Composting and Fermentation of Biowaste
– Contribution to reduce Greenhouse Gases –

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1. Introduction 509

2. GHG measuring project, Definitions 509

3. Emission factors and discussion 510

4. Conclusions and summary 515

1. Introduction

Utilization of bio waste is very popular from the view of resource recovery and regenerative energy production as well. Composting and anaerobic digestion (AD) have become a common treatment option for bio and garden waste in the European Union. Garden waste composting in windrows is state-of-the-art in all the EU countries and covers about half of the treatment capacity in Germany. Other half of the facilities is turned and aerated in-vessel composting. Some plants are combined with an AD step for producing biogas. In future the amount of organic waste treated by composting is expected to increase in order to recycle the carbon and the nutrients in the waste material. Microbial degradation of organic substrate entails the production of various gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ammonia (NH_3). Some of this gases are classified as greenhouse gases (GHG), thus contributing to climate change. Currently only few GHG emission data from composting facilities are available. The dynamic and diffuse nature of GHG production and emission from different composting systems challenge the quantification of these.

2. GHG measuring project, Definitions

Between 2006 and 2011 GHG emissions of about thirty different composting plants were analyzed in a research project founded by the German Federal Environmental Agency (Umweltbundesamt). All plants were continuously measured several times in different seasons and over a period of at least one week; parameters: TOC (Total Organic Carbon, continuous FID method), CH_4 and N_2O (continuous NDIR method), NH_3 (discontinuous absorption in H_2SO_4). The representative sampling was complex and laborious because of different types of emission sources: active point (stack), active area (biofilter) and passive area (windrow surface). Large compartments of biofilters were temporary capsulated by thin foil, open windrows were capsulated by large wind tunnel of 10 meters length (Figure 1), samplings in pipes or from stacks were done easily like a typical point source method (Figure 2).

Goals of the research project carried out:

- Identification of relevant emission sources,
- Quantification the GHG emissions,

- Summarize all emission sources with respect to the plant throughput (= emission factor),
- Emission control and mitigation of GHG,
- Guideline and recommendations into the process management for operators.

Figure 1: Sampling method: active open Source (left: biofilter), passive fugitive source (right: windrow)

Figure 2: Sampling method: active point source (pipe)

3. Emission factors and discussion

First of all it is obvious that most emissions various in a very wide range. The emissions depend on input material: substrate (bio, garden, yard, kitchen, sludge) and season, C:N ratio, water content, structure and porosity. And the emissions depend on process conditions seriously: oxygen saturation, temperature, pH-value. So it is very important to regulate the right process by mixture and homogenization of input materials, dimensions of rotting piles, anaerobic potential in case of digester output, active aeration for aerobic milieu, turning and watering.

Table 1: Steps and Types of composting plants, considered in figures

Plant No.	Abbreviation	Steps and Types of composting plants
[1]	Anl+Aufb	material delivery + pre-processing
[2]	KOA g (FrischK)	In-vessel composting (fresh compost)
[3]	KOA g (FertigK)	In-vessel composting (finished compost)
[4]	KOA tg (FertigK)	In-vessel + open composting (finished compost)
[5]	KOA sM	membrane cover composting, aerated
[6]	KOA o (Bio+Grün)	open windrow (bio+garden)
[7]	KOA o (Grün)	open windrow (garden)
[8]	VA	anaerobic digestion
[9]	VA + NR g	anaerobic digestion + in-vessel curing
[10]	VA + NR o	anaerobic digestion + open curing

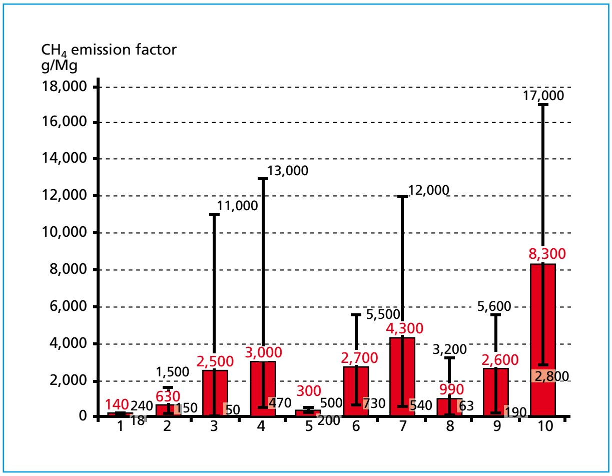

Figure 3:

Methane (CH_4) emission factors – means and ranges

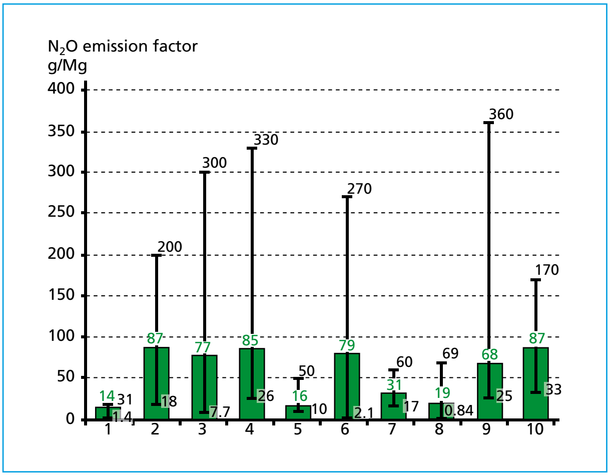

Figure 4:

Nitrous oxide (N_2O) emission factors – means and ranges

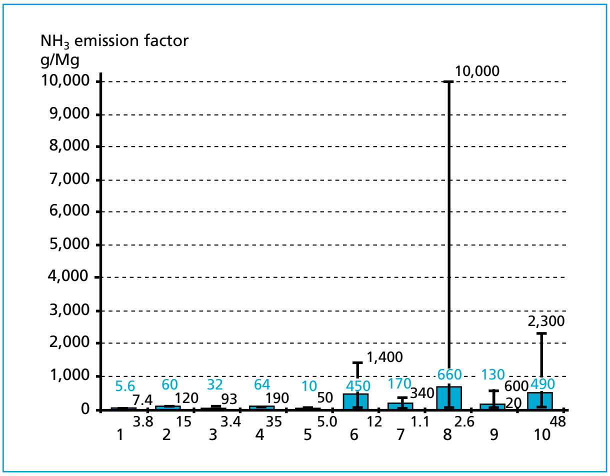

Figure 5:

Ammonia (NH_3) emission factors – means and ranges

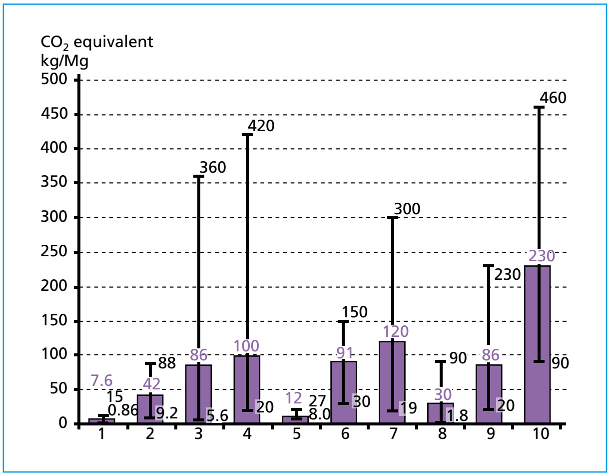

Figure 6:

Carbon dioxide equivalents (CO_2eq.) – means and ranges

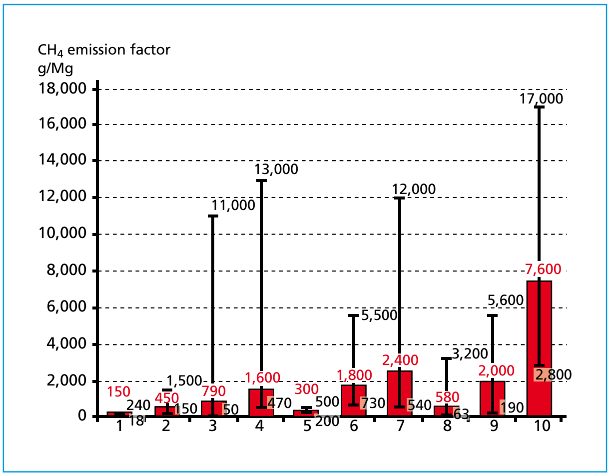

Figure 7:

Methane (CH_4) emission factors – medians and ranges

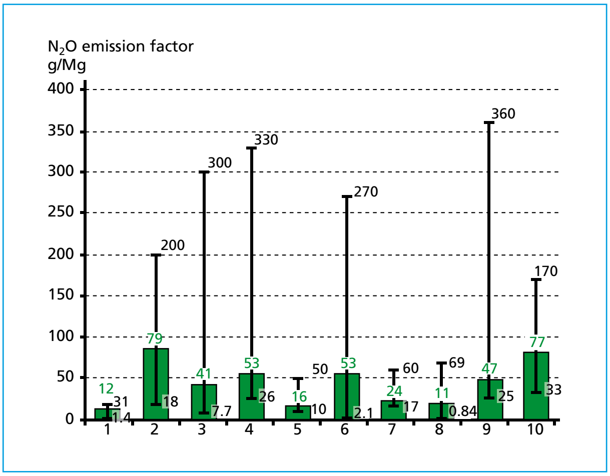

Figure 8:

Nitrous oxide (N_2O) emission factors – medians and ranges

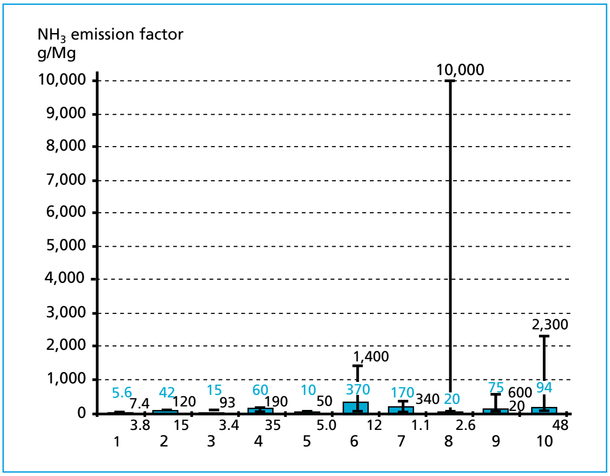

Figure 9:

Ammonia (NH_3) emission factors – medians and ranges

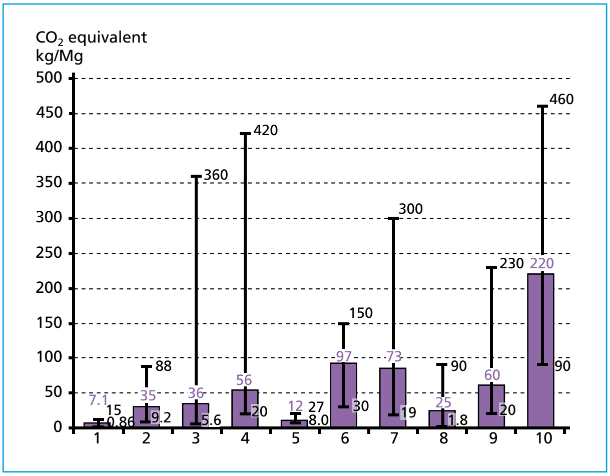

Figure 10:

Carbon dioxide equivalents (CO_2eq.) – medians and ranges

The emission of GHG like methane and nitrous oxide could be minimized only in the biological process of degradation. Methane occurs under anaerobic conditions (high temperature, no oxygen, high water content). Nitrous oxide is produced by nitrification ($NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$) especially in the curing phase under temperature < 45 °C.

In all biological systems methane is minimized by sufficient aeration, best done with positive aeration and smart geometric dimensions, e.g. easily performed by cover systems.

In all biological systems nitrous oxide is reduced by high C:N value > 25 and temperature > 45 °C in the curing phase.

In all biological systems ammonia emissions are reduced by high C:N value < 25, low pH-value < 7 and low temperature < 60 °C. Plant [8] is equipped with a thermal drying for the digestate, therefore ammonia emissions are on that high level of 10 kg/Mg input. In biofilters NH_3 is absorbed and mineralized around 60 %, but formation of secondary N_2O is negative

For AD systems aerobization and in-vessel curing with active aeration is recommended. All storage tanks with anaerobic liquid and reactive prozess water should not be open but connected to the biogas system. To reduce high ammonia emissions it is necessary to have acid scrubber before biofilter.

Additional exhaust treatment cannot reduce GHG methane and nitrous oxide. High pH-level > 7 and high temperature > 45 °C lead to rising ammonia emissions. Low C:N ratio < 17 supports both, decreasing ammonia and nitrous oxide emissions. Acid scrubbers are useful and sometimes – in case of composting after AD – necessary to absorb ammonia before biofilter. It helps to reduce disturbing the accumulation of N-compounds and the new formation of nitrous oxide in biofilters. Normally sulfur acid is used and the product is ammonia sulfate that could be used as fertilizer.

Deficiencies in dimensioning and missing maintenance cause major problems in biofilter operation. Efficiency of degradation is different depending on the organic substances in the waste gas, so it may be reasonable to differ emission control of VOC (Volatile Organic Compounds) into nonmethane VOC + methane. The biodegradability of methane is very low (mean value 10 %) compared to the mixture of various NMVOC from biological waste

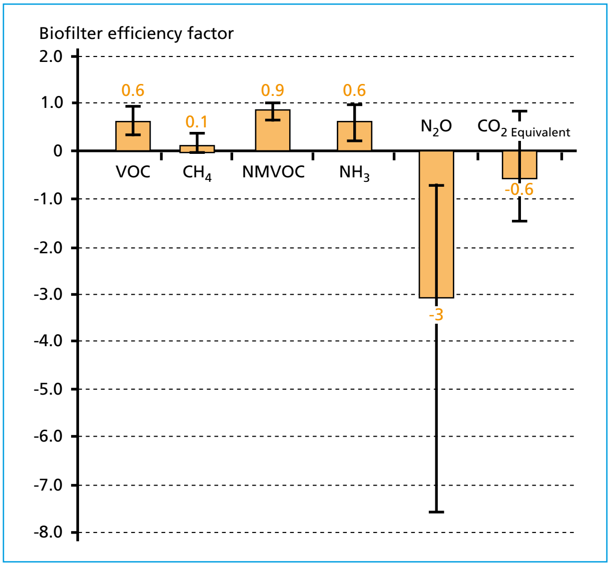

Figure 11:

Biofilter efficiency factors for VOC, CH_4, NonMethaneVOC, NH_3, N_2O, CO_2eq.

treatment with a high rate (mean value 90 %). The degradation of ammonia in biofilter results in high increase rate of nitrous oxide in the clean gas. This is the reason for negative GHG efficiency (CO_2eq.) of biofilters with high ammonia load (Figure 11).

4. Conclusions and summary

Gewitra company carried out R&D project of the German federal environmental agency (UBA) on determining gaseous emissions from different types of large scale treatment plants for bio waste in Germany: open windrow, in-vessel systems and composting plants with integrated anaerobic digestion step. Measurement data of emission control are VOC (FID), CH_4, NH_3 and N_2O; emission factors and CO_2-Equivalents (CH_4 factor GWP 25, N_2O factor GWP 298) will be calculated as well.

Arrangements to optimise/minimise process emissions to air are Guidelines: *Good practice of composting*. They are well known by operators but sometimes superior necessities swing a decision. On principle for a well done process the material characteristics should have structure (high porosity) and water content of max. 65 – 70 %, the C/N ratio should be 25 – 35 to avoid ammonia and nitrous oxide emissions. Important process parameters are water content: 50 – 60 %, O_2-supply, turning cycles (intensive phase 1 – 2 times per week, phase of declining activity 0.5 times per week). Windrow profile: height max. 2.50 m (positive aeration), height max. 1.50 m (passive aeration), best available technology must be decided case-by-case.

Depending on the rotting milieu there is an opposed formation of CH_4 (anaerobic) and N_2O (aerobic) within the biological process. It is a principle that minimisation of the CH_4 and N_2O emissions to air is the result of the right material characteristics and the right process parameters for the entire time of aerobic treatment. Because there is no end-of-pipe technology to reduce CH_4 and N_2O in exhaust gas treatment, like scrubber and biofilter.

Arrangements for the emission control with acid scrubber and biofilter are shown to the components. For methane (CH_4) there is only very less < 10 % in biofilters at suitable air loads > 50 $m^3/m^3 \cdot h$. For N_2O there is no reduction, but rather new generation due to NH_3 degradation in biofilter. For nonmethane Volatile Organic Compounds (NMVOC) there are normally good reductions of easily degradable compounds (~ 90 %) at well operating biofilters and suitable air loads < 100 $m^3/m^3 \cdot h$. Ammonia (NH_3) has deposition rate 60 % in biofilters, accordingly to new generation of N_2O and NO, declining pH value -as a result of nitrification-reinforces accumulating NH_4. Acid scrubber (H_2SO_4) precipitates NH_3 > 90 %, mostly necessary after anaerobic step. Ammonium sulfate from acid scrubbers could be used as fertilizer in agriculture.

Emission factors from composting in practice:

CH_4	low: 100 – 200 g/Mg	average: 250 – 1,000 g/Mg	high: 1,200 – 1,800 g/Mg
N_2O	before biofilter: ~50 g/Mg	clean gas after biofilter: ~100 g/Mg	
NH_3	before biofilter: ~200 g/Mg	clean gas after biofilter: ~20 g/Mg	

Emissions of CH_4, N_2O and NH_3 from anaerobic digestion could be higher than from composting.

CO_2-Equivalent (data from CH_4, N_2O) from biological treatment of bio waste is in the waste gas ~ 30 – 40 kg/Mg and in the clean gas after biofilter ~ 70 – 80 kg/Mg. The estimated specific contingent for CH_4, N_2O and NH_3 from composting/digestion is rather low (< 0.5 % of total national emission).