NEWport
Nutrient-/Energy-/Water-tech portfolio

DEMON
deammonification process

Pre-Design Description

PROJECT:	Industrial WWT Petro-Chem
COUNTRY:	
CLIENT:	AMV Chemie Technologie GmbH, Austria
DATE:	11.05.2023

Content

Project

To reduce the nitrogen load of effluents of a petrochemical plant containing high loads of ammonia and urea, anammox based biological treatment (deammonification) is proposed.

DEMON® process

Process characteristics

The DEMON process performs biological deammonification in a single stage configuration providing equilibrium conditions between nitritation (by ammonia oxidising bacteria, AOBs) and anaerobic ammonia oxidation by anammox bacteria (AMX) for optimal performance. Therefore, the design is based on the stoichiometry of the overall process and the kinetics of the applied process steps. Since the involved bacterial species require different conditions in terms of dissolved oxygen and biomass retention in the system, the DEMON process includes pH/DO-based aeration control and biomass selection by micro screens. The process is operated continuously. The deammonification stoichiometry carried out by anammox biomass is given as:

$$NH_4^+ + 1.32NO_2^- + 0.066HCO_3^- + 0.13H^+ \rightarrow 0.26NO_3^- + 1.02N_2 + 0.066CH_2O_{0.5}N_{0.15} + 2.03H_2O$$

The process design is based on a design temperature of 30°C. The main fraction of the suspended biomass in the reactor consists of aerobic, autotrophic ammonia oxidisers and autotrophic anaerobic ammonia oxidisers which utilise the nitrite that has been produced by the AOBs as electron acceptor. Sufficient availability of inorganic carbon (bicarbonate, given as alkalinity) is a pre-requisite for the treatment performance. The selection of the granular anammox biomass by a micro screen provides two different sludge retention times for ammonium oxidising bacteria and anammox biomass. Depending on the influent characteristics, DEMON 2.0 is suitable for municipal (Figure 1) and industrial applications (Figure 2). Under standard feed conditions (no inhibitory compounds in the feed) the system serves 90% ammonia and 75% total nitrogen reduction.

Figure 1: DEMON installation at a municipal wastewater treatment plant.

Figure 2: DEMON installation at a food processing facility.

Process scheme

The basic process scheme consists of a buffer/sedimentation tank which receives the centrates/process waters to be treated (Figure 3). The influent is continuously pumped to the DEMON reactor, the flow rate is depending on the level in the buffer tank. In the reactor, ammonia is partially oxidized to nitrite by intermittent aeration and then converted to nitrogen gas together with the remaining ammonia. The biomass produced is discharged as waste sludge over the micro screen

which retains the slowly growing anammox granules in the system. The treated effluent is then separated from the biomass via a baffle wall.

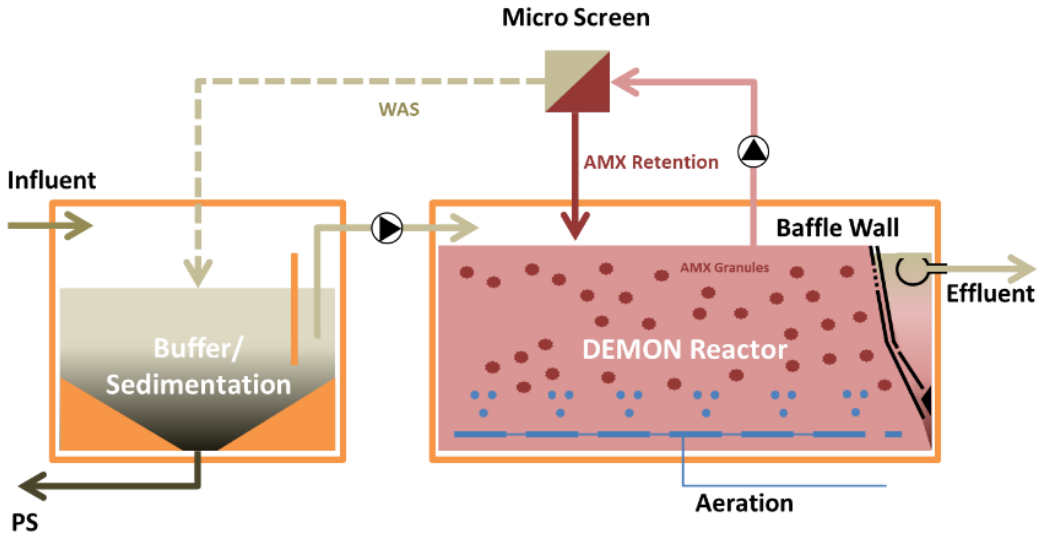


Figure 3: Basic flow scheme of a DEMON installation.

Process control

DEMON process control is based on pH controlled intermittent aeration combined with DO control. The continuous feeding of the process leads to pH increase whereas the pH is decreased during aeration due to alkalinity consumption of nitritation. This leads to the characteristic control pattern of pH and DO show in Figure 4. DEMON control is delivered as pre-programmed Edge-Executing system pre-assembled in a small cabinet with PLC, HMI and communication interface.

The integrated WebSCADA functionality allows the remote access for operation support and long-term performance evaluation and optimization. Additional to the pH/DO control core, ammonia/nitrite control functions are available according to the measurement set up.

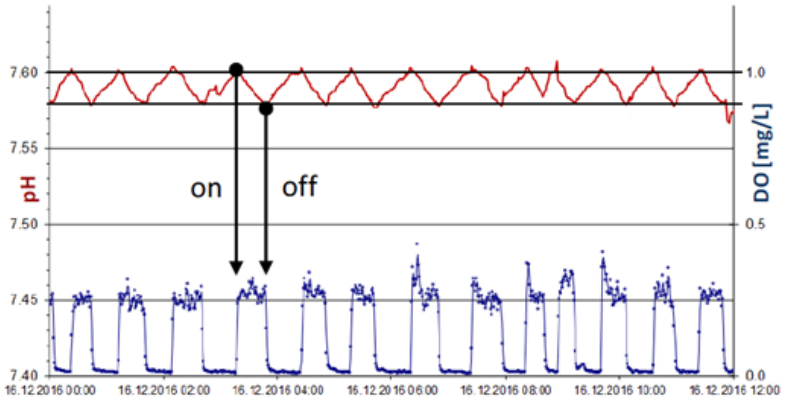


Figure 4: Typical control pattern of pH and DO in the DEMON reactor.

Equipment

Controller

The DEMON process control is based on an Edge-Executing control philosophy which is a combination of a pre-programmed standard DEMON PLC (Edge) with the local process control (Executing). The DEMON PLC receives all data on the system operation (e.g. status signals, on-line measurements) from the local process control and returns control requests based on the system settings defined by the operator. The control requests are then executed by the local process control. The control system is accessible via HostedSCADA without connecting to the client's network.

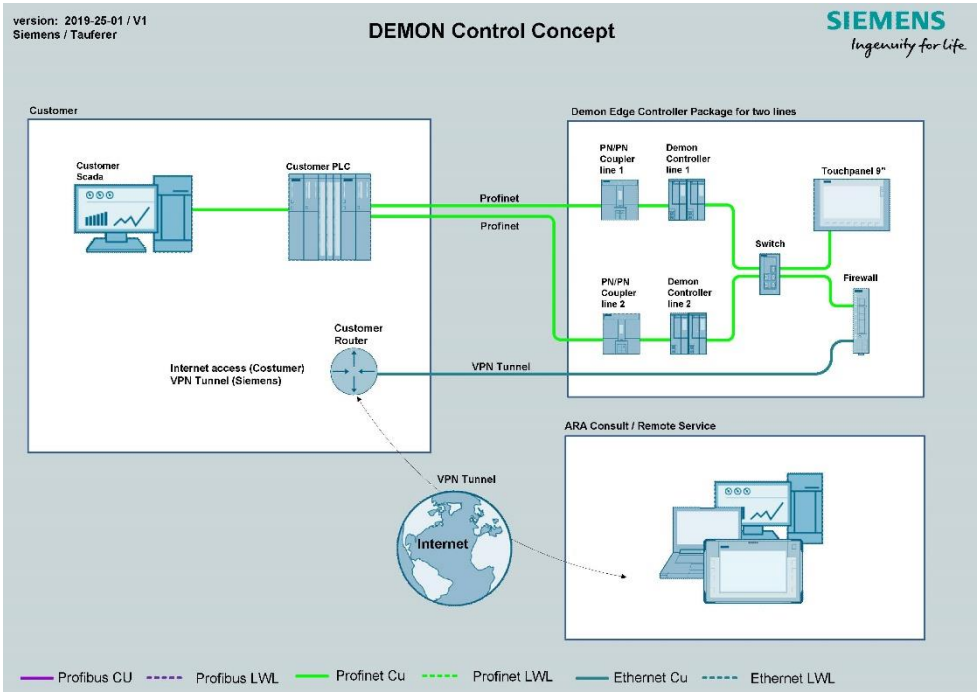


Figure 5: Edge- Executing concept of DEMON control.

The core of the DEMON control is the pH-controlled aeration as described above. Besides DO control, ammonia and nitrite (nitrate) can be activated as additional control parameters. Up to three DEMON lines can be controlled by one single CPU. Optional a multiple CPU setup can be chosen. The system is available for continuous flow and SBR operation.

The DEMON Edge components are factory pre-programmed and pre-tested. They come either completely pre-installed in a separate cabinet or as components for on-site integration into the main control cabinet. The controller package includes an HMI (Figure 6). Communication protocols available are Profinet, Modbus, Ethernet-IP and Profibus.

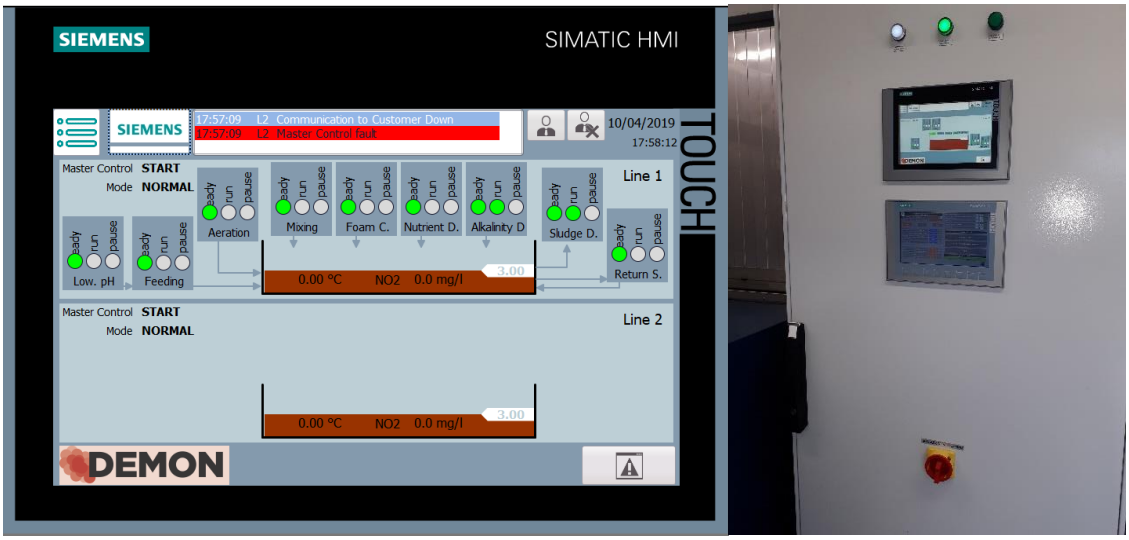


Figure 6: DEMON HMI at the electrical cabinet of the installation.

The modular control system provides the following control features which are activated according to the facilities technical set-up:

- Influent and effluent flow
- Aeration and mixing
- Sludge discharge and micro screen operation
- Return sludge
- Antifoam dosing
- Nutrient dosing
- Alkalinity dosing
- Sludge dosing
- Dilution

As described above, the system allows secure remote access via HostedSCADA for optimal start-up and operation support (

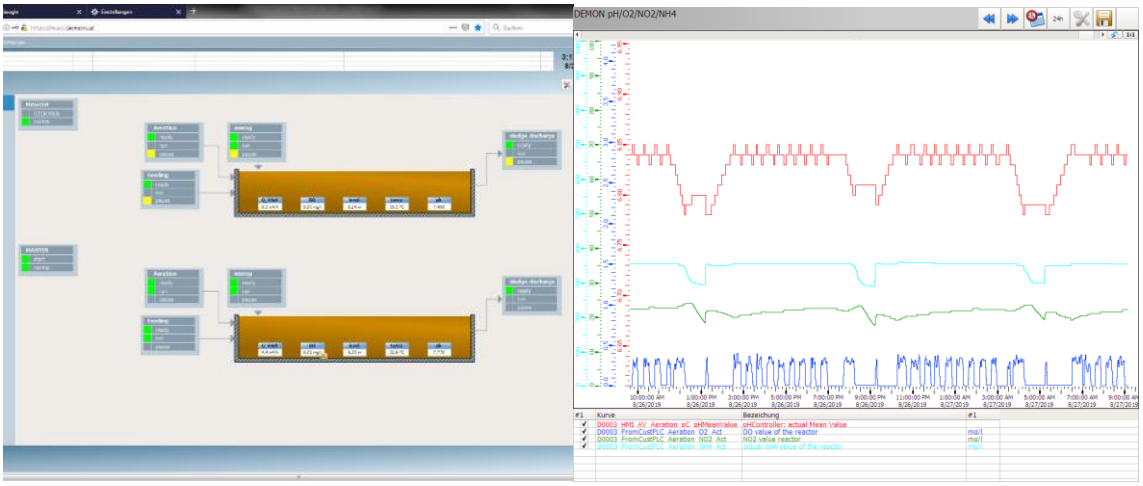


Figure 7: Plant overview and trending via HostedSCADA.

Measurements

The input data for process control is derived from online-measurements in the reactor. The basic instrumentation set-up is as follows:

- pH, Temperature
- Dissolved oxygen (optical)
- Conductivity
- Nitrate and Ammonia (ion-selective)

Micro screen

The DEMON® static run-down filter (SRF) is a core equipment of the DEMON® process. The suspended DEMON® biomass is pumped to the inlet-vessel and flows over the bow bars of the mechanical filtration device. The fine solids fraction smaller than 150 µm (mainly flocculant nitrifier biomass) passes through the bar openings and is withdrawn via the effluent outlet at the bottom. The coarse particle fraction >150 µm (mainly granular anammox-biomass) slides down the bars and is directed back into the reactor (Figure 8). Intermittent spraying from behind the bars prevents blocking of the bow bars. The cleaning system is time controlled and operated using four automated valves for a consecutive cleaning pattern from top to the bottom. Standard cleaning intervals are between 30 min and 60 min with sequential cleaning of 1-2 minutes. To prevent freezing of any liquor after the end of the filtration/wasting period, the inflow channel is automatically emptied using another automated valve.

Figure 8: Static run-down filter for anammox biomass selection.

Baffle Wall

The Baffle Wall is a core component of the continuous DEMON process and provides efficient biomass retention (appr. 95% MLSS retention). The stainless-steel structure is directly installed in the DEMON reactor tank against the concrete-wall. The mixed liquor passes the staggered openings of the double wall, with a laminar pattern of the flow the inter-space. When entering the inner settler-volume the liquid fraction rises towards the over-flow-structure and the settling solids are sliding down the sloped wall to the bottom-outlet, which is protected by a deflector against air-bubble-

intrusion. There is no need for sludge pumping, the retained biomass settles by gravity inside the Baffle Wall and gets lifted by the draft induced by aeration outside the Baffle Wall. The effluent is discharged by free flow via an effluent pipe behind the baffle wall. The design is modular with standard heights for 4.5 to 7.0 m side water depths. Each element of 1.2 m length has a flow capacity of 115 to 160 m3/d.

Figure 9: Drawing of DEMON baffle wall with three elements (left) and installation in the reactor (right).

Aeration and mixing

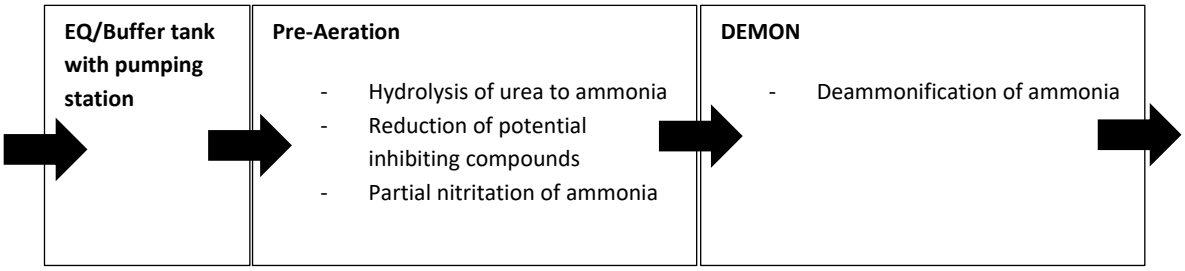
Intermittent aeration of the reactor is provided by fine bubble diffusers. During non-aerated periods mixing is provided to keep the biomass in suspension.

Design Concept

General

The DEMON® process shall be applied to treat process water containing high oil, ammonia, and urea from a petrochemical plant. The treatment shall be applied downstream of solid reduction by coagulation/ flocculation and dissolved air flotation.

Urea represents about half of the nitrogen load and must be hydrolysed to ammonia before it can be metabolized by deammonification biomass. Therefore, and to reduce the risk of inhibition by different organic and inorganic constituents, the setup is proposed as a two-stage process:



The first stage is a pre-aeration step which allows to convert the urea to ammonia and to degrade potentially inhibiting organic components. Further, ammonia will be partially converted to nitrite. This first step is carried out by conventional activated sludge. Following pre-aeration, deammonification takes place. As described below, ammonia and nitrite eliminated by the DEMON process using anammox biomass. Both process steps have intermittent aeration with similar equipment. In addition to that the DEMON reactor is equipped with a biomass selection unit. We suggest two similar reactors as shown in Figure 10.

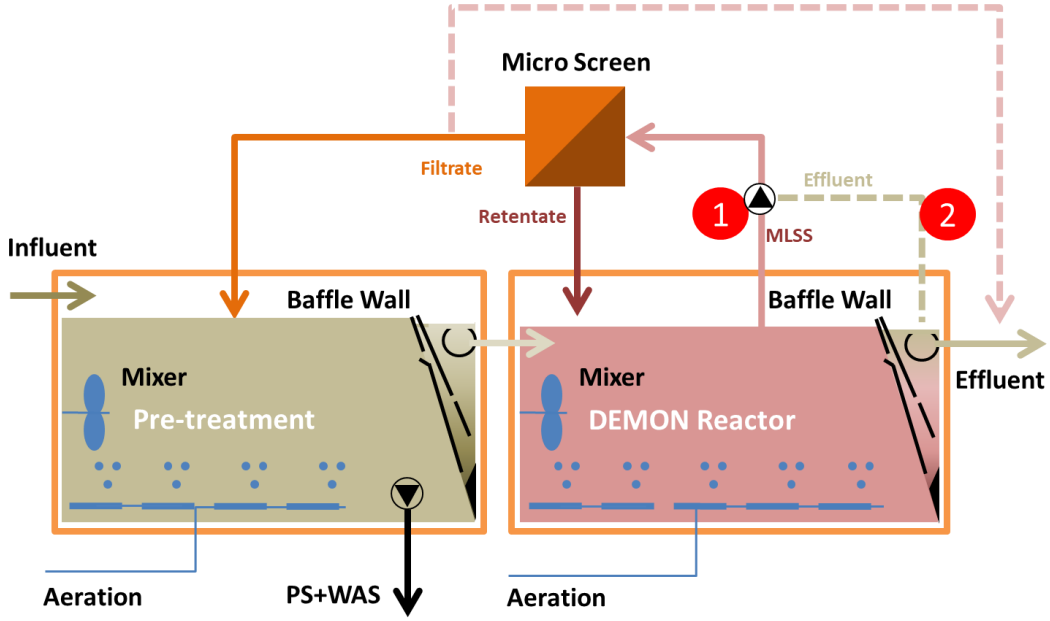


Figure 10: Scheme of the DEMON set-up with pre-aeration.

The overall design concept is to build two new reactors to create the continuous DEMON® treatment system downstream of a smaller buffer tank (12-24h HRT). Mixers and aeration system shall be placed in each reactor for providing the mixing energy for re-suspension of the granules, proper mixing distribution of the influent feed flow and provide the necessary aeration. Integrated baffle walls will be used to separate the biomass from the treated wastewater. One PLC with HMI will be provided to control the process of the two reactors. A micro screen will be applied for the selection of the slowly growing AMX biomass.

Influent characteristics

The following characteristics of the process water have been provided and are the basis for the design calculations. The average flow values have been used to calculate the load conditions relevant for the pre-design of the DEMON® process. It was assumed that all nitrogen compounds are given as nitrogen (N).

- Flow rate: 480 m3/d
- Nitrogen load (ammonia and urea): 710 kg/d
- COD load: 110 kg/d
- TSS load: <5 kg/d
- pH: 8.0
- Temperature: 7-35°C (required 25-35°C))
- Alkalinity / ammonia molar ratio: 0.4 (required: 1.0)

The provided influent characteristics show that various heavy metals and organic compounds with potentially inhibiting properties are present. The alkalinity level is low compared to the nitrogen load to be treated.

Pre-Design

Based on the given information, the pre-design results to:

- Pre-aeration volume: 500 m3
- DEMON reactor volume: 500 m3
- Baffle wall for pre-aeration: 5 elements
- Baffle wall for DEMON-reactor: 5 elements
- Micro screen for DEMON-reactor: 1 pcs.
- Aeration pre-aeration: 600 Nm3/h
- Aeration DEMON: 700 Nm3/h

Note that the given information is preliminary. Influent characteristics must be verified for their suitability for treatment.

Concept summary

The implementation of a pre-aeration reactor and a DEMON® reactor with a total reactor volume of about 1000 m^3 with an upstream buffer tank (250 m3) allows up to 85% reduction of 710 kg daily ammonia and urea nitrogen load. Pre-requisite of this assumption is the effective inactivation of potentially inhibiting substances during pre-aeration. To verify this, inhibition testing is imperative. Addition of sufficient alkalinity source is necessary to reach full performance. Considering the strong variations of the influent and ambient temperatures, a heat exchanger for heating/cooling shall be foreseen at the pre-aeration tank.

The system consists of two equal reactors with 500 m3 of volume with suspended biomass, aeration, mixing and sludge discharge with biomass selection. The intermittent aeration is controlled by a pre-programmed EDGE-Executing control system. Biomass selection is provided by a micro screen at the DEMON reactor. In both pre-aeration and DEMON reactor, the biomass is retained by a baffle wall.

Scope of supply

NEWport provides the following core equipment and services for the installation:

- Process design
- Process license
- Inhibition testing
- Process control package
- Inoculum
- Micro screen
- Baffle Wall
- Start-up support
- Operation support (remote assistance)