Vapour Phase Nitrous Oxide Emissions and the Potential for Biological Treatment

N.J.R (Bart) Kraakman[1,2], R. Kleerebezem[1] & M.C.M. van Loosdrecht[1]

[1]Delft University of Technology, Julianalaan 67, 2628 BC, Delft, The Netherlands

[2]Bioway International, PO Box 361, 6710 BJ , Ede, The Netherlands

INTRODUCTION

Nitrous oxide (N_2O) is a volatile compound at ambient temperature and is considered as an important greenhouse gas with a long lifetime in the atmosphere of 120 years (IPCC, 2006). Different anthropogenic sources contribute to the steady exponential increase of atmospheric N_2O concentrations, currently about 300ppb_v (Stein, 2003).

N_2O emission from activated sludge sewage treatment is one of the anthropogenic sources and is estimated to contribute about 25% to the total greenhouse gas emission of the water chain, being the sum of drinking water production, water transport and wastewater treatment (Frijns, Roorda et al. 2008). During the nitrogen removal processes nitrification and denitrification, part of the nitrogen is not converted into nitrogen gas (N_2) but into nitrogen oxides like nitrous oxide (N_2O) (Kampschreur 2009).

OBJECTIVES

The objective is to investigate the feasibility of N_2O removal from off-gas emitted from wastewater processes to reduce their carbon footprint.

Because the off-gas from wastewater treatment plant contains oxygen, a biological conversion under aerobic conditions is preferred. Thermodynamically, the aerobic conversion is theoretically possible when N_2O act as an electron donor is the presence of oxygen as electron acceptor to form nitrate (ΔG^1 = - 156kj N/e-mol^{-1}).

METHOD AND MATERIALS

To determine the best treatment method the feasibility of biological conversions under both aerobic and anaerobic conditions are studied.

Bench-scale biotrickling filters, standard batch tests and chemostate are used to study biological conversion of nitrous oxide.
N_2O generated from a lab-scale nitrifier denitrification wastewater treatment process treating high nitrogen loads, is used to feed N_2O into the biotrickling filters operating under aerobic conditions.

A very thin PDMS membrane is used and shows an efficient method to study N_2O conversions under anaerobic conditions and intermittent aerobic conditions in the chemostate (Fig. 2).

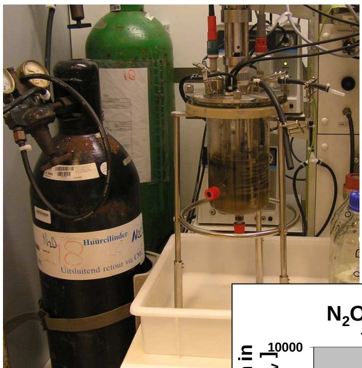

Fig. 1: Chemostate fed with N_2O via PDMS membrane converting N_2O under anaerobic conditions.

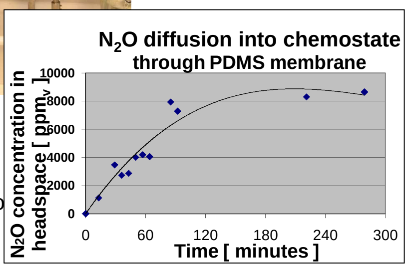

Fig. 2: N_2O diffusion into the chemostate through the PDMS membrane.

To improve the mass-transfer of the relatively poor-water-soluble nitrous oxide (N_2O) from the gas to the water phase also different additives in the water are tested. The potential enhanced uptake of N_2O by water was tested measuring the change in Henry-coefficient in closed bottle with N_2O injected in the headspace.

RESULTS

N_2O conversion under aerobic conditions is not observed in both biotrickling filter and batch experiences.

Anaerobic N_2O conversion is observed. The conversion rate is approximately 7 mg N_2O gr^{-1} h^{-1}. The anaerobic N_2O conversion is only temporary (30 minutes) inhibited after a 20 minute aerobic period (Fig 3a and 3b).

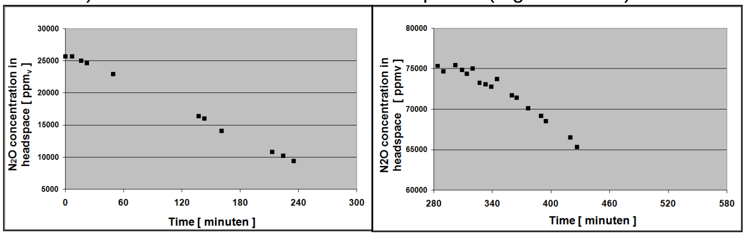

Fig. 3a: N2O concentration (ppm_v) in headspace of chemostate under anaerobic conditions with acetate as electron donor.
Fig. 3b: N2O concentration (ppm_v) in headspace of chemostate under anaerobic conditions after a 20 minutes period of aerobic conditions with acetate as electron donor.

Some additives in water improve, although slightly, the uptake of N_2O in water (Fig. 4).

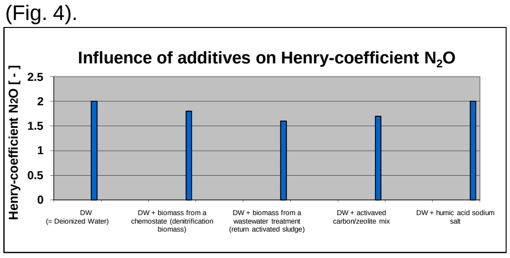

Fig. 4: Additives in water to enhance the uptake (reduce Henry-coefficient) of N_2O in water.

CONCLUSION

Anaerobic conversion (denitrification) is the only biological N_2O conversion observed. N_2O conversion under aerobic conditions is not observed in both biotrickling filter and batch experiences.

Some additives in water enhance the absorption of N_2O in water, although slightly, improving the scrubbing of waste gasses containing N_2O.

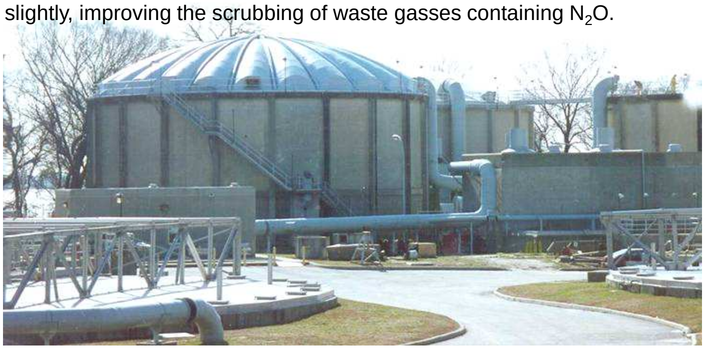

Fig. 5: A municipal wastewater treatment plant.

References:
Frijns, J., J. Roorda, et al. (2008). "Op weg naar een klimaatneutrale waterketen." H2O **10**: 36-37.
IPCC (2006). IPCC guidelines for national national greenhouse gas inventories. , GES, Japan.
Kampschreur, M., J., H. Temmink, R. Kleerebezem, M.S.M. Jetten, M. C.M. van Loosdrecht (2009). "Nitrous oxide emission during wastewater treatment." In press.
Stein, L. Y., Y.L. Yung (2003). "Production, isotopic composition, and atmospheric fate of biologically produced nitrous oxide. ." Ann. Rev. Earth Planet Sci. **31**: 329-356.