Online Monitoring of Nitrogen Elimination in Vienna's Main Sewage Treatment Plant

WATER WASTEWATER

DI Franz Hofstädter & DI Andreas Weingartner, s::can Messtechnik GmbH, Brigittagasse 22-24, 1200 Vienna - Austria.
Tel: +43 12197393 - 0 Fax: +43 1 2197393 - 12 Email: office@s-can.at Website: www.s-can.at

Vienna's Main Sewage Treatment Plant was expanded in the years of 2004 and 2005, now designed for a population equivalent of 4.0 million and able to clean 680,000 m^3 of wastewater per day. In the tender, the operator of the plant had specified online spectrometry to be the method for monitoring of COD, Nitrate and TSS. s::can Messtechnik GmbH, Vienna, obtained the order for on-line instrumentation as a sub-supplier for Siemens AG Austria. In the beginning of 2005, 27 spectrometric probes of different types were purchased, most of them immediately installed and set into operation. The results of a test run for "verification of uniformity & accuracy" during a tough commissioning procedure proved high reliability, low operational costs and best precision of the installed s::can measuring instruments.

Vienna's Main Sewage Treatment Plant

The preliminary mechanical purification of the wastewater collected in the sewers of Vienna removes up to 30% of the organic pollution. In four primary-stage aeration tanks micro-organisms break down the dissolved, largely organic pollutants. 15 secondary-stage aeration tanks consist of three cascades: The first cascade forms a pre-connected non-aerated denitrification tank, connected to two subsequently passed circulation tanks (cascade 2 and 3) in which nitrification and denitrification take place simultaneously. Phosphate precipitation is supported by adding ferric(III)chloride to the aeration tanks. Secondary sedimentation tanks separate sludge from wastewater. Most of the sludge is returned to the aeration tanks to increase the concentration of micro-organisms and to maintain a stable decomposition process. Following secondary clarification the treated water discharges into the Danube Canal.

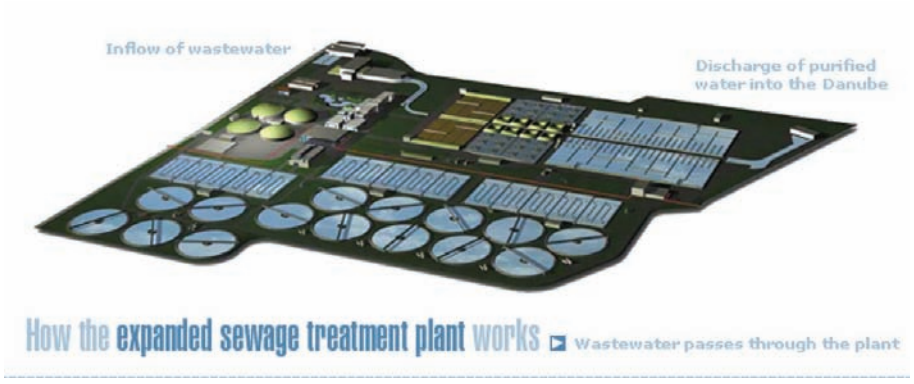

Figure 1: Vienna's Main Sewage Treatment Plant

During heavy precipitation or thunderstorms, Vienna's expanded Main Sewage Treatment Plant has to cope with up to 1.6 million cubic meters of extremely diluted wastewater per day. The wastewater passes through the plant covering a total area of 40 hectares in around 20 hours.

Table 1: Vienna's Main Sewage Treatment Plant: Wastewater figures before and after expansion

	before expansion	after expansion
Population equivalent (design)	2,5 million	4,0 million
Purification capacity (BOD5)	85%	> 95%
Nitrogen removal	no legal requirement	> 70 %
Average time wastewater spends in the plant	approx. 5 hours	approx. 20 hours

Table 2: Vienna's Main Sewage Treatment Plant: New Plant Technology

Compressor station	5 turbo compressors: 45,000 Nm^3/h each
Intermediate pumping station	14 pumps: 2.6 m^3/s to 2.7 m^3/s each
Distribution plant	15 inductive flow meters, DN 1200
Aeration tanks	15 tanks, total volume 171,000 m^3

Process Measurement and Control

The new biological purification procedure follows a multistage process controlled by an innovative on-line measuring system. Based on the results of a two-year-long trial series in a specially designed pilot plant, two modes of operation ("bypass-process" and "hybrid-process") are applied. The first priority target is to manage the wastewater treatment process both cost-efficiently and for the highest possible removal of pollution. Ideally, the sensors controlling the processes of nitrification and denitrification have to be operated free of maintenance and free of failure to support this. After 2 years of intensive tests, s::can spectrometer probes had been selected as being best suited, particularly superior as compared to conventional UV probes. Main advantages are the potential to measure several parameters at the same time with one instrument only, and the very much reduced cross-sensitivity between the measured parameters.

Figure 2: s::can nitro::lyser™ installed at Vienna's Main Sewage Treatment Plant

In January of 2005 the initial set up of s::can's instruments was carried out by Siemens AG Oesterreich as the main contractor for instrumentation, supported by s::can Messtechnik GmbH as the sub-contractor for spectrometer probes.

Today Vienna's main sewage treatment plant uses 27 s::can instruments (the types are nitro::lyser™, carbo::lyser™ and spectro::lyser™) in order to monitor the primary-stage and the secondary-stage aeration tanks (NOx-N & TS) as well as the influent (COD, NO3-N, TS). In case of the secondary-stage aeration tanks the process of denitrification is controlled in real time by using nitro::lyser™ for managing the operation of the pumps re-circulating the activated sludge from aeration back to denitrification. The challenge to run in this large, complex and most innovative plant within just a few months was met most successfully by the team of plant operators and contractors.

"Verification of Uniformity & Accuracy"

After approximately 5 months of continuous operation the first test phase of the commissioning procedure was accomplished successfully by all s::can instruments without any problems. Furthermore, a test run called "Verification of Uniformity & Accuracy" had to be carried out on site in order to verify the requirements specified in the tender for measurement instrumentation. This challenging trial included eight instruments and was started up by a team consisting of experts both from Siemens AG and s::can GmbH. Three and five nitro::lyser™ respectively had to be operated in parallel, monitoring the process of nitrification/denitrification for a period of two weeks. Even the smallest intervention to the monitoring system was prohibited: It was neither allowed to touch the measurement instrumentation itself physically nor to modify both hardware and software settings.

First of all a special mounting device had to be designed in order to place several nitro::lyser™ next to each other. In addition an individual PLC had to be configured for the purpose: Besides recording and visualizing of the readings also online calculations comparing readings of adjacent instruments had to be carried out.

During this period the operational staff of the treatment plant ran diverse operating modes in order to validate the instrument's performance under most challenging operating conditions. Samples were taken to be analysed using standardized laboratory methods by an external approved laboratory. Target was the validation of the stability of the instruments as well as of the precision, the uniformity and the accuracy of their readings.

Impressive Results

The time series of eight s::can nitro::lyser™ were complete, without any interruption (i.e. no instrumental breakdown), thus the availability of all 8 instruments was 100 %. Using the automatic cleaning with compressed air, no indication of window fouling or instrument drift could be monitored.
Caused by different operating conditions the structure and constitution of the activated sludge did change several times. Because of the spectral algorithms s::can spectrometer probes use for compensating any cross-sensitivities, this did not affect the readings of nitrate. There was no need to calibrate the works calibrated instruments (so called "Global Calibration" for WWTP aeration basin) on site.

In opposition to another, more complicated spectrometer buoy recently introduced by another manufacturer, the speed and quality of the nitro::lyser™ measurement is independent of the settling properties of sludge. nitro::lyser™ read NO3-N at +/- 0,05 ppm every single minute, even at floating sludge conditions when the said spectrometer buoy does not provide any NO3 concentrations at all or only with great delay.

As ferric(III)chloride is added to the aeration tanks and some operating conditions require the dosing of organic polymers, the composition of the wastewater varies over hours. A newly developed spectral algorithm compensates cross-sensitivities caused by ferric oxides and/or polymers dissolved in the wastewater and/or precipitating at the optical surfaces of the probes; it was validated successfully. Both substances would have caused unacceptable interferences to conventional UV probes using one or two wavelengths only. The online tests were accompanied by extensive chemical analysis performed by an external approved laboratory. Samples were taken from different measuring points and standardized laboratory methods were used for analysing TSS, TS, NO3-N, NOx-N and COD. These results were compared to the online results of s::can instruments and the detected accuracies were clearly within the limits of the specification.

Results in Nitrification

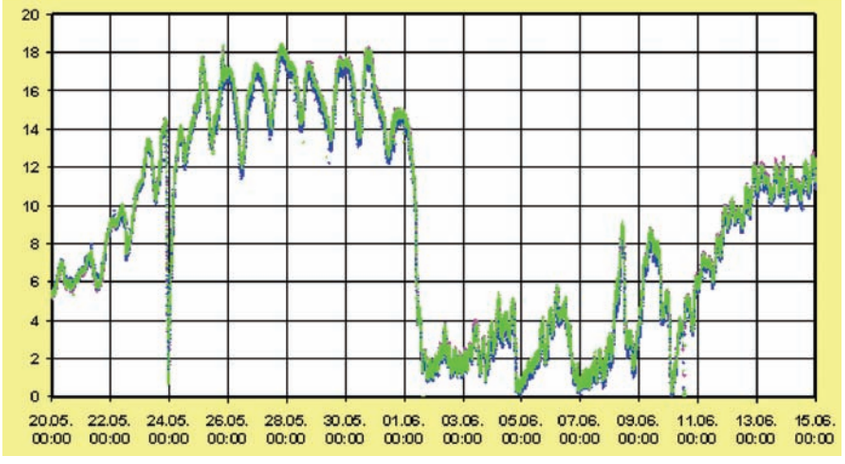

Figure 3: Three s::can nitro::lysers™ running parallel monitoring Nitrification

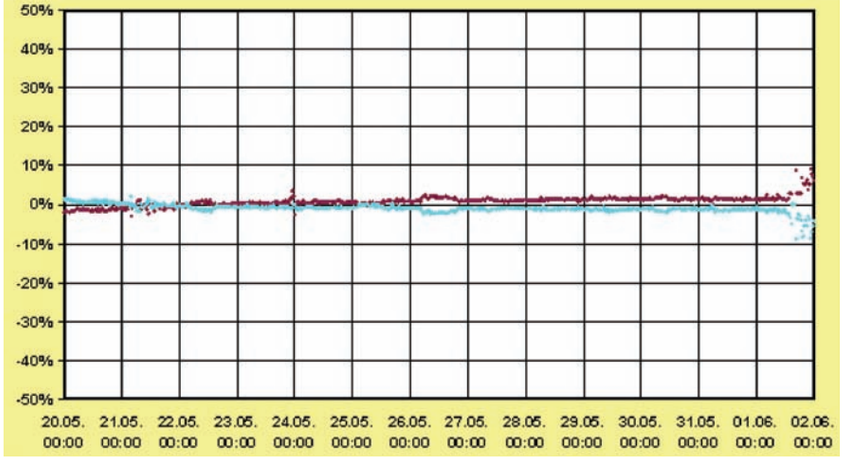

Figure 4: Percentual difference of adjacent s::can nitro::lyser™ running parallel (see also Figure 3)

The time series shown in the following figures were monitored by different s::can nitro::lyser™ placed next to each other, readings of one colour corresponding to one instrument. The time series of three s::can nitro::lyser™ in Figure 3 show identical concentration values respectively in nearly perfect accordance. The readings cover a range of approximately 19 mg/l NO3-Neq, thus the chosen optical path length of 0,5 mm fulfils the needs of the customer for monitoring the process of nitrification even at very high solids concentrations. The sudden declines of the readings close to 0 mg/l NO3-Neq (1st and 3rd of June) demonstrate impressively that the automatic cleaning device via compressed air did completely prevent window fouling.

Results in Denitrification

The time series of five s::can nitro::lyser™ (see Figure 5) show identical concentration values respectively in nearly perfect accordance. A range of approximately 7 mg/l NO3Neq is to be covered, thus the chosen optical path-length of 1,0 mm fulfils the needs of the plant for monitoring and controlling the denitrification process.

The periodical characteristics of the nitrate concentration correspond in detailed pattern to the operational measures carried out by the operators on site. Figure 5 demonstrates impressively that all used s::can nitro::lyser™ monitored the concentration of nitrate reliably. Even in case of smallest nitrate concentrations, changes of the compositions of the local wastewater caused by switching between several operational modes did not cause any noticeable interferences.

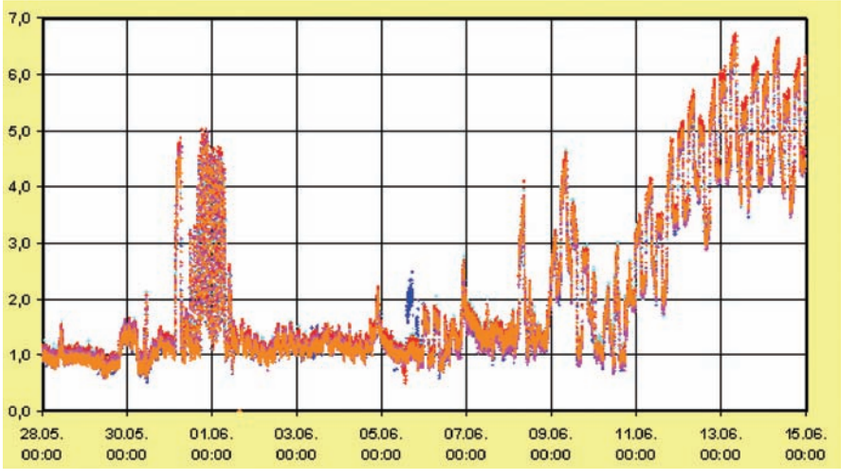

Figure 5: Five s::can nitro::lyser™ running in parallel monitoring the denitrification process

The percentual differences between nitrate readings of adjacent s::can nitro::lyser™ have been calculated using the results of Figure 5. The inter-instrumental comparability was clearly within the limits of 10% specified by the customer in the tender.

Summary

Vienna's Main Sewage Treatment Plant uses 27 s::can instruments (nitro::lyser™, carbo::lyser™ and spectro::lyser™) in order to monitor/control the processes of nitrification and denitrification as well as the influent and effluent of the plant. An intensive commissioning procedure took place from January to August of 2005 including long term reliability tests and eight instruments running in parallel for two weeks. All instruments showed identical concentration values respectively in nearly perfect accordance, and inter-instrumental comparability as well as accuracy were clearly within the specified limits. This success is considered a milestone for online sensors and further evidence for the suitability of spectrometric on-line in-situ probes as an efficient means for the control and management of wastewater treatment plants (Lit.*). *(Lit*) - Please ask for our literature and reference lists on CD !*