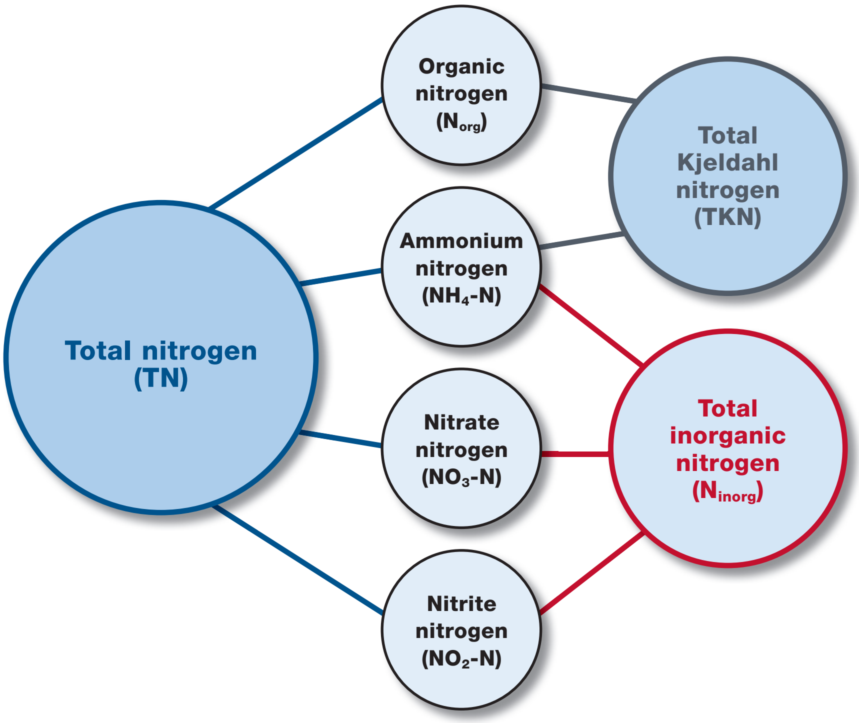
PRACTICE REPORT
LABORATORY ANALYSIS & PROCESS ANALYSIS
NUTRIENTS
NITROGEN COMPOUNDS



Nitrogen parameters: Nitrification, Denitrification

The **elimination of nitrogen compounds** is a fundamental aspect of wastewater treatment. **Nitrification** and **denitrification** have to be controlled as efficiently as possible to ensure that outflow concentrations comply with the legal requirements. This is where analysis comes in, as enduringly stable and cost-effective plant operation depends on targeted and comprehensive measurements of the individual N parameters. The best results are obtained using a **combination of laboratory analysis** (cuvette tests) and **process measurement technology** (online sensors) at suitable measurement locations in and at the end of the wastewater treatment process.

Author:
Petra Pütz
- "Diplom-Ingenieur", chemistry
- HACH LANGE applications laboratory products

Wastewater treatment: elimination of nitrogen

Fig. 1: Ideal for balancing and outflow monitoring – LATON cuvette tests for the determination of total nitrogen (TN)

Fig. 2: Spectrophotometer for the precise evaluation of LANGE cuvette tests, e.g. for nitrogen analysis

Fig. 3: NITRATAX sc for continuous monitoring of nitrate nitrogen and for controlling the nitrification process

Legislative background

Nitrogen compounds have a variety of effects on surface waters:

- ➔ N_{org} – strongly oxygen depleting
- ➔ NH_4^+ – oxygen depleting; bei pH > 8, toxic to fish
- ➔ NO_3^- – eutrophying
- ➔ NO_2^- – highly toxic to fish

Legislators have therefore defined limit values for nitrogen compounds in wastewater discharges to surface waters. According to the EU Directive concerning urban waste water treatment (91/271/EEC), the total nitrogen (TN) in the outflow of a sewage treatment plant must not exceed a limit value of 15 mg/L or 10 mg/L (depending on the size of the plant), or must be at least 70–80 % lower than the concentration in the plant inflow. Most Member States impose additional requirements. In Germany, for example, the General Administrative Framework Regulation on Wastewater [Abwasserverordnung] specifies minimum requirements for NH_4-N and N_{inorg}. Moreover, the total nitrogen in inorganic compounds is used to determine wastewater charges.

Nitrogen elimination

Nitrogen in the inflow of a municipal sewage treatment plant is largely present as organic ammonium (urea, proteins, etc.) and ammonium nitrogen. The exact relationship of the two parameters to each other depends on various factors, including the length of the sewage network, which is where the conversion of N_{org} to NH_4-N begins. The process of ammonification continues in the sewage treatment plant, so that most of the nitrogen in the inflow to the aeration tank is in the form of NH_4-N.

➔ Nitrification

During the biological wastewater treatment stage, NH_4-N is converted with the help of added oxygen to NO_2-N and then NO_3-N. The microorganisms responsible for nitrification (Nitrosomonas and Nitrobacter) are, however, extremely sensitive. They require constant temperatures of not less than 12 °C, together with a favourable C:N:P ratio and an adequate supply of added oxygen. The sludge age should be adjusted to the slow multiplication of the nitrifying bacteria. If the nitrification process breaks down,

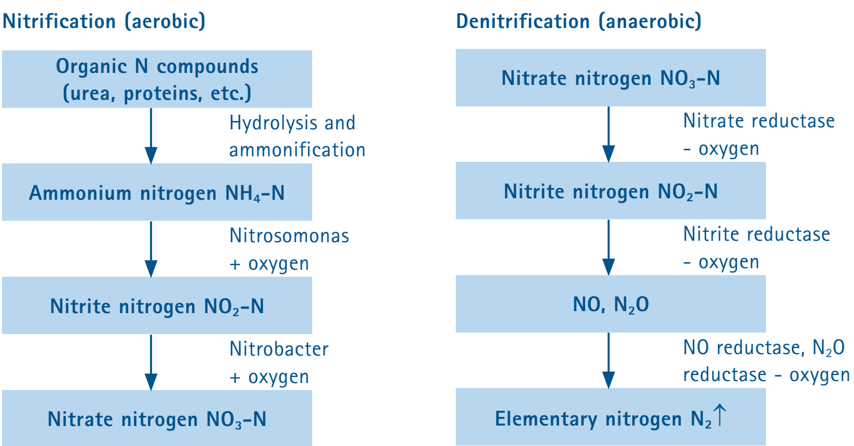


Fig. 4: Degradation processes associated with nitrogen elimination

Table 1: Overview of individual nitrogen parameters and determination options

N compounds	Formula	Sample preparation	Cuvette tests	Process instruments	Measurement points, relevance
Organic nitrogen	N_{org}	Homogenisation, digestion			Sewage treatment plant inflow; conversion to NH_4-N during the course of the wastewater treatment
Ammonium nitrogen	NH_4-N	Filtration	LCK302 LCK303 LCK304 LCK305	AISE sc AN-ISE sc AMTAX sc	Sewage treatment plant inflow, aeration, sewage treatment plant outflow; control of nitrification/denitrification, monitoring of limit values
Nitrate nitrogen	NO_3-N	Filtration	LCK339 LCK340	NISE sc AN-ISE sc NITRATAX sc	Aeration, sewage treatment plant outflow; control of nitrification/denitrification, monitoring of limit values
Nitrite nitrification	NO_2-N	Filtration	LCK341 LCK342 LCK541		Aeration, sewage treatment plant outflow; relatively unstable intermediate product of nitrification/denitrification, monitoring of limit values
Inorganic nitrogen (= NH_4-N + NO_3-N + NO_2-N)	N_{inorg} (in the legislation often confusingly referred to as N_{total})	Filtration	LCK302/303/ 304/305 + LCK339/340 + LCK341/342/541		Sewage treatment plant outflow; monitoring of limit values, relevant parameter for wastewater charges
Kjeldahl nitrogen = N_{org} + NH_4-N	TKN	Homogenisation, digestion			Sewage treatment plant inflow; balancing
Total nitrogen (= N_{org} + NH_4-N + NO_3-N + NO_2-N)	TN	Homogenisation, digestion	LCK138 LCK238 LCK338		Sewage treatment plant inflow, sewage treatment plant outflow; balancing, limit value monitoring in accordance with EU directive
Important: In wastewater analysis, concentrations are always expressed in terms of the N content! The results are therefore shown as xx N (conversion factors: NH_4-N × 1.3 = NH_4^+ / NO_3-N × 4.4 = NO_3^- / NO_2-N × 3.3 = NO_2^-).					

several days may be elapse before it stabilises again.

➔ Denitrification

Under anoxic conditions, NO_3-N is converted to elementary nitrogen via the intermediate products NO_2-N and NO/N_2O. Denitrification is carried out either before (upstream), during (simultaneous) or after (downstream, rare) the biological treatment stage.
The presence of sufficient readily biodegradable carbon is important for this process. No dissolved oxygen must be present.

Literature

- HACH LANGE Practice Report "The right process measurement technology for N and P degradation", February 2008.
- HACH LANGE Practice Report "Optimal nutrient ratios for wastewater treatment", March 2008
- EU directive of 21 May 1991 concerning urban waste water treatment (91/271/EEC)

Fig. 5: Ion-selective sc probe with innovative CARTRICAL technology for stable, continuous monitoring of ammonium nitrogen content.

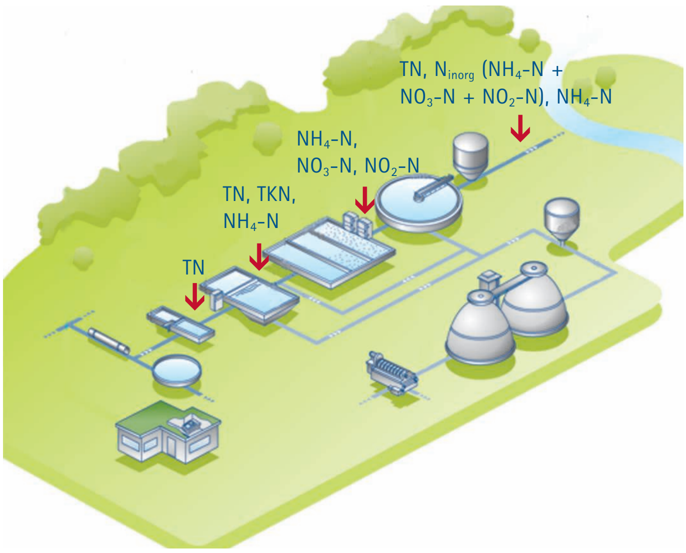
N elimination: optimal operational reliability through optimal analysis

Only regular, targeted measurements of the individual nitrogen parameters make lastingly functional and therefore cost-effective nitrogen elimination possible: **Online with process sensors** (NH_4-N, NO_3-N) and **in the laboratory with the LANGE cuvette test system** (NH_4-N, NO_3-N, NO_2-N, TN). Changes to the plant or variations in the inflow make even closer monitoring necessary, as the microorganisms adjust only slowly to the new conditions. This is especially true of the sensitive nitrifying bacteria. A number of days may pass before the biological system adjusts to the changes and maximum biodegradation efficiency is restored. The same applies when an incident that impairs the biological system occurs (e.g. an extreme inflow peak or an inflow of toxic substances). Extreme inflow peaks can flush microorganisms out of the aeration tank, to the long-term detriment of the nitrification process.

Stable and reliable limit values in the outflow are best achieved by maintaining uniform loading of the biological system. An exact (analytical) assessment of the individual nitrogen degradation processes is therefore necessary, to ensure that any undesirable influences deriving from the sewage network, the plant load or the plant procedures are quickly detected. Immediate counter-measures can then be initiated before the biological processes are seriously disrupted.

Typical measurement locations for the nitrogen parameters

- → Sewage treatment plant inflow: TN
- → Inflow to aeration tank: TN, TKN, NH_4-N
- → Outflow from denitrification stage: NH_4-N
- → Outflow from nitrification stage: NO_3-N, NO_2-N
- → Sewage treatment plant outflow: TN, N_{inorg} (NH_4-N + NO_3-N + NO_2-N), NH_4-N



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Hazard symbols
Corrosive (LCK339/340/138/238/338)
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Dangerous for the environment (LCK302/303/304/305)

DOC040.52.10015.Oct12

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