Climate Change Research: Evaluation and Policy Implications
S. Zwerver, R.S.A.R. van Rompaey, M.T.J. Kok and M.M. Berk, (Eds.)

Potential of controlled anaerobic wastewater treatment in order to reduce the global emissions of methane and carbon dioxide

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Abstract

An estimation is made of the current global methane and carbon dioxide emissions from wastewater treatment and disposal. Furthermore, the potential of controlled anaerobic treatment to reduce these emissions is investigated. Considered wastewaters are: domestic wastewater and wastewater from the Food & Beverage and Pulp & Paper industry.

The current methane emission is estimated to be about 5 Tg/y, and is mainly the result of uncontrolled degradation of untreated wastewater in developing countries. Carbon dioxide emission is estimated to be 15 Tg/y, which is mainly due to aerobic wastewater treatment in the developed countries.

Anaerobic wastewater treatment, provided a minimization of the percentage methane loss and an optimal reuse of biogas, can significantly reduce the current emissions.

1. INTRODUCTION

Little is known about the quantities of the atmospheric CH_4 emission from the treatment, storage, and discharge of domestic and industrial wastewaters. Thorneloe (1993) roughly estimated this to be about 26-40 Tg/y, thereby representing about 8-11% of the total anthropogenic CH_4 emissions. However, large uncertainties concerning this estimation are recognized.

In most CH_4 emission reduction technologies the aim is to avoid uncontrolled anaerobic degradation and to promote aerobic degradation. However, by promoting aerobic treatment the CO_2 emission due to fossil fuel consumption will strongly increase. Aerobic treatment, as conventionally applied in most wastewater treatment systems, is rather energy consuming since this process depends on a more or less intensive aeration.

A very interesting alternative is formed by anaerobic treatment. Under anaerobic conditions organic material can be completely degraded into CO_2, CH_4, water, and a small amount of biomass. The produced biogas can be used as a fuel. By doing so, anaerobic degradation has the following advantages over aerobic degradation: 1) Production of a valuable fuel, the use of which can lead to a reduction of the amount of fossil fuel consumed, 2) no energy requirement for aeration, and 3) significantly less sludge production. On the other hand, if anaerobic degradation occurs in an uncontrolled way, CH_4 can be emitted to the atmosphere where it can enhance the greenhouse effect.

In our study we made an estimation of the present emissions of CH_4 and CO_2 from wastewater treatment. Furthermore, we estimated the potential production of CH_4 from anaerobic wastewater treatment and the possible reduction of the CO_2 emission due to the use of this CH_4. The treatment of the produced sludge is not yet taken into account.

2. ESTIMATION METHODS

In our estimations the following cases are considered:

1) **Complete anaerobic treatment.** Within this case, three options are regarded:
   * all CH_4 is flared (FLARING)
   * CH_4 is partly used, only for the maintenance of the wastewater treatment plants. The excess is flared (PARTIAL)
   * CH_4 is completely used for energy production (COMPLETE)

2) **Complete aerobic treatment** (AEROBIC)

3) **Current situation** (CURRENT)

In each case the calculated emissions are the energy related CO_2 emission and the CH_4 emissions from controlled treatment systems and from uncontrolled degradation in the environment. The world was divided into underdeveloped (UND) and developed (DEV) countries.

Relevant data concerning the amount, composition, and degradability of the different types of wastewater were collected from literature and queries. The same method was applied for the information on the treatment systems (efficiency, sludge growth, energy demand, methane emission factors and frequency of operation). All data were assembled in QUATTRO-spreadsheets.

Models were developed for the estimations of CH_4 and CO_2 emissions at different assumptions (Lexmond & Zeeman, 1994). Different percentages of CH_4 loss were used: For aerobic systems all CH_4 formed (Czepiel *et al.*, 1993) is emitted to the atmosphere, and for anaerobic systems a fixed percentage of loss (due to leaking, low concentrations, etc.) is assumed. Finally, the influences on the total global warming potential (GWP) due to wastewater treatment were calculated.

The most important assumptions made were:

1) The presence of oxidizing compounds, such as nitrate, oxygen, and sulphate, in the wastewater (which can result in lower CH_4 production), as well as possibly toxic compounds is ignored.

2) The influence of the temperature is ignored.

3) A certain percentage of CH_4 produced within anaerobic treatment systems is lost (0-20%).

4) The energy requirement (in kWh per unit of organic material removed) of anaerobic treatment systems is about 25-30% of that of aerobic systems. We calculated our CO_2 emissions based on an energy requirement of one third of that of the Dutch aerobic systems (CBS, 1992).

5) We used an average carbon dioxide emission factor (in m^3/kWh) for the conversion of energy (viz. electricity) into CO_2 emissions (Blok, 1994).

6) For the current situation of emissions we had to estimate the extent of the use of different treatment systems. Due to the scarcity of information about this, we had to assume these values. Because the large influence of these values on the results, we give

the assumed values in table 1. Especially the percentage of uncontrolled aerobic and anaerobic degradation of discharged wastewater in underdeveloped countries, is a very important parameter in the model. We assume that a large part of the wastewater is discharged on surface waters. Disposal at sea is assumed not to result in significant CH_4 emissions, disposal on large waters and on land is assumed to result in some CH_4 emissions, and the disposal on small waters and lagoons will result in significant CH_4 emissions. Furthermore, we assume that in underdeveloped countries average temperatures are higher and consequently the percentage of anaerobic degradation for untreated wastewater will be somewhat higher.

Table 1. Assumptions concerning the treatment of wastewater and the division in aerobic and anaerobic degradation

	treated (%)			untreated (%)		
	total	aerobic	anaerobic	total	aerobic	anaerobic
underdeveloped countries						
* domestic	10	70	30	90	75	25
* industrial	50	85	15	50	75	25
developed countries						
* domestic	90	90	10	10	80	20
* industrial	95	85	15	5	80	20

3. RESULTS AND DISCUSSION

In figure 1 the CH_4 and CO_2 emissions and the resulting GWP for the treatment of the total amount of wastewater at the 5 different conditions are summarized, assuming a total CH_4 loss percentage of 10% and a time horizon of 100 years. For the current situation a CH_4 emission of 5 Tg/y is estimated from the investigated wastewater streams, which is considerably lower than the estimated 14-20 Tg/y by Thorneloe (1993).

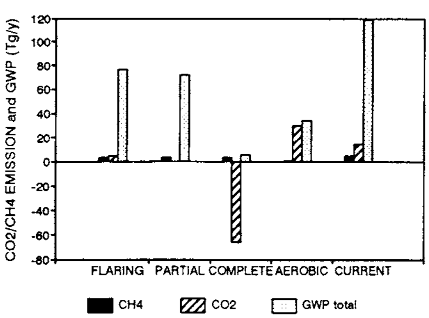

Figure 1. CH_4 and CO_2 emissions and the resulting GWP (time horizon 100 years and 10% CH_4 loss) in different cases

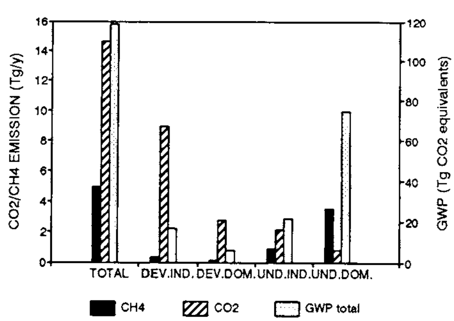

Figure 2. Current CH_4 and CO_2 emissions and the resulting GWP (time horizon 100 years) from the different sources

Figure 2 presents the CH_4 and CO_2 emissions and the resulting GWP from the different sources in the current situation. The amount of treated and untreated wastewater, the applied treatment system, and the conditions at which the untreated wastewater is disposed of determine the current emissions.
From figure 2 it can also be seen that the total GWP of wastewater treatment and disposal in the current situation is mainly determined by CH_4 emissions from domestic wastewater in underdeveloped countries. The extent of anaerobic digestion of untreated wastewater in underdeveloped countries is highly affecting the estimated GWP of the current state.

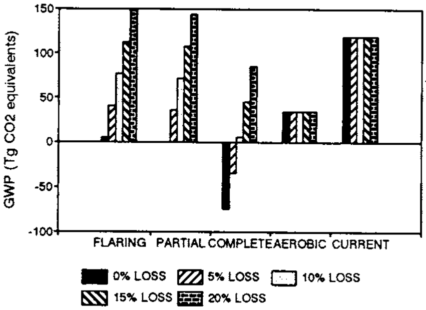

Figure 3. GWP due to wastewater treatment at different percentages of CH_4 loss in the different cases

If we, for instance, assume that the amount of uncontrolled anaerobic degradation is not 25% but 50%, the total CH_4 emission will increase from 5 to about 11 Tg/y. Unfortunately very little data are available on this subject for most countries. To be able to estimate the present emissions more accurately, more information is required.

In figure 3 the effect of the percentage CH_4 loss in anaerobic treatment systems is shown. It is clear that the percentage CH_4 loss should be minimized. In the current situation this is not so important because only a small percentage of the wastewaters is actually treated anaerobically (see table 1).
The current CO_2 emission is about 15 Tg/y and is mainly the result of aerobic degradation of wastewater in the developed countries.

So, not only from the human health point of view treatment of wastewater should be encouraged. Our results show that, providing a minimization of the CH_4 loss and an optimal reuse of the produced CH_4, anaerobic treatment should be stimulated in order to reduce the emissions of greenhouse gases.

5. REFERENCES

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