# Engineering Concept Case Study: Brownfield Asset Renovation – Regulatory Drift

## Conceptual Retrofit Design / Compliance Assessment - Mitigating Operational & Environmental Liability in Aging Infrastructure (AwSV)

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**Abstract** — This case study presents a modernization concept and compliance assessment for a 40-year-old industrial wastewater treatment plant in the D-A-CH Region. The facility processes acidic wastewater with an average flow of 35 m³/day and peak loads up to 100 m³/day. The project involved aging infrastructure, material degradation, regulatory compliance with current water protection legislation ("regulatory drift"), and operational efficiency improvements while maintaining continuous operation. The study shows combined approaches to chemical handling, precipitation-flocculation treatment, and modern process control implementation. The project identified imminent environmental and compliance risks; in case of a spill or leakage event, such deficiencies may increase regulatory enforcement exposure and, depending on circumstances, potential civil and criminal-law implications (e.g., may trigger civil liability under § 89 German Water Resources Act, WHG and criminal prosecution, § 324 German Criminal Code, StGB) caused by non-compliant chemical storage and dangerous design flaws in the waste water neutralization in a 40-year-old asset.

**Keywords**: Industrial wastewater treatment, facility modernization, chemical precipitation, neutralization, regulatory compliance, secondary containment, process control, water protection, regulatory drift

## 1. Introduction

Industrial wastewater treatment facilities face multiple challenges when upgrading aging infrastructure, including regulatory compliance, material degradation, operational continuity, and technological advancement. This case examines a manufacturing facility requiring comprehensive renovation of its wastewater neutralization and treatment system while maintaining production schedules that allowed only a two-week shutdown period.

## 2. Initial Conditions and Challenges

### a. Existing System Configuration

The facility operated a multi-component treatment system constructed approximately 40 years prior, consisting of:

- Steel and polymer (PP/PVC) storage tanks and piping
- Neutralization system primarily using sodium hydroxide (NaOH) for acidic wastewater
- Two 15 m³ pre-storage tanks with insufficient mixing
- Undersized 2 m³ treatment reactor
- Steel inclined plate clarifier
- Open outlet chamber filter press
- Multi-layer filtration system in PE-FRP construction

### b. Primary Issues Identified

**Material Degradation**: UV exposure caused embrittlement of PP tanks and PVC piping, necessitating replacement. The control system was obsolete and no longer met current technical standards.

**Regulatory Non-Compliance**: The chemical filling station for sulfuric acid ($H_2SO_4$) and sodium hydroxide (NaOH) did not meet current water protection regulations, lacking proper containment systems during tanker truck filling operations. A spill (NaOH) would bypass treatment and drain directly into the municipal sewer, likely causing a biological collapse of the municipal wastewater treatment plant (WWTP) at worst, resulting in (in worst case scenarios) massive third-party liability claims. Operational areas consisted of permeable asphalt surfaces insufficient for acid/alkali resistance. Storage tanks were sited in non-compliant masonry containment structures with prohibited bottom outlets, necessitating complete reconstruction.

**Capacity Limitations**: The treatment reactor volume of approximately 2 m³ was insufficient for peak flow rates of 4.1 m³/h during four-shift operations.

**Operational Constraints**: Limited shutdown windows (maximum 2 weeks) with external disposal costs of approximately € 500 (2026, actual price) per intermediate bulk container if exceeded with costs ~ € 17,500 – € 50,000 per day in case of plant shutdown.

A Greenfield approach was deemed economically unviable given that the new plan will cost around € 2.0 million and involve a construction phase lasting several months. Due to a lack of space, this will result in additional plant downtime for several months, resulting in estimated downtime costs of € 0.5 million to € 1.5 million per month for the external offsite disposal costs alone.

## 3. Design Parameters and Technical Requirements

### Wastewater Characteristics

- **Average flow**: 35 m³/day
- **Peak flow**: 100 m³/day (4.1 m³/h maximum)
- **Primary characteristic**: Consistently acidic pH requiring neutralization
- **Operation**: Four-shift continuous production
- **Composition**: various heavy metals, anonymized

### Treatment Process Design Criteria

For continuous-flow systems, the following parameters were established:

**Reaction Times**:

- Precipitation and flocculation with NaOH: 30 minutes
- Alternative lime milk application: 45-60 minutes
- Flocculation tank: 30 minutes
- Settling tank (sludge-clarified water): 45-60 minutes

**Mixing Equipment Selection**:

- Treatment tank: Gear mixer ~80 W/m³ or turnover rate of 2x tank volume per minute (“fast”, only suitable for small treatment tanks)
- Flocculation tank: Gear mixer ~20 W/m³ (“slow”, to prevent damaging the floc)

**Auxiliary Systems**:

- Filter press: Dewatering once per shift
- Filter press pump capacity: Minimum 12x filter press volume (operational rule of thumb)
- Multi-layer filter: Closed design with filtration velocity < 10 m/h

## 4. Proposed Technical Solutions

### Chemical Storage and Handling System Upgrade

**Regulatory Framework Compliance**: The renovation addressed requirements for facilities handling water-hazardous substances, including double-walled polyethylene (PE) tanks with certification, leak detection systems, and overfill protection, § 18 AwSV.

**Storage Tank Specifications (above ground)**:

- Material: Double-walled PE with regulatory certification (“DIBt”)
- Capacity: 3 m³ each for NaOH and $H_2SO_4$
- Configuration: Top filling and emptying only
- Safety systems: Leak detection and overfill prevention
- Maximum fill level: 95% minus piping volume

**Containment System Design**:

The filling station required comprehensive secondary containment with the following specifications:

*§ 2 (18) AwSV, § 2 (16) AwSV in conjunction with § 15(1) No 1 AwSV in conjunction with DWA-A 779:2023:*

*Volume Requirements*:

- Pump delivery during filling operation: 100 L (based on 8 m³/h pump capacity with 45-second dead-man switch activation)
- Stormwater retention (15-minute design storm, 5-year return period): 1,109 L for 66 m² collection area (calculated based on DWA-A 779 using KOSTRA-DWD 2020 data; specific grid cell omitted for anonymity)
- Alternative calculation (72-hour consideration without controlled drainage): 5,306 L

*Spatial Configuration according to § 15(1) No 1 AwSV in conjunction with DWA-A 779:2023 6.1.5.1 ff*

- Primary containment zone: 2.5 m radius around connection points

- Hose protection zone: 0.5 m around transfer hoses (when compliant hoses are used)
- Typical full containment area: 13 m × 5.1 m (66.3 $m^2$)

*Construction Materials*:

- Medium stress classification, according to DWA-A 786.
- Options included: Concrete with simplified leak-tightness verification, coated concrete systems, plastic lining systems with protective layers
- Temperature resistance considerations: Materials must withstand potential neutralization reaction heat (up to 50 °C temperature rise) plus ambient conditions

## 5. Treatment System Modifications

**Pre-Treatment Optimization**: Implementation of mixing systems in the 15 $m^3$ pre-storage tanks to achieve pH homogenization, reducing load on the main treatment reactor. The configuration included sloped bottoms for hydroxide sludge removal and membrane pumps for solids handling.

**Treatment Reactor Enlargement**: Maximum feasible expansion of the 2 $m^3$ neutralization reactor based on available space, addressing the operational limitation of insufficient residence time during peak flows.

**Chemical Feed Systems**: Ferric chloride ($FeCl_3$): PE storage tank with secondary containment and certification. The Polyacrylamide flocculant (dry powder): PP mixing vessel with sloped bottom, integrated into PE storage tank with secondary containment. Dosing systems: Relocated from 100 L on-reactor tanks to centralized configuration.

**Solid-Liquid Separation**: Steel inclined plate clarifier: Retained in existing condition. Filter press upgrade: Conversion to enclosed chamber design eliminating spray losses, odor emissions, and enabling internal plate acid washing. VFD-driven pumps support energy-efficient operation (§3 (2a) AbwV) and improve controllability for permit- and process-related flow constraints: Implementation for both filter press feed and multi-layer filter feed to meet regulatory requirements for flow optimization.

**Polishing Filtration**: Multi-layer filter reconstruction in steel with polyamide (PA) internal coating to facilitate maintenance access. The design addressed hydroanthracite media loss issues encountered with PE-FRP vessels due to thread wear during frequent openings.

## 6. Process Control and Instrumentation

**Control Architecture**:

- PC-based SCADA visualization
- Data logging capability for all switching states enabling fault diagnostics
- Automated valve actuation with position feedback
- Instrumentation specifications:
  - pH electrodes: digital Memosens technology (e.g. Knick, Endress+Hauser)
  - Turbidity monitoring: Post-filter press with 5-minute recirculation loop control
  - Final pH verification: Automated diversion to recirculation on deviation
  - Level measurement: Multi-technology approach (vibrating fork, radar, ultrasonic) with local indication
  - Flow measurement: Electromagnetic flowmeter on final effluent

**Mixing Equipment**: Steel agitators with PP coating for chemical resistance.

### Alternative Technologies Evaluated

**Lime Milk vs. Sodium Hydroxide**: The facility's low alkaline wastewater production justified continued NaOH use without implementing separate acidic/alkaline stream segregation for mutual neutralization.

**Selective Ion Exchange**: Evaluation determined this technology was unsuitable due to manganese content in the wastewater. Manganese oxidation to Mn(IV) at neutral-alkaline pH (≥6.5) produces manganese dioxide, which reacts with hydrochloric acid during resin regeneration to generate chlorine gas, creating unacceptable occupational safety hazards.

$$MnO_2 + 4\,HCl \rightarrow MnCl_2 + Cl_2 + 2\,H_2O$$

Manganese would also cause further damage to the resin if $H_2SO_4$ were used as the regeneration acid. However, since the wastewater stream also contains Ca, its use is not possible due to gypsum formation in the selective exchanger.

**Multi-Layer Filter Media**: Standard multi-layer media configuration, acknowledging hydroanthracite layer frequent maintenance requirements (after regularly being flushed out, an easy opening is required).

## 7. Implementation Strategy

**Phased Construction Approach**: The renovation concept allowed for staged implementation beginning in 2026, accommodating budget constraints and minimizing operational disruption.

**Installation Logistics**: Large vessel installation required either wall penetration near the control cabinet or roof removal, with the facility having prior experience in such operations.

**Continuous Operation Maintenance**: System design emphasized uninterrupted operation throughout renovation, with contingency planning for external wastewater disposal if the two-week shutdown window proved insufficient.

## 8. Regulatory Compliance Considerations

The project addressed multiple regulatory frameworks:

**Water Protection Regulations**: Comprehensive compliance with water hazardous substance regulations including especially:

Secondary containment requirements; navigating the current regulatory gap in § 20 AwSV regarding fire water retention ('Löschwasserrückhaltung') by applying the rescinded LöRüRL as recognized rule of technology (§§ 20 AwSV in conjunction with 15 (1) No 1 AwSV in conjunction with DWA-A (TRwS) 779:2023 No 5.4 (2) in conjunction with DWA-A (TRwS) 779:2006 8.2 (4) in conjunction with LöRüRL). However, the reference to the technical rule only covers the assessment limits, not the exemption limits.

Furthermore, Material specifications and certifications must be compliant to § 62 WHG (in conjunction with AwSV), adhere to inspection protocols (commissioning, one-year post-commissioning, recurring inspections (intervals depend on installation type and hazard classification; often multi-year cycles per AwSV Appendix 5), and decommissioning inspections for higher hazard class substances) and meet documentation requirements including facility data sheets.

**Discharge Standards**: Variable frequency drive implementation for compliance with indirect discharge requirements regarding flow optimization.

**Safety Systems**:

- Collision protection for filling cabinets, tanks, and accessible piping
- Spill response materials on-site
- Operating procedures for stormwater management in containment systems

## 9. Discussion

This case shows the complexity of industrial wastewater treatment facility modernization, requiring integration of:

1. **Engineering fundamentals**: Proper sizing of treatment reactors, mixing equipment, and solid-liquid separation systems based on established design parameters
2. **Regulatory compliance**: Contemporary water protection standards significantly exceed requirements when the original facility was constructed
3. **Operational continuity**: Renovation strategies must accommodate ongoing production requirements
4. **Material science**: Selection of construction materials addressing both chemical compatibility and regulatory requirements
5. **Process control**: Modern instrumentation and control systems enabling optimization and compliance demonstration

**Key Technical Insights**:

The undersized treatment reactor (2 m$^3$) operating near theoretical capacity limits highlights the importance of design margins. Proper residence time calculations are essential, particularly for facilities with variable flow patterns.

The chemical filling station compliance requirements illustrate how regulatory frameworks have evolved. Secondary containment must address not only chemical release volumes but also stormwater management, requiring either covered systems or substantial storage capacity (1,200-6,000 L range depending on configuration and drainage capabilities).

Material selection considerations extend beyond chemical compatibility to include UV resistance, regulatory certification requirements, and maintenance accessibility. The PE-FRP to PA-coated steel conversion for the multi-layer filter exemplifies this multi-factor decision-making.

Pre-treatment homogenization in storage tanks represents a cost-effective optimization strategy, reducing chemical consumption and stabilizing main treatment system loading.

Regulatory Drift Risk: Assets compliant in 1980 act as hidden liability traps today. This case illustrates that relying on ‘grandfathering’ may be insufficient for installations handling water-hazardous substances, especially where aging materials and changed regulatory expectations intersect.

## 10. Conclusions

Successful modernization of aging industrial wastewater treatment infrastructure requires comprehensive evaluation of process engineering, regulatory compliance, operational constraints, and economic factors. This case demonstrates that systematic analysis can identify practical solutions addressing multiple requirements simultaneously.

The facility modernization concept provides:

- Regulatory compliance with current water protection standards
- Improved treatment capacity through reactor enlargement and pre-treatment optimization
- Enhanced operational reliability through modern control systems and instrumentation
- Reduced environmental risk through proper secondary containment
- Maintenance efficiency improvements through material selection and equipment configuration
- Flexibility for phased implementation

The approach presented here offers a system applicable to similar industrial wastewater treatment facility upgrades in the D-A-CH Region, and even globally with appropriate adaptation to local regulatory requirements and site-specific conditions.

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Author Note:

This case study is published to contribute to the professional knowledge base regarding brownfield and related technology applications. All parties, technical details and specific locations which may identify the individuals or the location have been anonymized. Practitioners facing similar challenges are encouraged to engage qualified specialists familiar with industrial waste water treatment.

Frank Naujoks acts as a Strategic Risk Architect for industrial water infrastructure. Uniquely combining the qualifications of a fully qualified lawyer (RA) and a certified technical planner (AwSV), he serves as CEO of Decker Verfahrenstechnik GmbH in Germany. Backing his expertise with operational reality, he operates a centralized treatment plant for heavy metal effluents serving hundreds of industrial clients. He specializes in mitigating technical and contractual liabilities in complex plant engineering. Frank lectures at the Nuremberg Institute of Technology and shapes industry standards as Spokesperson for the DWA Working Group 2.36 and member of the DWA Steering Committee IG-2.

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