

Methane emission of the Amsterdam urban area.

D. Veenhuysen and P. Hofschreuder

Department of Air Quality, Wageningen Agricultural University
P.O.Box 8129, 6700 EV Wageningen, The Netherlands.

Abstract

Within the Dutch National Research Programme on Climate Change, the emission of methane from urban areas was considered to be one of the uncertain sources in the national methane budget. Amsterdam was chosen to be the urban area for methane emission assessment. An emission inventory was made and concentration fields were calculated using the Danish OML model. Calculated concentration values were compared to concentrations measured continuously by ECN. The methane emission of the Amsterdam area is low. Main sources are traffic emissions (1.3 ktons.y^{-1}) and the gas distribution network ($0.45 \text{ ktons.y}^{-1}$). The emission inventory tends to overestimate the total emission by a factor of about ten.

1. INTRODUCTION

Methane is one of the non- CO_2 greenhouse gasses, that gets increased attention last years. This attention is triggered by the relatively short lifetime of the gas, the rapid growth rate of ambient concentrations of about 1 % per year, and the low reduction of emissions (10 %) to stabilize atmospheric concentrations [1]. The global emission of methane of 520 Tg/year, based on estimates on source and sink strength by atmospheric chemistry [1] is generally accepted. The relative importance of source strengths for particular source categories can only be assessed with large uncertainty when global models are used.

Assessment of the fluxes of greenhouse gases from important and accessible sources is useful for constraining the source strengths of unknown sources and for policy making. Determination of the source strength of methane emissions with high uncertainty and detection of unknown sources was part of the Dutch National Research Program on Climate Change. An overview of important Dutch methane sources is given by van Amstel [2]. The production of gas and oil is the third largest source of methane in the Netherlands after enteric fermentation and landfills.

Production of natural gas is coupled to the distribution of the gas. The dense articulated distribution networks in urban areas was considered to be a large potential source of methane by leakage. Verification of urban methane emissions was the aim of this project. Instead of a costly approach of intensive measurements, we chose for a combined program of making an emission inventory, modelling methane concentrations and monitoring methane concentrations at a fixed site. The Amsterdam urban area (1,000,000 inhabitants) was chosen to test the emission inventory and eventually detect unknown sources of methane. A permanent monitoring station was installed by ECN at Vuurtoreneiland, a little isle in a lake east of Amsterdam to have a uniform fetch and no local sources next to the monitoring site.

2. EMISSION INVENTORY

To obtain an estimate of the source strength for methane of urban areas an emission inventory was made. The natural gas distribution network, road traffic, landfills, high industrial stacks, wastewater treatment plants and some minor sources like deep water and air traffic were considered as possible sources for methane. Dairy farming of ruminants around Amsterdam will also cause emissions due to enteric fermentation. This emission, however, was not taken into account. Their influence on immision concentrations at the monitoring site could be cancelled out by subtracting the background Cabauw methane levels from the Amsterdam data. Cabauw is high level (200 m.) measuring station in the centre of the country. Around both monitoring sites, a comparable agricultural situation exists. Although the soil in the rural surroundings was very humid, one may not consider these meadows as wetland, because the topsoil is aerobic. The topsoil is also covered with grass, which does not have like rice hollow stems to convey rapidly methane from anaerobic soil layers to the atmosphere. Table 1 list the methane emissions for the Amsterdam urban area. Most recent emission factors for gas leaks, traffic [3] and industrial sources [4] were used.

Table 1
Methane emissions in the Amsterdam urban area (ktons/y).

Gas distribution network	0.45
Road traffic	1.30
Industry (except power station)	0.06
Power station	confidential
Landfills	minor
Wastewater treatment	minor
Canals	?

Emissions of the gas distribution network were based on a number of 700 leaks discovered per year, an average leak rate of $0.04 \text{ m}^3 \cdot \text{h}^{-1}$ and incidental venting of pipes ($35 \text{ km} \cdot \text{y}^{-1} \text{ } \varnothing 0.2 \text{ m}$) for reconstruction, venting of new main lines ($30 \text{ km} \cdot \text{y}^{-1}$) and regulating. These emissions are low because of the high quality polyethylene tubing used. They are 0.08 % of the throughput of $751,500 \text{ m}^3 \cdot \text{y}^{-1}$. The methane content of the natural gas is 83 %.

For road traffic detailed data on traffic density on highways were available [5] on an hourly basis. For traffic in the city districts only daily mean values were available. We used the hourly mean traffic densities for work days and weekend to obtain one hour resolution for the traffic density in the city districts. This resolution is needed for dispersion calculations as traffic density and meteorology have strong diurnal trends. Emission factors for traffic categories and percentage of catalyst equipped cars were from recent date (1993).

Industrial emissions play a minor role in Amsterdam. The largest source is a power plant, but emissions take place from a high stack and do not influence the concentrations at the monitoring site.

Emissions of landfills are highly uncertain, but no recent landfills were found in the sector from the Amsterdam urban area to Vuurtoreneiland. No emissions were fed to the

dispersion model.

Waste water treatment plants produce methane, which is reused in the process. Incidentally a surplus of gas occurs. This gas is flared.

Emissions from deep water surfaces and canals are highly uncertain. They depend on the thickness and anaerobic situation in the sludge and the availability of a oxidizing zone in the upper part of the sludge and in the water. No emissions were fed to the dispersion model.

The Airport was that far away and emission estimated so low, that these emissions were not taken into account.

The total emission for the urban area was estimated to be about 1.8 kton methane per year.

3. MODELLING METHANE CONCENTRATIONS

The Danish OML model [6] was selected for calculation of immission concentrations after an inventory of appropriate models for this purpose. This Gaussian plume model has a preprocessor to calculate dispersion height, atmospheric stability and turbulent mixing from synoptic and radiosonde measurements. The synoptic measurements were obtained from Schiphol Airport, the radiosonde data from de Bilt. The model can handle up to 100 emission sources of point type or area type. Line emissions like highways were implemented as multiple point sources. Traffic emissions from a district were located in the centre of the district. Emissions from gas leaks were evenly distributed over the urban area.

The surface roughness is a very uncertain factor to be put in the model. A town is very heterogenous and a Gaussian model only allows for a constant value. Calculated results are very sensitive to this parameter. For the comparison of calculated and measured data a value of 1 m. was chosen. Emission data and dispersion data from the meteorological preprocessor were fed to the OML model to calculate iso-emission concentration lines and concentrations at the continuous methane monitoring station at Vuurtoreneiland. Only the frequency distribution of hourly concentrations was calculated because of the statistical nature of the model and the large uncertainty in individual calculated hourly values.

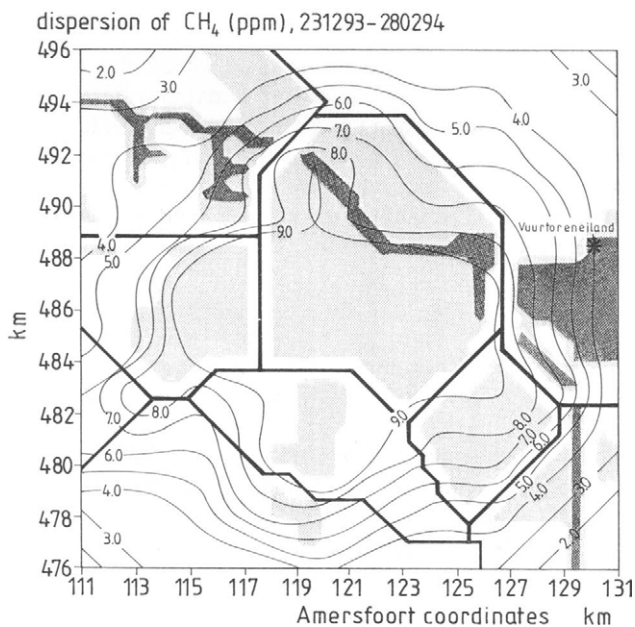


Figure 1. Long term average distribution of $[\text{CH}_4]$ calculated with OML and a roughness length of 1m.

This was done for a 180-320 degree windsector, being the sector in which the monitoring station is influenced by the urban plume and results were related to stability. Long term average CH₄ concentrations around Amsterdam are given in figure 1.

4. OBSERVED METHANE CONCENTRATIONS

The calculated emissions were compared with data gathered at the permanent methane monitoring site run by the Netherlands Energy Research Foundation (ECN). To obtain an estimate of the increase in ambient methane concentrations due to the urban plume, methane immission concentrations of Cabauw (some 40 km south of Amsterdam) were subtracted from the Vuurtoreneiland data. Results will be published separately.

5. RESULTS AND CONCLUSIONS

Both calculations and measurements resulted in a low increase in methane concentrations due to urban emissions (some tenths of a ppm). The measurements indicated some incidental elevated concentrations of some ppm. Although Gaussian models are not well suited to predict immission concentrations for exceptional situations, the model was used for more detailed analysis. The elevated concentrations resulted merely from extreme meteorological conditions and the vicinity of major highways south of the monitoring site. No major unknown sources of methane could be detected. Calculated concentrations were higher than measured concentrations. Elevated concentration levels showed the same magnitude. One should realize that in Gaussian dispersion modelling a margin of error of about $\pm 100\%$ is usual. Even if this margin is considered and uncertainty in roughness length is taken into account the calculated averages are a factor of five to ten higher than the observed ones. This may be the result of a too high emission factor for traffic or a higher percentage of catalyst equipped cars and methane oxidation in the soil around gas leaks. The urban contribution to the national methane budget is small.

6. REFERENCES

- 1 J. Lelieveld, P.J Crutzen, C. Brühl, *Chemosphere*, Vol 26,1-4 (1993).
- 2 A.R. van Amstel, et al. Methane the other greenhouse gas, Research and policy in the Netherlands, RIVM report no: 481507001, (1993).
- 3 C. Veldt, P.F.J. van der Most, *Publikatiereeks Emissieregistratie* Nr 10, (1993).
- 4 J.J.M. Berdowski, W.J. Jonker, *Publikatiereeks Emissieregistratie* Nr 14, (1993).
- 5 Adviesdienst Verkeer en Vervoer, *Verkeersgegevens, Jaarrapport 1992*, Ministerie V&W
- 6 P. Løfstrøm, H.R. Olesen, *User's guide for OML-MULTI, An air pollution model for multiple point and area sources*, MST-LUFT-A126, National Environmental Research Institute, Roskilde, Denmark, (1992).