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# Design of a Digital Twin for stress scenarios of WWTP

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**Abstract:**

Digital twins are used in a wide range of industries. New concepts for this technology are also constantly emerging in the water sector. This study examines the use of digital twins to increase the resilience of critical infrastructure and proposes a possible process scheme for the communication between digital and physical component. Strengthening the resilience of critical infrastructure is particularly important in the context recent crises. To increase resilience, measures must be taken at a structural, organizational and functional level. This research focuses, in particular, on process-related stressors. In order to obtain data for different stress scenarios a pilot wastewater treatment plant was set up at the University of the Bundeswehr (Unibw M). A dynamic model based on the activated sludge model no. 3 (ASM3) is used to simulate the performance of the treatment process. The model has been calibrated with data from normal operating conditions. The model and the pilot plant are connected via an Open Platform Communication (OPC) interface, which allows the exchange of operational data. Starting from this structure a design for a digital twin for fault detection and decision support during stress events is presented.
**Keywords**: Decision support; Digital Twin; Disruption; Resilience

## Introduction

In recent years framework conditions have been created at European level to increase the resilience of critical infrastructures (EU RCE, 2022). For complex systems like WWTP resilience measures need to cover structural, organizational and functional stressors (Pankow et al., 2024). With the digital transformation new possibilities to support operators can be developed. This research investigates DT design for a WWTP supporting operators during stress events in the biological treatment. Therefore, two main goals were identified. The first one, being the establishment of structural draft for a digital twin for the identification of process stress. An activated sludge model (ASM) is used to simulate the process. Simulating stress scenarios requires data deviating from normal operation, that, in the best case, can be clearly attributed to a stressor. However, this data is usually not directly accessible to plants and cannot be recreated at a municipal wastewater treatment plant. For this reason, a pilot WWTP was set up at the University of the German Armed Forces for the construction of such a DT.

## Design of physical component

The plant was designed according to the activated sludge process with upstream denitrification. **Figure 1** shows the plant layout with a population equivalent of 2 PE and a throughput of 300 L/d. The nitrification tank has a volume of 128 L and denitrification 90 L. The plant is equipped with extensive measurement, control and regulation technology according to the state of art with built-in devices from Endress+Hauser, s::can, Hach. Since August 2023, the plant has been operated with wastewater from the university site. The system is monitored by grab samples and composite samples. The laboratory analysis of the university site wastewater showed similarities to composition to municipal wastewater for the primary influent with higher concentrations of ammonium and total suspended solids (see **Table 1**).
In a first phase, data for the normal process operation was collected. In the next phase stress scenarios will be tested. Parameters that are easy to detect or track, such as pH or conductivity, are changed first.

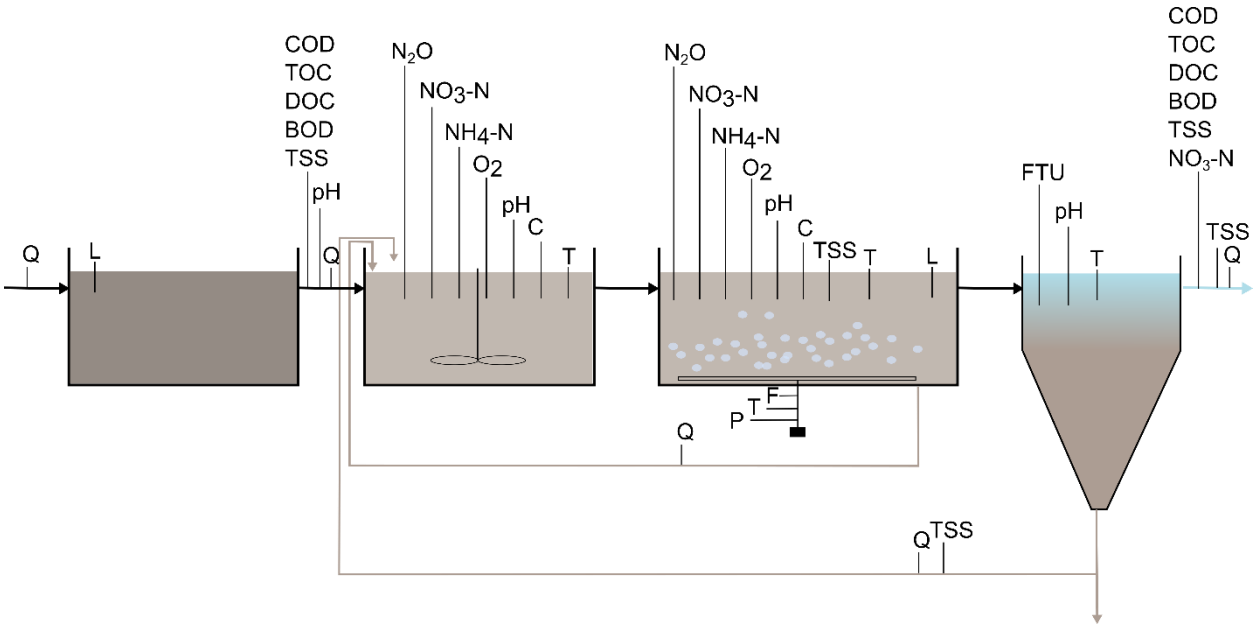


**Figure 1** Pilot plant layout. The added vertical lines indicate the parameters measured

**Table 1** Parameter for primary influent of the pilot plant

| | COD<br>gCOD $m^{-3}$ | TKN<br>gTKN $m^{-3}$ | $NH_4$-N<br>g $NH_4$-N $m^{-3}$ | $P_{total}$<br>g $P_{total}$ $m^{-3}$ | TSS<br>g TSS $m^{-3}$ |
|---|---|---|---|---|---|
| Mean | 370 | 59 | 39 | 8 | 44 |
| Std | 54 | 15 | 10 | 2 | 19 |

## Design of digital component

The digital twin is understood as the virtual image of a physical system. The DT processes the data generated by the physical twin. The data can, for example, be fed into a data analysis or a model. Communication in a DT is bidirectional, i.e. it runs in both directions. However, the implementation of the bidirectional connection can vary. For example, the DT could intervene directly in the control of the system or send the options for action to the personnel. The implementation depends on the objectives in the application of the DT. **Figure 2** shows the process diagram with both described options (manual or automated interference). For now, the system can exchange certain process information on demand via open platform communication (OPC/UA) and a Python script. The Python script controls the data flow and activates the simulation program. The presented design in **Figure 2** would allow a more extensive exchange. The DT's feedback to the PT was of particular interest here. Data must be evaluated in a targeted manner to detect faults in the biological treatment. If a deviation from standard operation parameters is detected it could either be due to a fault in measuring devices of a plant, deviating water composition or a fault in the process technology. Checks of plausibility of data can be used to identify faults in measuring devices. Deviating water composition or a fault in the process technology can have various effects on the WWTP in the worst case leading to a deterioration in process quality. A dynamic simulation can show the predicted impact under changing conditions.

The data gained from the PT is fed to an AS model. The model was designed with the program gPROMS. The Python script communicates with a go:python module by starting the simulation and exchanging values. The model is currently calibrated with data from the normal operation. Model prediction quality was assessed with Mean Absolute Residuals (MAE) and standard deviation.

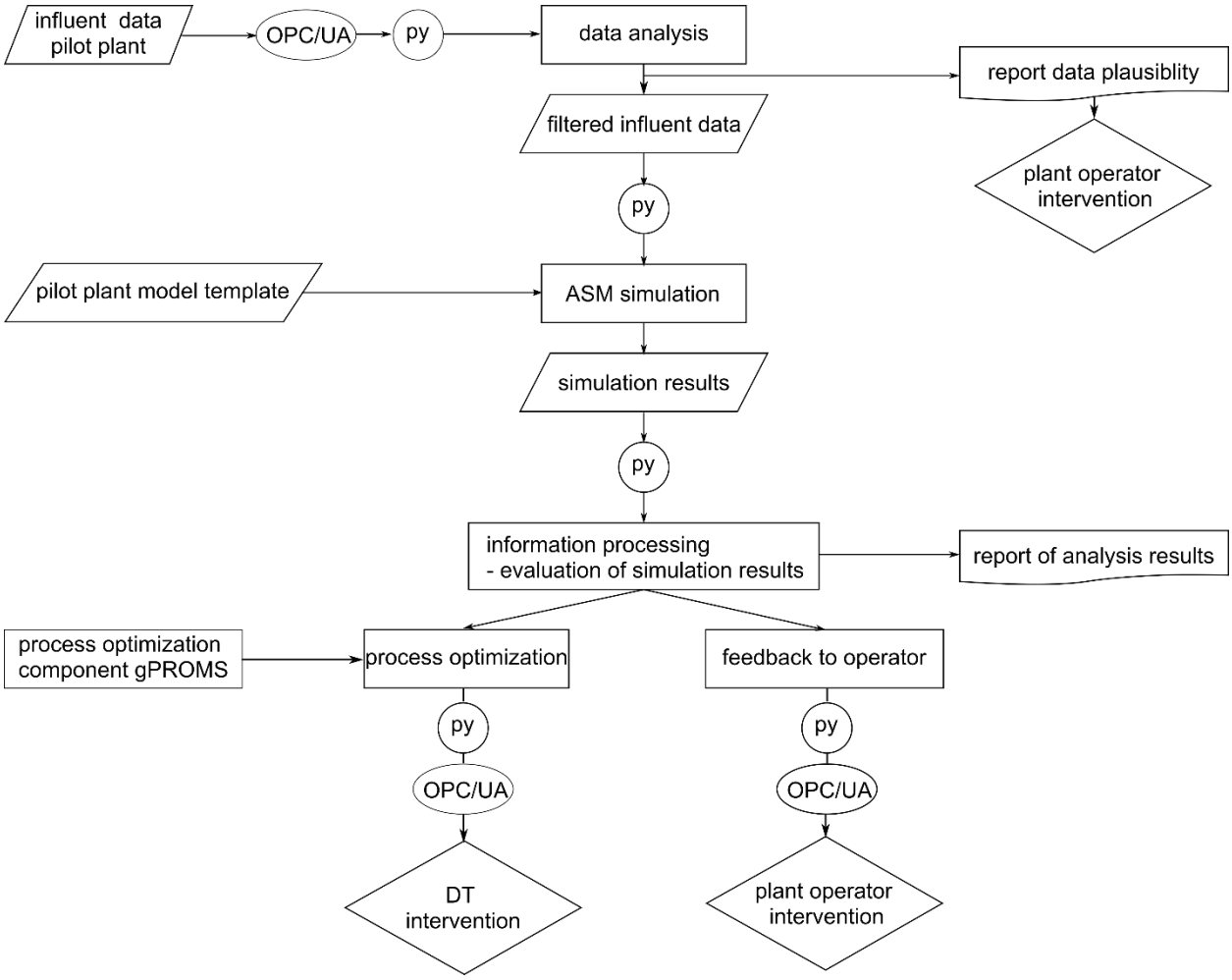


**Figure 2** Process diagram of the communication sequence between PT and DT. (py is a Python script)

## Discussion and outlook

Increasing resilience in the different areas of a WWTP needs different approaches. Here, a DT to support operators in stress events in the biological treatment process is presented. In order for the DT to support the operator a refined information processing is needed, which must be suited to the specific function of the DT. Apart from the process sequence, there are also questions remaining regarding the necessary time intervals for the loops and the extent of data analysis.

In order to build process-related resilience possible impacts need to be understood. Therefore, more data on stress scenarios is needed. Here data from a pilot plant will be used. Furthermore, the results need to be compared to real plant data.

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