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Monitoring gaseous pollution in the air in livestock buildings

Monitoring gazowych zanieczyszczeń powietrza w budynkach inwentarskich

Summary. The aim of the study was to monitor the gaseous pollutants in farm pigs, rabbits and mink air. Among the identified impurities obtained with the highest concentration of methane was observed in the air of domestic rabbits (33.04 mg/m^3). In contrast, the highest level of ammonia and hydrogen sulfide was found in breeding pigs. The concentrations of gaseous impurities exceeded the permissible safe value for animals. The air samples also showed significant amounts of toluene and p-oksylenu (BTX). The highest level of BTX compounds was reported in the air from pigs (19.80 mg/m^3), while the lowest value was observed in the air samples taken from the rabbit farm.

Key words: pigs, rabbits, mink, methane, ammonia, hydrogen sulfide, BTX

INTRODUCTION

Today, animal production which relies on intensive methods of animal nutrition and maintenance can trigger numerous harmful effects to the environment. Intensive animal farming is one of the major sources of gaseous pollutants emitted to the environment.

Those gaseous pollutants from livestock buildings are emitted by animals, their feces, feedstuff and equipment. The air in livestock buildings is composed of several times higher amounts of carbon dioxide (CO_2), ammonia (NH_3), methane (NH_4), hydrogen sulphide (H_2S) and nitrogen oxides (NOx). Additionally, other numerous gases such as benzene, toluene, xylene, indole, phenol, skatole, mercaptan and others are emitted from animal farming [Marciniuk and Romaniuk 2005]. Hellebrand [1993] describes 136 identified types of gases that are emitted from animal farming. Besides having a negative impact on the ecosystem, most of them cause an unpleasant smell and are not neutral to animal health and productivity. The conditions of animal farming are one of the most important factors that can directly impact on production results. Accordingly, maintaining complete homeostasis within animals in the environment they are raised is indispensable [Nowakowicz-Dębek 2001]. This is particularly important for indoor large-scale animal production.

This research is aimed at monitoring gaseous pollutants in the air in piggeries, rabbit and mink houses.

Research material and methods

The piggery was naturally ventilated, whereas the rabbit housing, mechanically. The air was monitored in the houses for 80 (LU = 11.2) pigs with bedding, 600 (LU = 4.2) rabbits and 100 (LU = 0.25) mink. The air was sucked into Tedlar gas sampling bags or bubble scrubbers to specify the concentration of sulfur, methane and BTX compounds and ammonia, respectively. Chromatographic techniques are used for air sample analysis. The concentration of volatile organic compounds in the air made by gas chromatography and thermal desorption using flame ionization detection FID. The pollutions were specified by the use of permeation patterns and special laboratory analyser software. Table 1 depicts the concentrations of released gases in each type of housing and Table 2 shows the statistical analysis of the values obtained.

Results and discussion

The highest concentration of the pollutants identified was of methane in the air in the rabbit housing which reached 33.04 $\mu g/m^3$. The air samples from the pig and mink houses contained respectively much lower and approximated amounts of methane (Tab. 1). In animal production, the most significant source of methane emissions, i.e. 71.7% is enteric fermentation of livestock, mainly that of ruminants and 28.2% is from livestock manure. Currently, the most difficult task is the efficient management of pig manure which releases large amounts of methane, e.g. 100.83 Gg in 2008, and the share of methane emissions from agriculture in Poland amounts to 35.5% [KASHUE-KOBiZE 2011]. The amount of methane released from manure depends mainly on a method of manure storage, which is influenced by the temperature and oxygen available because the greatest oxygen emissions are under anaerobic conditions [Myczko *et al.* 2002; Kolasa-Więcek 2011].

The study also showed a significant concentration of ammonia in the air samples. The ammonia emissions were highest in the air samples from the piggery. The average concentration measured at the animal breathing level was 16.77 mg/m^3 of the air and was slightly lower, i.e. 13.69 mg/m^3 in the rabbit housing. The smallest amounts of ammonia were reported in the air samples from the mink house (Tab. 1). The statistical analysis showed significant statistical differences in the concentration of ammonia both in the air samples from the piggery and the rabbit housing relative to the air samples from the mink house (Tab. 2). Ammonia concentrations in both of the air samples were higher than 20 ppm (13.91 mg/m^3), defined as permissible in the Regulation of the Minister of the Environment [Dz.U. 2010 nr 16 poz. 87].

Ammonia is emitted into the atmosphere chiefly by agriculture, i.e. 80-95% of the total ammonia emissions. About 80% of the ammonia emissions from agricultural sources is from livestock production. Ammonia is obtained from the microbial decomposition of amino acids, amides, urea and uric acid; and annual ammonia emissions from animal farms around the world is estimated for about 26 million tons, which is about 42% of the global ammonia emissions [Myczko *et al*. 2005]. The ammonia emissions from agriculture depend on animal species, an animal husbandry system, a method of manure storage and a technique of its application to soil [Bieńkowski 2010, Mielcarek 2012].

Similarly to ammonia, the highest concentration of hydrogen sulfide was also reported in the air samples from the piggery, i.e. 8.92 μg/m^3, whereas the lowest one in the air samples from the mink house. The concentration of H_2S in the air samples from the rabbit housing was lowest, i.e. 2.26 μg/m^3 on average (Tab. 1). The differences between the concentrations of hydrogen sulfide in the air samples from the mink house and those from the piggery and rabbit housing showed statistical significance (Tab. 2). In none of the samples analysed, the concentration of hydrogen sulfide was exceeded; its concentration in livestock buildings is specified as 5 ppm (7.5 ug/m^3). Hydrogen sulfide is released from animal manure as a result of microbial decomposition of proteins containing sulfur amino acids. That gas is heavy so it can accumulate at the bottom of sewage pipes and can be dangerous for both animals and farmers, especially when they clean sewage pipes. Literature data indicate that the average level of hydrogen sulfide in the air in livestock buildings can range from 20 ppb to above 1200 ppb [Buczyńska and Szadkowska-Staczyk 2010].

Table 1. The concentration of pollutants in the air of studied objects
Tabela 1. Koncentracja zanieczyszczeń w powietrzu badanych obiektów

Animal species Gatunek zwierząt	Hydrogen sulfide Siarkowodór μg/m^3		Methane Metan μg/m^3		BTX BTX μg/m^3		Ammonia Amoniak mg/m^3	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Pigs (T) Trzoda chlewna	8.92	5.68	18.26	9.76	19.80	5.90	16.77	4.25
Rabbits (K) Króliki	7.99	2.26	33.04	21.70	16.91	6.02	13.69	4.9
Mink (N) Norki	1.98	0.33	15.13	8.58	19.53	5.07	1.88	0.20

$\bar{x}$ – the arithmetic mean/średnia arytmetyczna.
SD – standard deviation/odchylenie standardowe.

Table 2. Statistical analysis of the results
Tabela 2. Analiza statystyczna wyników badań

Probability/ animal species Prawdopodobieństwo/ gatunek zwierząt	Hydrogen sulfide Siarkowodór	Methane Metan	BTX BTX	Ammonia Amoniak
P – T/K	0.729	0.200	0.433	0.291
P – K/N	0.003	0.115	0.950	0.008
P – T/N	0.058	0.577	0.935	0.003

Statistically significant values for $p \leq 0.05$/Wartości istotne statystycznie przy $p \leq 0,05$.

Many researchers claim that the nitrogen from manure can spread across the environment more than the nitrogen from fertilizers by the oxidation of ammonia and nitrogen oxides into the atmosphere [Dendooven *et al.* 1998; Erd and Tymczyna 1998; Sorensen and Amato 2002]. The greatest greenhouse gas emissions into the environment are from ruminant manure and 'digestive gases'. Ruminants produce much more ammonia, methane, and nitrogen compounds than monogastric animals [Nowakowicz-Dębek *et al.* 2011]. Podkówka and Podkówka [2001] report that the annual ammonia emissions from a single cow cubicle can reach 40 kg. Also, pig manure contains a lot of organic nitrogen. According to the study by Petersen *et al*. [2001], the loss of nitrogen from pig manure chiefly as ammonia amounts to 2.94 kg/t. That gas is emitted in significant quantities from poultry production. As reported in the research by Krawczyk and Walczak [2010], the ammonia emissions from chicken manure are about 3 kg per ton of manure over a period of three months. According to Guz and Guz [2005], the ammonia emissions from 1 m^2 of turkey housing amounts to 1.05 kg each year.

The above-mentioned gaseous pollutants were not the only substances identified in the air samples. Chromatographic analysis identified aromatic compounds, including benzene, toluene and xylenes (ortho-xylene, para-xylene, meta-xylene) known as BTX. Average levels of those gases were similar to the values for piggeries and mink houses. Slightly lower concentrations were recorded in the air samples collected from the rabbit housing (see Tab. 1). As specified in the Act of 25 February 2011 on chemical substances and their mixtures [Dz.U. 2011 Nr 63 poz. 322], benzene is carcinogenic (Carc. 1A), mutagenic (Muta. 1B) and toxic to target organs. Also, it is a highly flammable liquid and vapor that can irritate the skin and eyes. Mononuclear hydrocarbons are toxic, highly capable of forming tropospheric ozone and involved (toluene, xylenes) in the formation of secondary organic aerosols that are toxic to humans and the ecosystems [Olszowski 2012; Nowakowicz-Dębek *et al*. 2001, 2010, 2013].

Studies on the occurrence of BTX in the air from livestock buildings are hardly discussed in the scientific world literature and virtually neglected in Poland.

Basically, the negative impact of animal farming on the environment can be reduced only if animal farming follows the objectives of sustainable development by adopting in animal production Best Available Techniques (BAT) as specified in the Council Directive 96/61/EC concerning integrated pollution prevention and control known as the IPPC Directive. According to Art. 3 (10) of the Act of 27 April 2001 – Environmental Protection Law [Dz.U. 2001 Nr 62 poz. 627], the best techniques available shall be the most effective and advanced level of technology and methods of operation, used as a basis determining emission limit values designed to eliminate emissions or if it is possible, to reduce emissions and their impact on the environment.

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Streszczenie. Celem pracy było monitorowanie gazowych zanieczyszczeń w powietrzu fermy trzody chlewnej, królików oraz norek. Największe stężenie wśród zidentyfikowanych zanieczyszczeń miał metan w powietrzu fermy królików (33,04 µg/m^3), natomiast największe stężenie amoniaku i siarkowodoru stwierdzono w fermie trzody chlewnej. Stężenia gazowych zanieczyszczeń przewyższały dopuszczalną, bezpieczną wartość dla zwierząt. W próbkach powietrza wykazano również znaczne ilości toluenu i p-oksylenu (BTX). Największe stężenie związków BTX stwierdzono w próbkach powietrza pochodzących z fermy trzody chlewnej (19,80 mg/m^3), natomiast najmniejsze w próbkach z króliczarni.

Słowa kluczowe: trzoda chlewna, króliki, norki, metan, amoniak, siarkowodór, BTX