastewater, flooding of basements and exceedance of effluent standards.

Based on identified failure mechanisms and event trees the components have been determined of which operational and failure data need to be collected. The selection criteria are based on the potential consequences of a failure and the frequency and duration of failures. Each aspect (consequences, frequency and duration) is weighed based on expert judgement.

In general, data are required of components, which are essential for the primary processes of wastewater systems, i.e. sufficient transport capacity and minimal emissions. For each component of the wastewater system a distinction is made between essential and optional data. The data comprise both operational information and failures.

3 RESULTS AND DISCUSSION

3.1 Shortcomings of current practice

Current failure registrations are a mixture of ‘real’ failures (i.e. the component is not working) and operational data such as water level and power. Often the operational data are translated into failure reports (such as ‘level high’ warning). Failure registrations are mainly intended for warning, informing and directing fault-clearing services. Generally, the more detailed the failure registrations, the more operational data are included as ‘failures’ and the more information is provided for the fault-clearing service in order to determine the required actions.

However, more detailed failure registrations are more specific for a single location. Consequently, current failure registrations are not uniform (see e.g. Figure 2). Different suppliers of telemetry systems and wastewater system managers use different failure definitions specific for a particular situation. The background of failure definitions, however, cannot always be traced, e.g. ‘installation failure’ which consist of a combination of several ‘less urgent’, but not clearly defined, failures. As a result, an installation failure may indicate a pump failure.

Many operational data are registered in (semi) continuous way but only registered as daily totals in order to reduce data storage capacity. However, a reliable process analysis requires data with a sampling frequency that is high enough to indicate relevant changes in the process of transport and treatment of wastewater. This frequency depends on the characteristic time scale of the processes.

Thermal failure P1+P2
Thermal failure P1
P1 thermal failure
P1+ P2 thermal failure
P1 thermal failure P2 clogged
Thermal failure p1/p2
Thermal failure p1 2
Therm. P1/p2
Therm p1p2
Term p1

Figure 2. Example of different registrations of the same failure at one pumping station

Finally, the availability of logs describing the nature of failures and repairs is of vital importance. In current practice, however, information in logs is far from complete and needs to be improved in order to study correlation between system performance, case history and failures.

3.2 Data required for process analysis

Answering questions on process control requires only part of the data collected in practice. In general, process data and failure registrations are needed of components of the wastewater system which affect the primary process (i.e., transport and treatment of wastewater).

The required data are classified as follows:

- cluster 1: description of the wastewater system. System data and set points describe the characteristics of a wastewater system. They describe the components to be managed and the performance requirement s of each component.
- cluster 2: process data of the wastewater system. Failure registrations and process data are collected for several purposes, including warning the fault-clearing service, process control or assessment of wastewater system performance. They describe the actual performance of (a component of) the wastewater system. Their registration is strongly process-driven.
- cluster 3: externally driven data. Inspections, observations and complaints comprise data which are not driven by the process and have a very incidental character. They provide additional, but often essential, information on the performance of (components of) the wastewater system. Inspections, for example, enable condition monitoring of components such as sewers, pumping stations and clarifiers. However, the inspections of different parts of the wastewater system are not uniform because methods and frequencies differ largely.

Failure data and measurements to be registered and exchanged are listed in a uniform data exchange format named SUF-SAS. The registration of failures is strongly based on available systems. However, only reports, which indicate that a component is not working, are included. This means that reports such as 'level high' and 'too many swich ons' are neglected. For each component the following information is registered:

- identification of component (number, name);
- date and time of failure (dd-mm-yyyy hh:mm);

- status of failure (on/off).

Next to failures, process data need to be registered. Table 1 summarises the components of the wastewater system of which process data are collected. For each parameter of a component it is indicated whether the registration is standard (S) or optional (O). The registration format resembles the format for failures. In addition, a registration frequency is prescribed.

The table is based on conventional components of the wastewater system. In practice, however, new technologies will be introduced, such as local treatment of CSO's with, for example, Densadeg and Actiflow (EPRI, 1999 and Plum et al., 1998). These technologies become more and more high tech which means that additional process parameters will be registered. New parameters can be easily added to the list of Table 1. The only requirement is that the registration remains uniform.

	pumping station	pressure main	sedimentation/storage tank	(adjustable) orifice/valve	vortex regulator	grit removal	sand trap	primary clarifier	aeration tank	secondary clarifier
water level	S		S	S	S					
flow	O	O	O	S	O	O	S	S	S	S
pressure	O	O								
energy consumption	S									
operation time	S									
on/off switches	S		S							
position regulator				O						
grit production						S				
sand production							S			
primary sludge production								S		
O2									S	
energy aeration									S	
chemical dosing									S	
NH4									S	
NOX									S	
P									S	
activated sludge MLSS									S	
SVI									S	
T									S	
pH									S	
secondary sludge production										S
sludge level										O

Table 1. Process data SUF-SAS (S = standard, O = optional)

4 CONCLUSIONS

The objective of this paper is to describe a uniform registration format for failures of wastewater systems. Qualitative risk analysis has been applied in order to select the required process parameters. The selection procedure is based on a combination of identified failure mechanism and alarm filters of management authorities.

The registration format consists of failure reports and process data. However, only failures indicating that a component is not working, are included. The additional process data are needed to detect partial failure, where the component still functions but at an unacceptable level of performance. In order to test this uniform data format, several case studies will be carried out in practice.

A uniform format for failure data has several advantages. First, it enables co-operation of the different management authorities on the operational level. Data exchange becomes easier and cheaper. Second, a comparison of the performance can be made between different wastewater systems and changes in the performance of system components can be identified more easily. The advantage is that such a benchmark is based on clearly defined operational data. Third, failure data can be used as an explanation for unusual emission measurements at CSOs or WWTPs. This enables operators to improve their maintenance and repair scheme.

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