

THE EFFECT OF SOLID MANURE INCORPORATION INTO THE SOIL ON THE EMISSION OF GASES AND ODOURS

Paulina MIELCAREK, Institute of Technology and Life Sciences, Department of the Technology and Emissions Development in Farms, Address: Biskupińska 67, 60-463 Poznań, Poland; e-mail: p.mielcarek@itp.edu.pl (*corresponding author*)

Wojciech RZEŹNIK, Institute of Technology and Life Sciences, Department of the Technology and Emissions Development in Farms, Address: Biskupińska 67, 60-463 Poznań, Poland; e-mail: w.rzeznik@itp.edu.pl

Zbyszek ZBYTEK, Industrial Institute of Agricultural Engineering, Testing Laboratory for Agricultural Machines, Address: Starołęcka 31, 60-963 Poznań, Poland; e-mail: zbytek@pimr.poznan.pl

The aim of the study was to determine the level of emission reduction of selected harmful gases and odours following immediate manure incorporation into soil, using the prototype manure applicator. The research was carried out at the Experimental Station of the National Research Institute of Animal Production, in September 2016. Two experimental fields size 6 x 100 m were located on corn stubble in the distance of 40 m. In field A, the solid manure was incorporated into the soil using the prototype manure applicator. In field B, manure application was made by manure spreader. The prototype manure applicator was designed and made by Industrial Institute of Agricultural Engineering. The concentration of harmful gases (NH₃, CO₂, CH₄, N₂O) and odours was measured during the study. Measurements were made in the following periods: immediately after application and 2, 4, 6, 10 and 14 hours after application. The concentration of studied gases was measured immediately after sampling by the photoacoustic spectrometer (Multi Gas Monitor Innova 1312). The odours concentration was determined within 30 hours after air sampling by dynamic olfactometry using the TO 8 olfactometer. The solid manure incorporation reduced NH₃ emissions by an average of 66%. For the other studied gases the differences in concentration were too small or this concentration was similar to concentration of these gases in surrounding air. The incorporation of solid manure limited also odour emissions. The level reduction decreased with time and amounted to an average of 25%.

Keywords: solid manure, fertilization, odour emission, ammonia emission

INTRODUCTION

Emission of harmful gases to the atmosphere: ammonia (NH₃) and greenhouse gases (methane-CH₄, nitrous oxide-N₂O, carbon dioxide-CO₂) from agricultural sources is currently the major problem both in terms of environmental and economic. One of the main sources of emissions is the manure management. During storage, natural fertilizers may release about 20-50% of contained nitrogen as ammonia (Chadwick, 2005; Marcinkowski, 2000). Moreover, while application on agricultural land, natural fertilizers may lose next 25 to 95% of nitrogen (Sapek, 2005). It is estimated that total nitrogen emission in the form of ammonia during the manure management is about 80% (Pietrzak, 2006). Emissions of methane from manure management is about 12%, and nitrous oxide is about 14% (Olecka et al., 2017). The release of these gases into the atmosphere negatively affects the environment. Ammonia causes acidification and eutrophication of natural ecosystems. Methane and nitrous oxide contribute to the greenhouse effect, and additionally nitrous oxide causes the ozone layer depletion (Dämmgen and Erisman, 2005; Schils et al., 2007).

According to the Announcement of the Minister of Agriculture and Rural Development of 17 February 2014 on the publication of the consolidated text of the Regulation of the Minister of Agriculture and Rural Development on the detailed method of application of fertilizers and training in their use, natural fertilizers should be applied over the all field and it should be covered or mixed with soil no later than the day following their application (Announcement..., 2014). Manure, which is not quickly incorporated into the soil, lose nitrogen by ammonia emission to the atmosphere and surface runoff. Therefore the soil gets less nutrient elements used by plants during their growth. Additionally, manure left on the field is a source of unpleasant odours (Kleinman et al., 2002; Maguire et al., 2011).

Manure spreaders, with vertical or horizontal shredding and scattering beaters, are commonly used for application of manure in fields. Generally, these devices spread the manure in a very wide area, what limit possibility of using them in cooperation with other tools, as modular construction. The commonly used machines spread the manure with such a force, that it usually falls down on the cultivator or behind it. Therefore, the second tractor with a cultivation tool is necessary to incorporate the manure into the soil.

The aim of the study was to determine the level of emission reduction of selected harmful gases and odours following immediate manure incorporation into soil, using the prototype manure applicator.

MATERIALS AND METHODS

The research was carried out at the Experimental Station of the National Research Institute of Animal Production, in the Kostkowice Farm, in September 2016. Two experimental fields size 6 x 100 m were located on corn stubble in the distance of 40 m. In field A, the solid manure was incorporated into the soil using the prototype manure applicator. In field B, manure application was made by manure spreader (Fig. 1). The prototype manure applicator was designed and made by Industrial Institute of Agricultural Engineering, as part of the BIOGAS & EE project (Fig. 2). This applicator in a single working pass spreads manure and then incorporates it into the soil. During one operation the manure is transported, spread and incorporated (Talarczyk et al., 2016; Strategic program...).

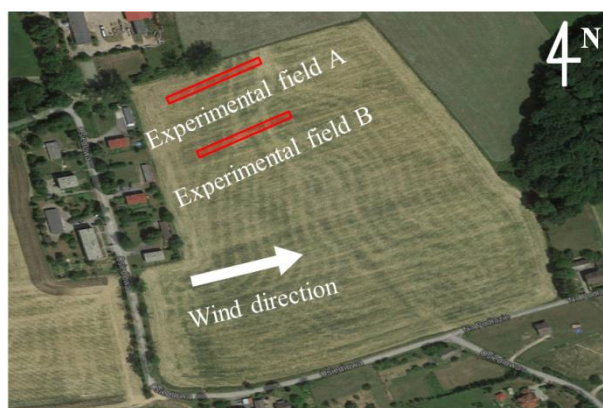


Figure 1. Location of experimental fields

During the study the concentrations of selected gases: ammonia (NH_3), carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) were measured and odour concentration was determined. The concentration of studied gases was measured by the photoacoustic spectrometer (Multi Gas Monitor Innova 1312), immediately after sampling. The detection limit of the studied gases was: $0.06 \text{ mg} \cdot \text{m}^{-3}$ (0.03 ppm) for N_2O , $0.28 \text{ mg} \cdot \text{m}^{-3}$ (0.4 ppm) for CH_4 , $9.89 \text{ mg} \cdot \text{m}^{-3}$ (5.1 ppm) for CO_2 and $0.15 \text{ mg} \cdot \text{m}^{-3}$ (0.2 ppm) for NH_3 . Before manure application, the concentrations of these gases were measured in surrounding air (background).

The odours concentration was measured within 30 hours after air sampling. The tests were made in Laboratory of Agricultural Technology and Biosystems of the Institute of Technology and Life Sciences in Poznań. The odours concentration was determined by dynamic olfactometry according to PN-EN 13725:2007 standard, using the TO 8 olfactometer. Evaluation of odours concentration was conducted by a team of four experts.

Measurements were made in the following periods: immediately after application and 2, 4, 6, 10 and 14 hours after application. The concentrations of the studied pollutants were measured in the air sampled at a height of 0.4 m above the experimental fields. Before sampling, the selected parts of experimental fields were covered with special chambers for the sampling air from surface sources (Fig. 3).



Figure 2. Prototype manure applicator



Figure 3. Research chamber

The time of a single air sampling was 5 minutes. The CSD30 sampler from Ecoma and 8-liter disposable bags made of Nalophan (PET) were used for sampling. It was assumed that the stream of air (VR) between following

measurements was the same for both experimental fields. Based on the measured concentrations of the studied gases and odours, the concentration distribution of the pollutants in the air was estimated for the study period. The equation of concentration in time $f(t)$ was calculated using the regression analysis, which also represented the changes in air pollutant emission, because the stream of air was the same. The total emissions (E_{tot}) during the measurements were calculated using equation (1):

$$E_{tot} = VR \int_0^{14} f(t)dt \tag{1}$$

where:

- VR – ventilation rate
- t – time
- $f(t)$ – regression equation

The level of reduction of studied gases and odours resulting from immediate manure incorporation into the soil was determined on the basis of total emissions.

RESULTS AND DISCUSION

The mean values of concentrations of studied gases measured at defined intervals of time after the application of cow manure are presented in table 1. It includes also the concentrations of NH₃, N₂O, CH₄ and CO₂ in the surrounding air before manure application (background). Statistically significant differences ($p \leq 0.05$) in gas concentrations between fields were noted for NH₃ and CO₂. For all study, the concentrations of these gases in the field, where the manure was immediately incorporated into the soil were less than on the other field. The concentration of NH₃ and CO₂ in the experimental fields decreased in time and it reached value similar to this noted in the background after 14 and 10 hours, respectively. For N₂O and CH₄, measured concentrations were comparable to background and unclear variability in time did not allow to determine the effect of manure incorporation on the emission.

Table 1. Mean concentration values of studied gases (Bartkowiak et al., 2017)

Time (h)	Gas concentration (mg·m ⁻³)							
	NH ₃		N ₂ O		CH ₄		CO ₂	
	Field A	Field B	Field A	Field B	Field A	Field B	Field A	Field B
0	2.33	18.29	0.83	0.79	0.66	1.27	1080.90	1146.76
2	2.29	6.71	0.73	0.98	0.61	0.04	934.38	953.73
4	1.57	4.14	0.71	0.88	0.19	0.04	905.72	987.36
6	0.74	1.12	0.73	0.67	0.36	0.09	853.31	869.49
10	0.43	0.39	0.71	0.67	0.62	0.47	828.80	834.14
14	0.27	0.24	0.72	0.66	0.24	0.06	804.29	811.07

Field A – prototype manure applicator; Field B – manure spreader

The difference in NH₃ concentration between the experimental fields decreased over time from 87% (immediately after application) to 34% (6 hours after application). For CO₂, there were statistically significant differences in concentrations between the fields in each study period, but the reduction effect was not as high as for NH₃ and ranged from 0.6 to 8.3%. Despite the differences, their values were too small and dependent on other factors (soil moving), so the effect of immediate manure incorporation on CO₂ emissions cannot be determined.

Figures 4 and 5 show the changes of mean ammonia concentrations in time, for both experimental fields.

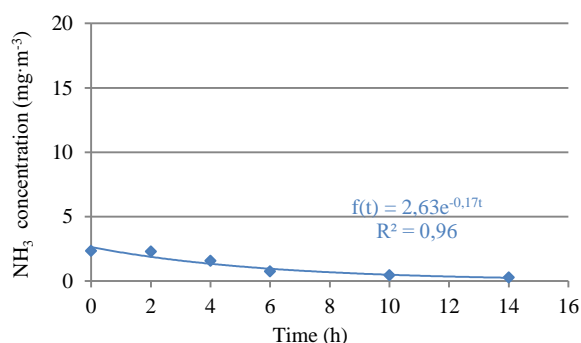


Figure 4. NH₃ concentration in field A

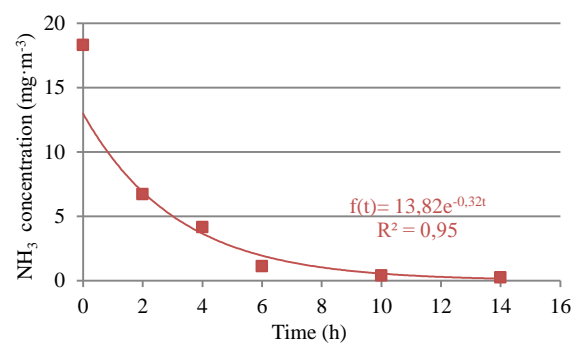


Figure 5. NH₃ concentration in field B

The mean level of NH₃ reduction resulting from immediate manure incorporation, based on total emissions calculated from equation (1), was 66%. Similar results have been reported in earlier studies, but the manure incorporation

in those studies was done using a second tractor with a plough, disc harrow or cultivator. Webb et al. (2004) found that the immediate incorporation of pig manure reduced NH₃ emissions by an average of 92%. In other experiment, Webb et al. (2014) investigated the effect of immediate incorporation of solid manures such as cow manure, pig manure and poultry manure using a mouldboard plough, disc or tine on two types of soils. They have shown that immediate incorporation by plough reduces NH₃ emissions by 90% and by 60% by disc and tine. McGinn and Sommer (2007) measured a reduction in NH₃ emissions of about 80% from immediate incorporation by a double-offset cultivator. Pote and Meisinger (2014) studied the effect of application and incorporation methods of poultry manure on NH₃ emissions. Compared to conventional surface spreading of poultry manure, NH₃ emission decreased an average of 67% when the manure application was followed by light disking, and it decreased an average of 88% when the manure was applied by using the prototype USDA ARS applicator.

The values of odour concentrations measured in experimental fields and their variability in time are presented in figures 6 and 7 (Bartkowiak et al., 2017). During the study, in the field, where the manure was immediate incorporated into soil, lower concentrations of odours were observed. The difference in the concentrations of odours between experimental fields decreased in time from 41% (immediately after application) to 4% (6 hours after application).

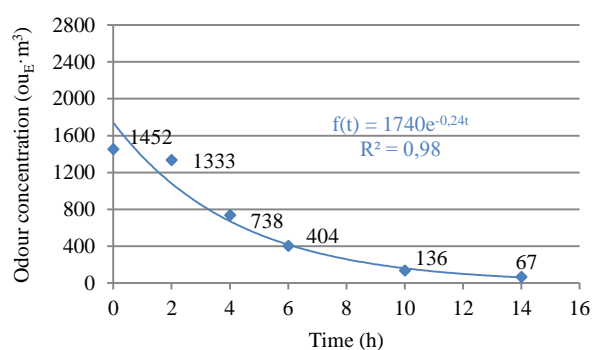


Figure 6. Odour concentration in field A

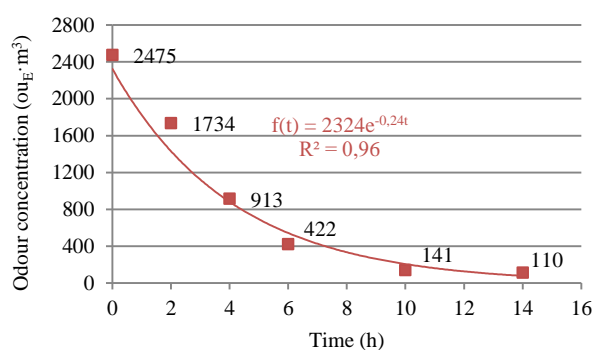


Figure 7. Odour concentration in field B

Based on calculations of total emission, in accordance with equation (1), the reduction in emission of odours associated with the immediate manure incorporation was determined, which is 25%. Similar results were reported by Hanna et al. (2000), investigating the effect of six different techniques of pig manure application on odour emission. They observed that most of the tested techniques involving some soil incorporation reduced odour emissions by 20 to 90% compared to broadcast application. Additionally, the level of odour decreased quickly with time and often within a single day was statistically insignificant with the level of odour from untreated soil. Lau et al. (2003) found that the swine manure odour emission rate with subsurface application was reduced by 8 to 38% compared with conventional splash-plate application. Pain et al. (1991) observed a reduction in odour emissions of 85% in the first hour after slurry ploughing immediately after application. The using of a rotary harrow reduced the odour emissions by 45%.

Moreover, simultaneous application of manure and immediate incorporation into soil allows the execution of the two agricultural treatments in a single working pass, which reduces the operating time, the operation cost and reduces the negative influence of traction on the soil by the lower compaction and limited over-drying field surface.

CONCLUSIONS

Based on the research and obtained results the following conclusions can be drawn:

- The immediate manure incorporation into soil resulted in an average of 66% reduction of NH₃ emissions from experimental fields. This reduction decreased in time from 87 to 34%.
- For CO₂, N₂O, CH₄ the differences in concentration were too small or this concentration was similar to concentration of these gases in surrounding air before manure application.
- The immediate manure incorporation into soil reduced odour emissions about 25%. This reduction decreased in time and ranged from 41 to 4%.

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