NAR: NITROGEN RECOVERY FROM CONCENTRATED SLURRIES

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Abstract

Anaerobic digestion is sensitive to high NH_3 concentrations, which are inhibiting and at certain levels even toxic. Poisoning is depending on concentration and pH due to the NH_3 - NH_4^- equilibrium. Bacteria in the thermophilic range (50 - 60 ^{0}C) are even more sensitive than the bacteria in the mesophilic (30 - 40 ^{0}C) range. Generally the level of N Kjehldahl is toxic at a level of 7,000 mg/l at a pH of 7.2 for mesophilic bacteria. For thermophilic bacteria the level is 4,500 mg/l at pH of 7.2.

During anaerobic digestion of manure, COD and BOD are removed by 70 - 80 %. Nitrogen is hardly removed and the only removal is due to cell synthesis, therefore the effluent of the anaerobic treatment often features a too high COD/N ratio making it difficult to treat by aerobic biological treatment and reach the desired consent on nitrogen.

The Nijhuis Ammonia Recovery unit or NAR, has been developed to remove NH_3. This technique is based on stripping of NH_3 from liquid. The carrier gas is washed with sulfuric acid in order to form ammonium sulfate, which is accepted as a nutrient and can be used for agricultural purposes. Because NH_3 separates easier at high temperature and pH the process is foreseen to run at approximate 80 ^{0}C and pH 8.5.

Keywords

NAR, Nitrogen recovery, removal, digestate treatment, nutrient production.

NAR PROCESS

Nijhuis Water Technology has developed a new type of ammonia stripper (NAR) to recover nitrogen from concentrated streams. In figure 1 a flow diagram is shown of the ammonium stripper.

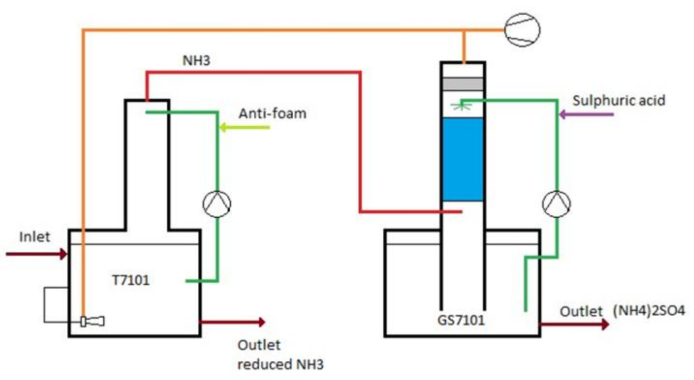

Figure 1: NAR flow diagram

The substrate in the stripping tank (T7101) is adjusted to optimal conditions, 60 to 80 °C and pH 8 – 9, in order to strip the ammonia from the substrate. Gas is circulated through the substrate in the stripping tank and the contact column and transports ammonia from the stripper tank to the scrubber column. Fresh air is pumped into the circulation gas flow which increases the pH in the stripper tank and improves transport from ammonia into the gas phase.

Heating takes place into two steps:

- Heat exchanging from effluent to influent in order to recover energy.
- Final heating with steam or other available heat source.

The gas containing Ammonia **(GS7101)** is washed in a scrubber column with sulphuric acid. Ammonia and Sulphuric acid are converted into an Ammonium sulphate ($(NH_4)_2SO_4$) solution eq. (1).

$$2NH_3 + 2H^+ + SO_4^{2-} \rightarrow 2NH_4^+ + SO_4^{2-} \text{ (dissolved } (NH_4)_2SO_4) \quad (1)$$

Carrier gas free from Ammonia is reused in the Stripping tank. The produced ammonium sulphate solution can be used as a liquid fertiliser in agriculture.

Following process configurations are possible;

Removal during hydrolysis

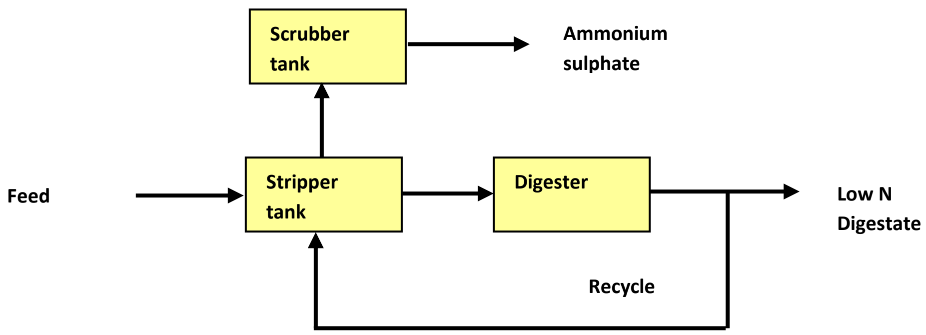

Figure 2: Ammonia recovery during hydrolysis

In this configuration the stripper tank acts also as a (chemical/physical) hydrolysis tank. The stripper tank is operated at high temperature (70 - 90 ^{0}C). Optionally a part of the digestate can be recycled in order to dilute the feed and to enhance the removal efficiency.

- Ammonia is removed prior to digester, which removes the toxic effect of NH_3 and makes the application of a thermophilic digester more often possible.
- Stripper tank also acts as a hydrolysis tank. Hydrolysis of suspended solids increases the treatability of the slurry which is stripped, a higher gas yield is expected.
- The feed is pasteurized in the stripper tank.

Ammonia removal post digester

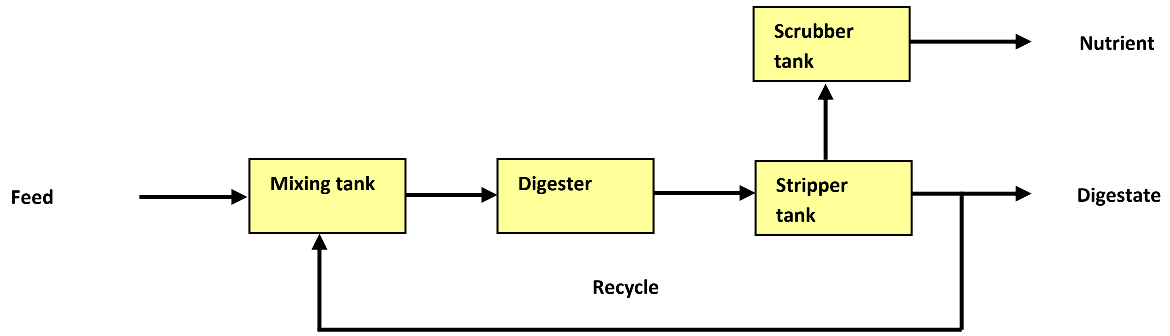

Figure 3: Ammonia recovery post digester

In this configuration the stripper tank is positioned after the digester. The stripper tank is operated at high temperature (70 – 90 °C). A part of the digestate can optional be recycled in order to dilute the feed and to enhance the removal efficiency.

- The NH_3-N/total-N ratio is for raw manure approximately 0,5. For digestate this ratio is approximately 0,7 - 0,8. This makes the stripper efficiency after the digester higher than before the digester.
- The feed is pasteurized in the stripper tank.
- Digester still has high N loading (also depending on recycle flow) which can lead to a toxic level in the digester. Thermophilic process is not always feasible with a high N loading.
- No high temperature hydrolysis prior to digester.

Laboratory scale testing

In cooperation with Wageningen University a series of batch tests have been executed. During these test it was shown that 75 % of the ammonia can be removed at a temperature of 80 °C and pH of 8.5.

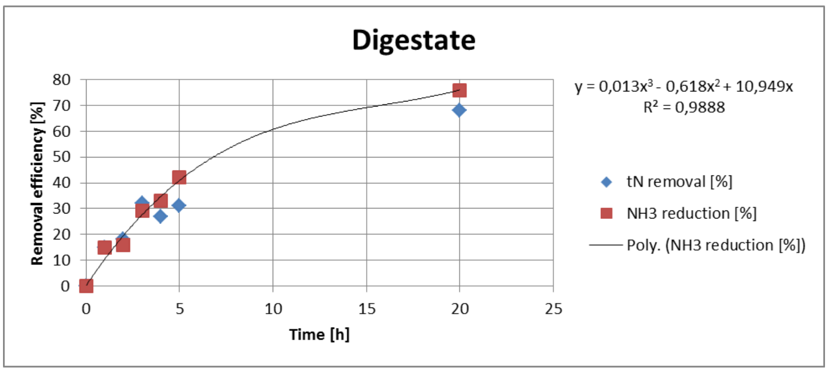

Figure 4: Performance overview of laboratory scale batch test at 80 °C.

Pilot scale testing

The system has been scaled up to a continuous pilot plant (see figure 5). The pilot is currently in operation at a manure digestion plant. Data from the pilot research are accumulated and evaluated into a process calculation model.

Figure 5: NAR Pilot plant and mass balance of a pilot result

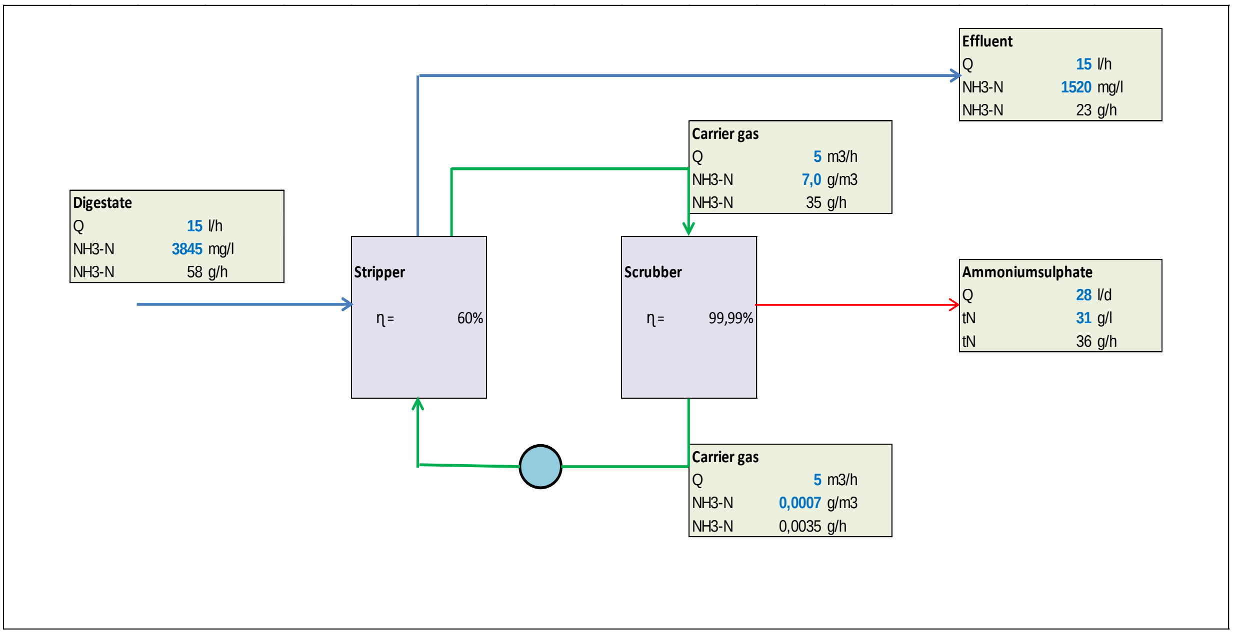

Figure 6: Pilot mass balance

During the pilot scale the effect of the treatment on total COD and dissolved COD was recorded. The total COD showed a slight reduction of 5 – 15 %, the dissolved COD showed an increase of 20 – 30 % on digestate from pig manure. This effect is caused by further hydrolysis of solids in the stripper tank at high temperature. It is expected the hydrolysis increases the treatability of the slurry which is stripped, a higher gas yield is realised if the stripper is before the digester or better conversion in an aerobic post treatment.

Full scale plant

Based on the accumulated data a full scale plant has been built. While the process equipment is containerised in a 40 feet container (see figure 7), the stripper tank, contact column and the scrubber column are positioned outdoor (see figure 8).

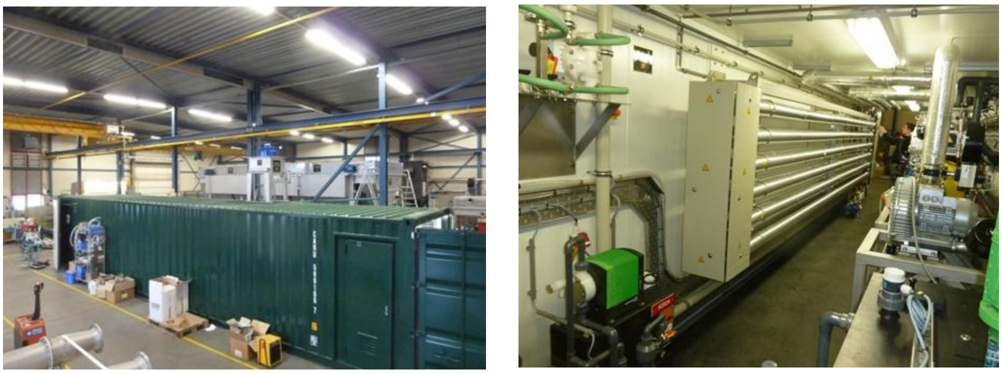

Figure 7: Container under construction in the Nijhuis work shop.

Heat from the effluent is recoverd with the use of pipe heat exchangers to pre-heat the influent from 35 to 70 ^{0}C. Additional heat is required to heat slurry from 70 to 80 ^{0}C. Heating is accomplished with steam injection.

In order to control the ammoniumsulphate concentration both the stripper and scrubber are heated.

The full scale plant is presently in a commissioning phase.

Figure 8: NAR under construction at Bernard Matthews site, in the back ground the anaerobic digester is visible.

CAPEX – OPEX

The operational cost of the ammonia stripper has been calculated based on annuities:

Type	-	NAR100	
Capacity	-	100	m^3/d
$\eta_{total\ N}$	-	80	%
N removal	-	192	kg N/day
Operation	-	24	h/d
		365	d/year
Corrected interest	-	4	%
Economic lifetime			
Mechanical	-	10	years
Electrical	-	10	years
Civil	-	15	years
Electrical cost	-	0.075	GBP/kW
Sulphuric acid cost	-	0.11	GBP/kg 50 % sulphuric acid
Steam cost	-	15	GBP/kg

Table 1: Economic review of the NAR 100 concept

Parameter	Units	CAPEX	OPEX	Total
Total cost	GBP/year	31,000	60,500	91,500
Cost per ton treated	GBP/ton	0.85	0.87	1.72
Cost per kg of N removed	GBP/kg	0.44	0.87	1.31

In Table 2 cost of different N removal techniques are compared.

Table 2: Total operation cost compared to alternative technology

System	Concentration range	N reduction	Cost
Stripping	>2000 mg N/l	70 – 90 %	1.20 – 1.40 GBP/kg N removed
Biological treatment	<250 mg N/l	>95 %	2.1 – 3.8 GBP/kg N removed
Sharon, Anamox	>250 mg N/l	<75 %	1.5 – 3.0 GBP/kg N removed

Conclusion

Based on the research done the following can be concluded:

- At a temperature of 60 – 80 C NH_3 can be removed up to 80 %.
- Stripping increases hydrolysis of the substrate, $COD_{soluable}$ of digested pig manure increased with 20 – 30 %. This increases treatability both anaerobic an aerobic of the effluent.
- Anaerobic digestion can be inhibited by high ammonia concentrations. The NAR is developed to remove NH_3 prior to anaerobic treatment to avoid toxicity.
- Stripping is an economical technology to remove N from highly polluted slurries like digestate at a cost of 1.20 – 1.40 GBP/kg N removed.
- The removed nitrogen is captured in the form of a liquid fertiliser with residual value.
- The NAR makes digestion of N-rich substrate like chicken manure and slaughter waste possible.

Literature

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