Possibility of reduction of ammonia emissions from manure storage piles

M. Zemek, J. Mareček

Faculty of Agronomy, Mendel University of Agriculture and Forestry Brno, Brno, Czech Republic

ABSTRACT: According to the Gothenburg Protocol to abate acidification, eutrophication and ground-level ozone ammonia emissions need to be reduced by 40% in manure storage systems. An abatement of ammonia emissions, suggested in this paper, is based on application of the biotechnological agent Amalgerol. Ammonia emissions from farmyard manure storage piles from broiler and pig breeding were compared in order to verify the reducing potential of the applied biotechnological agent. The experiments carried out under operating conditions proved a positive influence of biotechnological agents on ammonia emissions reduction – decrease in the emissions from the broiler storage pile represented 41.16% and from the pig storage pile 35.85%, both in comparison with reference storage piles.

Keywords: ammonia emissions; biotechnological agents; emissions abatement; manure storage

Ammonia (NH_3) is a highly reactive gas that has important effects on atmospheric chemistry and sensitive terrestrial or aquatic ecosystems (Pain, Jarvis 1999). By 2010 NH_3 is likely to be the largest contributor to acidifying gaseous N emissions in Europe. Furthermore, NH_3 reacts with atmospheric acids forming (secondary) particles that contribute significantly to the burden of particulate matter, which is likely to threaten human health in Europe (Bull, Sutton 1998). Agriculture is estimated to produce 80–90% of European NH_3 emissions and ca. 80–90% of those emissions arise from excreta produced by livestock (Anonymous 1994). Non-agricultural emissions arise from a large number of relatively small sources (Sutton et al. 2000). The greatest reductions in NH_3 emissions therefore need to be achieved in the animal husbandry.

Gothenburg Protocol to abate acidification, eutrophication and ground-level ozone sets levels to reduce ammonia emissions in housing systems by at least 20%, in manure storage systems by 40% and by 30% in manure application systems. According to the Protocol an advisory code of Good agricultural practice needs to be established, published and disseminated taking into account the specific conditions within the specific territory and shall include provisions on:

- Nitrogen management, involving the whole nitrogen cycle;
- Livestock feeding strategies;
- Low-emission manure spreading techniques;
- Low-emission manure storage systems;
- Low-emission animal housing systems;
- Possibilities for limiting ammonia emissions from the use of mineral fertilizers.

The key legislation regarding ammonia emissions and their leakage from livestock stables is the Act No. 86/2002 on atmosphere protection and Act No. 76/2002 on integrated pollution prevention and control (IPPC). These acts significantly change the view of emissions of load gases as ammonia, methane, carbon dioxide, nitrogen oxides, hydrogen sulphide and other, e.g. odour gases. The Acts No. 76/2002 and 86/2002 specify categories of farm animals under their competence (Jelínek et al. 2004). Good agricultural practice resulting from the Czech legislation concerning atmosphere protection is based on the principle of ammonia abatement technologies. These verified technologies reduce ammonia emissions by certain percentage in comparison with reference technologies commonly used in the housing, storage and spreading systems.

At every stage of manure management (housing, storage, spreading) a proportion of total ammoniacal-N will be lost, mainly as NH_3 emissions, and the rest passed on to the next stage (Webb et al. 2005). This paper deals with ammonia emissions coming from pig and broiler farmyard manure storage piles

Supported by the Ministry of Agriculture of the Czech Republic, Project No. QF 3140 *Reduction of Greenhouse Gases and Ammonia Emissions from Agricultural Activities.*

and with a possible use of a biotechnological agent to reduce ammonia emissions. The application of biotechnological agents is one of the verified ammonia abatement technologies that could be used in the housing systems. These agents, when properly used, provably and significantly reduce ammonia emissions by certain percentage in comparison with reference technologies commonly used in the housing systems (Jelínek et al. 2004). The goal of this survey was to verify the reducing effect of the biotechnological agents on the ammonia emissions from pig and broiler farmyard manure storage piles.

MATERIAL AND METHODS

Ammonia emissions and airflow rate measurement

Ammonia concentrations were determined with the Innova system (Photoacoustic Multi Gas Infrared Analyzer). The system provided a real-time analysis and measured and displayed NH_3 concentrations. Measured data were related to standard conditions for temperature (0°C) and pressure (101.325 kPa). A special designed chamber was used to carry out the experiment. The chamber, with height of 27 cm, length of 60 cm and width of 40 cm, was laid on the storage pile with its opened section being in contact with the surface of the pile. The chamber, on its shorter side, is equipped with a set of suck-openings, each with a 5 mm diameter. On the opposite side of the chamber a fan with a 25 cm long duct (75 mm perimeter) is attached in order to enable constant flow rate from the chamber. Revolutions of the fan were adjusted to obtain a constant flow rate of 0.1 m/s. The air at the inlet of the chamber was taken up by the probe No. 1, the air from the outlet, behind the fan, was taken up by the probe No. 2. The difference in concentrations, measured by the two probes, gives a concentration of ammonia emissions from the storage pile.

Other parameters – temperature and air moisture content were also measured by the Commeter model D3121. This device enables the logging within a 10 minutes' interval. System Innova logged data ca. every 6 minutes.

Measuring instruments specification

Photo-acoustic Multi-gas Monitor, INNOVA Air Tech Instruments, Denmark, No. 028-002; year of production 2002
1309 Multipoint Sampler, INNOVA Air Tech Instruments, Denmark, No. 177-002; year of production 2002
D3121 Thermometer and air hydrometer with data record, Comet system, Ltd., No. 0910039; year of production 2001
TESTO 445 Air-flow speed meter with exchangeable probes, TESTO, Ltd., Germany, No. 00463417/011; year of production 2001
The measuring instruments comply with requirements of the standard ČSN EN ISO/IEC 17025.
The instruments measuring deviation:
1312 Photo-acoustic Multi-gas Monitor of INNOVA Air Tech Instruments. NH_3 ± 0.2 mg/m^3; CO_2 ± 3.4 mg/m^3;
COMMETER D3121, temperature ± 0.21°C; humidity ± 1.8%.

Method of measured results evaluation and calculation relation

Determination of the ammonia emission rate from 1 m^2 of the storage pile by calculation of the set value of the airflow rate according to the relation (1):

$$E_{\Sigma NH_3} = m \times V \qquad \text{(g/h)} \qquad (1)$$

where: $E_{\Sigma NH_3}$ – ammonia emission rate (g/h),
m – ammonia concentration (g/m^3),
V – flow rate (m^3/h), note: air velocity was 0.1 m/s, surface 1 m^2.

To determine ammonia emissions reduction, two different storage piles of both pig and broiler beddings were compared. One of the storage piles was treated with a biotechnological agent. The second storage pile was untreated – a reference storage pile. The reduction in ammonia emissions was referred to a reference storage pile.

Farms description

Two farmyard storage piles from two identical mechanically vented broiler sheds were compared in this survey. In both sheds 18,200 broilers on a surface of 880 m^2 were loaded. Average straw bedding height in the shed was ca. 10 cm. The bedding in one shed was treated with the biotechnological agent as described in the following section, while the bedding in the second shed remained untreated (the reference bedding).

A naturally vented pig shed was transversely divided in two identical sections. Surface of each section was 350 m^2, from which ca. 300 m^2 was designate for bedding and the remaining 50 m^2 made of heightened concrete was designated for the feeding and drinking systems. An average bedding height at the beginning of the fattening batch cycle was 15 cm, each 14 days a new supplement of a fresh wheat straw bedding was added. An average height of the pressed bedding at the end of a fattening cycle was ca. 50 cm. 157 pigs were loaded in the first – treated section and 160 pigs in the second – untreated section.

Biotechnological agent and its application

The biotechnological agent Amalgerol was used in this survey. It is a relatively thick liquid with the good ability to blend with water. The basic structure is created by an effective mixture of specific vegetable oils (sunflower, rape and soy in food quality) bound together with purposefully selected vegetable extracts, particularly those from selected sea algae, harvested from natural rejuvenated cultures, found in rich and clear coastal waters of Iceland. Their polyuronic structures together with selected essential oils and vegetable oil substance form the base of selective stimulated abilities of Amalgerol. These are in addition completed by a component of paraffin distillates of the pharmaceutical quality class. Amalgerol Classic stimulates development of microbial strains participating in biodegradable processes and simultaneously consumes products of this decomposition for cellular tissues of own strain within the process of rapid multiplication (Jelínek et al. 2004). It causes a significant limitation of current emissions – up to by 40–68%. Through the practical verification, its declared activity and effectiveness was confirmed by the utilization in our country (Jelínek et al. 2004; Návarová 2001) and abroad (Gjordslev 1992).

Before the loading of broilers, the bedding in the broiler shed was treated with the 3% solution of Amalgerol Stall Max FL in a dose of 0.25 dm^3 per 1 m^2 of the bedding surface. Amalgerol Stall Max FL is a biotechnological agent with disinfection and desinsection properties and was used instead of common desinfection and desinsection chemical-based agents. A portable sprayer was used to enable a uniform treatment. During the whole broiler grow out batch cycle, Amalgerol Classic was added to the drinking water in a dose of 0.2 dm^3 of the liquid per 1 m^3 of drinking water. The bedding from each shed was stored on a separate pile in order to prevent mutual mixing.

The bedding in the pig shed was treated every 14 days during 3 months of fattening batch cycle with 6% solution of Amalgerol Classic in a dose of 0.25 dm^3 per 1 m^2 of the bedding surface. The application was repeated just after 14 days of new bedding supplement, so that the new bedding was always treated. The portable sprayer was used to enable a uniform treatment.

Table 1. Ammonia concentration values (mg/m^3) – farmyard storage piles from broiler sheds

Treated storage pile		Untreated storage pile		Background air	Treated storage pile	Untreated storage pile
Probe No. 1 NH_3-inlet	Probe No. 2 NH_3-outlet	Probe No. 1 NH_3-inlet	Probe No. 2 NH_3-outlet			
3.63	10.20	3.44	3.78	2.09	6.57	0.34
4.00	10.45	4.22	6.72	3.20	6.45	2.50
4.87	9.96	4.83	6.01	2.81	5.09	1.18
4.44	10.59	3.76	4.62	2.87	6.14	0.85
4.04	10.21	3.56	8.40	3.74	6.17	4.83
4.57	9.94	3.80	13.69	3.49	4.36	9.88
5.68	10.92	4.17	15.84	3.87	5.24	11.67
6.10	10.24	4.54	17.57	3.01	4.14	13.03
6.01	10.04	4.73	17.92	3.85	4.03	13.19
6.27	10.69	4.67	18.59	3.61	2.42	13.92
5.11	10.74	4.57	19.56	3.56	5.63	14.99
6.45	10.83	4.79	19.46	3.32	4.38	14.68
6.55	11.30	4.44	19.59	3.29	4.75	15.14
Arithmetic mean (± standard deviation)				3.28 ± 1.36	5.26 ± 0.85	8.94 ± 5.78

The beddings stored in the form of storage piles from both the broiler and pig treated sheds were finally treated with the 3% solution of Amalgerol Classic in a dose of 0.25 dm^3/m^2. The portable sprayer was used again to apply the agent on the surface of the piles.

RESULTS AND DISCUSSION

The converted concentrations of ammonia emissions discharged from the broiler and pig storage piles are shown in Tables 1 and 2, respectively. Calculated ammonia emission rates from both the pig and broiler storage piles are shown in Table 3. Table 4 shows measured values of temperature and relative air moisture content in the surroundings of the storage piles.

Mean ammonia concentrations from the treated broiler storage pile and from the untreated broiler storage pile were 5.26 mg/m^3 and 8.94 mg/m^3, respectively. Comparing the treated storage pile with the reference (untreated) storage pile, the use

Table 2. Ammonia concentration values (mg/m^3) – farmyard storage piles from the pig farm

Treated storage pile		Untreated storage pile		Background air	Treated storage pile	Untreated storage pile
Probe No. 1 NH_3-inlet	Probe No. 2 NH_3-outlet	Probe No. 1 NH_3-inlet	Probe No. 2 NH_3-outlet			
2.08	10.39	3.81	17.97	0.71	8.31	14.16
1.83	10.29	3.81	19.75	1.04	8.46	15.94
1.93	10.95	3.94	18.31	1.02	9.02	14.37
2.07	11.34	3.46	20.58	0.68	9.28	17.12
2.02	12.12	3.57	17.61	0.04	10.10	14.04
2.17	12.39	3.62	16.94	0.21	10.21	13.33
2.18	12.59	3.56	20.88	0.41	10.41	17.31
2.02	12.62	3.67	22.65	0.49	10.59	18.98
2.06	12.41	3.43	19.73	0.45	10.35	16.30
1.86	12.72	3.59	19.46	0.56	10.86	15.87
2.01	13.68	3.74	18.61	0.62	11.67	14.87
1.92	13.03	3.82	19.21	0.81	11.11	15.39
Arithmetic mean (± standard deviation)				0.59 ± 0.28	10.03 ± 1.01	15.64 ± 1.56

Table 3. Decrease in ammonia concentrations and ammonia emission rates

	Broiler storage pile	Pig storage pile
Mean concentration – treated storage pile (EXP) (mg/m^3)	5.26	10.03
Mean concentration – reference storage pile (KONT) (mg/m^3)	8.94	15.64
Index EXP/KONT	0.59	0.64
Δ %EXP (decrease in NH_3 emissions)	41.16	35.85
Emission rate from 1 m^2 of storage pile (EXP) (g/h)	1.89	3.61
Emission rate from 1 m^2 of storage pile (KONT) (g/h)	3.20	5.63

Table 4. Measured temperature and relative air moisture content values

Measuring	Temperature (°C)	Relative air moisture (%)
Surroundings of broiler storage piles (outdoor)	16.06 ± 1.38	56.95 ± 5.03
Surroundings of pig storage piles (outdoor)	15.8 ± 2.22	55.57 ± 7.33

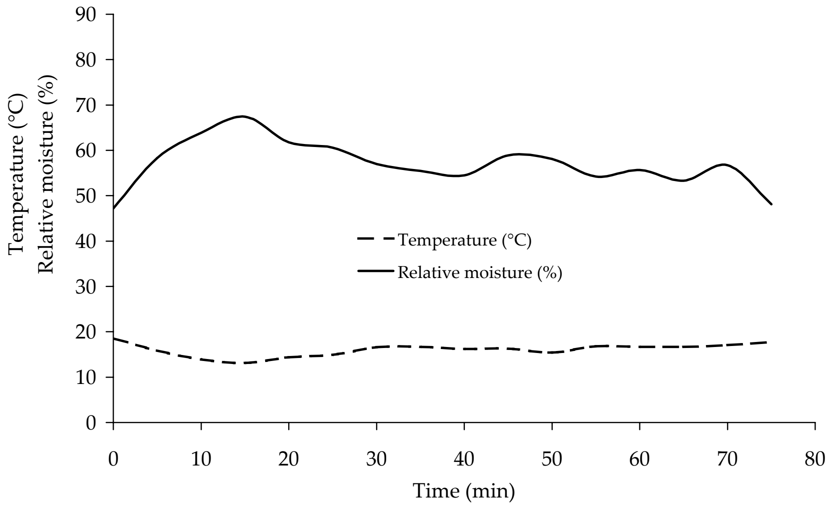

Fig. 1. Development of relative moisture and outdoor air temperature during measurements of the storage piles from broiler sheds

of the biotechnological agent caused a decrease in ammonia emissions by 41.16%. Ammonia emission rates from $1 m^2$ of the treated and reference storage piles surface were 1.89 g/h and 3.20 g/h, respectively. Speed of flowing atmosphere over the storage piles in both measurements was 0.1 m/s.

Mean ammonia concentrations from the treated pig storage pile and from the untreated pig storage

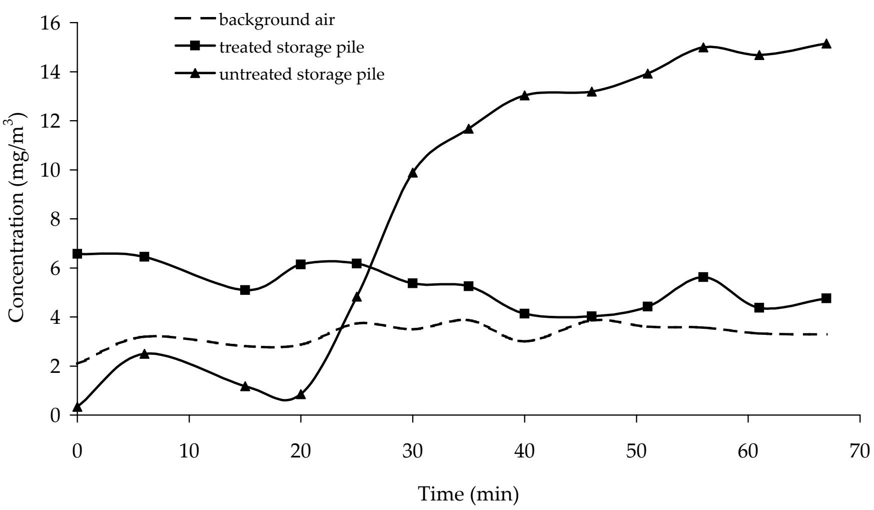

Fig. 2. Ammonia concentration progress – storage piles from broiler sheds

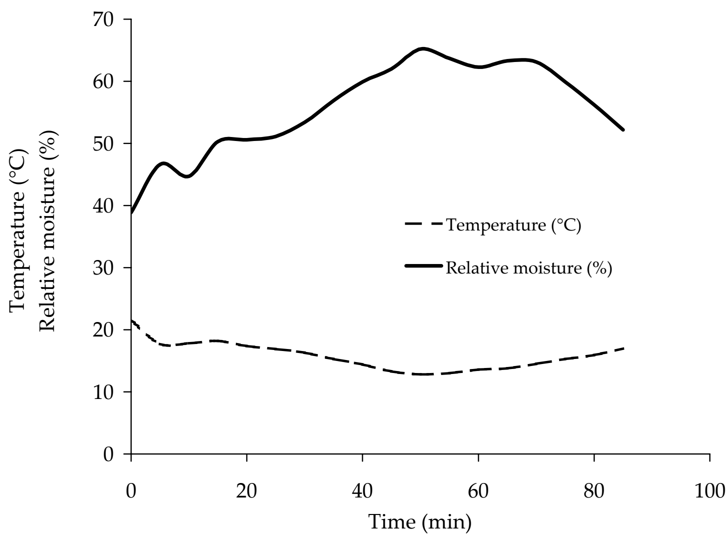

Fig. 3. Development of relative moisture and outdoor air temperature during measurements of the storage piles from pig farm

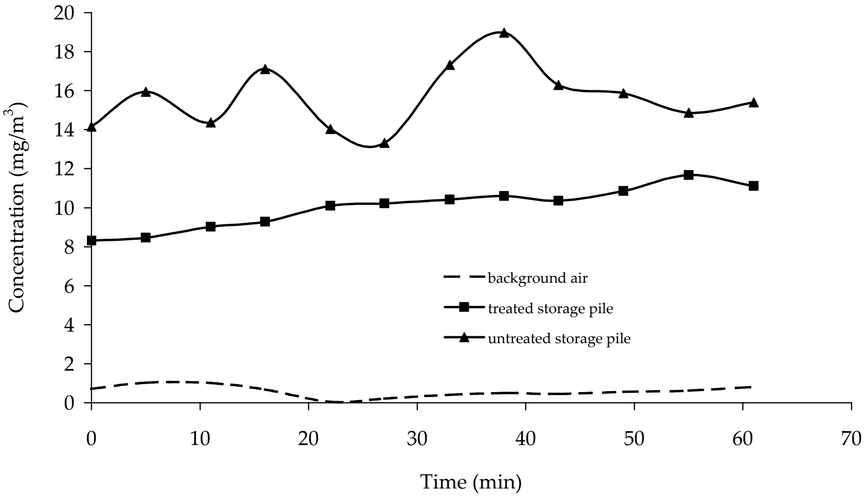

Fig. 4. Ammonia concentration progress – storage piles from pig farm

pile were 10.03 mg/m^3 and 15.64 mg/m^3, respectively. The use of the biotechnological agent caused a decrease in ammonia emissions by 35.85% compared with the reference storage pile. Ammonia emission rates from ammonia emission rates from 1 m^2 of the treated and reference storage pile were 3.61 g/h and 5.63 g/h, respectively. Speed of flowing atmosphere over the storage piles in both measurements was 0.1 m/s.

Figs. 2 and 4 show the ammonia concentration progress during the continuous measurement. Concentrations of ammonia in background air of the experimental storage piles were also measured (Tables 1 and 2). Average concentrations of ammonia in atmosphere were lower than concentrations measured from the storage piles. Concentration of ammonia in the atmosphere was 3.28 mg/m^3 – broiler storage piles surroundings and 0.59 mg/m^3 – pig storage piles surroundings. Figs. 1 and 3 graphically display the development of temperature and relative moisture during the measurement of the storage piles from the broiler sheds and the pig farm.

CONCLUSIONS

Application and verification of the biotechnological agent Amalgerol proved its reduction potential on ammonia emissions from manure storage piles. Whereas the EU requests to achieve the ammonia emission reduction by 40%, the results of Amalgerol are good – the 41.16% (broiler storage pile) and 35.85% (pig storage pile) reduction of ammonia emissions on the measured storage piles. The application of the suggested technology and methodology is one of the possible methods of the ammonia abatement for manure storage systems in terms of Good agricultural practice. Using this technology will help farmers to comply with conditions of the environmental legislation regarding atmosphere protection and integrated protection. Benefits of this technology are its low running costs and investment compared with other abatement technologies.

References

ANONYMOUS, 1994. Ammonia emissions to air in Western Europe. Technical Report: 62.

BULL K.R., SUTTON M.A., 1998. Critical loads and the relevance of ammonia to an effects-based nitrogen protocol. Atmospheric Environment, *32*: 565–572.

GJORDSLEV G., 1992. Amalgerol i Vådfordrind. København, Danske Siagterier: 8–11.

JELÍNEK A., DĚDINA M., PLÍVA P., SOUČEK J., 2004. Research of biological agents effects on reduction of ammonia concentration in stables of intensive farm animals breeding. Research in Agricultural Engineering, *50*: 43–53.

NÁVAROVÁ H., 2001. Effect on different litter materials and agent Amalgerol addition on NH_3 production and broilers yield. In: Proceedings of International Scientific Conference Topical Problems of Animals Bio-climatology 2001. Brno, Veterinary and Pharmaceutical University: 59–62.

PAIN B., JARVIS S., 1999. Ammonia emissions from agriculture. IGER Innovations, *3*: 48.

SUTTON M.A., DRAGOSITS U., TANG Y.S., FOWLER D., 2000. Ammonia emissions from non-agricultural sources in the UK. Atmospheric Environment, *34*: 855–869.

WEBB J., MENZI H., PAIN B.F., MISSELBROOK T.H., DÄMMGEN U., HENDRIKS H., DÖHLER H., 2005. Managing ammonia emissions from livestock production in Europe. Environmental Pollution, *135*: 399–406.

Received for publication October 4, 2005
Accepted after corrections November 4, 2005

Možnost redukce emisí amoniaku ze skládek chlévské mrvy

ABSTRAKT: Podle Göteborského Protokolu o omezování acidifikace, eutrofizace a přízemního ozonu je nutné omezit emise amoniaku v systémech skladování hnoje o 40 %. Navržené snížení emisí amoniaku je založeno na použití biotechnologických prostředků. K ověření účinnosti použitého biotechnologického prostředku Amalgerol se experimentálně porovnávaly emise amoniaku ze skládek chlévského hnoje, pocházejících z farem brojlerů a prasat. Experimenty se realizovaly v provozních podmínkách. Použití biotechnologického prostředku mělo pozitivní vliv na snížení emisí amoniaku – na skládce pocházející z farmy drůbeže bylo v porovnání s referenčními skládkami dosaženo snížení emisí amoniaku o 41,16 %, na skládce z farmy prasat se emise amoniaku snížily o 35,85 %.

Klíčová slova: emise amoniaku; biotechnologické prostředky; snížení emisí; uskladnění hnoje

Corresponding author:

Ing. Martin Zemek, Mendelova zemědělská a lesnická univerzita, Agronomická fakulta, Zemědělská 1,
613 00 Brno, Česká republika
tel.: + 420 545 132 375, fax: + 420 545 132 368, e-mail: xzemek0@node.mendelu.cz