Case study factsheet

DOW Terneuzen (CS1A)

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Project AquaSPICE

Terneuzen , **Netherlands**

Description

The Dow Terneuzen industrial site, located in the Terneuzen Industrial Park, operates in a water-stressed region with limited freshwater availability. To enhance water efficiency and circularity, this case study focuses on reducing freshwater intake by recycling Cooling Tower Blowdown (CTBD) and Dilution Steam Process Water (DSBD) while improving water monitoring and management. A series of advanced water treatment technologies were tested, including Bio-Activated Carbon Filtration (BACF), Ultrafiltration (UF), Reverse Osmosis (RO), Electrodialysis Reversal (EDR), and Membrane Aerated Biofilm Reactor (MABR) along the utilisation of the containerised modular pilot units IMPROVED and MERADES. The results demonstrated that BACF + UF + RO provided the best performance for CTBD reuse, whereas MABR showed potential for TOC reduction in DSBD treatment, though additional refinement is needed to meet boiler feed water quality requirements. The case study also integrated real-time monitoring and digital water management solutions to enhance operational efficiency and optimize water reuse.

Best practices

1. Electrocoagulation & Advanced Oxidation Processes (AOP):
   For effective electrocoagulation treatment, ensure the correct electrode material (e.g., sacrificial iron or aluminum) is selected based on the contaminants targeted for removal. Periodic monitoring of electrode wear is essential to maintain efficiency. Advanced oxidation processes (such as ozone or UV-H_2O_2) should be optimized for chemical dosing and reaction time to ensure thorough degradation of organic pollutants without excessive energy consumption.
2. Membrane Filtration (UF, RO, Nanofiltration):
   To maximize membrane performance, pre-treatment with coagulation or biologically activated carbon (BAC) filtration is recommended to reduce organic fouling. Regular backwashing and chemical cleaning schedules must be maintained to prevent scaling and biofouling, especially in nanofiltration and reverse osmosis units. Pressure monitoring and integrity testing should be conducted routinely to ensure proper operation.
3. Ion Exchange & Biologically Activated Carbon (BAC) Filtration:
   For ion exchange processes, resin regeneration cycles should be closely managed to minimize chemical consumption and waste production. Monitoring breakthrough curves is crucial to prevent the premature exhaustion of resin beds. BAC filtration should be operated with consistent flow rates and periodic backwashing to prevent clogging and ensure microbial activity remains optimal for organic compound degradation.
4. Cooling Tower Water Reuse & Blowdown Treatment:
   Cooling tower makeup water quality must be maintained to minimize scaling, corrosion, and microbial growth. The treatment of cooling tower blowdown should involve appropriate chemical conditioning, and side-stream filtration is recommended to remove suspended solids. Purge streams should be directed appropriately based on their chemical composition to avoid contamination of reclaimed water.
5. Smart Water Management & Digital Monitoring:
   The integration of WaterCPS (Cyber-Physical System) enables real-time monitoring and control of water quality and flow rates. Best practices include setting threshold alerts for key parameters such as conductivity, pH, and organic load to ensure proactive adjustments in treatment processes. AI-driven algorithms should be utilized to optimize water allocation based on real-time composition and site demands.
6. Operational Safety & Regulatory Compliance:
   Regular validation and calibration of sensors and analyzers (e.g., COD, ammonium, sulfide, and conductivity meters) should be performed to ensure accurate water quality assessments. Ensuring compliance with environmental discharge regulations and safety standards is critical, and all treatment processes should be documented with Standard Operating Procedures (SOPs) to facilitate consistent operation and troubleshooting.

Technology performance and best practices

Based on the results of the pilot at DOW Terneuzen, the GAC + UF + RO treatment train showed strong performance in meeting the quality criteria for reuse in cooling towers.

Specifically, in numerical terms:

- Total Organic Carbon (TOC):
  Reduced from 12.4 mg/L (feed water) to <0.5 mg/L (post-RO permeate).
- Electrical Conductivity:
  Dropped from ~2,500 µS/cm in the feed to <50 µS/cm in the permeate.
- Turbidity:
  Reduced to <0.1 NTU, ensuring excellent clarity and membrane protection.
- SDI (Silt Density Index):
  Post-UF values consistently below 3, within acceptable limits for RO feedwater.
- Recovery Rate:
  Achieved up to 75% recovery in RO step under optimized operation.

Synergistic benefits

1. Enhanced Water Quality through Sequential Treatment:
   The combination of Bio-Activated Carbon Filtration (BACF), Ultrafiltration (UF), and Reverse Osmosis (RO) provided an effective treatment sequence for Cooling Tower Blowdown (CTBD). This integration allowed for improved removal of organic matter and suspended solids, leading to higher-quality permeate suitable for reuse. The synergy between these technologies helped reduce membrane fouling, increasing the lifespan and efficiency of the RO system, thereby minimizing operational costs.
2. Biological Treatment Synergy for TOC Reduction:
   For Dilution Steam Blowdown (DSBD), the integration of Membrane Aerated Biofilm Reactor (MABR) and Granular Activated Carbon (GAC) was tested to enhance Total Organic Carbon (TOC) removal. Although TOC levels remained above the required threshold for boiler feed water, the MABR demonstrated a positive effect in reducing formate and acetate formation, indicating that biological treatment steps could be key for future optimization. This synergy suggests that combining membrane technologies with biological treatment could provide a more effective long-term solution.
3. Digitalization and Real-Time Monitoring Integration:
   The case study incorporated real-time sensor monitoring and automated sample takers, enabling better process control and decision-making. The Conductivity-Temperature-Depth (CTD) sensors and other monitoring tools provided valuable data on treatment efficiency and water quality variations. The integration of smart monitoring systems with treatment technologies allowed for proactive adjustments, optimizing chemical dosing, filtration performance, and water recovery rates.
4. Reduced Chemical Dependency and Waste Generation:
   By integrating multiple treatment steps, the case study helped reduce the need for excessive chemical dosing. The use of BACF and UF before RO reduced biofouling, leading to lower consumption of anti-scalants and cleaning agents. Additionally, the potential reuse of cooling tower water and dilution steam blowdown contributed to a circular water economy, decreasing overall water wastage and chemical discharge.

Requirements and conditions

1. Lack of Historical Water Quality Data:
   One of the primary challenges was the absence of historical data on the water quality of the two main process streams—Cooling Tower Blowdown (CTBD) and Dilution Steam Blowdown (DSBD). Since no prior records existed on fluctuations in water composition, an extensive sampling campaign was required before designing the treatment trains. This campaign, conducted between July 2021 and February 2022, helped define baseline water characteristics and assess effluent quality.
2. Variability in Water Composition & Treatment Efficiency:
   The high variability of contaminants in the water streams posed difficulties in selecting a single treatment train that could consistently meet reuse criteria. While Bio-Activated Carbon Filtration (BACF) + Ultrafiltration (UF) + Reverse Osmosis (RO) proved effective for CTBD treatment, DSBD treatment remained a challenge due to persistent Total Organic Carbon (TOC) levels, which made the treated water unsuitable for reuse as boiler feed water. Additional tests with Membrane Aerated Biofilm Reactor (MABR) showed promising results in reducing TOC, but no definitive treatment sequence was found to meet all industrial reuse specifications.
3. Operational & Infrastructure Constraints:
   The integration of new containerized treatment units into an existing industrial setup required careful coordination. The IMPROVED treatment containers had to be adapted to site-specific operational conditions, including space limitations, power supply constraints, and compatibility with existing water infrastructure. Additionally, some treatment processes, such as electrodialysis reversal (EDR) and ion exchange, required further fine-tuning to function effectively within the plant's variable load conditions.
4. Challenges in Digital Monitoring & Automation:
   The case study aimed to implement real-time monitoring and digital water management for better process control. However, achieving full automation was challenging due to sensor calibration issues and data processing limitations. The integration of Conductivity-Temperature-Depth (CTD) sensors and automated sampling systems required adjustments to ensure accurate and continuous data collection for optimizing treatment performance
5. Organic Acid Formation in Boiler Feed Water:
   A key concern was the formation of organic acids in the treated DSBD water when used in boiler feed applications. Mini-boiler experiments showed that organic acids, including formate and acetate, could still form, even after advanced treatment. This indicated the need to further limit TOC levels to avoid potential scaling and corrosion in industrial boilers. Despite promising results from MABR in reducing TOC, additional treatment modifications were required to meet stringent boiler water quality standards

Key lessons

1. Importance of Comprehensive Water Quality Data:
   A major challenge encountered was the lack of historical water quality data for Cooling Tower Blowdown (CTBD) and Dilution Steam Blowdown (DSBD). The high variability in contaminants required an extensive sampling campaign before designing the treatment trains. Future projects should prioritize long-term water quality monitoring before piloting treatment solutions.
2. Need for Pre-Treatment Steps to Reduce TOC:
   Despite extensive treatment, Total Organic Carbon (TOC) levels in DSBD remained too high for boiler feed water reuse. The use of Membrane Aerated Biofilm Reactor (MABR)

showed promise in reducing organic acids like formate and acetate, but additional pre-treatment steps may be necessary. This highlights the need for biological treatment integration to further break down organic contaminants before membrane filtration.

3. Synergy Between Treatment Technologies:
   The combination of Bio-Activated Carbon Filtration (BACF), Ultrafiltration (UF), and Reverse Osmosis (RO) proved highly effective for CTBD treatment. However, Electrodialysis Reversal (EDR) was less efficient at TOC removal and had higher operational costs. This reinforces the lesson that multi-stage treatment approaches can enhance overall performance, but the right technology mix must be carefully selected based on specific water quality needs.
4. Real-Time Monitoring Improves Process Optimization:
   The use of real-time sensors and digital monitoring tools provided valuable insights into process performance, enabling adjustments in chemical dosing and filtration parameters. However, achieving full automation required overcoming sensor calibration issues and ensuring compatibility with existing process control systems. Future projects should invest in better integration between digital monitoring and treatment processes for seamless automation.

Lessons learned from technology operation

1. Required Competence & Training Needs:
   The operation of advanced treatment technologies such as Reverse Osmosis (RO), Bio-Activated Carbon Filtration (BACF), Ultrafiltration (UF), and Electrodialysis Reversal (EDR) required skilled personnel with expertise in water chemistry, membrane system operation, and process monitoring. During the pilot phase, Dow employees received training on the IMPROVED containerized treatment units to ensure proper handling, troubleshooting, and performance optimization. Hands-on experience and continuous learning were necessary to effectively manage sensor-based monitoring and real-time water quality assessment.
2. Maintenance Challenges & Strategies:
   Routine maintenance was essential to ensure the efficient operation of the treatment units. Membrane fouling and scaling were identified as key issues in RO and UF systems, requiring periodic chemical cleaning and monitoring to maintain performance. Activated carbon filters needed regular backwashing to prevent clogging and loss of adsorption efficiency. Additionally, lamella settlers required frequent sludge removal to maintain optimal sedimentation performance. Preventive maintenance schedules were established to minimize operational downtime.
3. Technological Risks & Downtime Avoidance:
   The primary technological risks included sensor failures, membrane degradation, and unexpected variations in feed water quality. Real-time monitoring systems played a crucial role in detecting early signs of equipment failure or water quality fluctuations, allowing for proactive interventions. However, achieving full automation was challenging due to sensor calibration issues and data integration difficulties. Redundant sensors and backup data logging systems were introduced to mitigate the risk of data loss or inaccurate readings.
   Additionally, the formation of organic acids in boiler feed water was an unexpected challenge, impacting steam system performance. Despite advanced treatment, TOC levels remained above acceptable thresholds, highlighting the need for further research into biological treatment integration (e.g., Membrane Aerated Biofilm Reactor (MABR)).

Applied technologies

- **Electrodialysis**
- **Membrane aerated biofilm reactor (MABR)**
- **Reverse Osmosis**
- **Ultrafiltration & nanofiltration membranes as pre-treatment for reverse osmosis**
- **Water recovery technologies for water reuse**

Publications and references

- Comparison of cooling tower blowdown and enhanced make up water treatment to minimize cooling water footprint

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  https://doi.org/10.1016/j.jenvman.2024.121949

- Development of a hybrid model for reliably predicting the thermal performance of direct contact countercurrent cooling towers

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https://doi.org/10.1016/j.ijheatmasstransfer.2022.123336

Scale

Operational scale of this case study related to the application of tools and technologygies

- Local scale

Challenge

Challenge that is addressed through the application of tools and/or technologies to the case study

- Water Scarcity

Related tags

Ultrafiltration | electrodialysis | Smart Water Management | Industrial Water Efficiency | Reverse Osmosis | Membrane Filtration | Water Quality Monitoring | Water Recycling | Cooling Tower Treatment | Bio-Activated Carbon Filtration | Biological Water Treatment

Contact data

Involved organisation

1. DOW Chemical Company