Project *brief*

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The partial underfloor suction for reduction of emissions and enhancement of the animal protection at naturally ventilated cattle stables

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- **Tighter EU limits on ammonia emissions increase pressure on Germany**
- **The largest emitter of ammonia from agriculture is cattle farming**
- **The partial underfloor suction offers a possibility to actively influence the emissions of a naturally ventilated cattle stable**

Background

The emission of ammonia (NH_3) can lead to the acidification of soils and nitrogen accumulation in the soil and in water bodies - and thus to a strain on ecosystems. Therefore, NERC Directive 2016/2284 requires that these emissions in Germany - measured against 2005 levels - be reduced by 5% per year until 2029 and by 29% from 2030 onwards. Approximately 95% of the ammonia emitted comes from agriculture, of which 52% alone comes from cattle farming.

The partial underfloor suction

The basic principle of partial underfloor suction is to separate the air space into an above-floor area (where the animals stay) and an underfloor area (slurry cellar). The high ammonia concentrations near the floor are sucked into the slurry cellar under the slatted floor and fed to an exhaust air washer. This prevents the air pollutants from entering the breathing zone of the animals and, in the case of open barns, wind-induced natural ventilation with fresh air continues to take place. This concept has already been investigated in pig farming in forced-ventilation barns. The methodological challenge is to extract as little air volume flow as possible under the floor in order not to release additional air pollutants from the manure.

Procedure

The project investigated the extent to which the technique of partial underfloor suction from forced-ventilation pig farming can be used in dairy barns, which are mostly naturally ventilated.

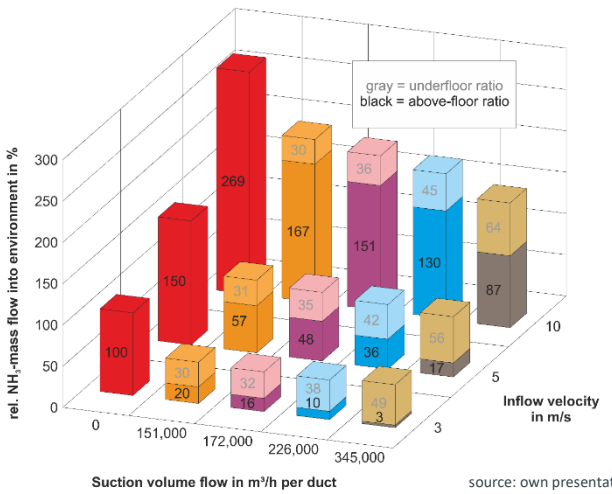
In order to evaluate the emission reduction potential, a numerical flow model of a real existing dairy barn for 255 animals with slatted floors was created with the commercial software Star-CCM+ and supplemented with partial underfloor suction. A large number of different boundary conditions (inlet velocity and flow angle) were analysed on this model and different configurations and combinations of windbreak nets and blinds were investigated.

For the evaluation of the emission reduction performance, the ammonia mass flow at the stable boundaries in the above-floor area was evaluated. Furthermore, a downstream air washer with a conservative cleaning performance of 70% was considered for the underfloor portion.

Results

Figure 1 shows the results of the simulations for different suction volume flows per duct (there are two suction ducts in the barn) and different inflow velocities (wind speeds outside the barn) perpendicular to the ridge.

Figure 1: Illustration of the NH_3 mass flow of a naturally ventilated cattle barn with and without partial underfloor suction at different inlet velocities and suction volume flows and an air washer cleaning capacity of 70%.



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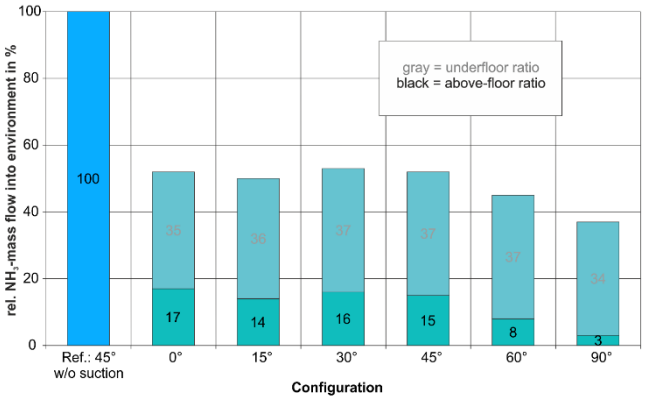
A suction volume flow of 0 m³/h represents the conventional barn without partial underfloor suction. The underfloor part of the emissions (the part leaving the air washer) is marked in grey

in Figure 1 and the above floor part (caused by natural ventilation) is marked in black.
For an air velocity of 3 m/s, the emissions can be reduced to about half, regardless of the suction volume flow. At an air velocity of 5 m/s, an increase in the suction volume flow leads only to a slight improvement in the emission behaviour. At 10 m/s however, a significant reduction of the total emissions of the barn system can be achieved. Overall, the use of a partial underfloor suction system in a naturally ventilated cattle barn shows great potential for reducing emissions.
In the further course, the influence of varying inflow angles was investigated. Here, too, the partial underfloor suction showed great potential for reducing emissions (cf. Figure 2). The emissions dropped by about half regardless of the angle of inflow.

Figure 2: Comparison of the NH_3 mass flow into the environment for the different inflow angles at an inflow velocity of 3 m/s, a suction volume flow of 104,000 m³/h per duct and an air washer cleaning capacity of 70%; reference: inflow angle 45° without partial underfloor suction



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Furthermore, different combinations of wind break mechanisms were considered. Depending on the inflow velocity, impermeable blinds cover a fine mesh at the bottom of the side wall and a coarser mesh at the top of the side wall (cf. Figure 3).
The evaluation of the ammonia mass flows again shows the reduction potential of partial underfloor suction (Figure 4). In contrast to the results in Figure 1, it becomes clear here that the emission behaviour of the barn system can be kept at the same level even at different external wind speeds through an intelligent interaction of wind break mechanisms and partial underfloor suction.

Figure 3: Configuration of the wind protection nets and blinds for different inflow velocities

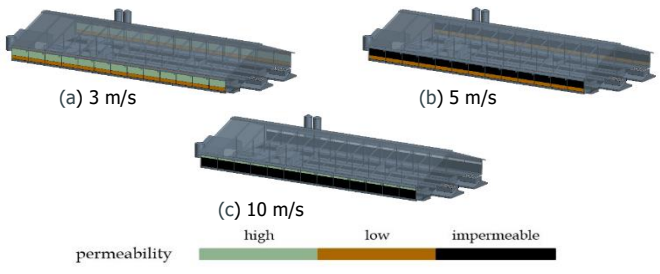

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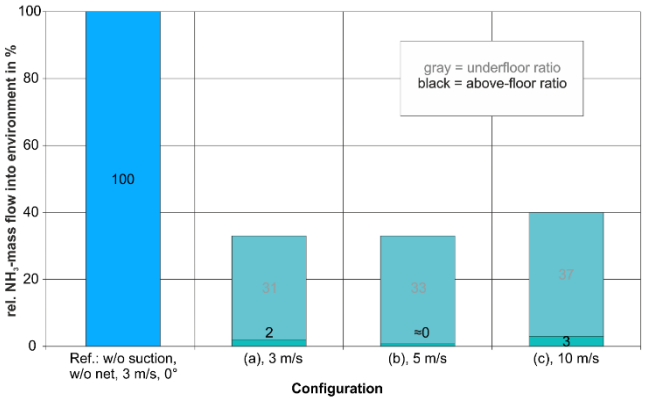
Figure 4: Comparison of NH_3 mass flow into the environment for optimised combinations of wind protection nets and blinds at a varying inlet velocity, a suction volume flow of 104,000 m³/h, a constant inflow angle of 0° and an air washer cleaning performance of 70%; reference: without partial underfloor suction, without wind protection nets, 3 m/s, 0°



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Conclusion

Numerical simulations have shown that partial underfloor suction in combination with a downstream exhaust air washer can significantly reduce ammonia emissions from naturally ventilated dairy barns under a wide range of boundary conditions. With an inflow perpendicular to the ridge, open side walls and a theoretical air washer cleaning capacity of 70%, a reduction of the NH_3 mass flow into the environment by up to 52% can be achieved. With a theoretical cleaning capacity of 85%, emissions could even be reduced by up to 72%.
When using the windbreak mechanisms, it must be kept in mind that the character of an outdoor climate barn is maintained. The investigations considered here took place against the background of minimising emissions.
It is now necessary to reproduce and validate these results in reality.

Further information

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Publications

Hartje J, Linke S (2020) Die partielle Unterflurabsaugung zur Senkung der Emissionen und Verbesserung des Tierschutzes bei natürlich belüfteten Rinderställen : DBU-Endbericht ; Förderkennzeichen 33789. Osnabrück: Deutsche Bundesstiftung Umwelt, 90 p

Hartje J, Linke S (2019) Die partielle Unterflurabsaugung zur Senkung der Emissionen und Verbesserung des Tierschutzes bei natürlich belüfteten Rinderställen. In: 14. Tagung: Bau, Technik und Umwelt in der landwirtschaftlichen Nutztierhaltung 24.-26. September 2019 in Bonn. Darmstadt: KTBL, pp 75-80

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