APPLICATION OF NON-THERMAL PLASMA TECHNIQUES (NTP) TO REDUCE EMISSIONS FROM ANIMAL HUSBANDRY

R. Kosch[1], A. Decker[2] and H. Van den Weghe[1]
[1]Research Centre for Animal Production and Technology, University of Goettingen, Universitätsstr. 7, 49377 Vechta, Germany [2]Company UltraKat Plasmatechnik AG, Max-Roth-Str. 1, 76571 Gaggenau, Germany

Introduction

In regions with high animal production density, it is a demand to develop efficient filters for the cleaning of exhaust air. Non-thermal plasma techniques (NTP) are used increasingly for various applications and provide an approach to destruct noxious manure gases, particulary ammonia, hydrogen sulfide, volatile organic compounds (VOCs) and biological particles (Rice R.G., 2003). Most of the work in this field focuses on the removal of green-house and toxic gases and odour by direct treatment in the plasma (Zhang R. et al, 1996; Wang Y. and Goodrich, R., 2003). However, it is a procedural problem to direct that great amounts of air flow through a reactor, that are accruing in pig or poultry production.

A plasma produces ozone and in addition to it a variety of chemical radicals with short lifetimes. It is to resolve, which contribution the products have to ammonia reduction.

In a current research project the application of a NTP-reactor for reducing emissions from an animal livestock is examined. The aim of this experiment was to draw conclusions about exhaust air cleaning with NTP by comparing the removal of ammonia in a flow-through and in a bypass configuration.

Materials and methods

The plasma equipment consists of a power supply and as plasma unit a dielectric barrier discharge (DBD) from UltraKat, Gaggenau (Germany). The volume of the reactor is 470 ml, with gap distance of 2mm. The power is continuously adjustable up to 2100 Watt. The plasma is generated by applying an alternating high voltage across the gap, leading to many small electrical breakthroughs (streamer) in the gap. The dielectric barrier between the electrodes prevent the formation of a conducting channel.

The experiment was carried out under laboratory conditions in two different strategies of the NTP application. With the help of a lateral channel sealer the air was pushed through the reactor with a flow rate of 60m³/h according to a space velocity of 6,0 m/s and a contact time of 16 ms.

In the first strategy, ammonia was added in front of the NTP reactor, in the second strategy, ambient air flows through the reactor and ammonia was mixed afterwards with air coming from the reactor. The experiment was carried out by using various ammonia concentrations (10, 50, 100 ppm) and electric power (0, 750, 1250 W). The concentration of NH_3, N_2O, NO, NO_2 and O_3 was determined by a FTIR-Spectrometer (ThermoNicolet).

Results

The temperature at the outlet of the reactor raised in the experiment up to 50°C when applying 750 W, and up to 70°C when applying 1250 W. Ammonia concentration was reduced by the flow-through treatment (Tab. 1) as well as by the bypass treatment (Tab 2), whereas the efficiency was higher in the flow-through configuration than in the bypass treatment. With increasing ammonia concentrations, the efficiency was decreasing by the flow-through treatment from 100% to 47% and from 80% to 24% in the bypass treatment with an applied power of 1250 W. Less power at the NTP reactor reduces the efficiency of ammonia reduction, too.

Tab. 1: Nitrogen exchange [ppm] by using flow-through treatment against initial ammonia concentration and power.

NH_3	Watt	NH_3	N_2O	NO_x	O_3
	0	11,5	0,8	0	0
10	750	0	3,0	1,9	2909
	1250	-	-	-	-
	0	52,7	0,8	0,5	2
50	750	28,3	3,8	2,3	2468
	1250	9,6	5,2	1,1	4329
	0	101,5	1,2	0,1	1
100	750	74,3	4,3	2,9	2603
	1250	53,8	6,2	2,1	4548

Tab. 2: Nitrogen exchange [ppm] by using bypass treatment against initial ammonia concentration and power.

NH_3	Watt	NH_3	N_2O	NO_x	O_3
	0	10,3	1,1	0,0	1
10	750	1,2	2,4	2,0	2632
	1250	2,1	3,3	1,8	5109
	0	55,6	1,0	0,0	3
50	750	43,3	2,5	2,6	2516
	1250	33,7	4,1	1,9	4800
	0	103,6	1,2	0,4	0
100	750	88,0	3,8	2,3	2974
	1250	79,0	5,4	2,0	5404

However, by using NTP other noxious gases can be generated. Laughing gas (N_2O) in this experiment increased up to 6,2 ppm and nitric oxides (NO_x) up to 2,9 ppm. To act as an indicator for ionized air, ozone originated in dependence of an applied electric power of 750 resp. 1250W up to 2537 resp. 4837 ppm O_3 that is an equivalent of 52 resp. 56 g(O_3)/kWh.

Discussion

As an indicator for ionised air ozone was the only species that was detectable by our measuring technique. The production of ozone is comparable with the devices that are used for ozone-generation with a DBE-reactor. We found a high correlation between ozone production and ammonia reduction, in good agreement with the work of Ruan et al. (2004) and Wang & Goodrich (2003). However, for the reduction of ammonia it is not mandatory that the air is fed through the plasma reactor. The higher efficiency in the flow-through treatment could base on radicals decaying fastly after leaving the reactor, thus in the bypass-treatment a huge amount of theses radicals should be decayed, and ozone is assumed to be responsible for ammonia reduction.

The plasma induced chemical process of ammonia-reduction is characterised through a lot of complicated reactions and it's not possible to acquire all this reactions. In an experiment of several days we found deposits of Ammonium nitrate. This is an indication, that ozone oxidises ammonia in humid air to nitric acid (Rip G. Rice, 2003), but the proportion of this reaction is unknown and has to be verified in further investigations.

Conclusion

The use of the NTP-application for the treatment of exhaust air is an innovative approach, but requires the avoidance of the synthesis of noxious gases by varying the flow rate, amplitude, duty cycle or temperature. The air treatment by using a bypass configuration could be a solution to the great amounts of air flow in animal husbandry. Furthermore it is necessary to implement a catalytic converter to eliminate ozone. In accordance of the results in this investigation it is projected to apply the DBE-reactor in a pig fattening stable with 10 pig places. The exhaust air should be feed to a part of 500m³/h through the DBE-reactor, the other part of air-flow should be treated in a Bypass-prozess.

Acknowledgements

The study described in this paper is part of a current research project entitled "Techniques of plasmaphysics to reduce anorganic and organic harmful substances and germs in stable climate and exhaust air" and is supported by the Federal Ministry for Education and Research, Germany (BMBF). It is a cooperation with the School of Veterinary Medicine Hannover and the Companies Ultrakat, Gaggenau and Peus, Bruchsal.

References

Rip G. Rice, Phd. (2003). Ozone for Air Treatment - Basic Principles. In: *International Ozone Association 16th World Congress*, 31.8-5.9.2003 in Las Vegas, pp. 1-23.

Ruan, R.R., W. Han, A. Ning, P. Chen, und P.R. Goodrich 2004: Reduction of Harmful Gases and Odorous Compounds by Non-Thermal Plasma. *ASAE Meeting Presentation*, Paper No. 974038.

Wang Y. and Goodrich, R. (2003). Destruction of Swine Manure Gases by a Non-Thermal Plasma Reactor. In: *International Symposium on Gaseous and Odour Emissions from Animal Production Facilities*, EurAgEng, Horsens 1-4 Juni, pp. 444-451.

Zhang R., Yamamoto T. and Bundy, D.S. (1996). Control of Ammonia and Odors in Animal Houses by a Ferroelectric Plasma Reactor. In: *IEEE Transactions on Industry Applications* 32/1, pp. 113-117.