COST EFFICIENT SLUDGE LIQUOR TREATMENT

P. Johansson, A. Nyberg[1)]
M. Beier, A. Hippen, C.F. Seyfried, K-H. Rosenwinkel[2)]

1). PURAC AB, Box 1146, SE-221 05 Lund, SWEDEN
2). Institute of Sanitary Engineering and Solid Waste Management, University of Hannover, Welfengarten 1, D-30167 Hannover, GERMANY

INTRODUCTION

For sludge liquors the normal way is to lead the different reject water streams back to the inlet of the treatmentplant thus producing high and irregular internal loads that can be difficult to control and which cause problem for the normal treatment. A solution to the problem is to introduce a separate treatment. Sludge liquors, discharge from land-fills and some industrial waters are highly concentrated in nitrogen and the known treatment methods for example ion exchange, ammonia stripping, membranes and biological nitrification/denitrification are expensive.

The operational costs for a biological nitrogen-removal process is highly dependent on the relation COD/N. Normaly external carbon must be dosed because the COD available for denitrification in the sludge liquor is not enough. Another cost is the high oxygen demand for the nitrification process. This paper presents results from pilot scale trials with alternative biological treatment of nitrogen-rich water waste. The methods tested have a lower carbon and oxygen demand than conventional nitrification/denitrification.

DIFFERENT PROCESSES

Nitrification is an aerobic two-step reaction where ammonia oxidants (*Nitrosomonas*) oxidize ammonium to nitrite and nitrite oxidants (*Nitrobacter*) oxidise nitrite to nitrate.

Nitritation $NH_4^+ + 1.5O_2 \rightarrow NO_2^- + 2H^+ + H_2O$
Nitratation $NO_2^- + 0.5\,O_2 \rightarrow NO_3^-$

Denitrification is an anoxic process where facultative anaerobic micro-organisms use the oxygen bound to nitrate or nitrite for respiration.

Denitratation $2\,NO_3^- + 10\,H^+ + 10e^- \rightarrow 2\,OH^- + 4\,H_2O + N_2$
Denitritation $2\,NO_2^- + 6\,H^+ + 6e^- \rightarrow 2\,OH^- + 2\,H_2O + N_2$

As nitrification and denitrification are carried out under different conditions and by different micro-organisms the experience show that the processes have to be separated in time or space. Now there have been many reports showing that known microorganisms under special conditions can eliminate nitrogen in other ways than conventional nitrification/denitrification. One of the moste interresting new processes is when nitrogen reduction takes place under aerobic conditions and without any need of carbon. *Bock et al (Ref. 3)* have shown that a mixed culture of Nitrosomonas and aerobic denitrifiers can eliminate ammonium to a high extent.

Strous et al (Ref. 4) report of ammonia reduction under anoxic conditions, the process have been named Anammox and the reaction can simplified be written as

Anammox $$NH_4 + NO_2^- \rightarrow N_2 + 2\,H_2O$$

The Anammox is considered to be autotrophic so there is no need for external carbon to support the formation of dinitrogen. As nitrite is used as electron acceptor it is interesting to make a process configuration of a pre-nitritation followed by an Anammox. The operational conditions for the process are pH around 8, no oxygen and a high temperature. *Strous et al (Ref. 4)* made their trials in a fixed- and a fluidised-bed and operated at a temperature of 36°C. They reached ammonia reductions of >80%.

Another new process is the Sharon reactor *Mulder and Kempen* (*Ref. 5) and Draaijer et al (Ref. 6)*. The Sharon process is a one reactor treatment with an aerated zone followed by a mechanically mixed zone. This is also a process that is designed to operate at high temperatures, around 35 °C. In the Sharon process it is considered that the reactions are conventional nitrification/denitrification alt. nitritation/denitritation where the high temperature and substrate concentration makes it possible to operate without any sludge recirculation. The denitrification/denitritation is supported by dosing external carbon. It is preferrable to restrict the process to nitritation/denitritation in order to save oxygen and carbon. Results from full scale plants show that ammonia can be reduced from 650 to <1 mg/l and the effluent NO_x is around 100 mg/l.

Hippen et al (Ref 1) describes nitrogen removal in the presence of oxygen and without any need of carbon that is refered to as aerobic deammonification. With this process more nitrogen is removed than that the BOD:N-ratio makes possible according to the traditional theory of biological nitrogen removal. The aerobic deammonification means transformation of ammonium into dinitrogen under oxygen limitation and without using carbon carried out by Nitrosomonas. It is thought that the ammonia is oxidised to nitrite which is then denitrified to dinitrogen *Bock et al (Ref 3)*, *Zart et al (Ref 7)*.

It seams as the growth of the microorganisms involved in the aerobic deammonification are favoured when the water have undergone anaerobic pre treatment (for example lechate from landfills and sludgewater) *Hippen et al (Ref 1)* have made an examination of a full scale plant treating water from a landfill in biological contactors were the results show that the process is direct deammonification. Concerning ammonia reduction the efficiency was higher than >80%. A traditional explanation to simultanously nitrification/denitrification is that anoxic zones are formed in the interiour of the activatesludge flocs or the biofilm. *Helmer and Kunst (Ref. 2)* shows in complementary laboratory tests with homogenised biofilm that the process is realy aerobic deammonification and that the end product is dinitrogen.

RESULTS FROM PILOT TRIALS

Purac has together with the University of Hannover run parallel tests of nitrification/denitrification, nitritation/denitritation and deammonification in order to find the conditions that allows a stable operation. The Kaldnes suspended carriers have been used in the trials because it is a suitable process for developping specialized biomass.

Materials and methods

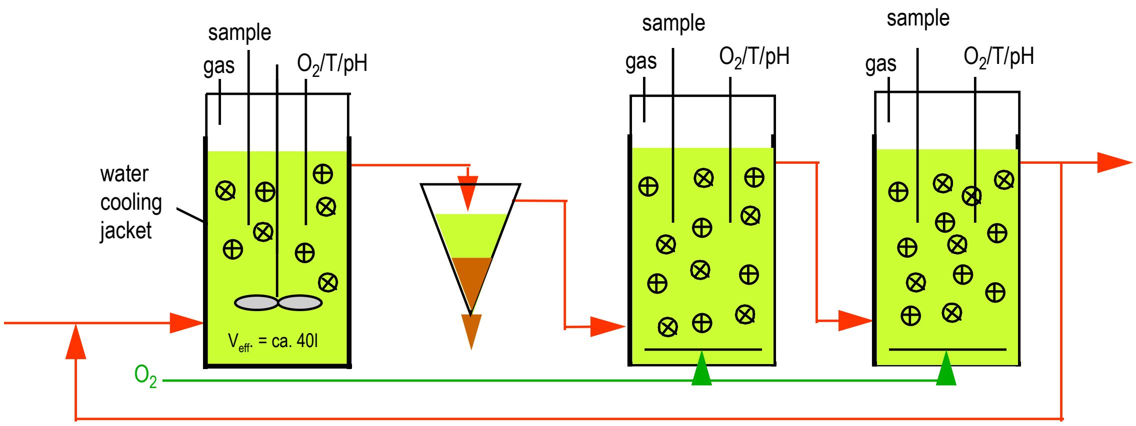
Each line of the pilot plant consists of three biological reactors and a sedimentation tank which can be used as secondary or intermediate clarifier. The biological reactors can be completely sealed off and have a water volume of 0.04 m^3. The influent is close to the bottom of the reactor and the effluent at the top. It is possible to add air or any given mixture between oxygen and helium. The gas is supplied through a ring shaped membrane aeration device at the bottom of the reactor. The reactors were filled with Kaldnes carriers to 20 %.

Specification of the Kaldnes carrier

Material	Polyethylene	
Density	Just below the density of water	
Diameter	9.9	mm
Lenght	8.1	mm
Wall thickne s	0.66	mm

Ødegaard et al (Ref 8) showed that according to high shearing power at the outside of the carriers there is no guarantee that biofilm will develop on the outside. In the calculations of the surface available for the biofilm processes only the inside of the carriers have been considered giving the Kaldnes material a surface of 500 m^2/m^3. With the actual filling of 20% this gives an active surface of 100 m^2/m^3. Mixing and circulation of the carriers in the bioreactors were made through aeration, or when the air supplied was insufficient, by mechanical mixers.

Nitrification/denitrification and nitritation/denitritation



Aerobic deammonification

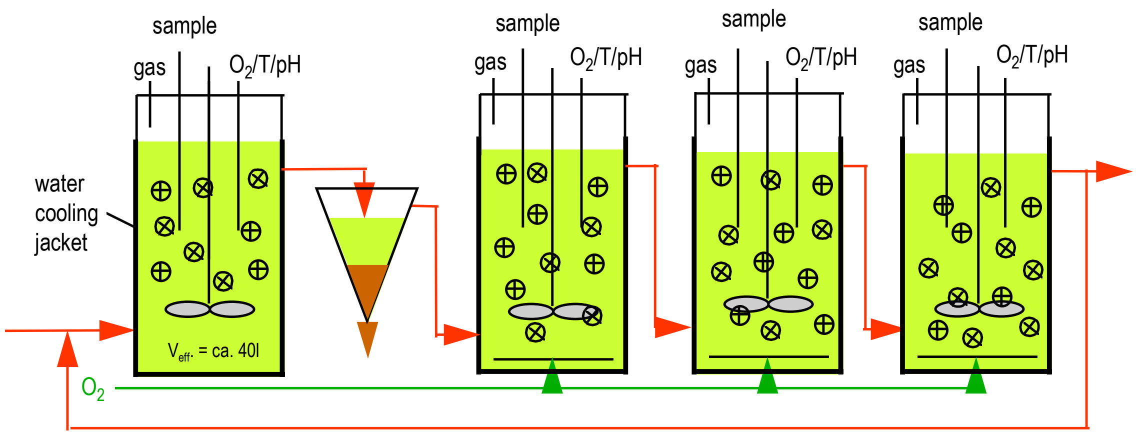


Figure 1.Experimental set-up of the pilot trials.

As an example of a waste water with high ammonia concentration and a low BOD/COD-ratio water from sludge treatment of a municipal plant have been used. The waste water was taken from the Gümmerwald plant, city of Hannover. Characteristics of the sludge water can be seen in table 1 below.

Table 1Average composition of the influent sludge water

Parameter		
COD	710	mg/l
BOD_5	220	mg/l
N-tot	1 300	mg/l
NH_4-N	1 200	mg/l
TSS	100	mg/l
pH	7,2	
Acid cap.	72	mmol/l
Temperature	30	°C

The operation conditions for the nitritation /denitritation and the deammonification lines are showed in tabel 2.

Table 2 Operatin conditions for the pilot

Parameter	(de)nitritation	deammonification	
Volume	40	40	l
Retention time	6.4	6.4	h
NH_4-N	250-350	250-350	mg/l
Surface load	7-12	4-8	g N/m^2,d
Oxygen	>6,0	<1,0	mg/l
pH	7.5-8.5	8.0-8.5	
Temperature	22-25	approx. 27	°C

The nitritation /denitritation line was operated several months with stable results. Degradation rates between 4-7 g N/m^2,d have been measured, see figure 2.

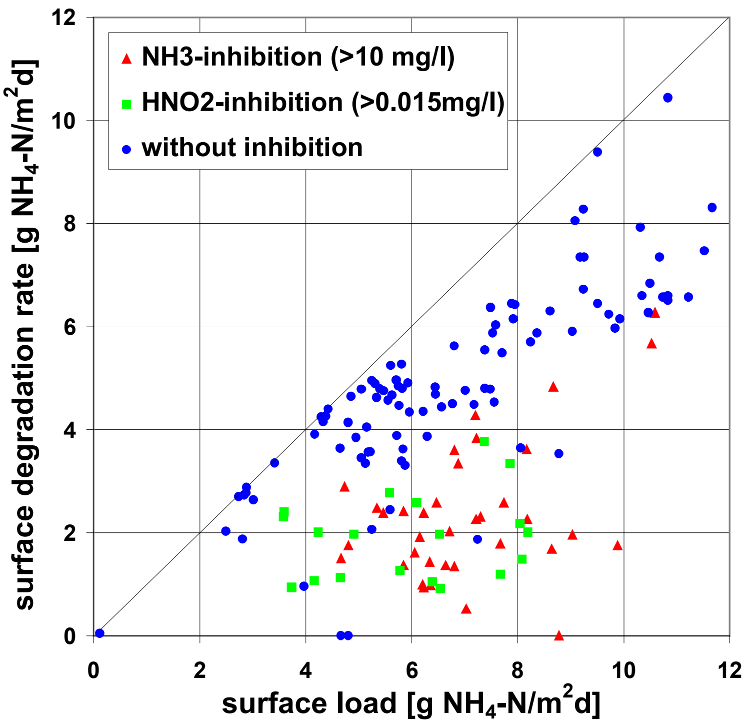


Figure 2. Surface degradation rate as a function of surface load in the nitritaton/denitritation.

For the nitritation/denitritation the measured total N loss was over 70 %.

The total N loss in the deammonification line was 60-70%. Surface degradation as a function of surface load can be seen in figure 3. A nitrogen balance for the deammonification line can be seen in figure 4.

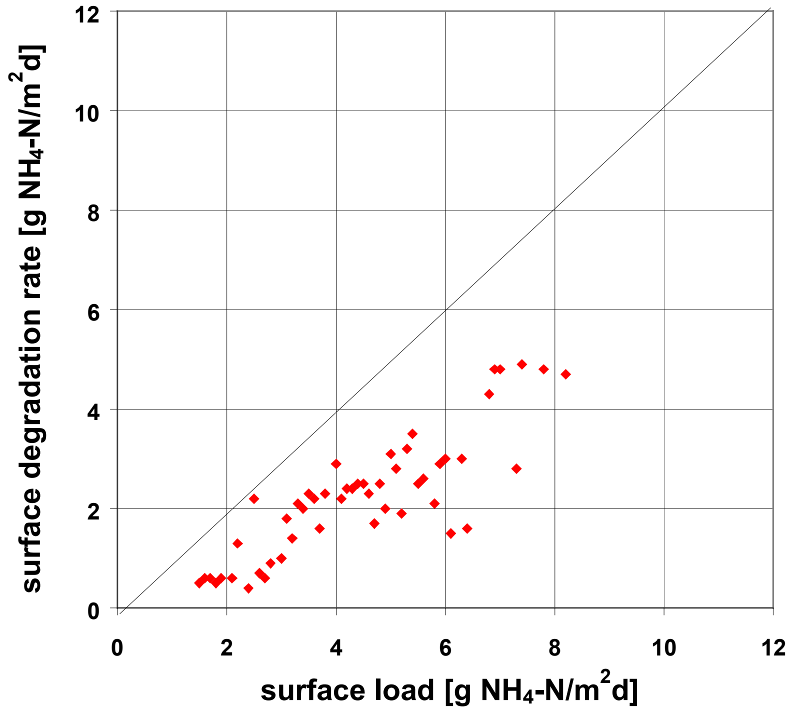


Figure 3. Surface degradation rate as a function of surface load in the deammonification.

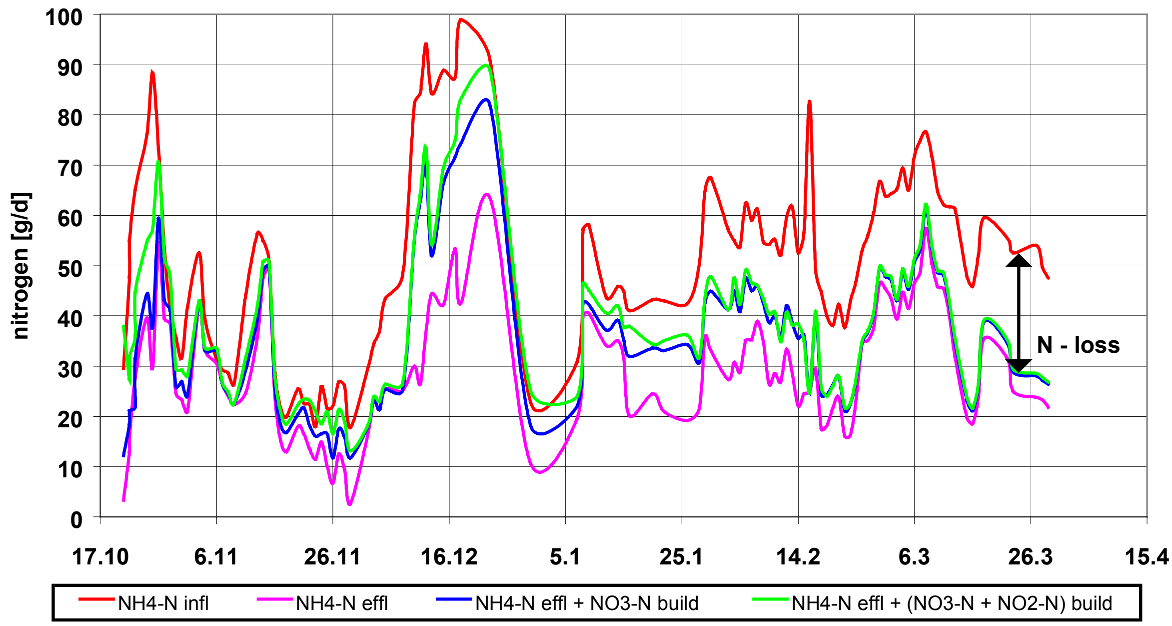


Figure 4. Nitrogen balance of the deammonification line.

It has been possible to run the nitritation/denitritation and the deammonification as continous processes during a long period (several months) with stable results.

Complementary pilot trials

During the last year PURAC has also made other pilot trials with the Kaldnes suspended carriers on municipal sludge liqours. Typical concentration of the treated sludge liqour can be seen in table 3 below.

Tabel 3. Characteristics of sludge liqour

Parameter	Concentration	
COD	5 400	mg/l
BOD_5	2 000	mg/l
N-Kj	1 100	mg/l
NH_4-N	900	mg/l

During these trials the sludge liqour have been treated by nitrification/denitrification and by nitritation/denitritation according to the traditional recirculation principle. One of the advantages with a recirculation process is that the influent concentration of ammonia is diluted thus avoiding toxicity of a too high ammonia concentrations. Another advantage with the recirculation process is that the pH is more stable when the influent water is dilluted. With the nitritation/denitritation an efficiency of 70% NH_4-N reduction could be reached. It was found that a optimal recirculation was around 400-500 %.

Sludge liqours are often a collection of many different streams and the composition of the water shows great variations. During the pilot trials it has been found that the biofilm process with suspended carriers adapt well to the variations and after periods of disturbance the process have rapidly recovered.

DISCUSSION

Seen from the point of view of a waste water treatment plants it is interesting to reduce the operational costs and in the mean time have a stable process. When comparing the processes nitrification/denitrification, nitritation/denitritation and aerobic deammonification, figure 5, it is seen that the deammonification is the most economic. It requires the smallest volume, the lowest amount of oxygen and no external carbon is needed. The comparison is valid for a waste water with high ammonia concentrations and temperature.

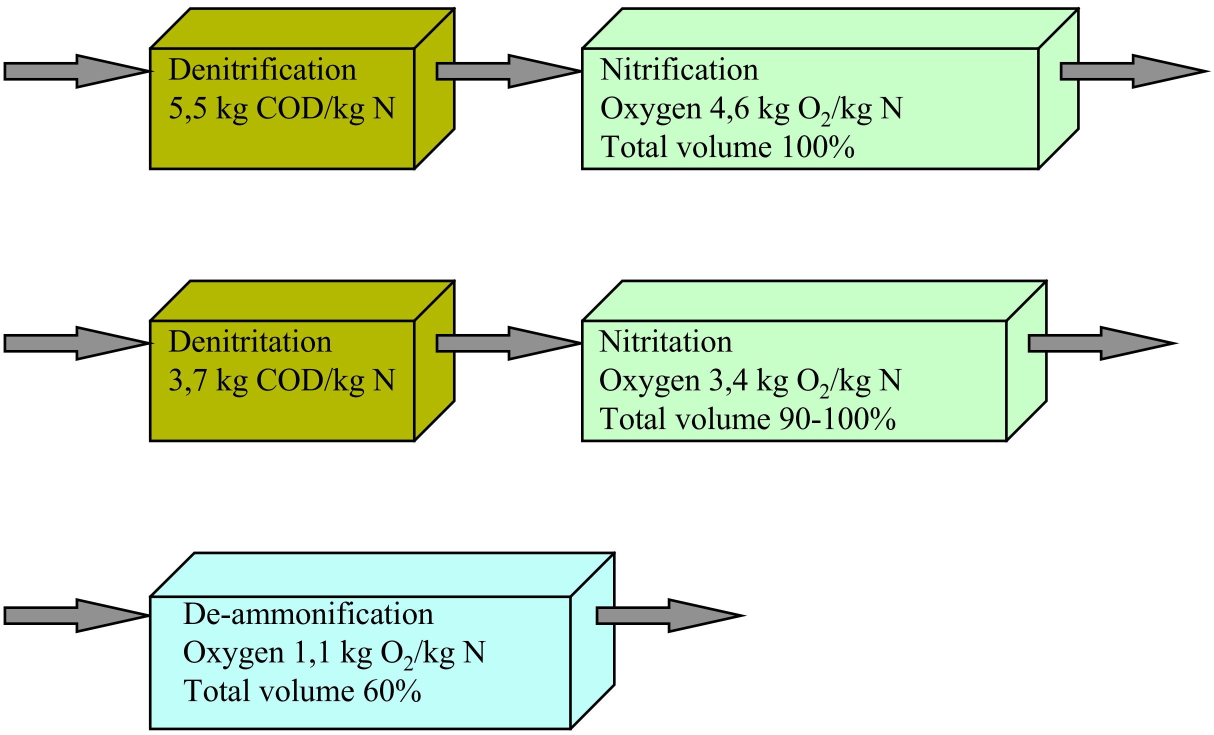


Figure 5.Comparison of different biological processes treating high strenght nitrogen water.

APPLICATIONS

The deamonification process is suitable for treating high strenght nitrogen waters such as sludge liquor, water from landfills and some industrial waters. It seems as the growth and selection of the biomass active in the process is favoured in waste waters that have undergone anaerobic conditions. Nitrogen concentration should exceed 200 mg/l and temperature >20^{o}C.

REFERENCES

1. Hippen, A., Rosenwinkel, K-H., Baumgarten, G., Seyfried, C.F. (1997) *Aerobic deammonification - a new experience in the treatment of wastewaters* Water Science and Technology Vol.35 No. 10, 111-120

2 Helmer, C., Kunst, S. (1998) *Simultaneous nitrification and denitrification in an aerobic biofilm system.* Water Science and Technology Vol. 37, No. 4-5, 1998.

3. Bock, E., Schmidt, I., Stüven, R., Zart, D. (1994) *Nitrogen loss caused by denitrifying Nitrosomonas cells using ammonium or hydrogen as electron donors and nitrite as electron acceptor.* Arch Microbiol 163:16-20, Springer-Verlag 1995.

4. Strous, M., Van Gerven E., Zheng, P., Kuenen J.G., Jetten, M. (1997) *Ammonium removal from concentrated waste streams with the anaerobic ammonium oxidation (Anammox) process in different reactor configuration.* Water Reserch Vol. 31, No 8, 1997.

5. Mulder, J.W., Van Kempen, R. (1997) *N-removal by Sharon* WQI March/April 1997.

6. Draaijer, H., Van Kempen, R., Buunen, A., Hellinga, C. (1998) *Debut performance* WQI March/April 1998.

7. Zart, D., Schmidt, I., Bock, E.(1996) *Neue Wege vom Ammonium zum Stickstoff.* Ökologie der Abwasserreinigung, Lemmer/Griebe/Flemming (Hrsg.), Springer-Verlag Berlin Heidelberg.

8. Ødegaard H. et al (1993) *Norwegian experiences with nitrogen removal in a moving bed biofilm reactor*. Dokumentation 9. EWPCA-ISWA Symposium, München.