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# Emission of greenhouse gases from wastewater treatment processes

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## Abstract

Biological wastewater treatment processes are a source of emission of the greenhouse gases $CO_2$, $CH_4$ and $N_2O$ into the atmosphere. Studies were carried out to quantify the emissions of these gases from the municipal wastewater treatment plants in The Netherlands, which in 1987 handle a total waste load of 17,049,000 population equivalents. On the basis of detailed calculations for the different treatment methods and assumptions for the formation of $N_2O$ the following emissions were calculated: $CO_2$ - 880 million kg/yr (0.5% of the total $CO_2$-emission in The Netherlands), $CH_4$ - 12.5 million kg/yr (1% of the total $CH_4$-emission) and $N_2O$ - 829,000 kg N per year (0.9% of the total $N_2O$-emission).

Measurements of $N_2O$-emissions from 2 low load activated sludge plants were carried out. First results indicated that the $N_2O$ formation and emission amount to 0.1% of the total N-load with the influent to the wastewater treatment plants.

## 1. INTRODUCTION

Biodegradation processes in soil and water are an important source of emission of greenhouse gases into the atmosphere. Municipal wastewater treatment plants incorporate various types of processes, which involve the biodegradation of organic matter and biological reduction and oxidation of nitrogen compounds. In general terms a biological wastewater treatment system involves the following processes, causing emission of greenhouse gases:

- aeration for bio-oxidation of organics and of nitrogen compounds (nitrification), which results in emission of $CO_2$ and possibly $N_2O$; $CH_4$ and $NH_3$ may also be emitted in these processes when process conditions are not optimal;
- anaerobic digestion of wastewater treatment sludge with production of biogas, mainly consisting of $CH_4$ and $CO_2$; the biogas is mostly used as an energy source in wastewater treatment plants, which positively effects the energy balance and hence the $CO_2$-emission from the wastewater treatment plant;
- reduction of nitrate (denitrification) with formation of $N_2$ and $N_2O$;
- disposal of wastewater treatment sludge, e.g. by use in agriculture, dumping at solid waste disposal sites or incineration, with the possible formation of $CO_2$, $CH_4$ and $N_2O$;

- biodegradation (aerobic and anaerobic) of residuals (organic and nitrogen compounds) discharged with treatment plant effluent into surface water, with formation of $CO_2$, $CH_4$, $N_2$, $NH_3$ and $N_2O$;
- consumption of external energy resources, in particular for aeration, causing the emission of $CO_2$.

In the period 1990-1994 several studies were carried out with the objective to quantify the emissions of greenhouse gases from the municipal wastewater treatment plants in The Netherlands. The results of these studies are summarized here.

## 2. EMISSION OF GREENHOUSE GASES FROM THE NETHERLANDS WASTEWATER TREATMENT PLANTS

In 1987 a number of 491 municipal wastewater treatment plants was in operation in The Netherlands treating a total organic waste load of 886,210 tonnes COD (equal to 17,049,000 population equivalents). In 1987 the most applied methods for treatment of municipal wastewaters were respectively:

| **Plant type** | **Organic waste load (population equivalents)** |
|---|---|
| Trickling filters | 1,259,000 |
| Aeration tanks (high load activated sludge) | 6,111,000 |
| Oxidation tanks (low load) | 833,000 |
| Carrousel (low load) | 3,537,000 |
| Other | 4,457,000 |
| Total | 17,049,000 |

For each type of wastewater treatment systems the emissions of greenhouse gases were calculated on the basis of the overall treatment efficiencies of the different systems and the consumption of external energy resources.

The total calculated $CO_2$-emission from the wastewater treatment plants in The Netherlands equals about 880 million kg $CO_2$ per year (about 0.5% of the total estimated $CO_2$-emission in The Netherlands). The specific emission equals 1.2 kg $CO_2$ per kg COD removed. These emissions originates from the following sources:

| **Source of $CO_2$** | **Percentage** |
|---|---|
| Aerobic biodegradation | 48 |
| Use of external energy sources | 27 |
| Use of biogas | 8 |
| Wastage of biogas | 1.5 |
| Biodegradation of organic residues after discharge | 8.5 |
| Sludge disposal | 7 |

$CH_4$ in wastewater treatment processes is generated by anaerobic sludge digestion and anaerobic decomposition of sludge disposed of to solid waste dumping sites. The total calculated $CH_4$-emission from wastewater treatment processes amounts to about 12.5 million kg $CH_4$ per year (1987), equivalent to about 1% of the total $CH_4$-emission in

The Netherlands. The specific emission equals 17 g $CH_4$ per kg COD removed. Most of the digestion gas, generated in the Netherlands wastewater treatment plants, is utilized as a source of energy, but some $CH_4$ is wasted or flared off. The $CH_4$-emission into the air originates for 20% from wastage of digestion gas and for 80% from anaerobic decomposition of sludge after disposal.

$N_2O$ in wastewater treatment processes is produced in nitrification and denitrification processes. Research results indicate that $N_2O$ is formed in the nitrification process as a result of non-optimal process conditions, and that in denitrification always formation of $N_2O$ takes place in conjunction with formation of $N_2$. The proportion between the quantities $N_2$ and $N_2O$ depends on the process conditions and the presence of particular micro-organisms. Literature data on $N_2O$-emissions from wastewater treatment processes show large differences, varying from 0.01 to 6% of the total N-load to the wastewater treatment plant, being converted into $N_2O$. For calculation of the $N_2O$-emission from the municipal wastewater treatment plants in The Netherlands the assumption was made that by nitrification 0.3% of the N-load in the influent minus the N-load in the effluent is converted into $N_2O$ and that 0.3% of the nitrate-N, formed by nitrification, is converted into $N_2O$. On the basis of these assumptions the total $N_2O$-emission from the Netherlands wastewater treatment plants would amount to 330 t N per year. On the basis that 1% of the residual N, discharged with the effluent, is converted into $N_2O$, it was calculated that the $N_2O$-emission from surface waters as a result of effluent discharge amounts to 415 t N per year. On the assumption that 1% of the N in sludge, disposed of to agriculture and solid waste disposal sites, it was calculated that the $N_2O$-emission from sludge disposal amounts to 84 t N per year. The estimated $N_2O$-emission from wastewater treatment processes equals about 0.9% of the total estimated $N_2O$-emission in The Netherlands.

## 3. MEASUREMENT OF $N_20$-EMISSION FROM WASTEWATER TREATMENT PROCESSES

In 1994 indicative measurements regarding the production and emission of $N_2O$ by two municipal wastewater treatment plants in The Netherlands were carried out. The photo-acoustic method for $N_2O$-analysis was applied. The measurements were carried out at the wastewater treatment plant in Capelle aan de IJssel, a carrousel plant with a covered aeration circuit and simultaneous nitrification and denitrification, and at the wastewater treatment plant in Alblasserdam, a Schreiber type plant with separated nitrification- and denitrification compartments. Samples of the air above the nitrification and denitrification compartments were taken according to a standardized method. The analyses were carried out over a period of about six hours, during which air samples were analyzed at intervals of six minutes. On the basis of the analysis results it was calculated that at the plant in Capelle aan de IJssel 0.006% of the N-load in the influent was emitted as $N_2O$ and 0.07% at the Alblasserdam plant.

## 4. REDUCTION OF THE EMISSION OF GREENHOUSE GASES FROM WASTEWATER TREATMENT PROCESSES

Measures for reduction of the emission of greenhouse gases from wastewater treatment processes should be considered in view of future effluent discharge quality standards, which gradually become stricter especially for the concentrations of N- and P-compounds. In The Netherlands the new limit values for discharge of effluent into surface waters are 10 mg N-total/l and 1 mg P-total/l. Such values can only be realized in highly efficient wastewater treatment plants with special process steps for nitrification/denitrification and P-removal (chemical or biological). For this purpose usually ultra low-load activated sludge systems, with aerobic sludge mineralization, are applied, since these systems are the most suitable for nitrification/ denitrification and incorporation of biological P-removal processes. However these low load systems are also characterized by the highest specific $CO_2$-emission (kg $CO_2$/kg COD removed), due to the high consumption of external energy. Hence optimization of these wastewater treatment processes should be considered in order to reduce the use of external energy resources. Measures to this effect may include:

- incorporation of less energy consuming oxidation methods, e.g. trickling filters or rotating biological contactors in the wastewater treatment process;
- application of anaerobic sludge digestion, with efficient use of the digestion gas, where possible.

Very little is known about the exact mechanisms for formation of $N_2O$ in biological wastewater treatment processes and there are not many representative data on measurements of the $N_2O$-emission from wastewater treatment processes. Research data indicate that the emission of $N_2O$ can be reduced by creating optimum process conditions for nitrification and denitrification.

## 5. REFERENCES

1 Emission of greenhouse gases from wastewater treatment plants (in Dutch)
Ministry of Housing, Spatial Planning and Environment
BKH Consulting Engineers
November 1990

2 Study regarding the formation of $N_2O$ in wastewater treatment plants (in Dutch)
National Research Programme on Global Air Pollution and Climate Change (N.O.P)
BKH Consulting Engineers
June 1994