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EMISSION AND DISTRIBUTION OF AMMONIA FROM TURKEY FARM

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The objective of the study was to determine the emissions of ammonia and the extent of its impact on the environment. On the farm there are two livestock buildings. The ammonia emission was calculated on the basis of the emission ratio per 1 m^2 of the usable area of the building, for females determined at 1.38 kg per annum [9]. The volume of emission and the dispersion of ammonia was calculated at the height of 0.0 m and 6.5 m above ground level with the KOMIN and RWW programs. Regardless of the height at which the calculation was done, the highest of the maximum concentrations was observed 16 m from the emitters situated in the roof ridge and 1 m from the emitters in the sidewall. The values of average annual concentrations and maximum 1-hour concentrations were higher for calculations at 0.0 m than 6.5 m. Within the area where the reference values were exceeded there is a compact rural residential area, whose west part is subject to very high above-standard ammonia concentrations much more frequently.

Keywords: livestock facility, emitter, ammonia emission, the extent of the impact of ammonia

1. INTRODUCTION

Animal production is one of the main sources of pollution harming the basic elements of environment, especially the atmosphere [12].

Poultry farms, beside pig farms, rank as the biggest emitters of gas pollution released in the air, including ammonia [4]. Ammonia is generated in large amounts in livestock facilities as a result of bacterial and enzymatic processes taking place in animal manure [1].

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The greatest ammonia loss occurs with the deep litter systems of managing animals. The gas, because of its physicochemical properties may cause significant decrease in the animals' productivity as well as health problems [13]. Therefore, depending on climatic conditions and the birds' requirements, poultry facilities must be ventilated naturally and mechanically. In Poland the mechanical supply and exhaust system of ventilation is commonly used with the ventilation chimneys distributed in the roof, the endwall or the sidewall [9]. Regardless of the design approach, the basic task of ventilation systems is to remove the polluted air out of the building.

The pollution emitted into the atmosphere undergoes numerous chemical transformations, whose products have a negative environmental impact [2,4,8,10,13,18,19]. Such chemical compounds as NH_3, CH_4, H_2S, ketones and mercaptans present in the air in livestock buildings and their surroundings not only cause discomfort to local residents, who have reason to complain about the odour nuisance but they may also become a serious health hazard to human health and the state of the environment [11,16].

The atmospheric air is the medium least resistant to pollution and is also characterized by the fastest pace and dynamics of its expansion into the other elements of the environment (water, soil) [3,14,15].

The problem of environment protection during animal production has not yet been solved despite numerous regulations by law such as acts, regulations and provisions. The Regulation of the Minister of the Environment [6] of 13.05.1995 requires that investment projects related to animal breeding with the stocking density of over 50 DJP, and 100DJP for litter rearing, be considered an environmental hazard. Regulation (EC) No 166/2006 of the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EEC and 96/61/EC imposes an obligation to make an assessment of environmental impact of intensive rearing of poultry for installations with more than 40 000 places, including turkey broilers.

The Regulation of the Minister of the Environment of 26 January 2010 on the reference values for certain substances in the air [7] includes the referential methodology of modelling of levels of substances in the air as well as reference values for air pollutants, including ammonia.

Ammonia is not a greenhouse gas but it contributes to rain acidification and even more so to the photochemical smog. When it settles on the ground, it is oxidized to nitric acid, which acidifies the lithosphere and hydrosphere.

The objective of this study is to determine the extent of the impact of the above-standard concentrations of ammonia emitted from livestock facilities in which turkeys are grown and fattened.

2. MATERIALS AND METHODS

The computer simulation of the dispersion of ammonia around livestock buildings was carried out for a poultry farm situated south-west of compact rural residential area and about 50 m from the nearest residential buildings.

There are two livestock buildings on the poultry farm (B1 and B2), each with the usable area of 1100 m^2. The ventilators in B1 and B2 have the same technical parameters: ventilator output - 5 000 $m^3 \cdot h^{-1}$; the inner diameter - 0.55 m; the geometric height of the ventilation chimney outlets in the roof ridge is 3.5 m and in the sidewall - 1.0 m. The exhaust gas velocity for ventilation chimneys in the roof ridge in B1 and B2 is 5.85 $m \cdot h^{-1}$ whereas in the sidewall it is 0.0 $m \cdot h^{-1}$ [7].

The calculation of emission volumes and the modeling of ammonia dispersion in the atmospheric air around the farm was made in compliance with the referential methodology specified in the Regulation of the Minister of the Environment of 26 January 2010 on the reference values for certain substances in the air [7].

To calculate the levels of ammonia emission and to visualize the extent of its impact, the following assumptions were used:

- the maximum composite average emission for one hour $E_{g\ max}$. calculated on the basis of the emission ratio per 1 m^2 of the usable area of the building, for females determined at 1.38 kg per annum [9]
- the pollutant background - for ammonia - 5 $\mu g \cdot m^{-3}$
- meteorological data: the statistics of steady states of the atmosphere, wind velocity and direction accepted for the weather station in Zielona Góra
- the average temperature of the atmospheric air in the calculation period - one year - 281.2K
- the temperature of exhaust gases from the emitter - 293.2K
- the calculations of substance levels in the air for sets of emitters were done on a geometric network of points with the coordinates X_p i Y_p
- the emitters' coordinates are set as Xe i Ye. The x-axis faces east and the y-axis faces north
- the contours of B1 and B2 were set in quadrant I of the Cartesian coordinate system XOY
- the aerodynamic terrain roughness coefficient z_0 = 0.5 m [7]

In accordance with the Regulation of the Minister of the Environment, to calculate the dispersion of the pollution plume the Pasquill formula was applied, which is a simplified solution of a differential equation of atmospheric diffusion of pollution in moving gaseous medium. The model disregards the appearance of inversion, stillness, the absorption of pollution by the ground and precipitation, chemical transformations of pollutants and the turn of wind at higher altitudes. For so determined conditions the equation describing the dispersion of pollution looks as follows:

$$S_{xyz} = \frac{E_g}{2\pi \bar{u}\, \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left\{\exp\left[-\frac{(z-H)^2}{2\sigma_z^2}\right] + \exp\left[-\frac{(z+H)^2}{2\sigma_z^2}\right]\right\}\cdot 1000$$

$$\left[\mu g / m^3\right]$$

S – the concentration of the gas substance at a point with the coordinates Xp, Yp, Zp
E_g – maximum emission of substance, mg·s^{-1}
u – the wind velocity, m·s^{-1}
σ_y, σ_z – horizontal and vertical atmospheric dispersion coefficients, m
H – the effective height of the release, m
z – the height for which the concentration of substance in the air is calculated, m.

The range of calculations of substance levels in the air includes the calculations of the distribution of maximum concentrations of the substance averaged for one hour including the statistics of meteorological conditions to ensure that at every point of the terrain surface the following condition was met:

$$S_{mm} \leq D_1$$

where:
S_{mm} – the highest of maximum substance concentrations in the air, μg·m^{-3}
D_1 – the reference value of the substance in the air or the permissible level of substance in the air averaged for one hour, μg·m^{-3}.

The calculations for B1 and B2 were done in a network with 5-metre intervals at the height of 0.0 m at ground level and 6.5 m above ground level. The calculation part of this paper was done by means of the KOMIN program whereas the graphic component illustrating the dispersion in the atmosphere of ammonia emitted in the turkey farm was done with the RWW program.

3. RESULTS AND DISCUSSION

The calculation results obtained with the KOMIN program are presented in Table 1.

Table 1. The volume of ammonia emission, the values of maximum average annual and 1-hour concentrations and the incidence of exceedance of annual and 1-hour concentrations depending on the height at which calculations were done.

Parameter	Height at which calculation was done Z [m]	Livestock facilities	
		B1, B2	B2
		Emitters in roof ridge	Emitters in wall
Highest of maximum ammonia concentrations [$\mu g \cdot m^{-3}$]	0.0	225.9	72804.4
	6.5	225.9	72804.4
Distance of emitter from point of concentration [m]	0.0	16	1
	6.5	16	1
Maximum of average annual concentrations [$\mu g \cdot m^{-3}$]	0.0	6894.5	
	6.5	1594.5	
Maximum of max. 1-hour concentrations [$\mu g \cdot m^{-3}$]	0.0	75433.4	
	6.5	30994.7	
Maximum of percentile S99.8	0.0	74552.3	
	6.5	30857.7	
Maximum incidence of concentration exceedance 50.0 $\mu g \cdot m^{-3}$ [%}	0.0	83.3	
	6.5	77.8	
Maximum incidence of concentration exceedance 400.0 $\mu g \cdot m^{-3}$ [%]	0.0	77.1	
	6.5	63.6	

Source: autor's calculations

As the data in Table 1. show, regardless of the height at which the calculations were done, the highest of maximum concentrations was 225.9 $\mu g \cdot m^{-3}$ and was observed 16 m from the emitters in the roof ridge.

Very high values of the highest of maximum concentrations were found at emitters along the sidewall in B2 and regardless of the height at which the calculations were done, the concentrations were 72804.4 $\mu g \cdot m^{-3}$ and were found at the distance of 1 m from the emitters.

The values of maximum of average annual concentrations calculated at the height of 0.0 m were much higher than those calculated at the height of 6.5 m above ground level. The difference was 5300 $\mu g \cdot m^{-3}$.

The highest of maximum 1-hour concentrations calculated at 0.0 m were higher by 44438.7 $\mu g \cdot m^{-3}$ as compared to those calculated at 6.5 m AGL.

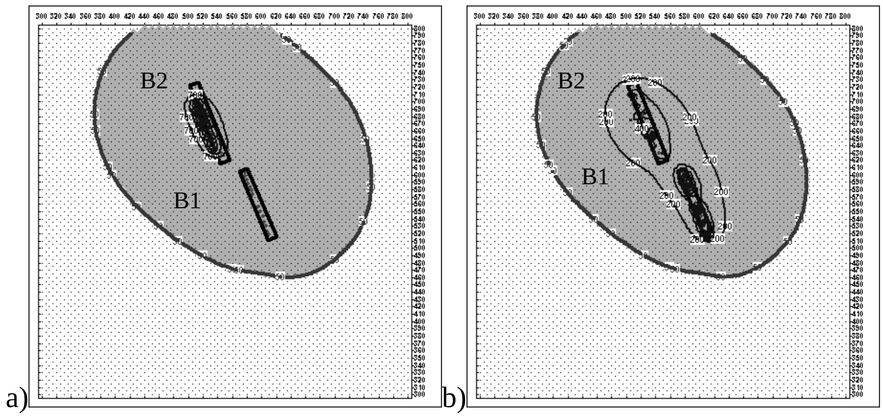
The calculation results showed that the maximum of percentile S99.8 for the height of 0.0 m was higher by 43694.6 $\mu g \cdot m^{-3}$ than that calculated for the height of 6.5 m AGL.

The maximum incidence of reference value exceedance for one year (50 $\mu g \cdot m^{-3}$) was higher by 5.6 percentage points for the calculation height of 0.0 m than for 6.5 m AGL.

The observed maximum incidence of reference value exceedance for one hour (400 $\mu g \cdot m^{-3}$) were higher by 13.5 percentage points for the calculation height of 0.0 m than for 6.5 m AGL.

The annual volume of ammonia emission from the farm was 85.03 tons.

Figures 1 - 6 present computer simulations illustrating the dispersion of ammonia from the farm buildings (B1 and B2) corresponding to the calculation height of 0.0 m and 6.5 m AGL. The rectangles represent the livestock facilities. The shadowed area represent the zone where the ammonia concentrations exceed the averaged reference values for a calendar year (50 $\mu g \cdot m^{-3}$) and for one hour (400 $\mu g \cdot m^{-3}$).

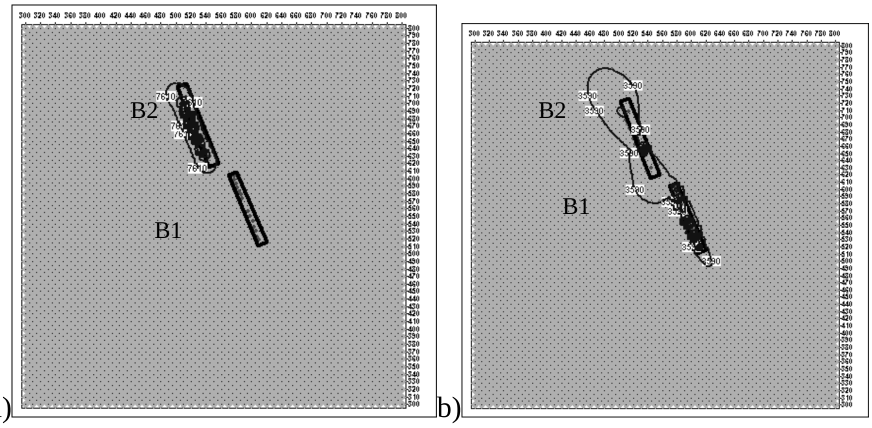


Source: author's calculations

Fig. 1. The distribution of average annual concentrations from the farm at 0.0 m (a) and 6.5 m AGL (b)

The distribution of contour lines presented in Fig. 1a) and b) shows that the area of above-standard average annual concentrations covers the farm area. For the calculation height of 0.0 m AGL very high concentrations (700 μg·m^{-3}) occur only around the building B2. A likely reason for such distribution of ammonia concentrations is the location of 10 emitters along the sidewall of B2.

The distribution of contour lines for calculations done at the height of 6.5 m AGL shows that also at this height there are high concentrations (400 μg·m^{-3}) around B2. The contour line representing 200 μg·m^{-3} covers a smaller area around B1 than B2. The impact zone of the above-standard average annual concentrations from B1 and B2 covers the west part of the compact rural residential area.



a) b)

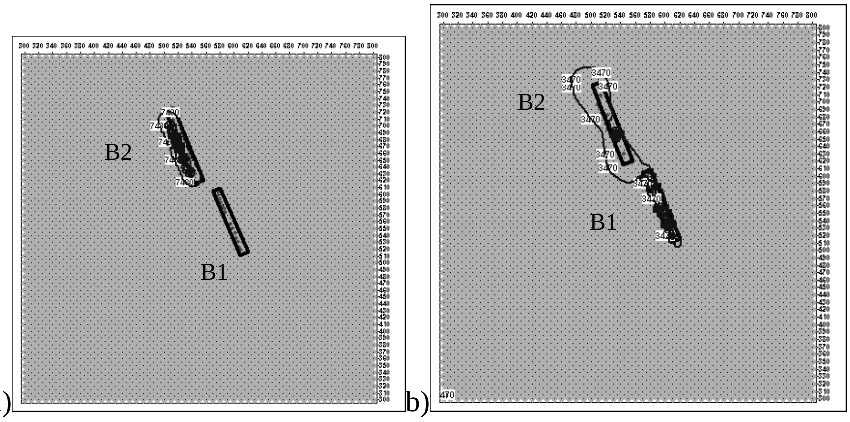
Source: author's calculations

Fig. 2. The distribution of maximum 1-hour concentrations from the farm at 0.0 m (a) and 6.5 m AGL (b)

Figure 2a) and b) shows that the extent of impact of above-standard 1-hour maximum concentrations is very large (the shadowed area) and covers the compact rural residential area. The distribution of contour lines shows that for calculations done at the height of 0.0 m the impact area of very high concentrations (7610 μg·m^{-3}) occurs only around B2. The position of contour lines for calculations done at the height of 6.5 shows that the extent of the impact of high concentrations (3590 μg·m^{-3}) covers B1 and B2, but is larger around B2.

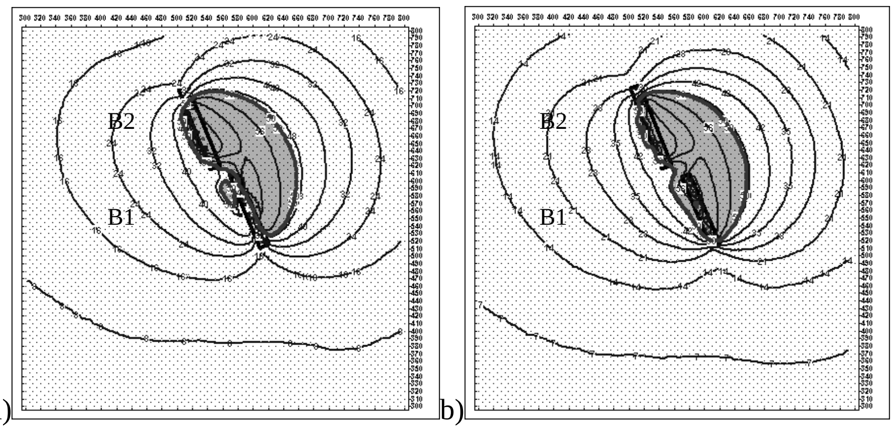
Figure 3a) and b) the contour lines illustrating the distribution of the maximum of percentile S99.8 show that the reference values were exceeded many times both for calculations at 0.0 m and 6.5 m AGL. For the calculation height of 0.0 m the contour line representing the highest value of percentile (7480 μg·m^{-3}) covered the area around B2 whereas for the calculation height of 6.5 m AGL the contour line representing the highest value of percentile (3470 μg·m^{-3}) covered B1 and B2.

The distribution of contour lines as presented in Fig. 4a) and b) show that both within the area of the farm and north-east of it the maximum incidence of the exceedance of concentration 50 μg·m^{-3} are very high. The maximum incidence of the exceedance of this concentration for calculations done at the height of 0.0 m and 6.5 m AGL were 83.33% and 77.77% respectively.

a)
b)


Source: author's calculations

Fig. 3. The maximum of percentile S99.8 at 0.0 m (a) and 6.5 m AGL (b)

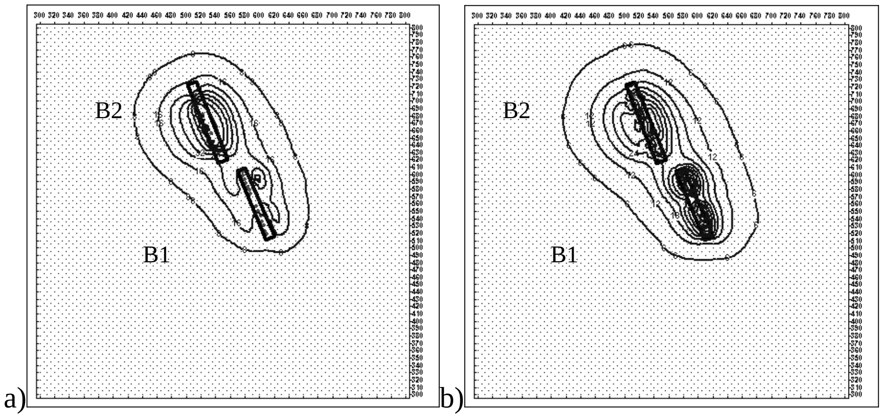
a)
b)


Source: author's calculations

Fig. 4. The maximum incidence of the exceedance of concentration 50 μg·m^{-3} at 0.0 m (a) and 6.5 m AGL (b)

The distribution of contour lines shows that within the compact rural residential area (north-east of the farm as presented in Fig. 4) the exceedance of the reference value for one year are much more frequent at the height of 0.0 m (16%) than at 6.5 m AGL (14%).

The contour lines illustrating the distribution of the incidence of exceedance show that the maximum incidence of the exceeded levels of concentration 400 μg·m^{-3} within the area of the farm are high and equalled 77.1% and 63.6% for the heights of 0.0 m and 6.5 m AGL respectively.



Source: author's calculations

Fig. 5. The maximum incidence of the exceedance of concentration 400 μg·m^{-3} at 0.0 m (a) and 6.5 m AGL (b)

The distribution of contour lines indicates that in the west part of the compact rural residential area the reference values for one hour are exceeded more frequently at the height of 0.0 m (8%) than at 6.5 m AGL (6%).

4. SUMMARY

The above calculations show that even a small poultry farm consisting of two livestock buildings emits considerable amounts of ammonia into the atmosphere per annum (85.03 tons).

The analysis of calculation results conducted with the Komin program showed that regardless of the height at which the calculation was done, the highest of the maximum concentrations was observed 16 m from the emitters situated in the roof ridge. Very high values of concentrations were also found at the distance of only 1 m from the emitters located in the sidewall.

The maximum average annual concentrations and the maximum 1-hour concentrations were higher for calculations done at 0.0 m AGL than 6.5 m AGL. A likely reason for such differences in the values of concentrations calculated at various heights is the location of 10 emitters along the sidewall of B2, from which the high concentration plume quickly reaches the ground surface. This is a highly unfavourable phenomenon as high concentrations of ammonia have a negative influence on animals and people in the building and around it. The distribution of ammonia concentrations shows that it is more beneficial to locate ventilation chimneys in the roof ridge of the livestock building.

The conducted analysis of the contour lines distribution showed that the impact area of the above-standard average annual concentrations of ammonia covers the area of the farm and the west part of the rural residential area. However, the extent of the impact of the above-standard maximum 1-hour concentrations is very large and covers a compact rural residential area. The contour lines illustrating the distribution of the maximum of percentile S99,8 show the reference values were exceeded many times regardless of the height of the calculation.

Within the area of the farm and north-east of it the maximum incidence of the exceedance of concentration 50 $\mu g \cdot m^{-3}$ are very high regardless of the height of the calculation.

The analysis of the distribution of contour lines shows that within the compact rural residential area the reference values for one year are exceeded more frequently for calculations done at the height of 0.0 m than 6.5 m AGL.

The contour lines illustrating the distribution of the incidence of exceedance showed that within the area of the farm 1-hour concentrations are high and more frequent for calculations done at the height of 0.0 m than 6.5 m AGL.

In view of the above analysis, it can be said that the area of the exceeded reference values covers the compact rural residential area, whose west part is more frequently exposed to the impact of the above-standard ammonia concentrations emitted from the buildings on the farm.

There should be no residential buildings within the area where permissible values are exceeded.

Dz. U. [5] of 2001 includes a provision which affirms that residential buildings owned by the party operating the installation may be located within the area exposed to above-standard impact of ammonia as long as they are situated in an area to which the party holds a legal title.

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EMISJA I ROZPRZESTRZENIANIE AMONIAKU Z FERMY INDYCZEJ

S t r e s z c z e n i e

Celem pracy jest określenie emisji amoniaku i zasięgu jego oddziaływania na środowisko. Na fermie znajdują się dwa budynki inwentarskie, w B1 jest 14. emitorów jest w kalenicy, w B2 4. emitory są w kalenicy a 10 w ścianie podłużnej. Parametry emitorów są takie same. Emisję amoniaku obliczono korzystając ze wskaźnika emisji z 1

m^2 powierzchni użytkowej budynku wynoszącym dla samic 1,38 kg rocznie [9]. Wielkości emisji i rozprzestrzenianie amoniaku wykonano dla wysokości 0,0 m i 6,5 m n.p.t. przy pomocy programów KOMIN i RWW. Niezależnie od wysokości obliczeń najwyższe ze stężeń maksymalnych wystąpiło 16 m od emitorów znajdujących się w kalenicy, oraz 1 m od emitorów w ścianie podłużnej. Maksymalne stężenia średnie roczne oraz stężenia maksymalne 1-godz były wyższe dla obliczeń na 0,0 m. niż na 6,5m. W zasięgu występowania przekroczeń wartości odniesienia znajduje się zwarta zabudowa a jej zachodnia część jest częściej narażona na oddziaływania bardzo wysokich ponadnormatywnych stężeń amoniaku. W obszarze występowania przekroczeń wartości dopuszczalnych nie powinny znajdować się budynki mieszkalne.