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Evaluation of Abatement Technologies for Pig Houses by Dynamic Olfactometry and On-site Mass Spectrometry

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The aim of the present study was to evaluate the effect of abatement technologies for pig houses on odour based on 1) on-site measurements of dynamic olfactometry and chemical odorants and 2) dynamic olfactometry with storage of air samples in sampling bags. The study was conducted at two facilities with growing-finishing pigs with either biological air cleaning or slurry acidification. Five measurements days were carried out at the facility with biological air cleaning and six days at the facility with slurry acidification. A mobile laboratory containing proton-transfer-reaction mass spectrometry (PTR-MS) and an olfactometer was applied for the on-site measurements. The mobile laboratory was connected to the odour sources by insulated and heated Teflon tubes that were flushed continuously with sample air. The sampling bags for dynamic olfactometry were collected simultaneously with the on-site measurements and were analysed after ca. 24 h. At each measurement day three repetition were performed before and after the biological air cleaner and in the pig house with slurry acidification and in an identical control pig house. Odour threshold values for the individual chemical odorants were used to estimate the odour activity value for each sample. The results demonstrated that evaluation of the abatement technologies based on the on-site measurements of dynamic olfactometry and the odour activity value based on chemical odorants were in agreement and showed the same trend in data. However, if the effect of the abatement technologies was evaluated based on dynamic olfactometry with storage in sampling bags the effect of the biological air cleaner was in general underestimated and the effect of the slurry acidification system was overestimated. In conclusion, the storage in sampling bags seems to bias the measurements of odour and this may influence the estimated effect of abatement technologies. More research is needed to limit the bias of sampling bags used for dynamic olfactometry.

1. Introduction

Odour nuisance from modern intensive animal production has gained increased attention during recent years and has resulted in development of abatement technologies (e.g. biological air cleaning and slurry acidification). The cleaning efficiency of abatement technologies in relation to odour is normally based on the European standard for dynamic olfactometry (CEN, 2003). However, this method requires collection of air samples in sampling bags that can be stored for up to 30 h before analysis. It has been demonstrated in several studies that the recovery of chemical odorants is impaired by the storage in sample bags (Hansen et al., 2012a; Koziel et al., 2005; Trabue et al., 2006) and this may influence the estimated effect of abatement technologies.

It has often been suggested that measurements of chemical odorants could be an alternative to olfactometry. Proton-transfer-reaction mass spectrometry (PTR-MS) has been shown to be a useful method to measure chemical odorants in air from both cattle (Ngwabie et al., 2008; Shaw et al., 2007) and pig production (Feilberg et al., 2010; Hansen et al., 2012b; Liu et al., 2011). The aim of the present study was to develop a mobile laboratory including an olfactometer and a PTR-MS and to evaluate the effect of abatement technologies on odour based on 1) on-site measurements of dynamic olfactometry and chemical odorants and 2) dynamic olfactometry with storage of air samples in sampling bags.

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2. Materials and methods

2.1 Mobile laboratory

A mobile laboratory was constructed in an insulated trailer that was divided into two rooms where one room contained an olfactometer (TO8, Odournet GmbH, Kiel, Germany) and the other room a PTR-MS (High sensitivity PTR-MS, Ionicon Analytik GmbH, Innsbruck, Austria), see Figure 1. The room for the olfactometer was equipped with air conditioning with a charcoal filter in the air inlet. The dilution air to the olfactometer was provided by an air compressor (Dr. sonic, Fini, Bologna, Italy) and before entering the olfactometer the dilution air was filtered by a column containing silica gel and charcoal. The air compressor was placed within 25 m of the mobile laboratory. The mobile laboratory was connected to two odour sources by insulated and heated Teflon tubes (inner diameter: 6 mm and outer diameter: 8mm, Mikrolab A/S, Aarhus, Denmark). The Teflon tubes were ca. 30 m long and were flushed continuously with a diaphragm Teflon pump (Capex L2, Charles Austen Pumps Ltd, Byfleet, UK) with a flow at ca. 7 L min^{-1}. Teflon filters (0.2 µm, POLYVENT^{TM} 16, GE Healthcare Europe GmbH, Brøndby, Denmark) were used in the end of the Teflon tubes to protect the analytical instruments from dust particles.

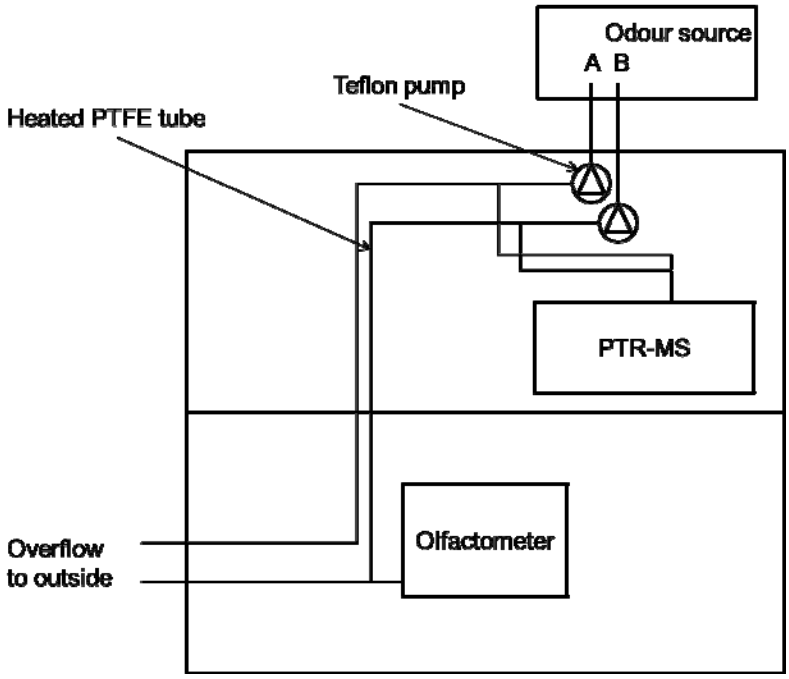

Figure 1: Schematic drawing of the mobile laboratory containing an olfactometer and proton-transfer-reaction mass spectrometry (PTR-MS).

2.2 Abatement technologies

The mobile laboratory was applied at two pig production facilities with abatement technologies. A biological air cleaner (Farm AirClean three-step Bioflex, SKOV A/S, Glyngøre, Denmark) was installed at a facility with ca. 350 growing-finishing pig (ca. 30-100 kg). The pig house was designed with one large pen with fully slatted floor and ad libitum dry feed. The ventilation system was a negative pressure system with wall inlets. The biological air cleaner was composed by three vertical filter walls of cellulose pads. Step one and two were 15 cm wide and step three was 60 cm wide. The filter walls in step one and two were irrigated with re-circulated water from a pond beneath the filter walls whereas the filter wall in step three was humidified by the air. A slurry acidification system (Jørgen Hyldgård Staldservice A/S, Holstebro, Denmark) was installed at a facility with ca. 650 growing-finishing pigs (ca. 30-100 kg) and was compared to an identical control facility. The pig houses were designed with 36 pens with fully slatted floor and restricted liquid feed. The ventilation system was a negative pressure system with a diffuse ceiling inlet. The slurry acidification system consisted of a process tank outside the pig house where the slurry was treated daily with sulphuric acid (96%). The slurry was acidified to a pH at 5.5 and afterwards a part of the slurry was flushed back into the pig house and the rest was transferred to a storage tank.

2.3 Experimental setup

Eight panellists were selected according to the European standard for dynamic olfactometry. At the facility with biological air cleaning five measurements days were performed and at the facility with slurry acidification six measurements days. Four panellists were used each day. At each measurement day three repetitions were carried out at each odour source (before and after biological air cleaner; control versus slurry acidification). At each repetition the concentrations of chemical odorants were measured by PTR-MS and odour concentration by dynamic olfactometry in the mobile laboratory. Simultaneously with the measurements in the mobile laboratory air samples were collected in 30 L Nalophan sample bags and sent to analysis at a stationary laboratory (Danish Technological Institute, Roskilde, Denmark) according to the European standard for olfactometry ca. 24 h after sampling. The olfactometer applied at the stationary laboratory was a TO8 from Odournet GmbH.

2.4 Calculation of odour activity value

The odour activity value (∑OAV) for each sample based on the chemical odorants measured by PTR-MS was calculated according to Eq(1), where OTV is the odour threshold value for each of the ten odorants included in the study. Odour threshold values reported by Nagata (2003) were used in the study.

$$\sum OAV = \sum_{n=1}^{10} \frac{\text{Odorant concentration}(ppb_v)_n}{OTV(ppb_v)_n} \quad (1)$$

3. Results and discussion

In Table 1 the average concentrations of ten chemical odorants measured by PTR-MS at two abatement technologies installed at pig houses with growing-finishing pigs are presented along with the average odour activity value (∑OAV) and the odour concentration measured by dynamic olfactometry in the mobile laboratory (Field odour) and in a stationary laboratory (Lab odour). The chemical odorants presented in Table 1 are considered to be some of the most important odorants found in air from pig houses with respect to concentration level and influence on odour (Hansen et al., 2012a).

Table 1: Average concentrations of chemical odorants (ppb_v) measured by PTR-MS at abatement technologies installed at pig houses with growing-finishing pigs along with odour activity value (∑OAV) and odour concentrations measured by dynamic olfactometry (OU/m^3).

Compound	OTV[a]	Biological air cleaner		Slurry acidification	
		Before	After	Control	Acidified
Hydrogen sulphide	0.41	578	62	306	33
Methanethiol	0.07	16	13	5.5	4.0
Dimethyl sulphide	3.0	13	9.3	2.7	2.9
Trimethylamine	0.032	30	<DL[e]	11	16
Acetic acid	6.0	568	2.1	616	1004
Propanoic acid	5.7	147	0.8	234	323
Butanoic acid	0.19	106	<DL	132	262
4-methylphenol	0.054	15	<DL	21	24
Indole	0.30	1.4	<DL	1.2	1.8
3-methylindole	0.0056	0.5	<DL	0.6	0.7
∑OAV[b]		3629	341	2500	2802
Field odour[c]		628	97	509	409
Lab odour[d]		1505	401	1093	440

[a] OTV: Odour threshold value (ppb_v) estimated by Nagata (2003); [b] ∑OAV: summation of odour activity values based on OTV and concentrations of chemical odorants; [c] Field odour: odour concentration measured by dynamic olfactometry in a mobile laboratory; [d] Lab odour: odour concentration measured by dynamic olfactometry in an stationary laboratory using sampling bags; [e] <DL: below detection limit.

It is clear from Table 1 that the biological air cleaner has an effect on most of the measured odorants except for methanethiol and dimethyl sulphide that are only slightly removed in the air cleaner. The odour activity value and odour concentration measured by dynamic olfactometry also reveals that the biological air cleaner has an effect on odour. The pig house with slurry acidification had a lower concentration of hydrogen sulphide and methanethiol compared to the control pig house whereas the concentrations of the other odorants were higher. Particularly the concentrations of carboxylic acids were higher in the pig house with slurry acidification. The odour activity value was slightly higher for the pig house with slurry acidification compared to the control pig house while the odour concentration measured by dynamic olfactometry demonstrated a lower odour concentration in the pig house with slurry acidification. The difference in odour concentration between slurry acidification and the control pig house was more pronounced for the stationary laboratory compared to the mobile laboratory.

In Figure 2 the average cleaning efficiency for the biological air cleaner is shown for each of the five measurement days based on the odour activity value and the odour concentration measured by dynamic olfactometry. The results in Figure 2 shows that during the three first measurement days the cleaning efficiency based on dynamic olfactometry in a stationary laboratory is lower compared to the cleaning efficiency based on odour activity value and dynamic olfactometry measured in the mobile laboratory without collection in sampling bags. At the last two measurement days the cleaning efficiency is almost the same for the three methods. However, at day 4 the odour concentration before the air cleaner based on the stationary laboratory was ca. 3-6 times higher than the other days and at day 5 the odour concentration after the air cleaner was ca. 2-3 times lower compared to other days. Based on the first three measurement days it seems that the odour concentration based on the stationary laboratory underestimates the cleaning efficiency of the biological air cleaner.
According to Table 1 it is mainly sulphur compounds that are present after the air cleaner. It has previously been demonstrated that sulphur compounds have a recovery in Nalophan bags between 70-90% over a storage period of 24 h, whereas 30-40% of carboxylic acids and less than 10% of phenols and indoles are recovered (Hansen et al., 2011). The results for the odour concentration before the biological air cleaner based on the stationary laboratory may be influenced by the low recovery of some odorants in sampling bags. This can result in too low odour concentrations before the air cleaner and may explain the underestimation of the cleaning efficiency.

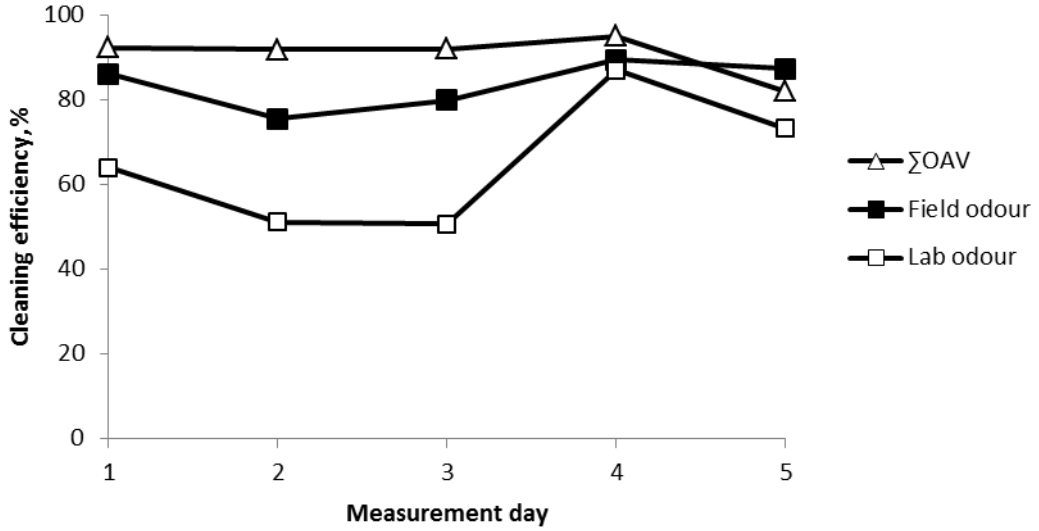

Figure 2: Cleaning efficiency for a biological air cleaner in a pig house based on the odour activity value estimated by measured concentrations of chemical odorants (∑OAV), odour measured by dynamic olfactometry in a mobile laboratory (Field odour) and odour measured by dynamic olfactometry in a stationary laboratory using sampling bags (Lab odour).

In Figure 3 the average effect of the slurry acidification system is shown for each of the six measurement days based on the odour activity value and odour measured by dynamic olfactometry. According to Figure 3 the effect of the slurry acidification system based on dynamic olfactometry in the stationary laboratory is between 40-75%. However, if the effect is based on the odour activity value or dynamic olfactometry measured in the mobile laboratory then it varies between positive and negative values and the trend in data is the same for these two methods. In general it seems that the odour concentration based on the stationary laboratory overestimates the effect of the slurry acidification system.
According to Table 1 there were higher concentrations of those odorants (carboxylic acids, phenols and indoles) that are poorly recovered in Nalophan bags in the pig house with slurry acidification compared to the control pig house. At the same time the pig house with slurry acidification had lower concentrations of sulphur compounds which are recovered to a higher extent in Nalophan bags. As a result the odour concentration based on the stationary laboratory may be influenced by the low recovery of some odorants in sampling bags. This can result in too low odour concentrations in the pig house with slurry acidification and may explain the overestimation of the effect.

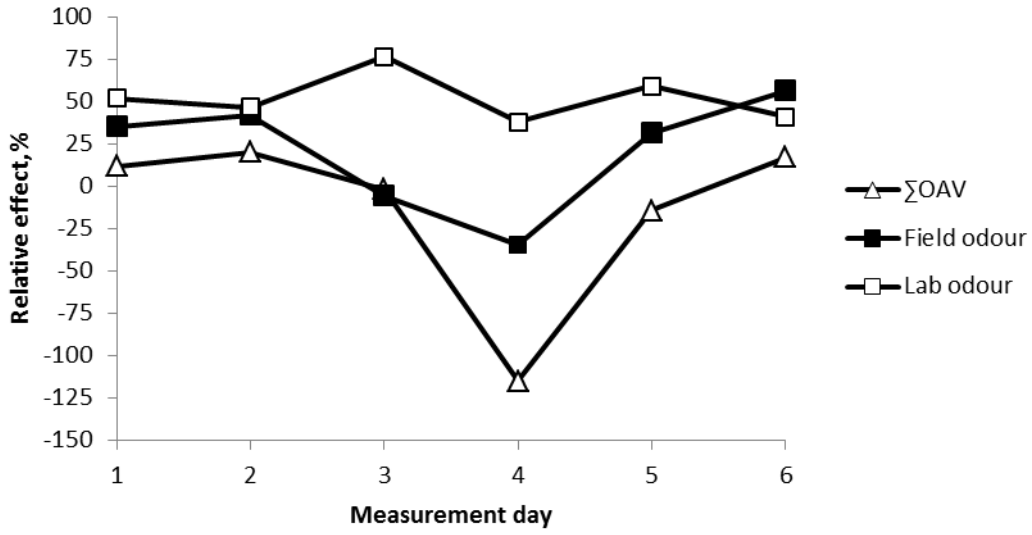

Figure 3: Effect of a slurry acidification system in a pig house relative to a control pig house based on the odour activity value estimated by measured concentrations of chemical odorants (∑OAV), odour measured by dynamic olfactometry in a mobile laboratory (Field odour) and odour measured by dynamic olfactometry in a stationary laboratory using sampling bags (Lab odour).

4. Conclusions

It can be concluded that the estimated effect of abatement technologies on odour based on dynamic olfactometry may be biased by the storage of air samples in sampling bags. The effect of the abatement technologies based on dynamic olfactometry without collection in sampling bags and the odour activity value based on chemical odorants measured on-site in a mobile laboratory were in agreement and showed the same trend in data. More research is needed to limit the bias of sampling bags used for dynamic olfactometry.

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References

CEN, 2003, Air quality - determination of odour concentration by dynamic ofactometry. EN 13725. European Committee for Standardization, Brussels, Belgium

Feilberg, A., Liu, D., Adamsen, A.P.S., Hansen, M.J., Jonassen, K.E.N., 2010, Odorant emissions from intensive pig production measured by online proton-transfer-reaction mass spectrometry, Environ. Sci. Technol. 47, 5894-5900.

Hansen, M.J., Adamsen, A.P.S., Feilberg, A., Jonassen, K.E.N., 2011, Stability of odorants from pig production in sampling bags for olfactometry, J. Environ. Qual. 40, 1096-1102.

Hansen, M.J., Adamsen, A.P.S., Pedersen, P., Feilberg, A., 2012a, Prediction of odor from pig production based on chemical odorants, J. Environ. Qual. 41, 436-443.

Hansen, M.J., Liu, D., Guldberg, L.B., Feilberg, A., 2012b, Application of proton-transfer-reaction mass spectrometry to the assessment of odorant removal in a biological air cleaner for pig production, J. Agric. Food Chem. 60, 2599-2606.

Koziel, J.A., Spinhirne, J.P., Lloyd, J.D., Parker, D.B., Wright, D.W., Kuhrt, F.W., 2005, Evaluation of sample recovery of malodorous livestock gases from air sampling bags, solid-phase microextraction fibers, Tenax TA sorbent tubes, and sampling canisters, J. Air Waste Man. Assoc. 55, 1147-1157.

Liu, D., Feilberg, A., Adamsen, A.P.S., Jonassen, K.E.N., 2011, The effect of slurry treatment including ozonation on odorant reduction measured by in-situ PTR-MS, Atmos. Environ. 45, 3786-3793.

Nagata, Y., 2003. Measurement of odor threshold by triangle odor bag method, In: Odor measurement review, Ministry of the Environment, Goverment of Japan, 118-127. www.env.go.jp accessed 27.03.2014.

Ngwabie, N.M., Schade, G.W., Custer, T.G., Linke, S., Hinz, T., 2008, Abundances and flux estimates of volatile organic compounds from a dairy cowshed in Germany, J. Environ. Qual. 37, 565-573.

Shaw, S.L., Mitloehner, F.M., Jackson, W., DePeters, E.J., Fadel, J.G., Robinson, P.H., Holzinger, R., Goldstein, A.H., 2007, Volatile organic compound emissions from dairy cows and their waste as measured by proton-transfer-reaction mass spectrometry, Environ. Sci. Technol. 41, 1310-1316.

Trabue, S.L., Anhalt, J.C., Zahn, J.A., 2006, Bias of Tedlar bags in the measurement of agricultural odorants, J. Environ. Qual. 35, 1668-1677.