Wastewater disposal concept with pressure pipe management and condition-based cleaning strategy

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Summary

A T rink and wastewater association whose disposal system was divided into two areas by a massive mountain range had a holistic, sustainable wastewater disposal concept developed for the entire catchment area. This provided for the conversion of a sewage treatment plant into a pumping station and the construction of new wastewater pressure pipes as a two-line system with flexible delivery options to a central sewage treatment plant. With the introduction and ongoing optimization of a largely automated pressure pipe management system and condition-based cleaning of the pressure pipe network using impulse flushing, a well-thought-out wastewater disposal concept has been created that will enable the association to position itself securely for the future .

Keywords: drainage systems, pressure pipe system, management, optimization, cleaning, impulse flushing process

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Abstract

A wastewater management plan with pressure pipeline management and a condition-based cleaning strategy

A drinking water and wastewater association whose waste management system was divided into two areas because of a moun- tain range commissioned a holistic, forward-looking wastewater management plan for its entire catchment area. This plan provides for turning a sewage treatment facility into a pumping station and installing new pressurized wastewater pipes as a twin system with flexible support options to create a centralized sewage treatment plant. The introduction and ongoing optimi- sation of a largely automated pressurized pipeline management system and condition-based cleaning of this network using a pulse rinsing technique create a well-designed wastewater man- agement strategy that successfully puts the association in good stead for the future.

Key Words: drainage systems, pressurized pipeline system, manage ment, optimization, cleaning, pulse rising technique

Initial situation

The T rink und Abwasserverband Bad Bentheim, Schüttorf, Salzbergen und Emsbüren (TAV) has been operating the wastewater disposal system for the three municipalities of Bad Bentheim, Schüttorf and Salzbergen since 1999. It is located in the south-west of Lower Saxony directly on the Dutch border and has a flat terrain profile apart from a ridge between Bad Bentheim and Gildehaus. However, this massive sandstone ridge towers above the surrounding terrain by around 60 m and divides the rainwater and wastewater disposal system in this area of the association into two disposal areas. This situation was also responsible for the fact that the TAV was still operating four wastewater treatment plants until mid-2016, some of which had to discharge into receiving waters with a low discharge rate.

This situation, the increased requirements for discharge, particularly into the small receiving waters, and the Cost optimization have prompted TAV to develop a holistic, sustainable wastewater disposal concept for the entire TAV catchment area as part of a study and to compare it with the responsible approval authorities and their requirements. The implementation of the concept will end with the final closure of the Salzbergen wastewater treatment plant in 2022.

Objectives of the wastewater disposal concept

At the time the concept was drawn up in 2002, TAV was still operating four wastewater treatment plants, the characteristic figures of which are summarized in Table 1 together with the basic data of the connected sewer networks.

The declared aim of the wastewater disposal concept was to close the Gildehaus and Salzbergen wastewater treatment plants and

	Waste water network			Sewage treatment plant		
	gravity sewer network [km]	Number of pumping stations	Pressure pipe network [km]	Expansion size [PE]	Design inflow [m³/d]	Peak inflow [m³/h]
Guildhall	37	13	19	8000	990	205
Bad Bentheim	54	16	10	18 000	2200	290
southern part	-	-	-	-	1430	200
northern part	-	-	-	-	770	90
Schüttorf	73	24	19	48 300	4670	455
Salzbergen	42	18	15	9000	1440	180

Table 1: Characteristics of the four wastewater treatment plants and connected sewer networks (as of 2002)

to relieve the Bentheim wastewater treatment plant, which discharges into a receiving water that is worthy of protection. It was decided not to close the Bad Bentheim sewage treatment plant completely, as the topography of the drainage area would otherwise have resulted in disproportionately high conversion costs.

Before the aforementioned measures could be implemented, however, the Schüttorf wastewater treatment plant first had to be upgraded to handle the wastewater from Gildehaus and Bad Bentheim. This required an expansion and optimization of the process, construction and plant technology. Following the completion of these construction measures in 2009, first the northern drainage areas of Bentheim and then the Gildehaus association area were connected to the Schüttorf wastewater treatment plant between 2010 and 2016.

With the connection of the Salzbergen drainage area to the Schüttorf wastewater treatment plant, which is currently being planned, the centralization process will be completed in 2022 and the wastewater concept will be implemented.

Basic technical features

Due to the existing boundary conditions:

- long distances between the individual wastewater treatment plants (up to 15 km)
- Challenging topography in the Bad Bentheim and Gildehaus area
- Various industrial wastewater dischargers across the association area
- Positive wastewater generation trend with increasing wastewater volume
- Wastewater regulations of the responsible authorities

the wastewater is transported between the individual wastewater collection points via two pressure pipes laid in parallel. The nominal diameter of one pressure pipe line is designed for the relevant dry weather volume and the shortest possible residence times in order to minimize odour formation and maintain minimum flow velocities. The second pipe section is responsible for transporting wastewater in the event of increased wastewater volumes with less polluted wastewater. In order to avoid constant switching between the two pipelines and to equalize the wastewater flow to the Schüttorf central sewage treatment plant, correspondingly large storage volumes were built at the relevant collection pumping stations. The design described above also makes it possible to react flexibly to future increases or fluctuations in wastewater volumes.

Figure 1 shows the entire pressure pipe network of the TAV with its nominal diameters and lengths. Figure 2 shows the possible flow rate ranges and the average daily flow rates. As can be seen from these figures, the pressure pipeline between the "Am Beschlag" pumping station and the main pumping station "Im Hach" is only designed as a single-section pipeline, contrary to the explanations above. This pipeline is capable of conveying all of the wastewater produced in the northern drainage area to the Schüttorf sewage treatment plant. If necessary, i.e. in the event of an excessively high volume of wastewater, malfunctions in the pressure pipeline system or overloading of the Schüttorf sewage treatment plant, a variable proportion of the wastewater generated in the northern area can be transported to the Schüttorf sewage treatment plant.

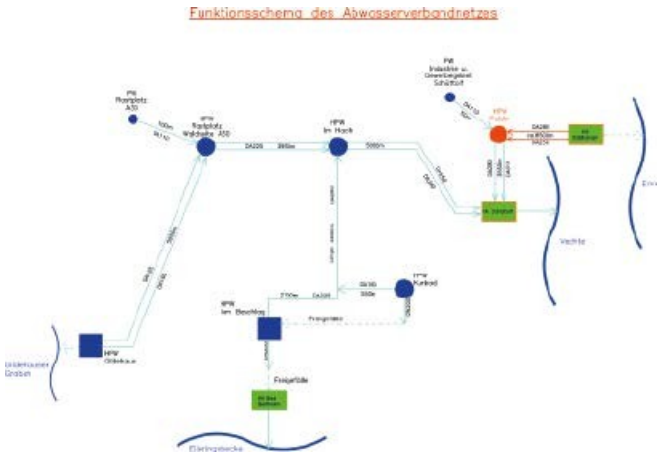


Fig. 1: Nominal widths and lengths of the entire TAV wastewater network

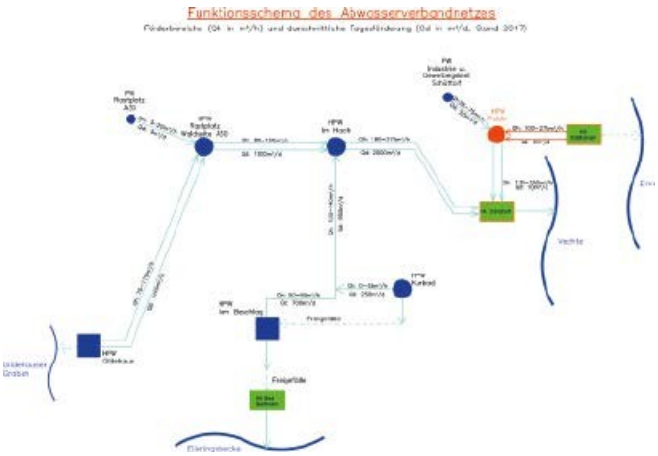


Fig. 2: Pumping areas and average daily volumes in the TAV wastewater network

The wastewater can also be conveyed to the Bentheim sewage treatment plant via existing pipelines. This means that there is also a "two-tier system with flexible conveying options" for the lower pressure pipeline section.

Problem definition - deposit formation and cleaning requirements

Following the commissioning of the pressure pipeline connection between the former Gildehaus sewage treatment plant and the Schüttorf sewage treatment plant at the beginning of 2016, the pressure pipeline system between Gildehaus, the northern part of Bad Bentheim and the Schüttorf sewage treatment plant was operated largely without any problems until the end of 2018, apart from the usual shortcomings (blockages in the pumps, etc.). The overriding operating objective was to feed the wastewater volume from this area of the association to the Schüttorf sewage treatment plant as evenly as possible, as there were no volume balancing options available at the Schüttorf sewage treatment plant site at this time, but there were at the main pumping stations in Gildehaus and Bentheim. For this reason, the pump flow rates of the relevant pumping stations were regulated to as constant a flow rate as possible by means of frequency converters and suitable control.

At the end of 2018, however, an inspection of the pumping station technology revealed that although the preset target delivery rates were being achieved by the pump technology and control system used, the maximum delivery rates, which should be well above the set target delivery rates, were no longer being achieved. Further analysis of the causes revealed that the pressure loss in the pressure piping system had increased significantly and it was therefore to be feared that the individual pipelines would slowly but permanently become clogged.

The following circumstances can be named as possible causes for clogging of the pipes:

- large quantities of sand washed into the Gildehaus sewer system due to the topography and a few very heavy rain events
- Gradual completion and commissioning of the pressure pipeline system, resulting in lower wastewater volumes and lower flow velocities in the pipelines
- Delayed detection of the beginning clogging of the pressure pipe lines due to the comparative driving style
- Delayed commissioning of the higher-level control/process control system with which the penstock system should be monitored and controlled (single or parallel operation of the double penstocks, reaction to rain events, compliance with minimum flow velocities, etc.).

However, before the elimination of the aforementioned possible causes could begin, it was absolutely necessary to restore the design flow rates in order to ensure wastewater discharge operation. Thorough flushing and cleaning of the penstock operation was therefore urgently required. The Comprex pulse flushing process from Hammann was chosen as the cleaning method.

The pulse rinsing process

There are basically several methods available for the effective cleaning of wastewater pressure pipes [1], with pigging or a special impulse flushing method being the obvious choice.

Pigging campaigns are associated with considerable expense. First of all, structural measures are required, as pig traps have to be installed. In many cases, it is also not possible to clean the wastewater pressure pipes during operation. Therefore, depending on

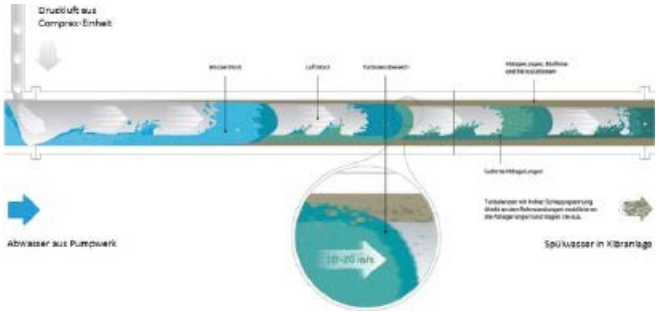
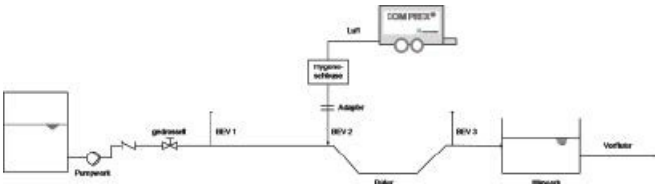


Fig. 3: Scheme of cleaning by means of impulse flushing of wastewater pressure pipes



(BEV: air release valve)

Fig. 4: Cleaning a culvert in a wastewater pressure pipe using the impulse flushing method

Depending on the local conditions, it may be necessary to retain wastewater using several suction and flushing vehicles. Personnel must be provided at several points for the measures. Furthermore, considerable quantities of water are required to move the pig. The risk of pigs getting stuck cannot be ruled out, meaning that civil engineering companies must be provided or kept available for the duration of the operation.

In the impulse flushing process used here, wastewater accumulated upstream of the pumping station is used as a cleaning medium together with compressed air. The wastewater flows slowly through a gate valve into the pipe section to be cleaned. The compressed air comes from a self-sufficient mobile unit, which also contains software for controlling the compressed air metering. Adapters connect the compressed air lines to the wastewater pressure line section (Figure 3). During cleaning, water and air blocks form in the cleaning section of the pipe. They move through the pipe at speeds of more than 15 m/s. The innovative control system modulates the water and air blocks in such a way that, on the one hand, high entrainment voltages are achieved to mobilize the deposits and, on the other hand, the mobilized particles are completely and reliably discharged.

This impulse flushing process works on wastewater pressure pipes during operation with accumulated wastewater without having to take the wastewater pressure pipes out of operation and empty them. The process can be used to clean pipes up to DN 1200. The impulse flushing technology

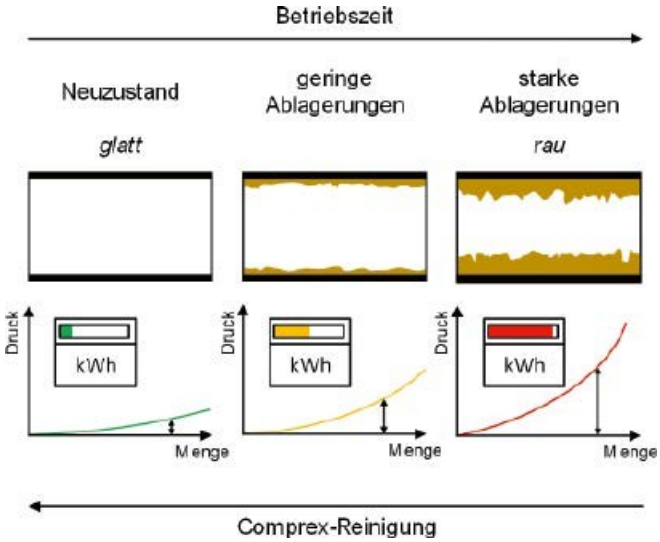


Fig. 5: Relationship between deposits in pipes and energy for wastewater transport

nik can be used in a mobile and targeted manner on individual pipe sections. This makes it possible to intensively clean critical areas, such as culverts, in order to reliably remove even large particles such as stones (Figure 4). Nominal diameter changes in the wastewater pressure pipes do not affect the cleaning performance. In contrast to pigging, the water and air blocks adapt to the geometry of the pipe and cannot get stuck. Fittings in the pipeline are also cleaned. Due to the cleaning method, it is possible to keep the degree of contamination of the flushing material as constant as possible, so that it can be discharged further without any need for suction and flushing vehicles.

Cleaning by means of impulse flushing - hydraulic aspect

Deposits impair the hydraulics of pipelines. The energy required to transport the water and thus the power requirements of the pumps increase when the cross-section of the pipeline narrows. Figure 5 explains the relationships.

The pipe characteristics provide information about the condition of the pipe. This information is quite easy to determine if pressure gauges and flow rate measurements, for example magnetic inductive (MID), are available. Figure 6 illustrates the hydraulic conditions based on pipelines.

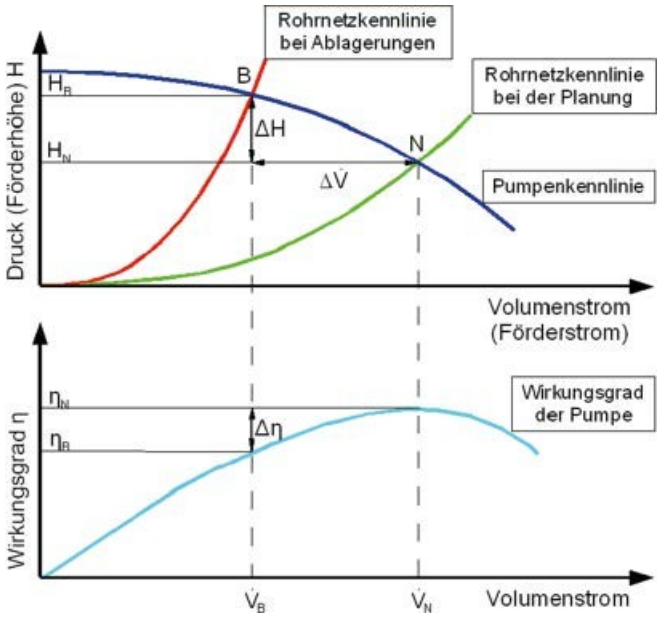


Fig. 6: Relationship between piping characteristic, characteristic curve and pump efficiency

characteristic curves. Worksheet DWAA 113 also deals with this [2].

As can be seen in Figure 6, the delivery pressure increases as the cross-section of the pipe narrows due to deposits. At the same time, the volume flow (flow rate) decreases. The efficiency of the pump also decreases. Decreasing volume flow (flow rate) means longer pumping times for the same volume or quantity of water. Cleaning improves the hydraulic condition of the piping. In the case of pipes with deposits, the pumping times are subsequently reduced as a result of cleaning. The costs for cleaning often pay for themselves after just a few months.

Condition-based maintenance and cleaning using pulse flushing

On the basis of legal regulations, the rules of technology, the condition of the pipe network and its operating conditions, the assurance of long-term economic efficiency and consideration of environmental compatibility, supply and disposal companies formulate maintenance targets and develop a corresponding maintenance strategy [3, 4].

The generic term maintenance is defined in DIN 31051 and includes measures to preserve and restore the functionality of a system and to determine and assess its current condition [5]. This is further subdivided into inspection, maintenance and repair. Regular or event-driven flushing and cleaning measures make an important contribution in the area of maintenance.

In the relevant specialist literature, maintenance strategies are divided into

- Preventive maintenance ("preventive strategy")
- Failure-related maintenance ("failure strategy")
- condition-based maintenance ("inspection strategy").

The preventive strategy is considered impossible and also uneconomical for supply and disposal companies in terms of the security of supply and disposal that must be guaranteed.

The failure strategy, on the other hand, reacts to damage that has occurred or to external events and measures and is therefore not a real strategy, but rather an outdated repair mentality. It is characterized by high downtime costs and risks due to unforeseen operational interruptions and acting under time pressure [4]. The inspection strategy considers the components of monitoring, maintenance and repair in conjunction. It is based on the determined actual condition and the development trends of the systems in comparison to a defined target condition and is therefore the strategy of choice for a Supply and disposal companies with the main objectives of

- Long-term profitability
- High availability and reliability
- Plannability of measures
- Environmental compatibility.

Accordingly, flushing and cleaning measures must also be carried out in a condition-oriented manner as part of maintenance. The cleaning measures are thus always carried out within a scope that is optimized with regard to safety and economic efficiency. Figures 7, 8, 9 and 10 illustrate the relationships for pressure pipelines with regard to deposit formation and cleaning.

Condition-based cleaning of wastewater pressure pipes ensures economical cleaning while maintaining the same level of quality.

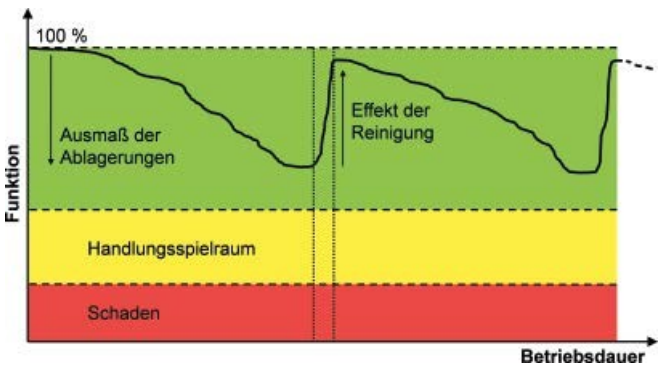


Fig. 7: Cleaning measures according to preventive strategy

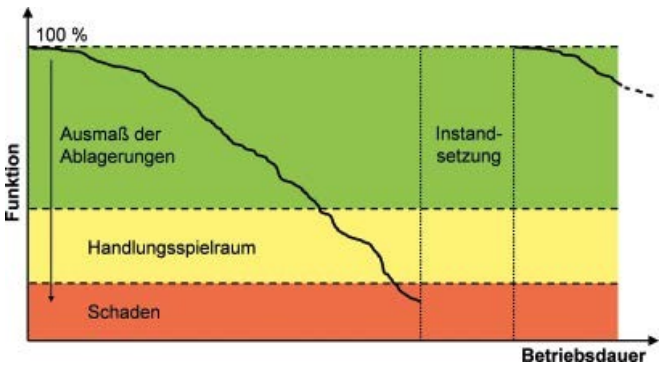


Fig. 8: Cleaning measures according to failure strategy

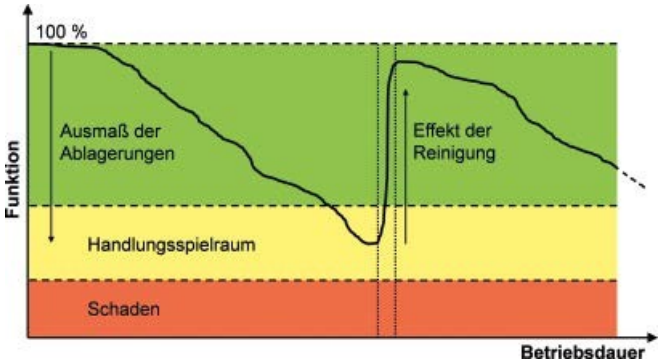


Fig. 9: Cleaning measures according to inspection strategy

operational safety is achieved. Together with the pressure pipeline management, this will effectively support the wastewater disposal concept of TAV Schüttorf in the future.

The impulse flushing process in use at TAV Schüttorf

TAV Schüttorf had already had wastewater pressure pipes cleaned using the impulse flushing method in 2016, 2017 and 2018. The process proved to be advantageous in terms of both process engineering and economic efficiency. For this reason, the TAV decided to have a basic cleaning of the wastewater pressure pipes carried out using the process in 2019 as part of the implementation of the described pressure pipe concept.

A total of five wastewater pressure pipes in the wastewater network were cleaned, starting from the districts of Gildehaus and Bad Bentheim to the Schüttorf wastewater treatment plant. The pipes are made of PEHD material and have nominal diameters of DN 125 to DN 250.

- HPW Gildehaus to HPW Rastplatz Waldseite A 30
- HPW Rest area Waldseite A 30 to HPW Im Hach
- HPW Im Hach to the Schüttorf *wastewater treatment plant*

the pipelines are designed as parallel double lines, as explained above. At the beginning of the cleaning

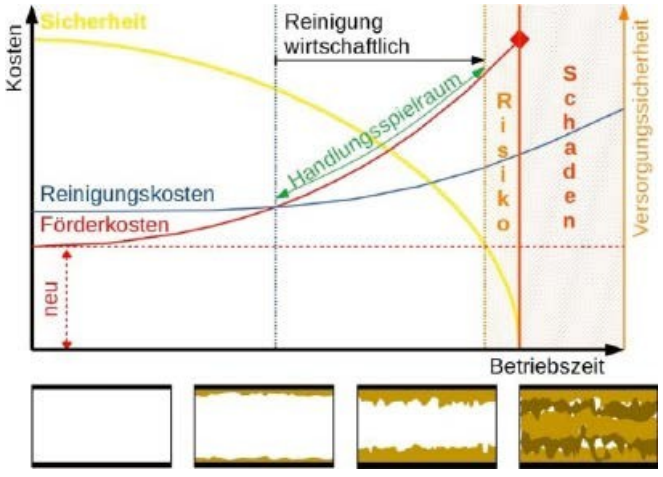


Fig. 10: Scope for action in the inspection strategy

In some cases, the pumping capacity was reduced by up to two thirds during the cleaning work. Sealing skin and deposits were removed, which, as expected, had a high sand content. The length of the cleaning sections was between 1000 and 5000 meters. During this operation, a pulse flushing unit manned by one technician cleaned a total of around 36 kilometers of wastewater pressure pipes over a total of 39 working days between 18 February 2019 and 11 April 2019. The success of the individual sections during cleaning was checked visually and on the basis of the deposits removed. The work was supported by a "pilot" provided by the TAV.

Result of the pressure pipe flushing

During the operation in spring 2019, large quantities of deposits were removed from the TAV pipelines: for example, around 6 m³ of sand was mobilized from an approx. 5,000-metre-long section with a nominal diameter of DN 150 alone. After the operation, the flow rates were comparable to those when new, which now enables efficient pump operation again. Overall, performance and disposal reliability were restored in line with the wastewater concept. The results of the operation are shown in Table 2 as an overview.

Further outlook

Experience with the operation of the pressure pipeline system has shown that, especially during heavy rainfall events - due to the existing topography - considerable quantities of water can be produced.

Line section	Q Design [m3/h]	Q before [m3/h]	Q after [m3/h]	Increase [m3/h]	Cleaning success [%]
HPW Gildehaus - HPW Rest area forest side	75-110	75	110	35	100
HPW Rest area Waldseite - HPW Im Hach	80-130	80	125	45	96
HPW Am Beschlag - HPW Im Hach	100-140	90	125	35	89
HPW Im Hach - *KA* Schüttorf	80-270	180	250	70	93

Table 2: Characteristics of the individual pipe sections before and after flushing

of heavy materials enter the pressure pipe system. With the current mode of operation, these heavy materials form deposits that cause a relevant reduction in the maximum pumping capacity in the long term. Since structural measures such as

- Changing the surface profile at particularly relevant terrain transitions
- Creation of sand retention areas and devices

Since the amount of heavy materials that can be discharged into the sewer network can only be reduced to a limited extent, the optimization of wastewater transport by means of suitable wastewater management is of particular importance.

As part of this optimized wastewater management, the first step is to adapt the pumping station control and process control technology, such as

- Specification of higher minimum flow velocities in the individual pipe sections
- Priority for single-line operation even with higher wastewater volumes
- Introduction of flushing cycles with buffered diluted mixed water
- Optimized monitoring of pump operation (e.g. by using additional pressure sensors) to detect loss of delivery capacity at an early stage

the transport of heavy materials should be optimized in order to avoid clogging of the penstock system or to delay it as long as possible. As it can be assumed that the above-mentioned measures will not be able to completely prevent heavy material deposits, a suitable penstock flushing program will be developed in a second step using the condition-based impulse flushing cleaning process. The aim is to have generated a penstock management system at the end of this optimization process that enables safe penstock operation in t h e long term.

Summary

TAV Schüttorf's wastewater disposal concept is on the home straight in terms of its implementation. With the conversion of the Gildenhaus sewage treatment plant into a pumping station and the new construction of the wastewater pressure pipes as a two-line system with flexible conveying options, a modern pressure pipeline system for transporting wastewater to the central sewage treatment plant has been realized.

With the introduction and ongoing optimization of a largely automated pressure pipe management system and condition-based cleaning of the pressure pipe network using the pulse flushing method, a well-thought-out wastewater disposal concept has been created that will ensure that TAV Schüttorf is fit for the future.

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