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Reducing acid consumption in waste air cleaning

The use of trickle bed reactors with pH control should be clearly preferred for ammonia separation from animal husbandries compared to uncontrolled installations. Data about the annual acid consumption of these installations at pig husbandries were not available so far. The evaluation of experiments from 2004 to 2008 resulted in a mean acid consumption of 1.2 kg/kg NH_3-N input at a mean annual washing liquid temperature of 14.7 °C. A marginal increase of the washing liquid temperature, particularly in winter, could reduce the acid consumption widely as the tests show.

Keywords
Waste air treatment, trickle bed reactor, ammonia, acid consumption

Abstract
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The waste air treatment in livestock husbandry will inevitably gain in importance because of a shortage of harmless locations with regard to the Federal Immission Law, increasing livestock sizes and a decreasing acceptance of environmental pollution. Additional production costs, however, impair the profitability of the farms which have to install a waste air treatment system. In face of the current profitability of livestock husbandry it is decisive for a better acceptance and the use of this technique to reduce the waste air treatment costs without constraints of the efficiency. The ammonia separation which is either realized by very high amounts of elutriation water (> 0.6 m³/fattening pig place a) or a high acid consumption (1 – 3 kg/kg NH_3-$N_{raw\ gas}$).

It was the aim of the work to determine the acid consumption of trickle bed reactors in the annual mean and to disclose options for its reduction.

Material and methods

For the experiments in the period from 2004 to 2008 a two-stage biological operating trickle bed reactor was used, which was loaded with waste air from a conventional pig fattening. The trickle bed reactor consisted of two completely separated water circulations. Plastic hollow bullets with a specific surface of 98.4 m²/m³ were used, whereas each stage was filled with 0.25 m³ of that material. The length of each filling was 0.9 m. As droplet catchers plastic wire mesh droplet separators with a layer thickness of 0.15 m were used. For irrigation of the filling bodies a self made sprinkler was operated in the first stage and an axial full cone nozzle in the second. The irrigation density of both stages was varied between 3 and 10 m³/m² h. Evaporation losses were balanced by automatically working level controls and the pH value was controlled to 6.5 in one washing unit at least. The mean ammonia concentrations in the raw gas varied between 4.1 and 10.7 ppm and the mean filter volume loads between 1500 and 2500 m³/m³ h. The mean NH_3-N loads varied between 130 and 265 g/m³ d.

For measuring the ammonia gas concentration an UV spectrometer (Optas TM) was used. The volume flow was measured with ITABAR flow sensors (type IBR) and standardised by accordant transmitters (type INT). Every three hours the NH_3-N mass flow was calculated from those data. The water sampling of the trickle bed reactor was carried out at least thrice weekly from the circulating pipe at constant water levels. Ammonium nitrogen was analysed from a mixed sample by distillation (DIN 38406-E5-2) and nitrite and nitrate nitrogen by ion exchange chromatography (EN ISO 10304 – 2) after membrane filtration [1]. The thermistor based temperature measurements were made in the water reservoirs.

Values from all in all ten experiments were classified according to calendar days, averaged for each washing unit and combined to average values per week, respectively. In addition, the mean percentages of NH_4-N, NO_2-N and NO_3-N were calculated from the average values per week, whereas the sum of it was fixed to 100 % (TIN = total inorganic nitrogen). As oxidised nitrogen (N_{ox}-N) the sum of NO_2-N and NO_3-N was additionally calculated. These values of both washing units were again averaged for NH_4-N, NO_2-N and N_{ox}-N.

Results

Temperature measurements during the experiments in the time period between 2004 and 2008 showed, that the washing liquid temperatures varied between 9.7 °C (washing unit 1, calendar week 9, end of February) and 19.9 °C (washing unit 2, calendar week 29, in the middle of July) (Fig. 1). The annual mean was 14.9 °C in stage 1 and 14.4 °C in stage 2. Thus the differences in temperature were marginal. In 49 calendar weeks the mean temperature of both stages was above 11 °C, in 34 weeks > 13 °C, in 23 weeks > 15 °C and in 14 weeks > 17 °C. During wintertime (calendar weeks 52 – 12) the mean washing liquid temperature was merely 11.7 °C, while it was 15.3 in spring (calendar weeks 13 – 25), 18.1 in summer (calendar weeks 26 – 38) and 13.9 in autumn (calendar weeks 39 – 51).

The mean percentages of NH_4-N, NO_2-N and NO_3-N in the washing liquid showed significant seasonal fluctuations (Fig. 2). In the first nineteen calendar weeks the mean NH_4-N percentage of the total inorganic nitrogen (TIN) was approximately 80 %, NO_2-N was between 10 and 22 % and the percentage of NO_3-N was below 8 %. In this time period the washing water temperatures varied between 10 and 15 °C. Up to calendar week 26 the NO_3-N percentage rose to 40 %, while the NH_4-N percentage decreased to 60 %, approximately. NO_2-N was below the detection limit at that time. From calendar week 19 to 26 the washing liquid temperature increased from 15 to 18.4 °C in average of the years 2004 to 2008. The NH_4-N percentage attained its minimum in calendar week 39 with 31.6 %, while the NO_3-N percentage achieved its maximum, simultaneously. In calendar week 39 the percentage of Nox-N (NO_2-N + NO_3-N) was the highest. After that the NH_4-N percentage increased continuously to values up to 80 % (calendar week 52), while the NO_3-N percentage already declined below 1 % in calendar week 28. The NO_2-N percentage ranged between 16 and 27 %. The mean washing liquid temperature decreased from 16.2 °C (calendar week 39) to 12.3 °C (calendar week 52).

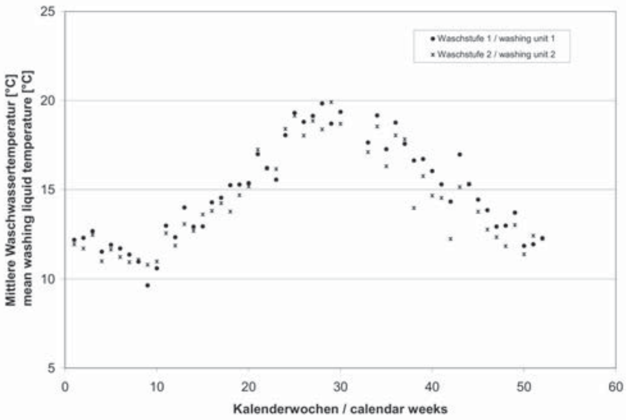
A nitrate nitrogen production even began at washing liquid temperatures of more than 14 °C, as the averaged results from the years 2004 to 2008 show. NO_2-N was already produced at temperatures of 10 °C, but not in an extent that would be sufficient for complete ammonia absorption.

The sulphuric acid demand declines the more the higher ammonia is microbiologically oxidised. Calculations, based on data from 2004 to 2008, resulted in consumption values between 0 kg (calendar weeks 33 - 42) and 2.5 kg/kg NH_3-$N_{\text{raw gas}}$ (calendar week 2) (Fig. 3). The annual consumption was 1.2 kg/kg NH_3-$N_{\text{raw gas}}$ in mean.

Conclusions

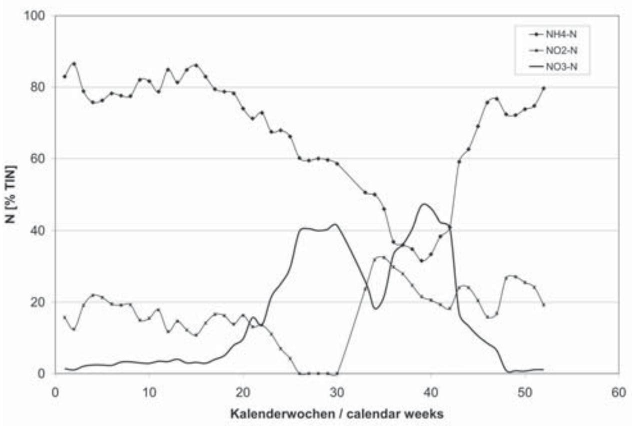
Based on current results the separation of 1 kg NH_3-N in common trickle bed reactors requires a sulphuric acid consumption of 1.2 kg (96 %) in the annual mean. The acid consumption can be reduced significantly by increasing the minimum washing liquid temperature above 14 °C. From temperatures of more than 17 °C the acid consumption should become negligible at ammonia ni-

Fig. 1



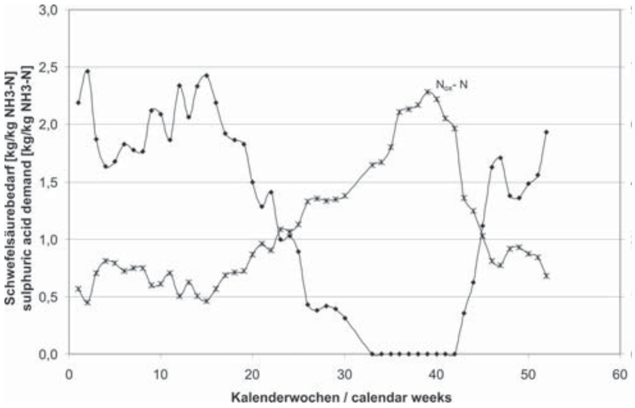
Mean washing liquid temperature course of a two-stage trickle bed reactor (measuring period: 2004 – 2008)

Fig. 2



Mean seasonal course of nitrogen compounds in the washing liquid of a trickle bed reactor (measuring period: 2004 – 2008)

Fig. 3



Calculated seasonal course of sulphuric acid demand for ammonia separation with a trickle bed reactor (measuring period: 2004 – 2008) trogen volume loads between 130 and 265 g/m^3 d and a pH control to 6.5. Therefore the avoiding of needless heat losses should be absolutely considered. Integration of the waste air treatment installation into the stable would be surely the best option in this regard taking piggery air temperatures from 16 to 32 °C into account. Alternatively the heat insulation of the trickle bed reactor and the preheating of fresh water by heat exchangers or solar heating systems should be scrutinised.

Literature

[1] Hahne, Jochen: Cutting costs for waste air cleaning. Landtechnik 63 (2008), Heft 3, S. 166-167

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