# Optimization of nutrient removal

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**KEY WORDS**

Instrumentation, nutrients, optimization, dissolved oxygen (DO), mixed liquor suspended solids (MLSS) concentration, ammonia, nitrate and phosphate, primary clarification, nitrification, denitrification, phosphate removal by precipitation, Colorimetry, UV absorption, Ion/Gas Selective Electrodes.

**INTRODUCTION**

The use of instrumentation in standard nitrification plants has limited acceptance. Flow and dissolved oxygen (DO) measurements are well accepted. Most of the time only flow is included in an automatic control strategy. Mixed liquor Suspended Solids, pH and ORP are used at times. The use of chemical analyzers to determine the concentration of ammonia and the inclusion in a control strategy remains an exception.

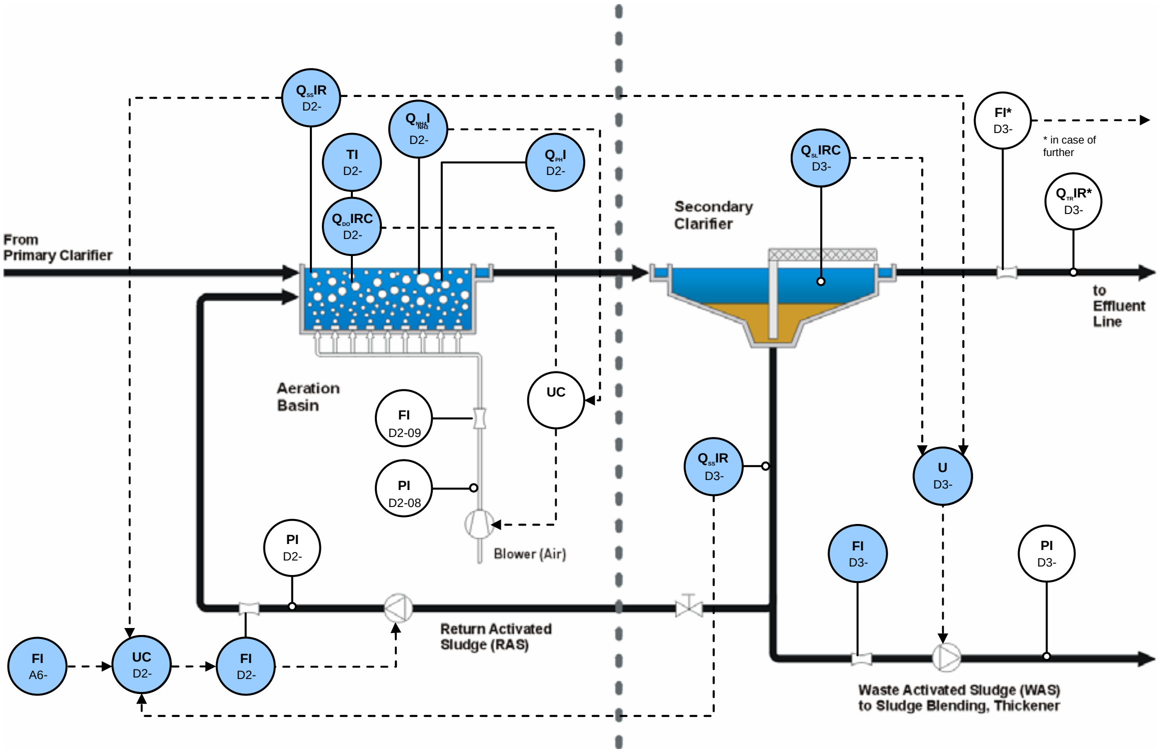
The complexity of the processes increases when denitrification and phosphate removal are added. Additional measurements such as nitrate and phosphate concentration become a requirement. Depending on the plant configuration the measurement of BOD, TOC or Methanol concentration could also be beneficial.

All the measurements required in the optimization of a process for nutrient removal require justification and recommendation for installation and use in a control strategy.

For each process we will define the best technology, the installation requirements for optimum performances and the role in the process optimization.

Those are some basic examples that can then be extrapolated to other processes

# NITRIFICATION




The biological treatment should be considered as one single process. For clarity we will cover aeration and clarification in 2 steps.

## Aeration

To insure nitrification, the first parameter to control is the amount of dissolved oxygen present in the mixed liquor. Membrane-covered amperometric sensor are widely used and accepted for monitoring. Instruments based on optical fluorescence technology are also available. Both technologies require a clean membrane. As for any type of instrument, the location is very important to provide a representation of the process. One must insure that at all times the sensor is submerged in the water and does not measure in the foam as the reading will be wrong. With the right quality of membrane, high velocity and turbulences provide enough cleaning to reduce maintenance. Automatic cleaning with air, water or chemical can be beneficial in some difficult applications when grease and fat are present or with little agitation.

The next measurement should certainly be a mixed liquor suspended solids (MLSS) concentration. The nitrification process can take place only if there is enough biomass to reduce the carbon load and transform the ammonia in nitrate. The other benefit of measuring the MLSS is that SRT can be defined. The best technology for that application is based on light scattering and absorption.

DO and MLSS measurements only insure that the aeration tank is in an acceptable status to perform its function. Additional information is required to optimize the process: bring the ammonia concentration at the desired level using a minimum of energy. When the ammonia load is low, the set point of the DO control loop can be reduced at least in the final part of the tank. This will reduce the energy consumption. But the discharge needs to be met, this means that the ammonia concentration should be known and controlled

Indirect measurements have tentatively been used to define the extent of nitrification in the tank. The measurement of pH can only be a warning that there is an upset in the plant. There is some intent to use Oxidation Reduction Potential (ORP) to monitor the nitrification level. In a laboratory, there is certainly a relation between nitrification / denitrification and ORP. When applied in a real wastewater plant, the correlation is very difficult to establish. Two reasons for this difficulty: the base ORP signal changes with time independently of the nitrification and an ORP sensor measures only a balance of oxidizing and reducing components. The raw water will have a changing ORP dependent of what has happened in the sewers and the primary treatment as well as the presence of dissolved salts. For Sequencing Batch Reactor applications, ORP could certainly provide a good help. The reason is that the same water stays in the tank all the time and the variation of ORP will show the reaction taking place. The control strategy should be based only on changes in ORP values not in absolute number.

The measurement of Ammonia or Ammonium is certainly the best information for process optimization. The installation point for the measurement must be selected based on the process. When it is possible to adjust the DO profile, ammonia must be measured at about half the nitrification tank. This provides the possibility to adjust the DO concentration in the last part of the tank: increasing the oxygen when ammonia is high and lowering it when the ammonia is low.

Ammonia can be measured using either colorimetry or ion/gas sensitive electrodes.

Colorimetry, based on the Beer Lambert law, is more accurate. The concentration is directly proportional to the absorption of light at the selected wavelength. The method limits the range of the instrument that is defined by the intensity of the light source, the sensitivity of the detector and the geometry of the measuring cell. Also the chemical reaction taking place takes time depending on the temperature. Instantaneous reading is not possible and temperature should either be measured and compensated for or the sample should be kept at constant temperature. Using multiple wavelengths, interferences from change of color of the water or presence of solids in the sample can be compensated. Ammonia, nitrate and phosphate can be measured using this technology.

Instruments based on Ion Selective Electrode have one advantage; they can work with a sample containing high concentration of solids. They also have a larger measurement range than instruments based on colorimetry. This could be an advantage in some industrial wastewaters. But those electrodes are not stable and require both frequent recalibration and adjustment of the sensitivity. Recalibration is done by filling the measuring vessel with a standard. Due to the size of the electrode itself, the measuring vessel is large and thus requires large amounts of chemical and sample. The adjustment for the change of sensitivity is usually done using the Single Known Addition method (SKA). A known amount of the chemical is added to the sample and a new measurement is taken. The slope of the sensor, its sensitivity, is then recalculated usually for each measurement. Ammonia and Nitrate can be measured using this technology

### Secondary clarification

A complete optimization of the nitrification stage must take into account secondary clarification. Three parameters have an influence on the overall performance of the nitrification process as they define the SRT and insure proper discharge: blanket level, RAS/WAS suspended solids concentration and suspended solids concentration in the overflow. In stable condition SRT can be used. For an operation with changing parameters Dynamic Sludge Age provides a better description of the reality.

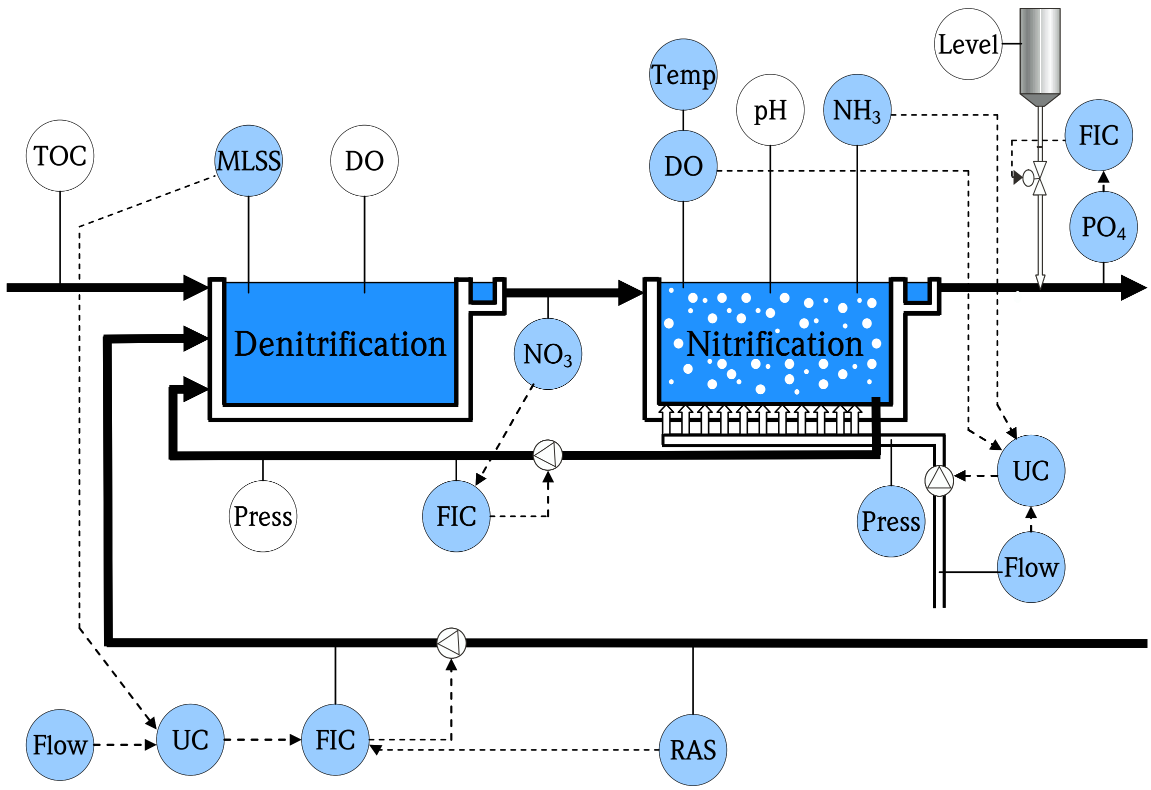
Nitrification is now under control and safeties are in place to set the process to the desired operation level.

## DENITRIFICATION

There are multiple processes to denitrify. Most of the denitrifying bacteria have similar requirements. They need energy to be able to extract the oxygen from the nitrate. Process will then use the organic material present in the wastewater as a source or add organic such as methanol to insure denitrification. The organic content, dissolved oxygen and nitrate concentration are the leading parameter to control the process.

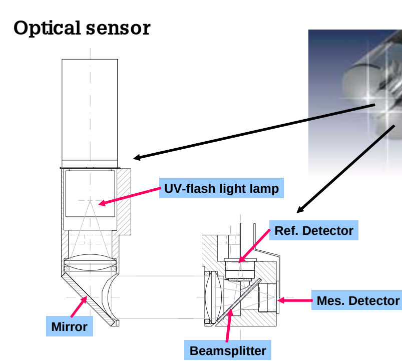
### Denitrification followed by nitrification

In the process illustrated below, the internal recirculation rate from the nitrification tank to the denitrification tank is the controlled parameter. It is not the objective of this paper to discuss the benefit of one type of process.




The recirculation rate will be based on the concentration of nitrate. UV absorption at 214nm is the easiest solution

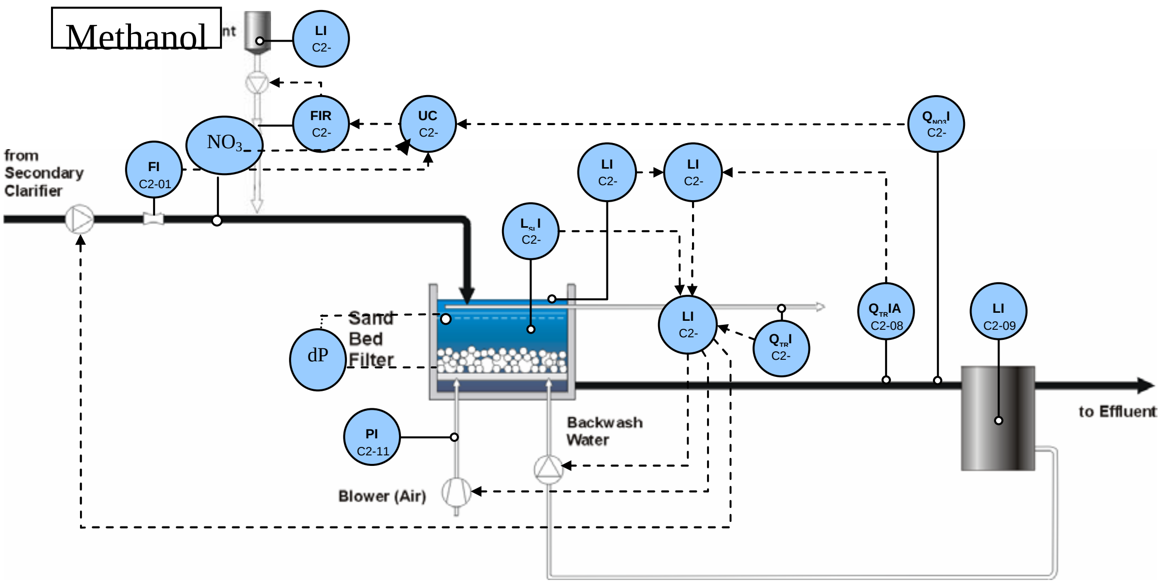
Nitrate has a strong absorption in the ultraviolet spectrum at 214 nanometers. This characteristic gives the possibility of a direct optical measurement with no need for reagents and significant reduced cost of ownership. The sensor is submersed in the process and compensates for changes in solids and color.




The denitrification will be more efficient if the organic content is high enough and if the DO concentration is very low. Measuring those two parameters insure the safety of the process. Because the DO concentration is ideally zero, the amperometric method can still be used but a three electrodes sensor will provide a better reading. For the organic measurement, there is a choice of technologies either determining TOC or BOD or dissolved organics. The same design as used for the nitrate sensor is available to measure dissolved organics because of the absorption at 254 nanometers. A correlation to TOC or

BOD can be established when the composition of organic material remain relatively stable. Again the cost of ownership favors the optical sensor.

**Denitrification with filtration**

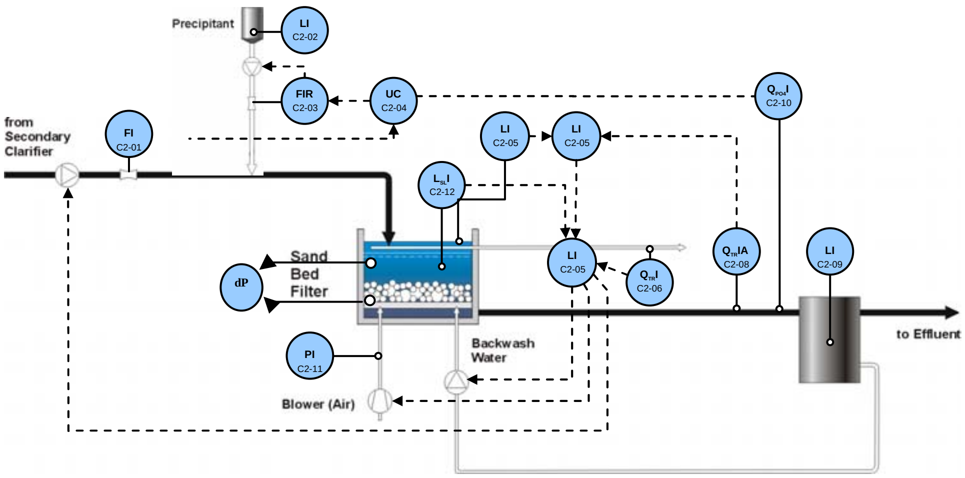



This type of process presents the same requirements for organic content, oxygen and the need for nitrate measurement. Because the organic content is low, methanol is usually added as carbon source. The dosification should be based on flow and the nitrate content the incoming water. Feedback will be based on the nitrate content of the filtered water. It is possible to measure the concentration of methanol with wet chemistry.

The other parameters measured around a filter such as flow, water level, differential pressure and turbidity are quite standard. The backwash can also be optimized by adjusting the backwash flow based on the measurement of bed expansion. It is very important to prevent the loss of filter material and insure good washing. This can be done using an ultrasonic blanket level. Measuring the turbidity of the backwash water provides a mean to define the end of the backwash. Once the backwash water reaches a low limit, the backwash can be stopped.

## PHOSPHATE REMOVAL

Phosphate can be removed biologically or by precipitation either in primary clarification, secondary clarification or filtration. Orthophosphate can only be measured using colorimetry. As for any colorimeter, sample preparation is the key to a successful operation of the analyzer. The sample preparation system depends on the application.




Phosphates can be measured only using Colorimetry. The base instrument measures orthophosphate that is dissolved in the wastewater. It uses the same principle as described for Ammonia. Measuring total phosphate is more difficult as it requires digestion to free the attached phosphorus and transform it into orthophosphate. It is possible but it may not be useful for control, as typically only the orthophosphate can be controlled by precipitation.

### Sample preparation systems

For most analyzers using Colorimetry or ISE the wastewater need some preparation before reaching the instrument. Filtered water can usually be measured directly. A continuous sampling line will feed the analyzer. The installation of a simple gasoline type filter will prevent large particles to reach the analyzer in case of upset in the filter. Membrane filtration can be used either on a sampling line or directly in an aeration tank.

Mechanical filter with automatic backwash are available for applications with low solids content such as secondary clarifier effluent. The filter has 50 microns holes. Water or pressurized air can be used for the backwash.

Automatic backwash reduces the requirement for maintenance.

**CONCLUSION**

The instrumentation is available for the optimization of nutrient removal. The addition of instruments increases the maintenance requirements. Thus each individual plant has to define its priorities based on

- Process limitations and complexity
- Return on investment
- Technical capability

Most suppliers of instrumentation can provide maintenance contracts. This may appear as an increase to the cost of ownership, but the gain in reliability has its own return on investment.

# WERF RFP No. 03-CTS-8

Stamosens In Situ UV Nitrate performances at the field test at the DC WASA WWTP.


The only instrument with:

- no out of conformance
- no recalibration
- no maintenance event
- no required supplier support
- the highest percentage of values within 1 mg/l of the lab values

QUOTE: "Based on this field test, the Endress+Hauser Stamosens most consistently and most accurately measured the nitrate concentration in the test tank when compared to the laboratory conformance measurement."

# Endress+Hauser chemical analyzers

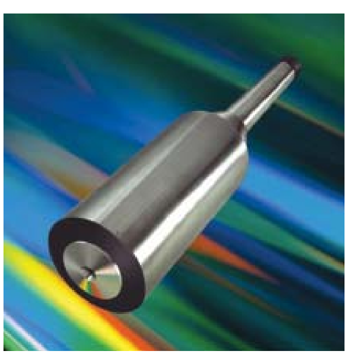

Stamolys systems for measurement of ammonia, nitrite, orthophosphate, silicate, manganese, hydrazine, total hardness, iron, copper, chromate, aluminum, and chlorine.

Stamosens in-situ systems for continuous nitrate measurement and continuous UV absorption measurement without the use of chemicals.

The BIOX and STIPTOX systems use a turbulent-bed bioreactor to continuously measure BOD or toxicity.

GENION systems use ion-selective electrode technology to measure ammonia.

SPECTRON systems use colorimetric/spectrophotometric methods to measure total phosphorus.



A STIP-Scan system consists of a multi-parameter probe, user interface (and weather-proof housing for installation outdoors) for the continuous measurement of nitrate, COD/TOC or UV254, and when placed in an aeration basin total suspended solids, sludge volume and sludge index. Requires no chemicals.

Endress+Hauser STIP Helios in-situ probes measure ammonia or phosphate through direct immersion in the sample.

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