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DESIGN OF A DECENTRALISED INTELLIGENT NETWORK FOR FIVE WET PIT PUMPING STATIONS

PROJEKTOWANIE ZDECENTRALIZOWANEJ INTELLIGENTNEJ SIECI PIĘCIU PRZEPOMPOWNI MOKRYCH

Abstract

This paper presents a design for a decentralised intelligent network of five wet pit pumping stations in a rural area. This enables the network to automatically respond to inflow conditions divergent to the base flow and use the storage capacity of the system to prevent sewer overflows. First results for the base flow and a simulation of the network in EPANET are presented.

Keywords: base flow of wastewater, intelligent network, wet pit

Streszczenie

W artykule przedstawiono projekt zdecentralizowanej inteligentnej sieci pięciu przepompowni mokrych położonych w obszarze wiejskim. Sieć umożliwia automatyczną reakcję w warunkach przyływu przekraczających wartość przyjętego natężenia przepływu ścieków, a jej pojemność magazynowa pozwala zapobiec przelewaniu się ścieków. Przedstawiono także pierwsze wyniki dotyczące natężenia przepływu ścieków oraz model sieci w EPANET.

Słowa kluczowe: natężenie przepływu ścieków, inteligentna sieć, przepompownia mokra

1. Introduction

Wastewater infrastructure for rural areas is characterized by extensive pipe length and, due to small populations, small volumes of sewage. To run a wastewater network economically, the wastewater utilities have a big area to operate. This makes the maintenance and monitoring of the system very personnel-intensive.

However, existing wastewater infrastructures are increasingly facing growing demands, especially in rural areas. While large amounts of runoff during heavy rain events cause existing wastewater systems to exceed their limits, the systems are underused in dry weather. This leads to unequal system requirements.

By using remote control technology for hydraulic monitoring, control and regulation of rainwater tanks and the use of dynamic controls to exploit existing retention volumes in sewer systems, an increase in operational reliability can be achieved.

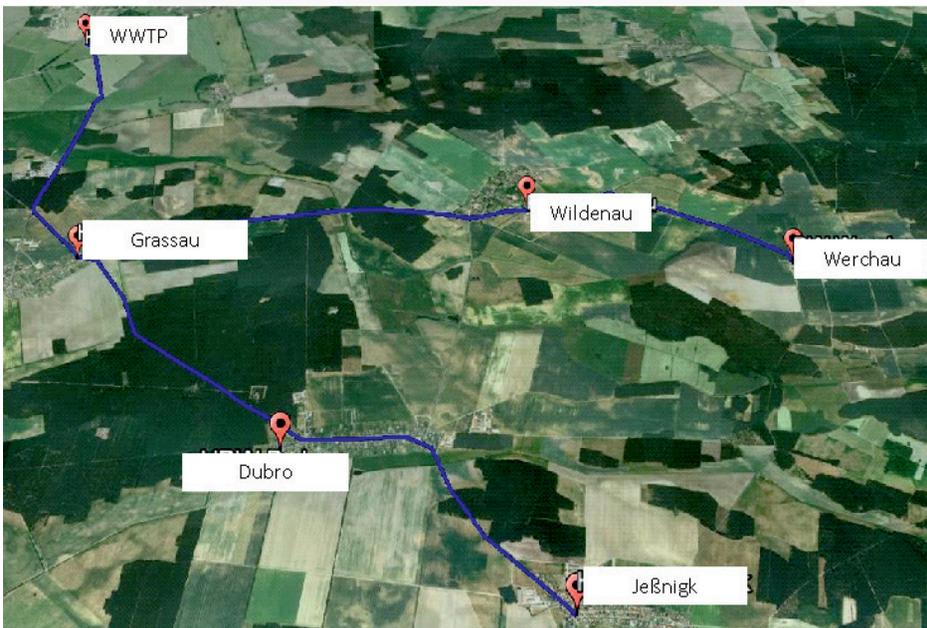


Fig. 1. Scheme of the wet pit pumping station network Grassau, displaying all five wet pit pumping stations and their relative positions to each other

The purpose of this research project was to prevent sewer overflow events of a wet pit pumping station (see Fig. 1, Grassau) located in the middle of a small village in a rural area. Therefore a decentralized, remote controlled network based upon the current operating condition of each wet pit of the system was installed.

2. Methods

In order to optimize the network and increase the operational reliability, an exact knowledge of the system is required. Also for the simulation in EPANET the hydraulic parameters of the system are needed. Besides, an inventory is also needed to identify unused retention volumes of the network.

2.1. Determination of characteristic curves

The characteristic curves of the pumps installed are later used to calculate the baseflow of wastewater in the system. They are also required to determine the operating point and to assess the performance or wear of the pumps since they are partially older than ten years.

To determine the characteristic curve, a mobile test stand was designed (see Fig. 2) and all ten pumps of the system were measured.

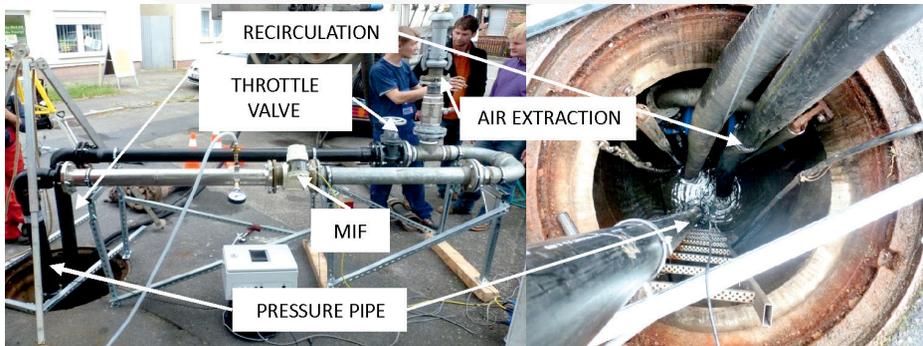


Fig. 2. Mobile test rig for determination of characteristic curve, in the case shown at wet pit pumping station Jeßnigk

The test rig allows to measurements of the pressure, the flow and the electric power consumption of the pump tested on the basis of ISO EN DIN 9906 [1]. Due to air pockets in the piping, a connection for a suction vehicle is needed to extract the air from the measuring section. The pressure sensor is installed directly at the water level of the pit at the discharge line of the pump.

2.2. Simulation of the network with EPANET

To simulate different scenarios of inflow and stormwater infiltration and the response of the system, the network was modelled in EPANET (see Fig. 3).

The network overview clearly shows the composition of the network. The data for the sizes of the wet pits, piping diameters and coordinates for inflow and outflow of every pit were provided by the wastewater network operator. After measuring the characteristic curves of the pumps,

they are implemented in EPANET using a multi-point-curve. Since EPANET cannot calculate open surface flows, every pipe is considered filled, which reduces the system capacity in relation to the real system. Before every pumping station, a knot is inserted which is defined as a source. In this way the dryweather inflow and the stormwater inflow into the wet pit pumping station is simulated. For the dryweather wastewater emergence, wastewater hydrographs are used (see Fig. 4). The stormwater inflow is simulated by a control, based upon probability of heavy rain events, rain intensity, runoff coefficient and the size of the catchment area [2].

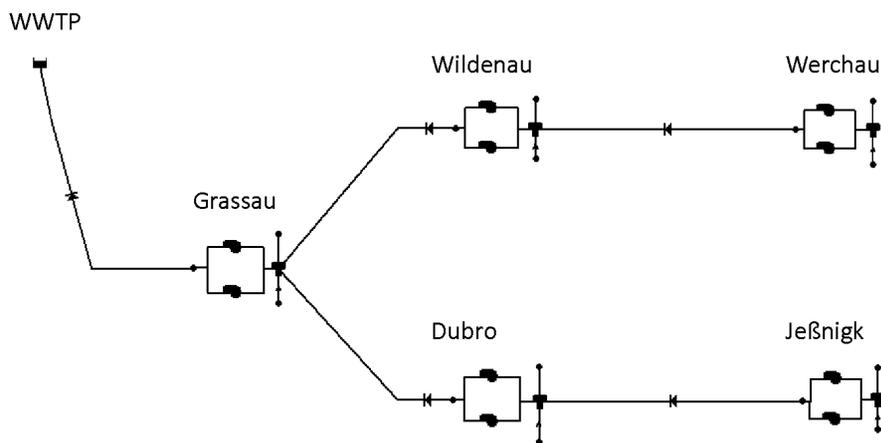


Fig. 3. Network model of the wastewater network

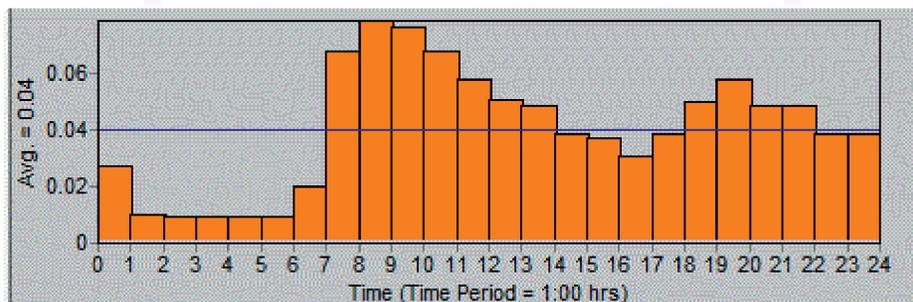


Fig. 4. Hydrograph for wastewater emergence at dryweather

2.3. Design of the decentralized network

For continuous online monitoring, all wet pits are equipped with pressure sensors, power consumption meters and a programmable logic controller (PLC). All signals from the pressure sensors, level meters, power consumption meters, on/off times of the pumps are saved onto a secure digital memory card (SD card) and sent via Email by a GPRS-

module. Since every PLC is equipped with a GPRS-module, data or information can be sent from every wet pit pumping station to the others. The operational reliability is increased by installing a redundancy in the control of the wet pits. If one PLC fails, the wet pit goes back to normal operation triggered by the installed level sensor.

2.4. Development of switching scenarios in dependence of load and flow

Normally, operation of a wet pit pumping station is controlled by a level sensor in the wet pit pumping station. Figure 5 shows the construction of a wet pit pumping station. In normal operation, the level rises up to a certain point. When the start-up level is reached the pump starts operating until the wastewater level falls below the end of operation level. The levels for switching the pumps on/off can be implemented in EPANET.

Normally, the start-up level is below the inflow pipe, but to increase the volume of the system, the limits of the start-up level are shifted up to 10 cm below the highest point of the pressure pipe. This enhances the storage capacity of the whole system (see Table 1). By this means, the overall capacity is nearly eight times bigger.

Table 1. Capacity of the wet pit pumping stations new vs. old control

Wet pit	Old control	New control	
	Volume in [m ³]	Volume in [m ³]	Factor
Grassau	0.94	12.88	13.7
Wildenau	1.26	12.88	10.2
Dubro	1.26	6.53	5.1
Werchau	1.26	9.42	7.4
Jeßnigk	1.88	11.0	5.8
Sum	6.6	52.71	7.98

The main goal of every control of the network is to prevent an overflow of any wet pit pumping station of the network. In the analysed network the wet pit in Grassau is the critical point, since all pumping stations feed this wet pit. In addition, it is also the smallest one.

During normal dry weather base flow, which was determined during long term monitoring of the system, the old levels for putting the pumps in and off operation apply. When there is a higher inflow into one or more wet pits, the levels of pump operation are extended to the ones mentioned above. To prevent an overflow, the wet pits communicate among themselves and exchange information about their levels. The basis of the control is that the upstream wet pit stops pumping into the wet pit downstream which has a strong rise in the level. Also the difference between the levels in the two lines of wet pits feeding Grassau is considered. The line with the least amount of wastewater according to the levels in the wet pits stops pumping to Grassau.

Every pumping station which is not pumping retains the wastewater to the extended level of 10 cm below the highest point of the pressure pipe. When this level is reached, the pumps start operating to prevent an overflow.

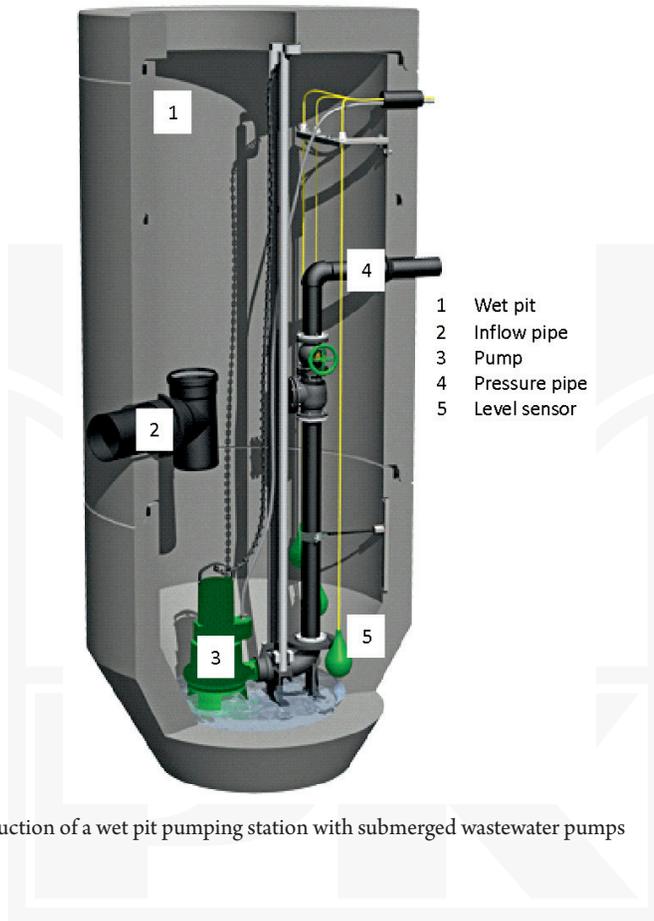


Fig. 5. Construction of a wet pit pumping station with submerged wastewater pumps

3. Results

In the following section the results for the developed switching scenarios, the dry weather base flow and the benefit of the control in dependence of load and flow are shown.

The first step was to determine the characteristic curves of all pumps in order to be able to draw a conclusion about the flow by looking at the pressure delivered by the pump. For redundancy, the monitoring of the electric power consumption, respectively the current draw, provides the same information, see Figure 6.

With this information it is possible to calculate the dry weather base flow of all wet pit pumping stations of the system by multiplying the operational time of every pump with their respective flow due to the determined characteristic curve and the continuous monitoring of the pressure signal. Table 2 shows the dry weather base flow of every wet pit of the system.

Table 2. Dry weather base flow

Wet pit	Inhabitants	Volume of wastewater in [m ³ /day]
Jeßnigk	286	34.56
Dubro	280	16.1
Werchau	144	13.95
Wildenau	182	7.84
Grassau	255	61.48

With these data, the network is simulated in EPANET and the inflow is distributed according to the wastewater hydrograph. Figure 7 shows the pumping intervals of the wet pits for the dry weather base flow during 24 hours.

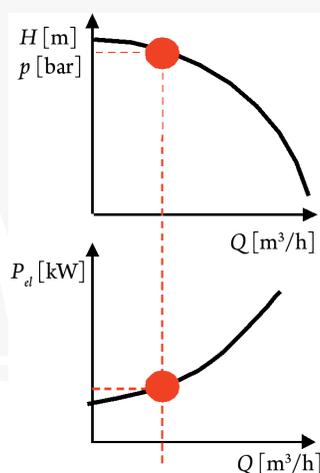
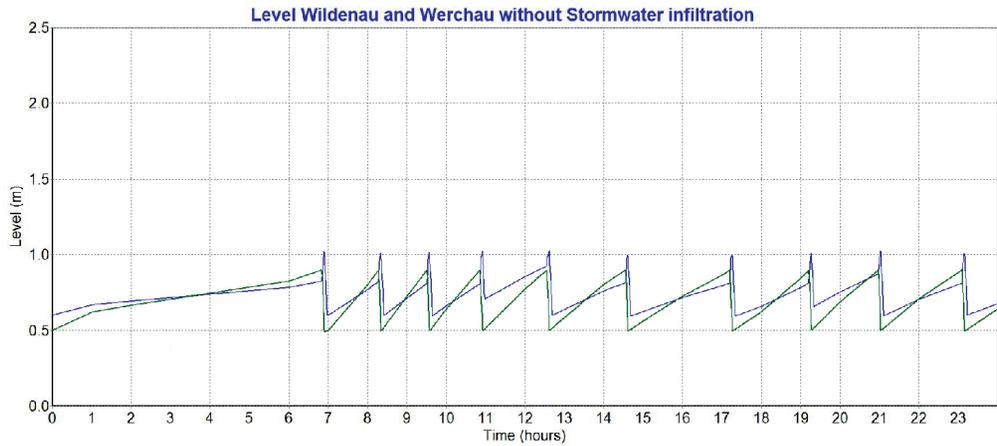


Fig. 6. Flow in dependency of pressure and electric power consumption

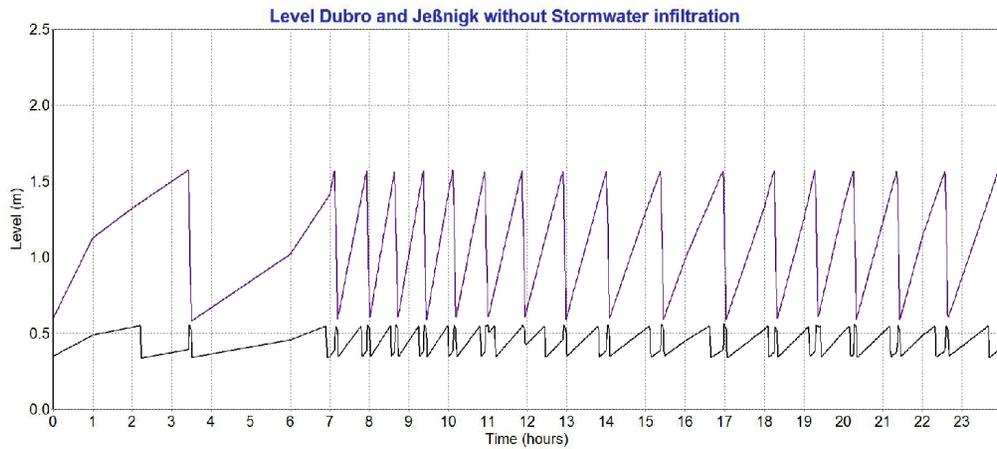
Since Grassau is the end of the line wet pit, the time of pump operation is the highest of all wet pits of the system. EPANET considers the pipes to be fully filled all the time, hence the level in the downstream wet pit increases strongly when the upstream wet pit goes into operation. In reality the pipes are not fully filled, so the peaks with the big gradient do not occur in reality.

Also the different levels of operation of every pumping station can be seen in Figure 7. For example the end of operation level for Werchau is a level of wastewater of 50 cm above the bottom of the wet pit whereas the start-up level is around 80 cm above the bottom.

To investigate the behaviour of the system for an additional inflow of stormwater, several different inflow scenarios have been investigated. Figure 8 shows the simulation of a heavy rain event with an estimated additional inflow of 5 m³/h into every wet pit, starting at 17h o'clock and ending at 19h o'clock.



— Wildenau — Werchau



— Dubro — Jeßnigk

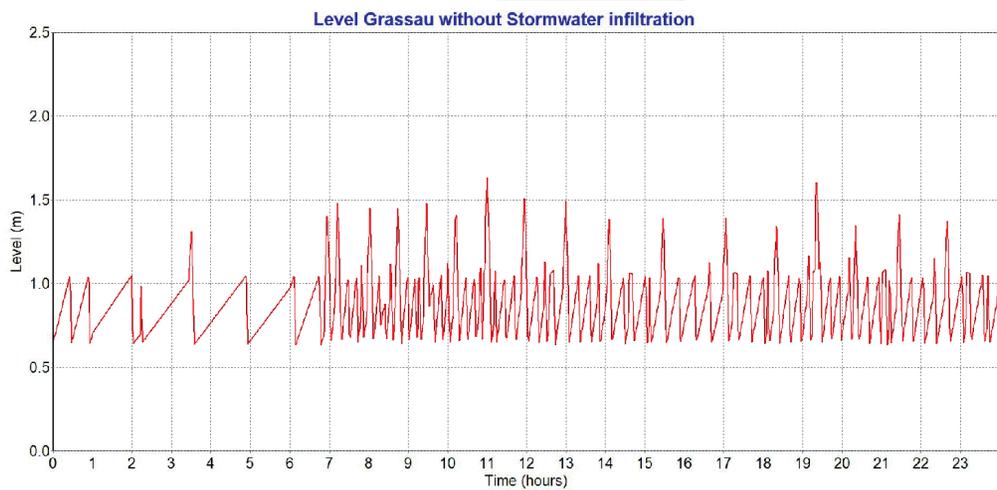


Fig. 7. Pumping intervals of the wet pits throughout one day at dry weather base flow

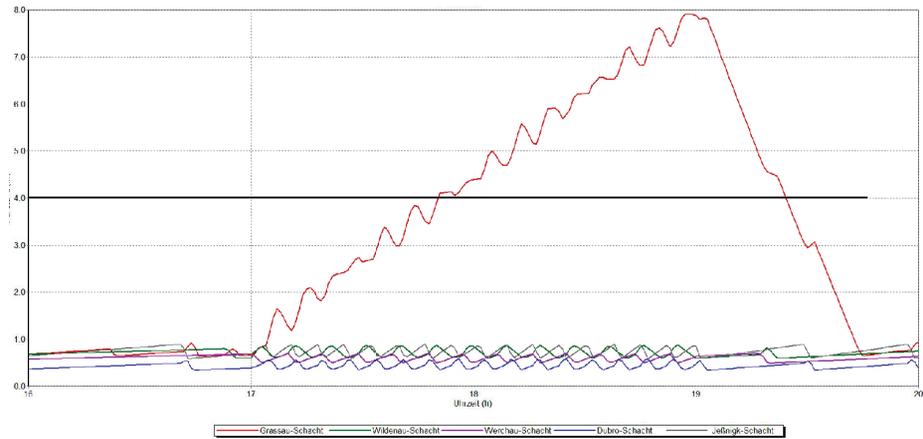


Fig. 8. Pumping intervals of the wet pits throughout one day with stormwater infiltration of 5 m³/h for two hours into every wet pit

The ground level at Grassau is 4.0 m above the bottom of the wet pit. In the simulated case, the wet pit at Grassau would overflow due to the ongoing pumping of the other wet pits. In contrast to Grassau, all the other wet pits would stay in their normal level limits.

Applying the new control and the extended levels of pump operation, the system uses the existing retention volumes and an overflow at Grassau is prevented (see Fig. 9). The wet pit pumping station at Wildenau would show the highest level throughout the time of stormwater infiltration. As mentioned above, the levels are rising in every wet pit and consecutively, the wet pits are restraining their wastewater to support the downstream pit. The first pit which is retaining the wastewater is Werchau at around 17.20 h. The wastewater

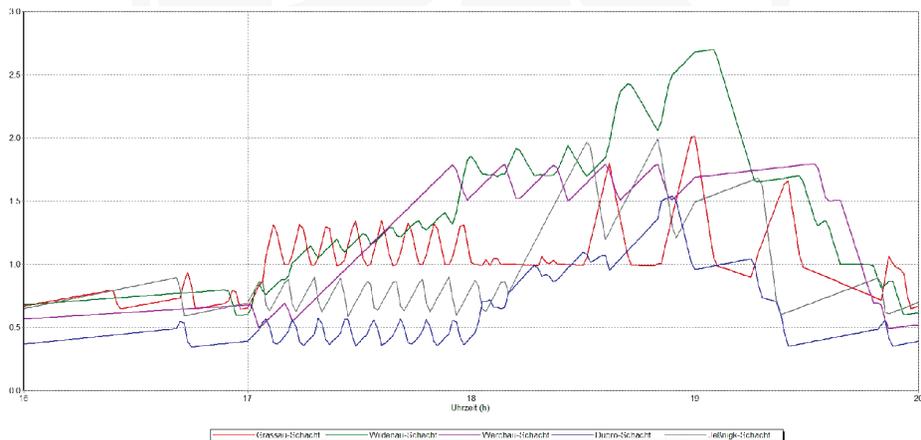


Fig. 9. Pumping intervals of the wet pits throughout one day with stormwater infiltration of 5 m³/h for two hours into every wet pit using the developed control



is accumulated up to 10 cm below the pressurised pipe. When this level is reached, the pumps go back into operation. Theoretically this would go on until all wet pits have reached their critical level and then all the pumps would go into operation. Since Wildenau is the wet pit with the most retention volume, it is the last one to go back into operation.

For the simulated event of an infiltration of 5 m³/h and using the developed control, the level of no wet pit pumping station in the system would be higher than the height of the pressurised pipe. The overflow of Grassau would be prevented.

References

- [1] DIN EN ISO 9906: *Rotodynamic pumps – Hydraulic performance acceptance tests*, International Organisation for Standardisation, Geneva, Switzerland 2012
- [2] Gujer W., *Siedlungswasserwirtschaft*, Springer-Verlag Berlin Heidelberg, 2007.

