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Odors and ammonia emission from a mechanically ventilated fattening piggery on deep litter in Poland

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Abstract: Livestock production is the basis of global food production and it is a serious threat to the environment. Significant environmental pollutants are odors and ammonia (NH_3) emitted from livestock buildings. The aim of the study was to determine the concentration and emission factors of ammonia and odors, in the summer season, from a deep-litter fattening house. The research was carried out during summer in a mechanically ventilated fattening piggery located in the Greater Poland Voivodeship. Ammonia concentrations were measured using photoacoustic spectrometer Multi Gas Monitor Innova 1312, and odor concentrations were determined by dynamic olfactometry according to EN 13725:2003 using a TO 8 olfactometer. The NH_3 emission factors from the studied piggery, in summer, ranged from 8.53 to 21.71 $g \cdot day^{-1} \cdot pig^{-1}$, (mean value 12.54±4.89 $g \cdot day^{-1} \cdot pig^{-1}$). Factors related to kg of body mass were from 0.11 to 0.23 $g \cdot day^{-1} \cdot kg$ b.m.$^{-1}$ (mean value 0.17±0.06 $g \cdot day^{-1} \cdot kg$ b.m.$^{-1}$). Odor concentrations in the studied piggery were from 755 to 11775 $ouE \cdot m^{-3}$ and they were diversified (coefficient of variation 43.8%). The mean value of the momentary odor emission factors was 179.5±78.7 $ouE \cdot s^{-1} \cdot pig^{-1}$. Factor related to kg of body mass was 2.27±1.71 $ou_E \cdot s^{-1} \cdot kg$ b.m.$^{-1}$. In Poland and many other countries, the litter systems of pigs housing are still very popular. Therefore, there is a need to monitor the pollutant emissions from such buildings to identify the factors influencing the amount of this emission. Another important issue is to verify whether the reduction techniques, giving a measurable effect in laboratory research, bring the same reduction effect in production buildings.

Introduction

Livestock production is the basis of global food production and the agricultural economy. The global demand for animal products has been increasing for many years and it is predicted to increase in the coming decades (Gerber et al. 2013). Meeting this demand is a huge challenge for agricultural production and at the same time it is a serious threat to the environment. Significant environmental pollutants are odors and ammonia (NH_3) emitted from livestock buildings (Blanes-Vidal et al. 2012). Odors have a local effect, negatively affecting, first of all, the quality of life of the local residents (Bokova et al. 2021). Long-term exposure to the odors has a negative impact on the well-being and behavior of people. It has been found that they can cause many ailments, such as insomnia, stress, irritability, depression, migraines, cough, runny nose or allergic reactions (Fomunyam 2019). Ammonia is a gas, which has a local and transboundary impact. It plays a key role in the acidification and eutrophication of ecosystems, and indirectly contributes to nitrous oxide emissions (Yunnen et al. 2016). In addition, it is a precursor of particulate matter formation in the atmosphere, which is transported with the wind over long distances (Viatte et al. 2020). Ammonia and odors emissions from livestock production may be interdependent, as ammonia is a strong odorant and its concentration in livestock buildings is relatively high.

Agriculture is the main source of ammonia emissions. In 2019, NH_3 emissions from agriculture accounted for approximately 95% of the total emissions of this gas in Poland. Ammonia is mainly emitted from manure management (80%), and the remaining 20% is due to the use of mineral nitrogen fertilizers (Bebkiewicz et al. 2021). Almost one third of this gas emission (30%) comes from pig production (Mielcarek-Bocheńska and Rzeźnik 2019).

Basically, two methods are used to quantify ammonia emissions from pig farms. The first is an indirect method in which the ammonia emission is calculated from the nitrogen balance. It is used, *inter alia*, during national pollutant emission inventories. The second method is based on *in situ* tests carried out in selected livestock buildings, in which the emission of this gas is determined based on the measurements of ammonia concentration and ventilation rate. Such research is used to find parameters impacted ammonia emission (Jo et al, 2020). Among many methods of odor concentration determination, the most appropriate are sensory methods, in which the measurement is carried out with the use of the human sense of smell. The most popular of them is dynamic olfactometry, which is standardized by the European Committee for Standardization (CEN 2003).

The theoretical ammonia emission factors used during the national inventories differ from the empirical values obtained in studies carried out in livestock buildings. The ammonia emission factors presented in national and foreign publications are diversified. This may be due to the measurements season, different micro- and macroclimatic conditions and the use of different measuring instruments. Similar relationships can be observed in the case of odor measurements. The conducted research concerns mainly slatted housing systems (Blanes--Vidal et al. 2008, Ngwabie et al. 2011, Philippe et al. 2007, Mielcarek and Rzeźnik 2015). It is related to the great popularity of this system in the European Union countries. The growing awareness of the society regarding the quality and origin of food causes the promotion of bedding systems which, despite higher costs, ensure better comfort for the animals. In Poland and many other countries, litter systems are still the dominant technology for pigs production. Therefore, there is a need to monitor pollutant emissions from such livestock buildings.

The aim of the study was to determine the concentration and emission factors of ammonia and odors, in the summer season, from a deep-litter fattening house.

Material and methods

The research was carried out during the summer in a mechanically ventilated fattening piggery located in the Greater Poland Voivodeship. It is a brick building with the roof made of 10 cm thick PIR sandwich panels (Fig. 1). Pigs are housed on deep-litter floor in four compartments (rooms) with three pens in each. The fatteners were housed from about 35 kg of body mass to the final mass (100–110 kg). The total stock of the studied piggery is 660 pigs. Manure is stored in pens and removed after the production cycle. The piggery has a mechanical vacuum temperature-controlled ventilation. Fresh air comes through the openings in the side walls into the corridor and from there to the pens. Two Ziehl-Abegg FC056-6ET exhaust fans for air removal are installed in each compartment. Each fan has a nominal capacity of 7950 $m^3 \cdot h^{-1}$. Additionally, the building is equipped with air cooling system – the Pad Cooling from Big Dutchman.

Measurements were carried out in one of the compartments with 165 pigs, during 10 selected summer days. The research

Fig. 1. Studied piggery

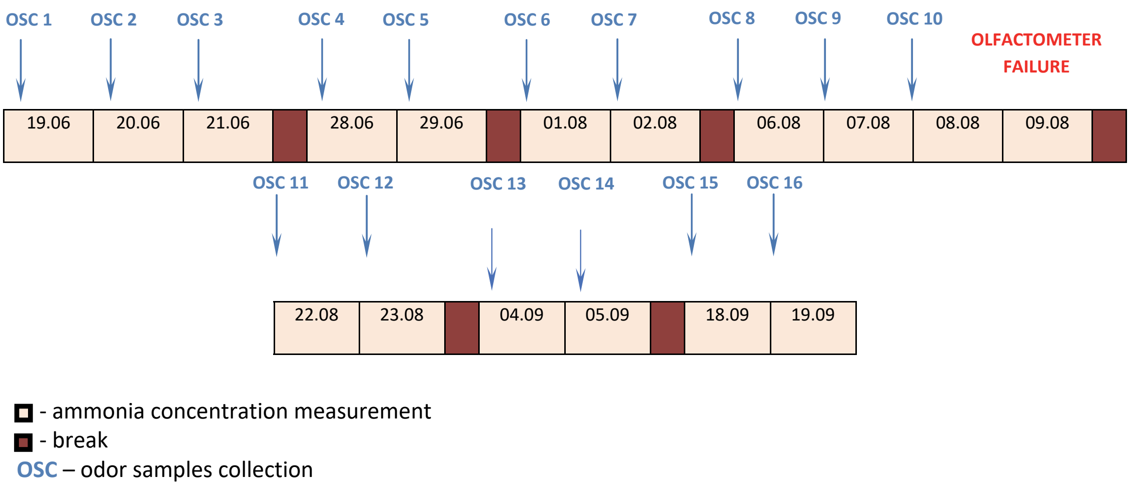


Fig. 2. Research schedule

day started at 10:00 am and finished at 10:00 am next day (Fig. 2). Ammonia concentrations were measured using photoacoustic spectrometer Multi Gas Monitor Innova 1312 (detection limit 0.15 mg·m^{-3}). The measuring point was below the inlet to the ventilation chimney (Fig. 3)

Also, temperature and air humidity inside and outside the building were monitored by means of two-channel temperature and humidity recorder Testo 175 H2 (accuracy 0.5°C and 3%). The measured parameters were recorded every half an hour. Only the outside NH_3 concentration was measured before the inside measurements. It was assumed that it was at a constant level during the 24-hour measurement period. The sampling point was located on the farm border from the windward side.

The ventilation rate was determined by the indirect method. Based on the air temperature registered inside the piggery, the ventilation control curve and the fan characteristics, the ventilation rate was calculated. The operating parameters of the ventilation system have been determined for each fattening period (Fig. 4).

The efficiency of the ventilation system in function of temperature for each fattening period is presented in Table 2.

Based on the data and equations in Table 2, the percentage efficiency of the ventilation system was determined. The ventilation rate was calculated based on the equation (1):

$$VR = \frac{P \cdot V_{max}}{100} \tag{1}$$

where:
VR – ventilation rate [m^3·h^{-1}],
V_{max} – maximum ventilation rate [m^3·h^{-1}],
P – efficiency of the ventilation system [%].

The ammonia emission was calculated according to the equation (2):

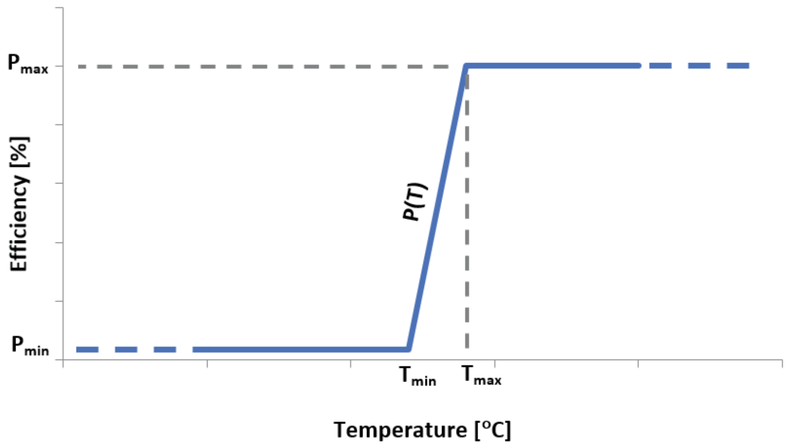
$$E_g = VR \cdot (C_{in} - C_{out}) \cdot 10^{-3} \tag{2}$$

where:
E – ammonia emission [g·h^{-1}],
VR – ventilation rate [m^3·h^{-1}],
C_{in} – inside ammonia concentration [mg·m^{-3}],
C_{out} – outside ammonia concentration [mg·m^{-3}].

Fig. 3. The compartment in studied piggery

Table 1. Number of pigs and body mass

Day	Mean body mass per pig [kg]
19/20.06.2018	94.3
20/21.06.2018	95
28/29.06.2018	102
01/02.08.2018	53.2
06/07.08.2018	57.2
07/08.08.2018	58
08/09.08.2018	58.8
22/23.08.2018	70
04/05.09.2018	81.7
18/19.09.2018	94.3



where:
P_{min} – minimum efficiency of the ventilation system [%],
P_{max} – maximum efficiency of the ventilation system [%],
T_{min} – minimum temperature [°C],
T_{max} – maximum temperature [°C],
P(T) – efficiency of the ventilation system in function of temperature.

Fig. 4. Operating parameters of the ventilatin system

Air samples for olfactometric analysis were taken at the same point where the ammonia concentration was measured. Two samples were collected at the beginning (between 10:00 am and 11:00 am) and at the end (between 10:00 am and 11:00 am next day) of each measurement day. During samples collection the momentary inside temperature and relative humidity were measured using measuring instrument Testo 635-1 (accuracy 0.2ºC and 0,5%). The odor concentration was determined within 24 hours from the time of air samples collection in the accredited olfactometric laboratory of the Institute of Technology and Life Sciences, National Research Institute in Poznań.

The odor concentration was determined by dynamic olfactometry according to EN 13725: 2003 using a TO 8 olfactometer (CEN 2003). The odor air samples selected on the basis of the individual odor threshold determination using n-butanol as an indicator gas were tested by the same team of four experts. The yes/no method was used to determine the odor concentration. The momentary odor emission was calculated according to the following equation (3):

$$E_{od} = VR \cdot C_{od} \quad (3)$$

where:

E_{od} – momentary odor emission [$ou_E \cdot s^{-1}$],
VR – ventilation rate [$m^3 \cdot s^{-1}$],
C_{od} – odor concentration [$ou_E \cdot m^{-3}$].

The value of the odor concentration was the geometric mean of two samples taken between 10:00 am and 11:00 am. The calculated momentary odor emission was gross value (the outside odor concentration was negligible).

Results and discussion

Table 3 shows the microclimatic and weather parameters during the measurements. The mean outside temperature ranged from 19.6 to 27.6ºC, which were typical values for the summer season. Relative air humidity during this period was from 46.3 to 80.3%. Inside the studied piggery, both for temperature and humidity, the range was smaller and amounted from 24.5 to 28.5ºC and from 56.8 to 79.4%, respectively.

The momentary values of temperature and relative humidity inside the building are shown in Figure 5 and Figure 6.

The values of ventilation rate, NH_3 concentrations and emission factors related to the pig and kg of body mass are presented in Table 4. Due to the outside air temperature, the ventilation system was operated at maximum efficiency during the measurements. Mean daily concentrations of ammonia ranged from 3.98 to 10.24 $mg \cdot m^{-3}$ and did not exceed the values from the norms (20 ppm = 13.931 $mg \cdot m^{-3}$) (RM 2010). The momentary values are shown in Figure 6. Analyzing the momentary values, the exceedings of the permissible NH_3 concentration values occurred incidentally for no longer than one hour. The time of day also affects the level of ammonia concentration. Generally, at night, when the activity of the animals is lower, the ammonia concentration is also lower.

In the literature, there is relatively little research on concentration of ammonia from deep-litter piggeries. This may be due to the moderate popularity of this housing system affected from higher operating costs than buildings with non-litter systems. Wang et al. (2011), conducting

Table 2. The efficiency of the ventilation system in function of temperature

Fattening day	P_{min} [%]	P_{max} [%]	T_{min} [°C]	T_{max} [°C]	P(T)
1–7	3.5	100	22	24	$P_{1–7} = 48.25 \cdot T – 1058$
7–14	4	100	22	24	$P_{7–14} = 48 \cdot T – 1052$
14–21	4.5	100	21	23	$P_{14–21} = 47.75 \cdot T – 998.25$
21–28	5	100	20	22	$P_{21–28} = 47.5 \cdot T – 945$
28–35	6	100	19	21	$P_{28–35} = 47 \cdot T – 887$
35	7	100	18	20	$P_{35...} = 46.5 \cdot T – 830$

Table 3. Outside and inside air temperature and relative humidity (mean±standard deviation)

Day	Outside temperature [°C]	Inside temperature [°C]	Outside relative humidity [%]	Inside relative humidity [%]
19/20.06.2018	23.7±2.2	26.8±1.0	80.3±9.9	79.4±2.3
20/21.06.2018	23.8±3.5	27.4±1.9	59.7±13.5	56.8±5.3
28/29.06.2018	21.9±2.3	26.4±1.4	63.1±8.1	60.4±3.0
01/02.08.2018	27.6±4.5	28.5±1.5	60.9±16.9	70.3±4.4
06/07.08.2018	21.3±4.4	24.5±2.1	62.1±17.6	65.1±5.7
07/08.08.2018	25.8±3.8	26.7±1.1	46.3±12.0	58.7±4.4
08/09.08.2018	27.2±4.7	28.0±1.7	57.1±13.7	68.4±4.1
22/23.08.2018	22.5±3.3	25.3±1.2	53.6±10.7	59.4±4.6
04/05.09.2018	19.6±4.2	25.0±2.5	70.5±21.3	62.6±9.0
18/19.09.2018	21.8±3.6	26.1±2.0	60.8±11.0	59.4±5.0

research in experimental chambers for 16 fattening pigs, for two periods of 22 and 13 days, recorded NH_3 concentration values 0.45±0.12 and 0.52±0.13 mg·m^{-3}, respectively. Such low values are probably due to tests in laboratory conditions, in which it is easier to maintain stable microclimatic conditions. Mielcarek et al. (2014), during research in production buildings (deep-litter fattening house for 480 pigs), measured NH_3 concentrations at the level of 4.15–24.74 mg·m^{-3}. These were the values measured for one year and covered three production cycles. The high NH_3 concentration values might result from the litter program. Research in production conditions (deep-litter fattening house for 160 pigs) was conducted by Margeta and Kralik (2006) and they noted the values of 7.02±1.28 mg·m^{-3}. Sousa et al. (2014) determined the concentration of NH_3 from deep-litter composed of wood shavings and sugarcane bagasse. The measurements were carried out from June to July in laboratory conditions, in chambers for 17 fattening pigs. The mean ammonia concentration ranged from 1.14 to 2.16 mg·m^{-3}. Also, for slatted systems, the NH_3 concentration values are highly diversified. Research on these technologies was carried out by Jo et al. (2020), Ni et al. (2019) and Wi et al. (2019), noting the following results: 3.14±2.18 mg·m^{-3}, 2.75±1.05 mg·m^{-3}and 11.16±3.75 mg·m^{-3}.

The ventilation rate during the study was constant and it was equaled to 15,900 m^{-3}·h^{-1}, what resulted from the high temperature during all measuring days. The daily values of the NH_3 emission factor ranged from 8.53–21.71 g·day^{-1}·pig^{-1} (mean for research period 12.54 ± 4.89 g·day^{-1}·pig^{-1}). Related to a kilogram of body mass, this range oscillated

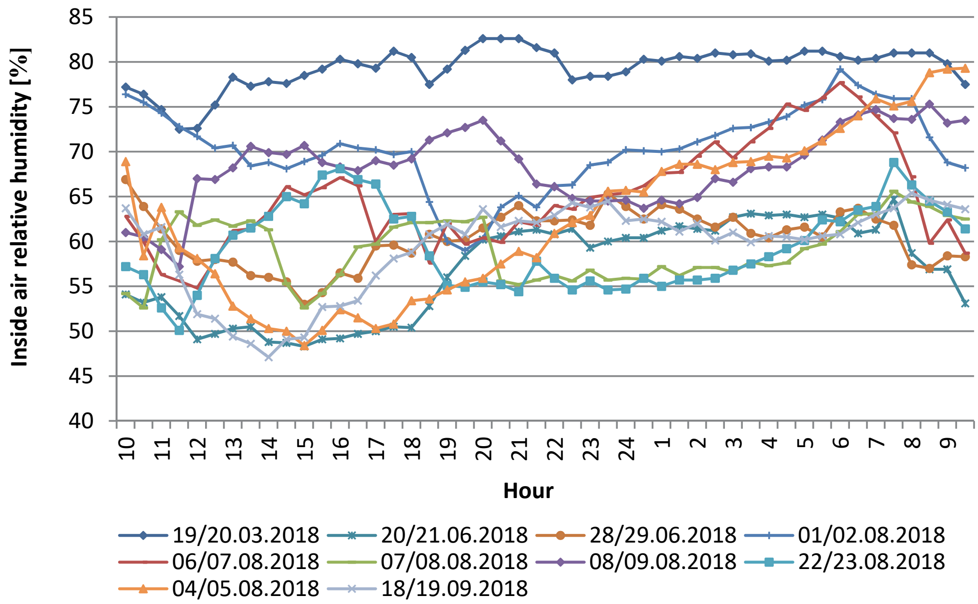


Fig. 5. The momentary values of air relative humidity

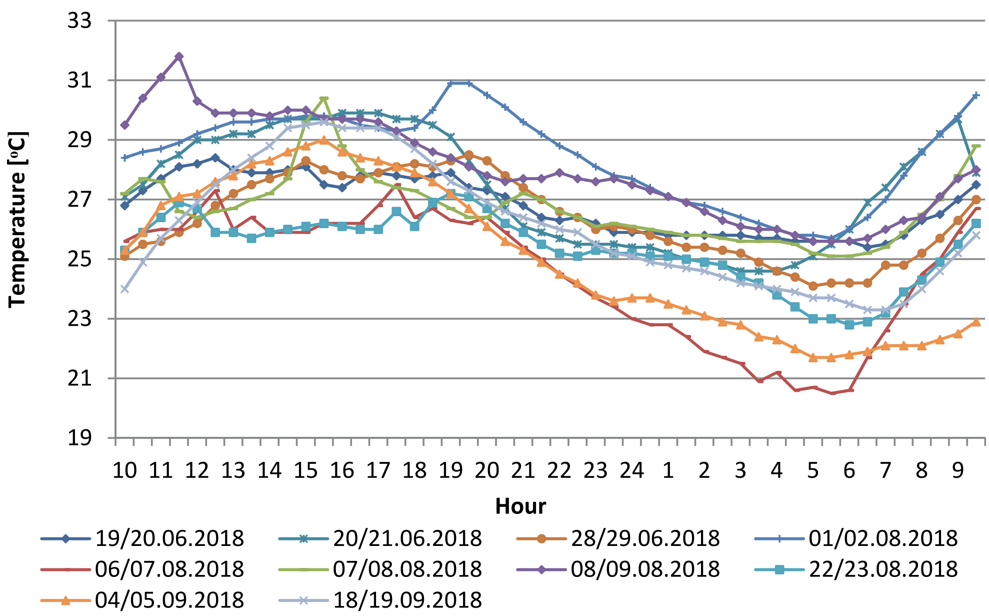


Fig. 6. The momentary values of air temperature

from 0.11 to 0.23 g·day^{-1}·kg b.m.$^{-1}$ (mean for research period 0.17±0.06 g·day^{-1}·kg b.m.$^{-1}$). Comparable results were reported by Philippe et al. (2007) and Nicks et al. (2004) conducting research in experimental deep-litter piggery. They obtained the following mean NH_3 emission factors of 13.1 and 13.6 g·day^{-1}·pig^{-1}, respectively. Lower values were reported by Wang et al. (2011) – 2.16 g·day^{-1}·pig^{-1}. Mielcarek et al. (2014), conducting research in a production building on deep litter, obtained a slightly lower value of the emission factor of 0.10± 0.02 g·day^{-1}·kg b.m.$^{-1}$. The latest publications mainly present the results of non-litter fattening houses. In most cases, the values of NH_3 emission factors are lower than the results of this work. Zong et al. (2015), Jo et al. (2020) and Ni et al. (2019) published the following mean values of NH_3 emission factors: 3.35 g·day^{-1}·pig^{-1}, 1.68 g·day^{-1}·pig^{-1}and 0.08 g·day^{-1}·kg b.m.$^{-1}$. Only Wi et al. (2019) determined a much higher factor, comparable to the results of this work, amounting to 3.12–16.56 g·day^{-1}·pig^{-1}.

The momentary ventilation rate was constant and it was 4.42 m^{-3}·s^{-1}. The odor concentration in the studied fattening house ranged from 755 to 11775 ou$_E$·m^{-3} and was diversified (coefficient of variation 43.8%). Rześnik et al. (2014), during research carried out in production buildings on deep litter, observed odor concentration values ranging from 137 to 1247 ou$_E$·m^{-3}. Conducting research in another piggery with the same housing system, Mielcarek and Rześnik (2017) recorded mean value of odor concentration in the summer season of 760 ou$_E$·m^{-3}. Wang et al. (2011) and Wei et al. (2010) also noted mean values of 67.5 and 67.52 ou$_E$·m^{-3} during research in deep-litter piggery. Also, for non-litter fattening houses, Heber et al. (2008), Guo et al. (2006) and Zhou and Zang (2003) measured variable values. Heber et al. (2008) who studied odor emission from piggery, where the floor was sprayed with oil to reduce odor volatilization, observed low odor concentrations, on average 292±129 ou$_E$·m^{-3}. Slightly higher concentration values were noted by Zhou and Zang (2003), who conducted research in 10 buildings, for various pigs production groups. It ranged from 131 to 1842 ou$_E$·m^{-3}. Guo et al. (2006) in non-litter industrial fattening houses noted odor concentration from 446 to 7797 ou$_E$·m^{-3}.

Table 4. Ventilation rate, ammonia concentration and emission factors (mean±standard deviation)

Day	Inside NH_3 concentration [mg·m^{-3}]	Outside NH_3 concentration [mg·m^{-3}]	NH_3 emission factor [g·day^{-1}·pig^{-1}]	NH_3 emission factor [g·day^{-1}·kg b.m.$^{-1}$]
19/20.06.2018	5.01±1.13	0.65	10.08±2.62	0.11±0.03
20/21.06.2018	6.32±1.46	1.09	12.10±3.38	0.13±0.04
28/29.06.2018	10.24±1.94	0.86	21.71±4.48	0.21±0.04
01/02.08.2018	5.94±1.22	0.58	12.39±2.83	0.23±0.05
06/07.08.2018	4.19±1.12	0.30	9.00±2.59	0.16±0.05
07/08.08.2018	3.98±0.60	0.30	8.53±1.38	0.15±0.02
08/09.08.2018	5.25±0.63	0.30	11.45±1.45	0.19±0.02
22/23.08.2018	6.94±2.12	0.22	15.54±4.90	0.22±0.07
04/05.09.2018	6.06±2.04	0.56	12.71±4.72	0.16±0.06
18/19.09.2018	5.70±1.13	0.55	11.92±2.62	0.13±0.03

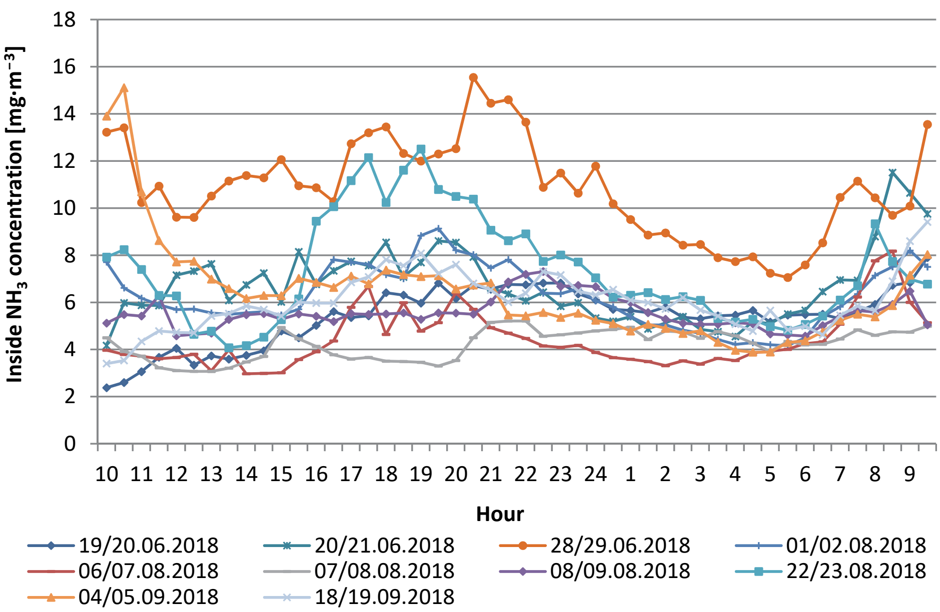


Fig. 7. Momentary inside NH_3 concentration

Table 5. Concentrations and odor emission factors

Day	Odor concentration [$ou_E \cdot m^{-3}$]	Odor emission factor [$ou_E \cdot s^{-1} \cdot pig^{-1}$]	Odor emission factor [$ou_E \cdot s^{-1} \cdot kg$ b.m.$^{-1}$]
19.06.2018	4144	110.93	1.168
20.06.2018	755	20.21	0.213
21.06.2018	8129	217.59	2.307
28.06.2018	8478	226.93	2.406
29.06.2018	7166.2	191.82	1.881
01.08.2018	10120	270.89	2.656
02.08.2018	9444	252.81	4.752
06.08.2018	9924	265.65	4.994
07.08.2018	10569	282.92	4.946
08.08.2018	4332	115.95	1.945
22.08.2018	10522	281.65	4.024
23.08.2018	10105	270.48	3.864
04.09.2018	7187	192.38	2.355
05.09.2018	11775	315.19	3.858
18.09.2018	4671	125.03	1.326
19.09.2018	5926	158.63	1.682

The mean values of the momentary odor emission factors related to the pig and kg of body mass were 179.5±78.7 $ou_E \cdot s^{-1} \cdot pig^{-1}$ and 2.27±1.71 $ou_E \cdot s^{-1} \cdot kg$ b.m.$^{-1}$, respectively. The published odor emission factors from deep-litter piggery are lower than results of this study. Rzeźnik et al. (2014) recorded values ranging from 0.06 to 0.20 $ou_E \cdot s^{-1} \cdot kg$ b.m.$^{-1}$. Guingand and Rugani (2012) determined the value of the odor emission factor for fattening pigs from 0.22 to 11.54 $ou_E \cdot s^{-1} \cdot pig^{-1}$, whereas Schauberger et al. (2013), conducting research in a non-litter fattening house, recorded the odor emission factor of 0.01 $ou_E \cdot s^{-1} \cdot kg$ b.m.$^{-1}$.

High variation of concentrations and emission factors, both NH_3 and odors, is related to the specificity of measurements in production buildings. During such research, some parameters are determined and controlled by the owner of the piggery. Parameters of bedding have a significant impact on the level of pollutant emissions into the air, including: the type and the frequency of bedding and the amount of straw used during bedding. Other factors that are difficult to control are the microclimate parameters (temperature and relative air humidity), mainly dependent on weather conditions.

Conclusions

Based on the research, the following conclusions have been formulated:

– The NH_3 emission factors from the studied piggery, in summer, ranged from 8.53 to 21.71 $g \cdot day^{-1} \cdot pig^{-1}$, (mean value 12.54±4.89 $g \cdot day^{-1} \cdot pig^{-1}$). Factors related to kg of body mass were from 0.11 to 0.23 $g \cdot day^{-1} \cdot kg$ b.m.$^{-1}$ (mean value 0.17±0.06 $g \cdot day^{-1} \cdot kg$ b.m.$^{-1}$).
– Odor concentrations in the studied piggery were from 755 to 11,775 $ou_E \cdot m^{-3}$ and they were diversified (coefficient of variation 43.8%).
– The mean value of the momentary odor emission factors was 179.5±78.7 $ou_E \cdot s^{-1} \cdot pig^{-1}$. Factor related to kg of body mass was 2.27±1.71 $ou_E \cdot s^{-1} \cdot kg$ b.m.$^{-1}$.

In Poland and many other countries, the litter systems of pigs housing are still very popular. Therefore, there is a need to monitor the pollutant emissions from such buildings to identify the factors influencing the amount of this emission. Another important issue is to verify whether the reduction techniques, giving a measurable effect in laboratory research, bring the same reduction effect in production buildings.

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Emisja odorów i amoniaku z tuczarni z wentylacją mechaniczną na głębokiej ściółce w Polsce

Streszczenie: Produkcja zwierzęca jest podstawą globalnej produkcji żywności i jednocześnie stanowi poważne zagrożenie dla środowiska. Istotnymi zanieczyszczeniami środowiska są emitowane z budynków inwentarskich odory i amoniak (NH_3). Celem pracy było określenie stężenia oraz emisji amoniaku i odorów, w sezonie letnim, z tuczarni na głębokiej ściółce oraz wyznaczenie wskaźników emisji amoniaku i odorów. Badania były prowadzone w sezonie letnim, w mechanicznie wentylowanej tuczarni zlokalizowanej w województwie wielkopolskim. Stężenia amoniaku zmierzono za pomocą spektrometru fotoakustycznego Multi Gas Monitor Innova 1312, a stężenia zapachowe oznaczono metodą olfaktometrii dynamicznej zgodnie z normą EN 13725:2003 przy użyciu olfaktometru TO8. W badanej tuczarni na głębokiej ściółce dobowe wartości wskaźnika emisji NH_3, w sezonie letnim, wahały się od 8,53 do 21,71 $g \cdot doba^{-1} \cdot szt^{-1}$ (średnio 12,54±4,89 $g \cdot doba^{-1} \cdot szt.^{-1}$). W odniesieniu do kilograma masy ciała wynosiły od 0,11 do 0,23 $g \cdot doba^{-1} \cdot kg$ m.c.$^{-1}$ (średnio 0,17±0,06 $g \cdot doba^{-1} \cdot kg$ m.c.$^{-1}$). Stężenie odorów w badanej tuczarni wynosiło od 755 do 11775 $ou_E \cdot m^{-3}$ i było zróżnicowane (współczynnik zmienności 43,8%). Średnia wartość współczynnika chwilowej emisji odorów wynosiła 179,5±78,7 $ou_E \cdot s^{-1} \cdot szt.^{-1}$. W przeliczaniu na kg masy ciała świni wskaźnik ten był równy 2,27±1,71 $ou_E \cdot s^{-1} \cdot kg$ m.c.$^{-1}$. W Polsce i wielu innych krajach wciąż dużą popularnością cieszą się systemy utrzymania świń na ściółce. Istnieje więc potrzeba monitorowania emisji zanieczyszczeń z takich obiektów, celu zidentyfikowania czynników mających wpływ na wielkość tej emisji. Innym ważnym zagadnieniem jest weryfikacja czy techniki ograniczające uwalnianie zanieczyszczeń, dające mierzalny efekt podczas badań laboratoryjnych, przynoszą ten sam skutek redukcyjny w obiektach produkcyjnych.