The effect of acidification of pig slurry digestate applied on winter rapeseed on the ammonia emission reduction

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Abstract. The Agriculture is the main source of ammonia emissions. It generates around 75% of global emissions of ammonia to the atmosphere and soil fertilisation accounts for half of agricultural emissions. Ammonia emissions have a negative impact on ecosystems and human health, as it is able to accumulate both as solid particles and as an integral part of acid cases. Measures to reduce ammonia emissions can be divided into three large groups: the first group is ammonia-reducing measures in animal housing, the second group is ammonia-reducing measures during manure storage, and the third group is ammonia-reducing measures during the application of manure. Measurements of ammonia emissions were carried out in the parish of Jaunberze, which took place on 30 April and 1 May 2018. Sulphuric acid was used for acidification of pig slurry digestate. Picarro G2508 was used for on field measurement of ammonia concentrations with 1 second interval, a measurement time of one session was 400 seconds. The volume of the chamber was 60 l and was connected to the Picarro G2508 using a 10 m long Teflon tube. The measurement of ammonia emissions was with three repetitions for each measurement, with a reference error of less than 5%. Emissions were measured at different time intervals: immediately after digestate distribution, 2 hours, 4 hours and the 24 hours after digestate application. The emission of ammonia from digestate without vegetation after 24 hours was 13 kg ha⁻¹, for acidified digestate without vegetation 8.5 kg ha⁻¹, while the acidified digestate with vegetation within 24 hours reached 2.5 kg of ha⁻¹ ammonia emissions, five times lower than that of non-vegetation.

1 Introduction

Agriculture is responsible for 75% of global emissions of ammonia in the atmosphere and is therefore the main source of ammonia emissions [1; 2]. Half of the agricultural emissions

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come from soil fertilization [3]. Ammonia emissions have a negative impact on ecosystems and human health as they can accumulate both as solid particles and as a component of acidic matter [4; 5]. Ammonia-reducing measures can be divided into three major groups: the first group is the ammonia-reducing measures in animal housing, the second group is ammonia-reducing measures during the storage of manure and the third group is ammonia-reducing measures during fertilizer application, which includes acidification measures [6].

Soil is just one of the sources of ammonia emissions, because emissions are only released if nitrogen fertilizer is added to the soil. There are several factors that can affect the evaporation of NH₃ from the soil. During the evaporation of the water in the soil, water vapour also carries NH₄⁺ and HCO₃⁻ ions, which increases the concentration of NH₃ gases in the top soil [7]. When the soil drains, the water moves to the lower layers of the soil, NH₄⁺ and HCO₃⁻ are brought deeper into the lower layers of the soil profile [8; 9]. The impact of acidification measures on ammonia emissions has not been tested in geomorphologic and climatic conditions in Latvia. The thesis suggests that acidification measures and vegetation reduce ammonia emissions [5].

The aim of the study was to find out whether and how the ammonia emissions change if the digestate of pig manure slurry is acidified and if emissions vary depending on the existence or absence of vegetation.

2 The Materials and methods

Measurements were taken on the winter rapeseed fields located in Jaunberze parish. They took place on 30 April and 1 May 2018. Measurements were made with cavity ring down spectroscopy device Picarro G2508, which was connected to a 60-liter volume chamber shown in Figure 1 using Teflon tubes. Picarro has developed high resolution scientific equipment for measuring gas concentrations. Picarro G2508 can simultaneously detect five gases: nitrous oxide (N₂O), methane (CH₄), carbon dioxide (CO₂), ammonia (NH₃) and water (H₂O) in the form of vapour. Water vapour measurements provide the determination of dry molecular concentrations of N₂O, CO₂ and CH₄ [10; 11]. The technology is based on the fact that any small molecule gas has a unique infrared light absorption spectrum at a lower pressure than the atmosphere. Under these conditions, the light absorption spectrum consists of a closely arranged row of well-identifiable sharp lines each with its own characteristic wavelength, which is prerequisite for the development of this methodology. Since any gas concentration can be determined depending on the absorption strength, that is, by meaning a specific absorption peak. The imperfection of traditional infrared spectrometers is that it is not possible to determine the gas concentrations due to the low absorption of the gases, and the measuring device is able to determine only the million parts of the concentration (ppm) [12]. CRDS (Cavity Ring – Down Spectroscopy) technology developed by Picarro Ltd. reduces the minimum detectable concentration to one billion parts (ppb) by using an efficient laser light beam, the path of which can reach up to many kilometres in the device measuring chamber with a frequency of several times per second [13]. The beam from one frequency laser diode in the device measuring chamber is moved by 3 mirrors, thereby ensuring continuous circulating laser movement. The photodetector captures the amount of light emitted through one of the mirrors that is proportional to the intensity in the measuring chamber. At the moment, when photodetector signal reaches the threshold level (tens of microseconds), the continuous laser beam is immediately turned off. The beams of light that are already in the device measuring chamber continue to reflect against the mirrors (about 100 000 times), but the mirrors have a reflectivity less than 100% (99.99%), the light intensity in the measuring chamber gradually decreases and exponentially decreases to 0. A downhill jump is recorded by a photometer in a unit of time [12; 13].
Measurements of ammonia with this cavity ring down spectroscopy device together with measurements of water vapour are more complicated to interpret than CO$_2$, NH$_3$, and N$_2$O. Ammonia (NH$_3$) can deposit in both tubes and other surfaces of device [10]. To avoid ammonia deposition and disturbance of measurement precision after each measurement session the chamber was ventilated 10 – 20 minutes until ammonia concentrations reach stay stable.

Fig.1. Ammonia emissions measurements using chamber of volume 60 l

For acidification of pig slurry digestate, a tractor with one cubic-meter volume container filled with sulphuric acid, as shown in Figure 2, was used. This system is connected to a pig slurry digestate tank, on which there is an sulphuric acid injection and mixer, which blends acid into the pig slurry digestate. The device has a sensor that continuously measures the pH level by automatically maintaining it at pH 6.4. The sulphuric acid together with the pig slurry digestate is applied to the soil by a diffuser with hollow tubes. Measurements of ammonia emissions were made for each technology in 3 repetitions all results was with standard error under 5%.

Fig.2. Application of pig slurry digestate with hanging hoses

3 Results and discussion

Ammonia emissions after pig slurry digestate application are shown in Figure 3. The highest amount of ammonia emissions 4500 g h$^{-1}$ ha$^{-1}$ was found in testing plot, where the pig slurry digestate was applied on soil without vegetation. Raised ammonia emissions can be explained by the high pH 7.9 level of pig slurry digestate. The lowest ammonia emission of 710 g h$^{-1}$ ha$^{-1}$ was found in testing plot, where acidified pig slurry digestate was applied in winter rapeseed fields, which can be explained with pH 6.4 and winter rapeseed ability to absorb ammonia. The applied pig slurry digestate without vegetation showed approximately two times higher emissions of ammonia compared to the pig slurry digestate with vegetation. The acidified pig slurry digestate with vegetation showed a triple reduction of ammonia emissions compared to the acidified pig slurry digestate without vegetation.
Fig. 3. Ammonia emission rate immediately after digestate and acid digestate application g h⁻¹ ha⁻¹

Ammonia emissions two hours after pig slurry digestate and acid digestate application are shown in Figure 4. The highest emission 3160 g h⁻¹ ha⁻¹ was found in testing plot for digitate without vegetation. The lowest ammonia emission 718 g h⁻¹ ha⁻¹ was found in testing plot, where acidified pig slurry digestate was applied on winter rapeseed field. The pig slurry digestate without vegetation showed approximately one and a half times higher ammonia emissions than the pig slurry digestate with vegetation. The acidified pig slurry digestate with vegetation showed a twice reduction of ammonia emissions compared acidified pig slurry digestate without vegetation. Comparing the emission amounts after pig slurry digestate application, the acidified pig slurry digestate shows the same emission amounts. In four hours after the pig slurry digestate application, the amount of ammonia emissions has decreased in all used technologies (Fig. 4.), however disparity between the used application technologies retains (Fig. 5). In 24 hours (Fig. 6) ammonia emissions have decreased by 30 times, but this fact can be explained with heavy rain in nighttime between measurements.

Fig. 4. Ammonia emissions rate two hours after digestate and acid digestate application g h⁻¹ ha⁻¹
Cumulative emissions of ammonia within twenty-four hours are given in Figure 7, where it can be seen that the ammonia emission from digestate without vegetation in 24 hours of time attains 13 kg ha\(^{-1}\), the acidified digestate without vegetation attains 8.5 kg ha\(^{-1}\), whereas the acidified digestate with vegetation attains 2.5 kg ha\(^{-1}\) within 24 hours, which is five times lower than for digestate without vegetation.
4 Conclusions

1. It is possible to use the Picarro G2508 for measurements of ammonia emissions on a condition that the measuring chamber radius and the height ratio is at least 1:20.
2. Acidification as ammonia mitigation measure in give significant decrease of ammonia emissions (40-90%) depending on a form of fertilizers (digestate, etc.) in cultivated land, climatic and soil agrochemical conditions.
3. To find out the acidification technology impact on ammonia emission decrease, further researches, where different soils and different acidification technologies are used, need to be made.

The results obtained are consistent with those obtained by other scientists and confirm the need to continue research [14, 15].

Acknowledgements

This research was implemented in gratitude of Interreg project „The Baltic Slurry Acidification in Baltic Sea Region”, „Latvian Rural Advisory and Training Centre” Ltd. and “Lauku Agro” Ltd. financial support.

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