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# MEASUREMENT OF AMMONIA EMISSIONS AFTER SLURRY APPLICATION TO GRASSLAND: INFLUENCE OF APPLICATION TECHNIQUES*

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A b s t r a c t. Following surface application of slurry to grassland between 1 % and 100 % of the ammonia-nitrogen of the organic fertilizer can be lost through volatilization of ammonia gas. For recording various influence factors on the ammonia volatilization after slurry application, three parallel operated windtunnels are used. Researches on the accuracy of this windtunnel system proved the reproducible measuring and quantification of ammonia emissions. The ammonia-nitrogen loss could be minimized through application techniques, which apply the slurry near or into the soil. In comparison to broadcast spreading with a splash plate, the ammonia emissions were reduced by 40 % using a trailing hose, between 50 % and 60 % with a trailing foot and even by 75 % using the trenching technique. Extensive research will be carried out to examine the influence of climatic conditions and different kinds of slurry treatments.

K e y w o r d s: ammonia emissions, windtunnel system, application techniques for slurry, grassland

## INTRODUCTION

Agriculture with intensive animal husbandry is the main producer of ammonia ($NH_3$) emissions. More than half of the $NH_3$ emissions in Germany are caused by landspreading of slurry. From 1 % to 100 % of the applied ammonia-nitrogen ($NH_4$-N) of the slurry can evaporate as $NH_3$ gas into the atmosphere [7]. The loss of $NH_4$-N fertilizer can rise up to 40 kg per hectar. Furthermore $NH_3$ gas causes environmental damages such as forest dying and acidification of water and soil.

## WINDTUNNEL SYSTEM OF HOHENHEIM

Sustainable agriculture demands a reduction of $NH_3$ emissions through suitable process improvements in slurry management. To record the influence of application techniques, climatic conditions and slurry treatments on $NH_3$ emissions following landspreading of slurry, the Institute of Agricultural Engineering of the University of Hohenheim developed a windtunnel system [11], (Fig. 1). The parallel operation of three windtunnels allow specific variations of one influence factor under similar ambient conditions.

Ambient air is sucked through a vertical pipe with a radial fan at the end of the system. Inside the suction pipe the air velocity is measured by means of an anemometer. For determination of the airflow, the anemometer was calibrated at a norm-orifice-plate-section according to DIN 1952 standards [4]. Through a throttle valve next to the fan, the air velocity above the measurement area is adjustable between 0.3 and 4.0 m/s. Normally it is adjusted

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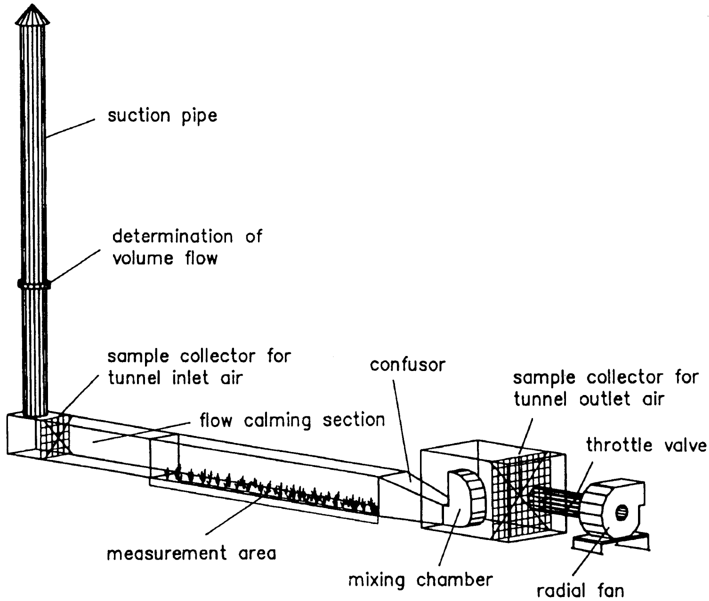


**Fig. 1.** The windtunnel system of Hohenheim.

to the average air velocity in South Germany of 1.0 m/s, corresponding to a main airflow of 15000 l/min.

After passing the suction pipe the air is lead through a flow calming section with an integrated straightener in order to receive a homogeneous air profile over the measurement area. The measurement area (4.0 x 0.5 m) is covered with a rectangular canopy of plexiglas or polyethylen. To avoid additional air intake the canopy is fixed 5 cm deep into the soil with a recessing sheet. Passing the measurement area the air gets enriched with ammonia gas emitted from the applied slurry. Finally the air is accelerated by a confusor and then reaches the mixing chamber. A buffle plate mixes the air to receive an equal $NH_3$ distribution over the whole cross section of the mixing chamber.

Two air samples are taken out of the windtunnel. First, a sample of the tunnel inlet air is taken out of the calming section for determination of the atmospheric $NH_3$ concentration. The second sample is taken out of the mixing chamber in order to determine the concentration of the tunnel outlet air. The emission is calculated by multiplying the airflow by the increase in $NH_3$ concentration over the measurement area. The sampling of the tunnel inlet and outlet air is identical and according to VDI 2461 [13], (Fig. 2).

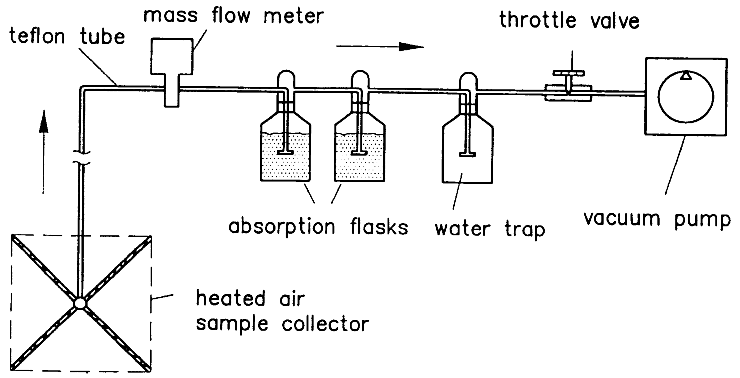


**Fig. 2.** Sampling of $NH_3$ out of the windtunnel.

Using a vacuum pump the air sample is sucked through Teflon tubes out of the windtunnel. The airflow is about 2.0 l/min and adjustable by a throttle valve. The constant ratio between main and sample airflow is 1:7500. The watertrap is for dehumidification of the air. The four-armed sample collector consists of stainless steel tubes with 40 take out points. Therefore a representative air sample is ensured. The sample collector is heated with a power of 70 W to a temperature of about 20 °C to minimize water condensation. A thermal mass flow meter measures continuously the sample airflow. The $NH_3$ itself is trapped in absorption flasks, filled with 100 ml of N 0.01 sulfuric acid. There are two flasks in a row to avoid overflow of $NH_3$-loaded air. Between 60 % and 90 % of the $NH_3$ is absorbed as ammonium ($NH_4^+$) in the first flask. The $NH_4$-N concentration of the absorption solution is colorimetrically analysed and detected with a photometer. The sampling is discontinuous due to manual changing of the flasks. The absorption duration is variable and depends on the expected emission. A measurement period lasts 48 h, in which seven samples are taken.

## ACCURACY OF THE WINDTUNNEL SYSTEM

Researches on the accuracy of the whole system were carried out with ammonia gas and slurry. Recovery rates ranged between 77 and 99 % and no constant correction factor could be calculated. Such varying recovery rates are typical for windtunnel systems [8,12]. Since there are three parallel operated windtunnels an equalization of the six $NH_3$ samplers and the three windtunnels was more important. By the equality of the different samplers a representative sampling was confirmed. An equalization of the three windtunnels gave a maximum $NH_4$-N difference of 200 mg/m$^2$ in 48 h as the total sum of measurement deviations. Thus, the acccuracy of the Hohenheim windtunnel is similar to other systems [8,12].

The half-open-dynamic windtunnel system hardly changed the climatic conditions. Depending on the kind of canopy, between 40 (polyethylen) and 90 % (plexiglass) of the ambient radiation reached the measurement area. The maximal differences of soil and air temperatures between inside and outside of the windtunnel were 8 K, the difference of the relative air humdity was 15 %. This was measured in May 1997 underneath the plexiglass canopy with a very high ambient radiation of 1000 W/m$^2$. With lower radiation or cloudy sky the differences decreased to 3 K and 3 %. Nevertheless, for valuating the emissions they had to be related to the climatic conditions inside the windtunnel.

## INFLUENCE OF APPLICATION TECHNIQUES

In the past years a lot of new application techniques for slurry to grassland have been developed [1,2,6]. The application techniques used in the researches are shown in Fig. 3 (changed after [2]).

According to the placement of the slurry between grassland plants and soil, the application techniques can be classified into broadcast and band spreading. Broadcast spreading with a splash plate is the most common application technique and it distributes the slurry on a large surface over plants and soil. The working width is about 15 m. Different working tools such as a pendular spreader or a swan neck are available. Band spreading between the plants and near the soil can be done with a trailing hose or a trailing foot. The row spacings range from 15 up to 40 cm. The trailing foot pushes aside the grass leaves by a metal foot and scratches a shallow slit of 1 to 2 cm depth into the sward. Thus, the slurry can be easier applied directly onto the soil between the plants. By the trenching technique two coulters cut a deeper slit into the soil, so that the slurry is applied 5 to 7 cm deep into the soil. The slit stays open and is not closed anymore by a pressure roller. The row spacing varies between 20 and 30 cm. The injection techniques, mainly used in the Netherlands [1,6], are not suitable for the grassland region of South Germany because of hilly terrain and high draft force requirement. A new development from Norway overcoming these problems is the Direct Ground Injection [10]. For more detailed information about different application techniques for slurry see [1,6].

| classification | type | placement of slurry | working tools |
|---|---|---|---|
| thrown over plants | broadcast spreading with splash plate | | splash plate |
| near the soil | band spreading with trailing hose | 15–40 cm | slurry hose |
| near the soil | band spreading with trailing foot | 25–40 cm | trailing foot, slurry hose |
| into the soil | trenching with coulters | 20–33 cm, 5–7 cm | coulter, slurry hose |

**Fig. 3.** Used application techniques for slurry on grassland (changed after [2]).

For all researches the application techniques had to be simulated by hand. Figure 4 presents a comparison of the $NH_3$ emissions from cattle slurry applied to grassland with splash plate, trailing foot and trenching. The $NH_3$ emissions are shown as the cumulative loss of $NH_3$-N expressed as percentage loss of applied $NH_4$-N from the slurry. The research was carried out at the end of June 1997 and lasted 48 h. The cattle slurry had a dry matter content of 7.1 %, at pH of 7.0 and $NH_4$-N concentration of 0.12 %. The amount of applied slurry was 3 kg/m$^2$ and the total amount of applied $NH_4$-N was 3600 mg/m$^2$, corresponding to 100 %. The climatic conditions inside the windtunnel are also shown in Fig. 4.

For the splash plate the total loss of $NH_4$-N amounted to 957.1 mg/m$^2$ in 48 h, that corresponds to a cumulative loss of 27 % of the applied $NH_4$-N. A total loss of 462.4 mg/m$^2$ in 48 h, resepectively a cumulative loss of 13 % of the applied slurry $NH_4$-N was found for the

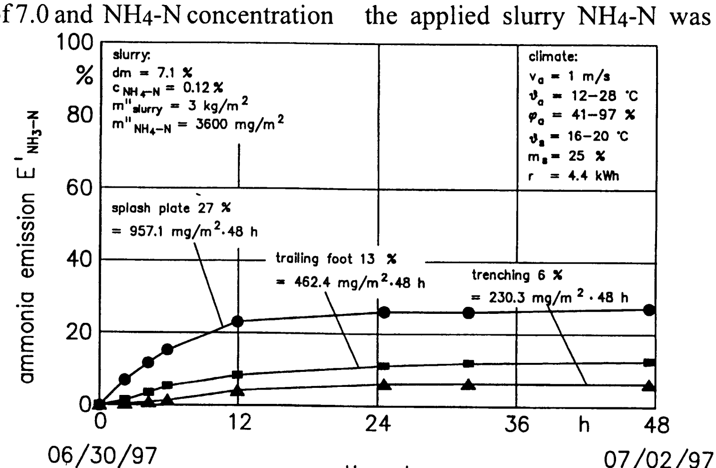


**Fig. 4.** Cumulative loss of $NH_3$-N expressed as percentage loss of applied $NH_4$-N from cattle slurry applied to grassland with splash plate, trailing foot and trenching.

trailing foot. The loss of the trenching was 230.3 mg/m$^2$ in 48 h or 6 %. The emissions of the splash plate were approximately twofold higher than the ones of the trailing foot and even fourfold higher than the emissions of the trenching. The reduction potential of trailing foot and trenching resulted from the lower contact surface between slurry and air as well as the incorporation of the slurry into the soil. Furthermore, the emission rates of those three application techniques were very different, too (Fig. 5).

Figure 6 presents a comparison of the emissions of broadcast spreading with a splash plate and narrow band techniques of trailing hose and trailing foot. The research was carried out at the beginning of August 1997. The cattle slurry had a dry matter content of 6.8 %, at pH of 7.3 and $NH_4$-N concentration of 0.129 %. The amount of applied slurry was 2.9 kg/m$^2$, so the total applied $NH_4$-N amounted to 3741 mg/m$^2$, respectively 100 %. The climatic conditions are also shown in Fig. 6.

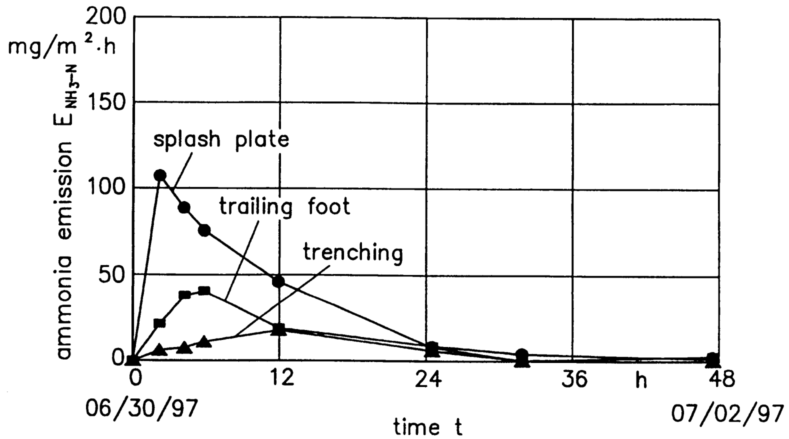


**Fig. 5.** Rate of $NH_3$ emission from cattle slurry applied with splash plate, trailing foot and trenching.

For all three application techniques the highest emission rate was determined during the first 12 h after slurry application. After 2 h the splash plate had the highest emission rate with 107 mg/m$^2$/h. The trailing foot showed the highest emission rate after 6 h with 41 mg/m$^2$/h and the trenching after 12 h with 18 mg/m$^2$/h. Those delayed maximum emission rates were caused by the application of the slurry underneath the canopy of plants and the incorporation of the slurry into the soil, why plants and soil could better absorb the $NH_4$-N of the slurry. But still the emission rate of the splash plate was more than double as high as that of the trailing foot and about eightfold higher than that of the trenching. For all the three application techniques approximately 90 % of the total emission occurred after 24 h. At the second day the emission rates were very low and the concentrations were only slightly over the atmospheric $NH_3$ concentration.

With a loss of 908.7 mg/m$^2$ in 48 h or 24 % of the applied $NH_4$-N the splash plate showed the highest emission. By the trailing hose emitted 557.9 mg/m$^2$ in 48 h or 15 % and the trailing foot had an emission of 350.8 mg/m$^2$ in 48 h or 9 %. Once again from twofold to threefold higher emissions were observed by broadcast spreading compared to band spreading.

## DISCUSSION

A comparison of the different application techniques is presented in Fig. 7. The $NH_3$ emissions are shown in relation to the application technique with the highest emission (splash plate). The trenching, which incorporates the slurry into the soil, had the highest potential for reducing the $NH_4$-N loss. Compared to the broadcast spreading of slurry, the trenching showed only 24 % of the emission value of the splash plate. This corresponds to a reduction of the $NH_4$-N loss of 76 %. For the trailing foot

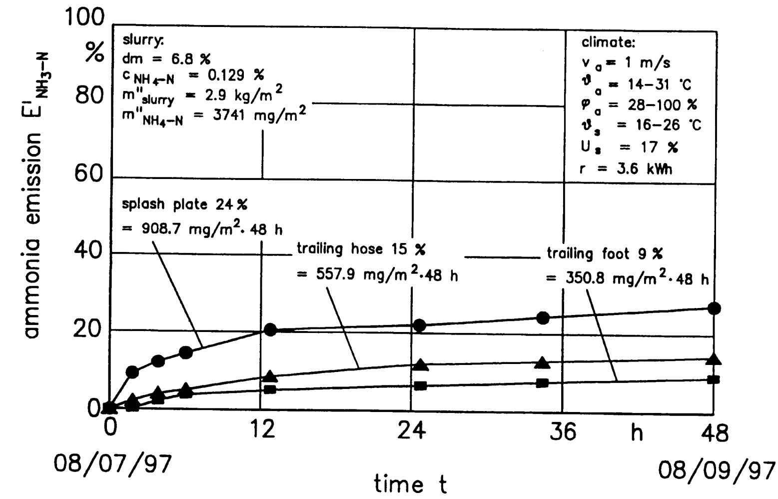


**Fig. 6.** Cumulative loss of $NH_3$-N expressed as percentage loss of applied $NH_4$-N from cattle slurry applied to grassland with splash plate, trailing hose and trailing foot.

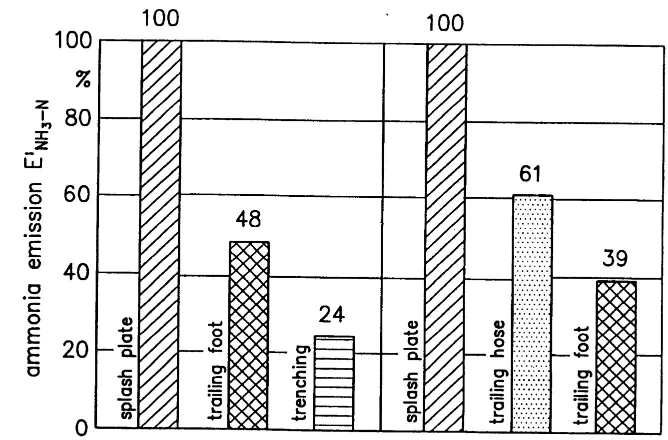


**Fig. 7.** Relative comparison of different application techniques.

48 %, respectively 39 %, of the splash plate value were found, thus the NH4-N loss could be reduced by approximately 55 %. Due to a reduction of 39 %, only 61 % of the amount of the splash plate emitted by using the trailing hose. In Table 1 those relative reduction potentials are compared with the results of [1,3,5,9].

Table 1 demonstrates, that the more the slurry is incorporated into the soil the higher is the reduction potential. Average reductions of the NH4-N loss were about 30 % for the trailing hose, 60 % for the trailing foot and 75 % for the trenching. The variation of the reduction potentials is mainly caused by variations in dry matter

**Table 1.** Relative reduction potentials [%] of different application techniques

| Aplication technique | Reitz *et al.* | Bussink [1] | Depta *et al.* [3] | Frick *et al.* [5] | Lorenz *et al.* [9] |
|---|---|---|---|---|---|
| Trailing hose | 39 | 41 | 26 | 26 | 30 |
| Trailing foot | 52 -61 | 63 | 45 | - | 70 |
| Trenching | 76 | 87 | - | 52 | 90 |

content and $NH_4$-N concentration of the slurry as well as by different soil and climatic conditions. All results demonstrate the necessity to apply the slurry near or into the soil to reduce the loss of $NH_4$-N fertilizer and the emission of environmentally harmful $NH_3$ gas.

## CONCLUSIONS

The windtunnel system of Hohenheim allows a reproducible measuring and quantification of $NH_3$ emissions after slurry application to grassland. The accuracy of the Hohenheim windtunnel is in the same order as the one of other windtunnel systems. Emissions of $NH_3$ can be reduced by the means of techniques, which apply the slurry near or into the soil. Compared with broadcast spreading the reduction potential for the $NH_4$-N loss was about 40 % for the trailing hose, between 50 % and 60 % for the trailing foot and about 75 % for the trenching. Because $NH_3$ emissions are influenced by many factors, further researches on the effects of climatic conditions and treatements of slurry have to be carried out.

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