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Cutting Costs for Waste Air Cleaning

Waste air cleaning with trickle bed reactors with no pH control causes high costs for storage and waste water application. One example from conventional pig fattening shows that this operating mode results in a waste water volume of at least 0.6 m3 per animal and year. In contrast to this, ammonium and nitrate concentrations found in the washing liquid could be increased considerably through pH control, thereby reducing waste water volume up to 77 %. Concentrating the waste water volume results in a cost reduction of over 50 % for storage volume, waste water application and fresh water consumption, despite the additional expenses for the pH control unit.

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The waste air treatment is not state of the art in German livestock husbandry but is increasingly used for far-reaching emission reduction as producer information show [1]. The application of this technique is connected with additional costs. Cost calculations are available from the year 2006 [2], whose size is disputed by some producers. For trickle bed reactors the total costs are specified with 18 to 21 €/pig place (air volume capacity: 50,000 m?/h). For installations with a capacity of 150,000 m^3/h the total costs may fall to 13 to 17 €/ pig place. On the basis of these calculations the operating costs are composed as follows: 50 % power consumption, 12 % water consumption, 16 % waste water application, 16 % maintenance and 6 % cost of repairs [02].

The relevant costs for fresh water consumption and waste water application finally result from the fact that microorganisms die off above certain salt and inhibitor concentrations. On the current level of knowledge a waste water production of 0.2 to 0.3 m^3 per kilogram ammonia nitrogen has to be assumed for trickle bed reactors, which should secure an enduring reliability. For a pig stable with 1 000 heads about 600 to 900 m^3 waste water are produced by the waste air cleaning with trickle bed reactors without pH control, taking the ammonia emission factor of 3.64 kg/pig place from the German Technical Instructions for Air Quality as a basis [3]. A storage capacity has to be provided for this amount of waste water. The investment costs for this amount to 35 €/m^3 [2]. Also the waste water application has to be calculated at least with 2.60 €/m^3.

Reducing the costs for biological waste air scrubbers without detrimental effects on their efficiency is the aim of this work. The concentrating of waste water without inhibition of microorganisms is one option for cost reduction. This implies that the concentrations of free ammonia and free nitrous acid are kept under their inhibition thresholds by pH control.

Material and methods

A two-stage biological operating trickle bed reactor (*Fig. 1*) was loaded with waste air from a pig fattening unit in 7 experiments, whereas the test periods varied between 72 and 155 days. At 6 experiments the pH was controlled to 6.5 with concentrated sulphuric acid, five times in stage 1 (S1) and once in stage 2 (S2). At the other stage no pH control was carried out, respectively. Evaporation losses were balanced with fresh water by an automatically working level control unit. There was no discharge of waste water. Sampling was done three times a week from the circulating pipe at a constant water level. Ammonium nitrogen was analysed from a mixed sample by distillation (DIN 38406-E5-2) and nitrite nitrogen and nitrate nitrogen by ion exchange chromatography (EN ISO 10304 – 2) after membrane filtration [4]. For analysing organic nitrogen a part of the sample was centrifuged, whereas the supernatant was rejected. The pellet was resuspended in deionised water and centrifuged again. The organic nitrogen assessment was finally made from the two times washed pellet by EN 25663.

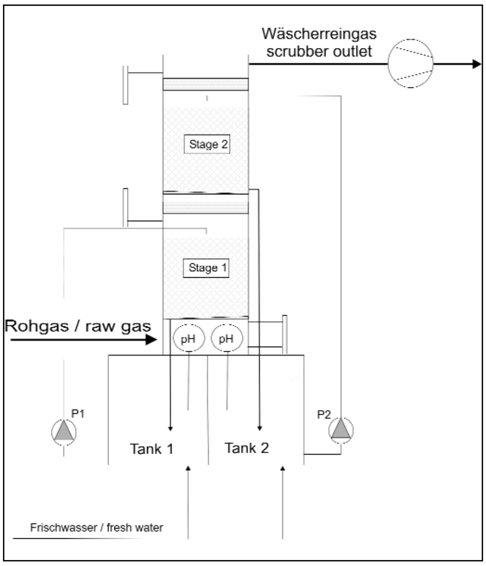

Fig. 1: Sketch of the biologically operated trickle bed reactor

Results

The ammonia reduction efficiency of trickle bed reactors strictly depends on the pH value in the washing liquid as is known. Tests with a pH value of 6.5 in S1 showed mean ammonia inputs of 261 g/m^3d into the washing liquid, while it were solely 122 g/m^3d in mean for the uncontrolled tests. In spite of the pH control in S1 ammonia was transferred into S2 and oxidized by microorganisms.

The maximum nitrogen concentrations (N_{min}= sum of NH_4-N, NO_2-N and NO_3-N) were in mean fivefold in excess in S1 compared to values from S2 (*Table 1*). Without pH control the ammonia separation efficiency was absolutely inadequate in S1. The achievable N_{min} concentration solely amounted to 28 % of that value obtained with pH control in S1. With pH control in S2 only the N_{min} concentration in this stage was 3.5-times higher than in S1.

With pH control to 6.5 in S1 NH_4-N and NO_3-N concentrations were achieved in a range from 8230 to 15720 mg/kg (12434 mg/kg in mean) and 182 to 5972 mg/kg (2332 mg/kg in mean), respectively. The comparable low NO_2-N concentrations in a range from 6.4 to 581 mg/kg (167 mg/kg mean) were important in this connection. An accumulation of nitrite in the washing liquid was thus avoided with the pH control. In the uncontrolled S2 an accumulation of 1903 mg/kg NH_4-N, 397 mg/kg NO_3-N and 1182 mg/kg NO_2-N occurred in mean. These results show a slight overloading of S1 on the one hand, but again a strong accumulation of nitrite without pH control on the other.

The NH_4-N concentrations without pH control in both stages amounted to 2370 and 2840 mg/kg in maximum or only 19 to 23 % of the mean value with pH control. In contrast to that the NO_2-N concentrations showed very high values with 1840 to 1931 mg/kg which exceeded the mean value from the controlled stage about the factor 11 to 18. The NO_3-N values, in contrast, accounted for just 8 to 12 % of the mean nitrate nitrogen concentration achieved with pH control.

The nitrite formation increased with the ammonia input into the washing liquid under uncontrolled conditions, while the nitrate production decreased. Ammonia inputs up to 173 g/m³d did not result in limitations of the nitrite formation in controlled operation. Limitations may be caused by a lack of dissolved oxygen (undervalued irrigation density) and / or by an enrichment of salts. The nitrite production rate increased up to N_{min} concentrations of 3000 mg/kg (= 100 %), whereas the $N_{oxidized}/N_{reduced}$ ratio was 0.9 in mean. At 4000 and 5000 mg/kg N_{min} the nitrite production rate decreased to 79 % and 21 %, respectively.

Tab. 2: Possible cost savings by a pH control in trickle bed reactors for a unit with 1000 fatteners

	Costs without pH control		Costs with pH control	
	Investment [€]	Operating [€/a]	Investment [€]	Operating [€/a]
pH control	-	-	1970	100
Acid consumption	-	-	-	263
Fresh Water[1]	-	298	-	69
Waste water	-	1547	-	360
Add. storage volume	10413	-	2415	-
Sum	10413	1845	4385	792

[1]: without evaporation

Cost savings potentials

As the results show, a maximum N_{min} concentration of 21.72 g/kg could be achieved with pH control to pH 6.5. Lasting limitations of the nitrification process didn't occur. Without pH control the maximum N_{min} concentration was 5.04 g/kg. If the latter can be increased 4.3-times, the waste water production would decline accordingly, as the following example shows.

For the discharge of a Nmin load of 3000 g/head and year (pig fattening, emission factor: 3.64 kg NH_3) only 138 litres of washing liquid are required at best with pH control (138 l • 21.72 g/kg = 2997 g). Without pH control, however, it would be 595 litres at least (595 l • 5.04 g/kg = 2999 g). Thus, the waste water production could be reduced about 4.3-times under optimum conditions.

In view of application costs (2.60 €/m³), investment costs for storage capacity (35 €/m³) and the costs for fresh water (0.5 €/m³) [2] considerable cost savings are possible despite a small additional consumption of acid (*Table 2*). Data from RIMU Lüftungstechnik (pH control unit) and KTBL-publication 451 (as of: 2006) provide the basis for the cost calculations. On basis of tests, the acid consumption was estimated at 10 % of the value for a chemical scrubber. A storage time of at least 6 month was assumed for the calculations of the additional storage volume.

Conclusions

The N_{min} concentration in the washing liquid of a pH controlled trickle bed reactor could be increased up to 21.7 g/kg without a lasting inhibition of nitrification. Without pH control it was 5.0 g/kg in maximum. Concentrating of N_{min} in the washing liquid results in a considerable reduction of required storage volume, waste water application and fresh water consumption. The expenses for these items can thus be reduced over 50 %.

No	unit	N-Input [g/m³ d]	pH control	NH_4-N [mg/kg]	NO_2-N [mg/kg]	NO_3-N [mg/kg]	N_{min} [mg/kg]
1	S1	97	-	2840	1931	269	5040
	S2	76	-	2370	1840	181	4391
2	S1	146	-	1910	1312	47	3269
	S2	287	+	10570	778	113	11461
3	S1	199	+	9930	581	182	10693
	S2	103	-	2570	1572	458	4600
4	S1	213	+	8230	185	4643	13058
	S2	43	-	618	373	419	1410
5	S1	353	+	15720	29	5972	21721
	S2	173	-	1820	1106	359	3285
6	S1	289	+	14570	32	322	14924
	S2	58	-	2550	1684	114	4348
7	S1	250	+	13720	6	540	14266
	S2	70	-	1960	1176	637	3773

Table 1: Maximum achieved nitrogen concentrations in the washing liquid of a biologically operated trickle bed reactor at different nitrogen inputs with and without pH control

Literature

Books are marked by •

[1] *Hahne, J.*: Aktuelle Entwicklung der Abluftreinigung in der Tierhaltung. Landtechnik 62 (2007), H. 3, S. 178 - 179

[2] • KTBL (Hrsg.): Abluftreinigung für Tierhaltungsanlagen, KTBL-Schrift 451, Darmstadt, 2006

[3] TA Luft 2002: Erste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz (Technische Anleitung zur Reinhaltung der Luft – TA Luft) vom 24. Juli 2002. GMBL 2002, Heft 25 – 29, S. 511 - 605

[4] Fachgruppe Wasserchemie (Hrsg.): Deutsche Einheitsverfahren zur Wasser-, Abwasser- und Schlammuntersuchung. Verlag Chemie GmbH, Weinheim, in der jeweils gültigen Fassung