“MIC-Performance-Test”

Test procedure to assess the resistance of construction materials in wastewater facilities against microbially induced sulfuric acid corrosion (MIC)

Test procedure in large-scale to assess the durability of construction materials under real and particularly critical conditions in wastewater facilities (Biogenic sulfuric acid corrosion, BSA)

BACKGROUND

About one-fifth of the approximately 575,000 km long public sewer systems in Germany have damages that must be repaired in the short or medium term. A large amount of the damage is due to biogenic sulfuric acid corrosion (BSA) with a combined organic-chemical attack. The selection of suitable construction materials, depending on the respective stress scenarios, is particularly important. However descriptive building material models often reach their limits. Especially models where the performance of the product must be proven for maximum stress scenarios and life expectancy of up to 100 years.

The following figure shows damage to a selection of construction materials observed during simulations in laboratories under technical wastewater stress.

A

B

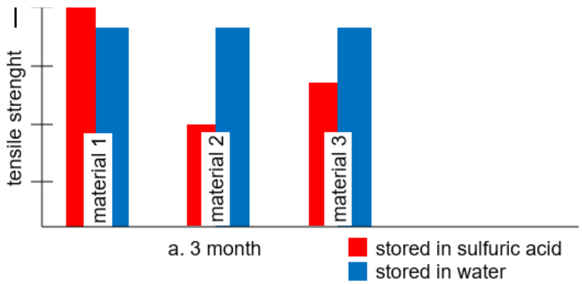
C

***Fig. 1:** Corrosion examples on concrete when stored in sulfuric acid:*

When using insoluble aggregate only the cement stone erodes (see A + B).

C shows examples of UHPCs (here pH: 2.5).

***Fig. 2:** Examples of corrosion after the storage of polymers in sulfuric acid: tensile strength of the material is an essential indicator of the corrosion process, as well as the possible occurrence of brittleness with the peeling off the coating (here pH: 1)*



The resistance performance and durability of construction materials against the above-mentioned stress in the area of BSA can be evaluated by a variety of test methods. The materials usually undergo long-term and time-lapse tests in sulfuric acid with different pH values as well as other test scenarios. These tests are partially regulated by normative standards. The evaluation criteria are determined depending on the material and the test procedure used.

Our “MPA-Performance-Test” was used for a realistic assessment of the concrete for the Emscher-project, the largest wastewater facility construction project in Europe in the past decade (calculated life expectancy of 120 years). This best practice procedure was later used in many similar construction projects and applications in the field of wastewater technology. In course of these projects, probabilistic lifetime models are also being developed.

A NEW POSSIBILITY: “MIC-Performance-Test” (in pilot phase called “ODOCO Pilot Plant”)

General

The "MIC-Performance-Test" offers the possibility of testing with real wastewater under controlled conditions in large-scale. In addition to the studies of the material resistance and the associated qualification of the biofilm under wastewater stress, investigations to prevent odour are also carried out on the plant. The plant is in a former pumping station of the *Berliner Wasserbetriebe*. It has been operating continuously since April 2010 and can be adapted to specific test conditions. In recent months the plant has been modernized and expanded with more possible applications. The "MIC-Performance-Test" is used for the evaluation of construction materials in large-scale projects (such as the Deep Tunnel Sewerage System DTSS II, Singapore), but different institutions such as the *Berlin Wasserbetriebe* use the results as evaluation criteria for their materials as well.

The advantages of the technicum

With the help of the "MIC-Performance-Test" (in pilot phase called “ODOCO Pilot Plant”) we can make a meaningful prediction about the lifespan of building materials. This enables repair work to be reliably planned in the long run and downtime costs to be reduced. Compared to other test methods, the "MIC-Performance-Test" offers the following advantages:

- The tests are carried out under real conditions on a large-scale. The data (e.g., the "drivers" of the harmful BSA, such as temperature, humidity, H_2S content) is registered and controlled by extensive monitoring.
- The interaction between microorganism and the building material, which influences the growth of bacteria and the degree of damage, is tested under real conditions. Microbially induced sulfuric acid corrosion (MIC) may produce different results, based on the materials being tested, then simulations in which materials are stored in acid baths.
- The temperature, humidity and H_2S concentration are adjustable in such a way that different attack levels (time-lapse effects) can simulate.

How does the "MIC-Performance-Test" work?

Berlin´s wastewater is continuously pumped out of the sewer network and heated to approximately 30°C with heat exchangers. Using an overflow system, the wastewater is transferred across a 200 m long fermenter. The wastewater is then pass through several gravity pipes (each 25 m, DN 400) into a reaction tank with sample holders (sample storage tank). Here, it flows down cascade-like reducing the H_2S content of the wastewater (see figure 5).

The result is perfect conditions in the gas chamber above the cascade, in which the material is stored for the formation of sulfuric acid on the sample surfaces. The growth of relevant bacterial cultures is specifically guided by this environment and corresponds to the critical scenarios in practice.

Samples of any kind can be stored in the system, even the installation of entire pipe segments is possible.

The system is calibrated for the first trial of a new project in such a way that a constant H_2S concentration of 100 ppm is ensured in the gas phase at approx. 30°C / 100% relative humidity. In addition, the pH level on the surfaces of the samples, the temperature and the biofilms are constantly analysed. All relevant parameters of the wastewater, such as COD (measurable via UV absorption), redox potential, conductivity, H_2S concentration and pH level are gathered by sensors and available through online monitoring.

The holding time in the fermenter, the flow rate, the flow conditions, and the ventilation are controlled automatically by an elaborate pumping technology and other control mechanisms. The wastewater is returned to the public sewage network after passing through the plant.

The following images show schematically the structure of the "MIC-Performance-Test".

Overview of the "MIC-Performance-Test" at the Technical Center in Berlin Neukölln

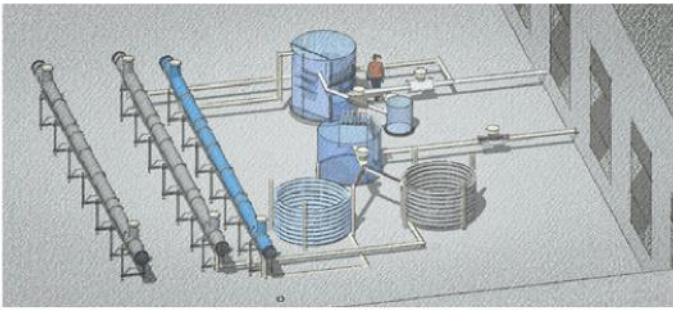


***Fig. 3:** 1 heating basin with heat exchanger | 2 fermenters | 3 free-flow pipe lines | 4 sample storage tank*

In the sample storage tank, which is shown schematically in figure 5, the samples are stored under defined conditions. The microbiological growth (biofilm) on the damp surface of the samples leads to the oxidation of the H_2S to sulfuric acid. This results in a direct chemical attack on the stored building materials.

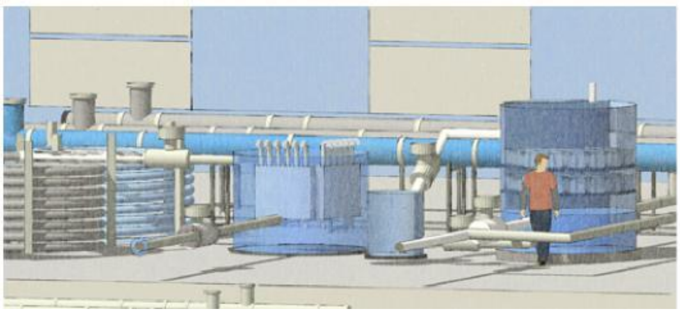


***Fig. 4:** Overview*

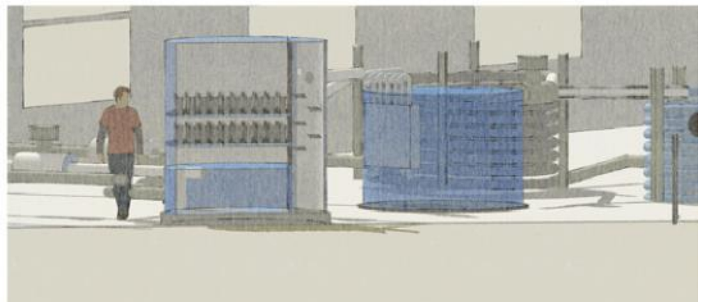


***Fig. 5:** Storage of the test objects above the wastewater (gas phase)*

MINERAL SYSTEMS

Concrete as well as mineral systems in general, which are damaged by the acid, develop two damage fronts over time, which are shown in figure 6. Only through optical microscopy/ polarization microscopy or scanning electron microscopy, an immediate and clear determination of these damage fronts is possible.

This direct determination of the overall damage depth is the most meaningful basis for the evaluation of the planned systems. Sound planning of wastewater plants can be derived based on these results.

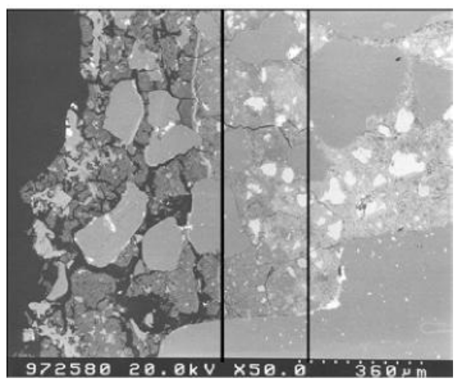


***Fig. 6:** 1st and 2nd damage front, determined on a thin grinding (SEM picture)*

At present, more and more lifespan assessments are required for static and structural systems, as well as systems with protective layers / sacrificial layers (e.g., a facing shell from concrete) as part of the planning process for wastewater systems. These requirements are best met by probabilistic service-lifetime models, taking into account the development of the damage and a defined default probability (Eurocode norm). Only these models can predict the design-service lifetime with sufficient security a defined probability of failure. The results from the "MIC-Performance-Test" can be used for this purpose. A graphical representation of our usual procedure is given in figure 7.

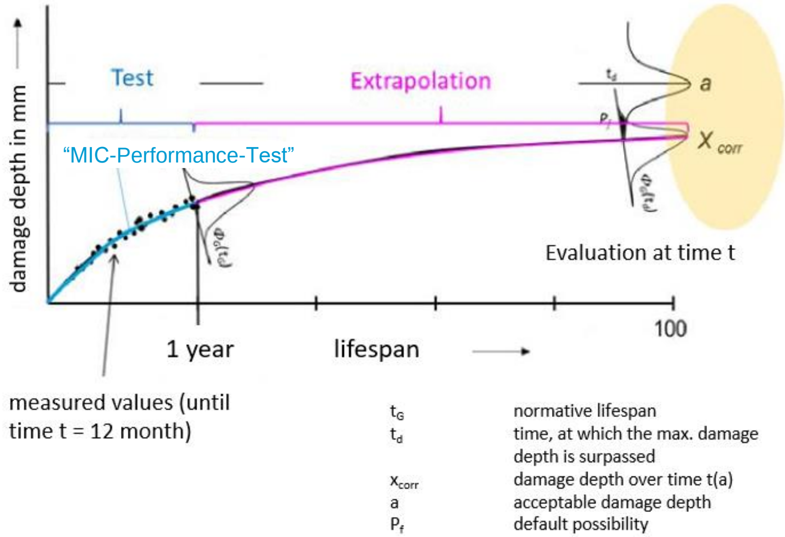


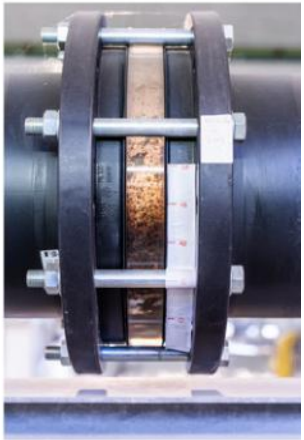
Fig. 7: *Graphic representation of the damage depths up to 1 year Evaluation of the lifespan with a predetermined safety level*

POLYMER-BASED SYSTEMS

Polymer-based systems are also significantly affected by the conditions in wastewater treatment plants. One example would be a significant decrease in strength as well as a change in its deformation behaviour.

We test the reaction of these materials using the “MIC-Performance-Test". The interaction between the attacking material and the different test materials with plastic-coating based on reaction resin leads to a wide variety of damage patterns. Examples can be lack of adhesion, embrittlement, or blistering. Plastic pipes and inliner systems based on HDPE, PP and GFRP also partially show changes in material properties, such as swelling or deformation.

Increased resistance can be demonstrated for specific polymer-based systems under selected critical real conditions in wastewater plants, based on these test results. This makes the comparison between the different systems easier.



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