

Impacts of zotechnical activities on environment and human health – a case study

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Abstract

This paper aims at analyzing the impact of pollutant dispersion and at assessing air quality under the circumstances of a shelter functioning for 55 heads of beef cattle.

The methodology consists in determining air quality before commissioning the objective, pollutant dispersion modeling, comparison with the limit values set by national legislation and conclusions regarding the influence of anthropogenic farming activity on air quality in the area.

Keywords: environmental protection, dispersion of pollutants, air quality.

1. Introduction

The land where livestock farming will be carried out is located in Costesti, Valcea County, and has an area of 670 square meters; the legal status: extravilan; category of use: hayfields.

The area of Costești includes hills, valleys and mountains. The climate is temperate continental with short summers and quite moderate winters, without strong storms. The average temperature is -8°C in winter and in summer it can reach 30°C . Prevailing winds come from the west and bring rainfall.

In the target area there are no economic activities that can generate air pollution. As customary in hill and mountain areas, the residents' main activity is animal breeding. Air emissions come solely from livestock activity and domestic heating. Air quality in the area is appreciated by experts as good.

The objective to be achieved consists in building a shelter for managing 55 beef cattle. The biological material will be made out of beef breeds and mixed breed produces meat and milk belonging to different age categories: cows and calves. The implemented technological process will be based on pasture feeding for approx. 6 months and foddering in the shelter for the other 6 months. Basically, the animals will stay in the shelter for more than 180 days - from November till April.

During their shelter stay, as a result of digestive processes, manure is obtained, and its management will be as follows:

- the liquid fraction is drained by gravity into two fosses located at the end of the shelter;
- the solid fraction will be evacuated from the shelter and it will be transported to the solid manure platform.

In conclusion there will be two sources of pollution: the cattle shelter, naturally ventilated through windows and doors, and the solid manure storage platform.

In the case of animal husbandry, the main impact on the environment stems from the air emissions generated by manures (SONNEVELD & al. 2008 [24]; OGINKA & al. 2013 [17]; QIU HUANGUANG & al. 2013 [18], RUSU T. & al, 2015 [16], SALTUK B. & al, 2016 [19], UNGUREANU G. & al, 2017 [26]). Damage to the air quality can also induce harmful effects on human health (an indirect impact) for the people living in the surrounding area (PEEL & al. 2013 [13]; SHRIKANT & al. 2013 [23]; LIDWIEN & al. 2014 [10], SHEHRAWAT P. S. & al. 2015 [22], SÂRB G. S. & al. 2013 [20]).

Pollutants from livestock activity are: ammonia; nitrogen oxides; powders; non-methane volatile organic compounds (NMVOC). Their impacts on environment and on human health are illustrated henceforth:

Ammonia

The source of NH₃ emissions from manure management is the azote excreted by livestock. Typically, more than half of the azote excreted by mammalian livestock is in the urine, and between 65 - 85 % of urine - azote is in the form of urea and other readily - mineralized compounds. (JARVIS & al. 1989 [8]; KIRCHMANN & WITTER, 1989 [9]; WEBB, 2000 [27]).

Urea is rapidly hydrolyzed by the enzyme urease to ammonium carbonate ((NH₄)₂CO₃) and ammonium (NH₄⁺) ions provide the main source of NH₃. Ammonium-N (NH₄⁺-N) and compounds, including uric acid, which are readily broken down to NH₄⁺-N, are referred to as total ammoniacal azote (TAN). In contrast, the majority of azote in mammalian livestock faeces is not readily degradable (Van FAASSEN & Van DIJK, 1987 [6]); only a small percentage of this azote is in the form of urea or NH₄⁺ (ETTALLA & KREULA, 1979 [5]) so NH₃ emission is sufficiently small (PETERSEN & all, 1998 [14]) for estimates of total ammoniacal azote (TAN) at grazing or in buildings to be based on urine-N, albeit TAN may be mineralised from faecal-N during manure storage.

Ammonia is emitted wherever manure is exposed to the atmosphere; in livestock housing, manure storage, after manure application to fields and from excreta deposited by grazing animal (AARNINK & al. 1997 [1]).

Reviews of the different existing methods for measuring the concentration, ventilation rate and emissions of different pollutants from livestock buildings can be found in the literature (AROGO & al. 2001 [3]; MOSQUERA & al. 2005 [11]). Differences in agricultural practices such as housing and manure management, and differences in climate have significant impacts on emissions. PHILLIPS & al. 2001 [15] provided an extensive review of measurement methods for ammonia emission rates from livestock buildings.

Effects on humans: Ammonia can be felt in the interval 5-25 ppm; at a concentration ranging between 50-100 ppm it may cause slight irritation on prolonged exposure; between 400-700 ppm it causes immediate irritation of eyes, nose and throat, with mild symptoms of upper respiratory tract.

Environmental effects: Ammonia is dangerous to aquatic life.

Nitric oxide

The processes of denitrification and nitrification, which release N_2O , also release NO and dinitrogen (N_2). Nitric oxide (NO) is formed through nitrification in the surface layers of stored manure or in manure aerated to reduce odors or to promote composting (DÄMMGEN & HUTCHINGS, 2008 [4], SCHMIDT A. & al. 2017 [21]).

Effects on humans: Nitric oxide is not toxic or irritant at concentrations below 100 ppm in breathing air. Nitrogen dioxide is known to be highly toxic for both humans and animals. People exposed to such pollutants may complain about breathing difficulties, air tract irritations and lung dysfunctions.

Environmental effects: Although not dangerous in concentrations below 100 ppm, the Nitric oxide can be oxidized in the presence of oxygen thus becoming nitrogen dioxide, which is responsible for acid rain.

Non-methane volatile organic compounds

Non-methane volatile organic compounds (NMVOCs) originate from undigested protein that decomposes in manure. Consequently, anything that affects the rate of protein degradation, such as the amount of straw added to the manure and the duration of storage, will affect NMVOC emissions. Sites of emission include livestock buildings, yards, and manure stores, fields where manure is spread and fields grazed by livestock. Emissions take place from manure managed in solid form or as slurry (HOBBS & al. 2004 [7]).

Recent studies have measured significant emissions of NMVOCs from livestock production (SPINHIRNE & al. 2004 [25]; NGWABIE & al. 2005 [12]), albeit emission estimates for manure management account for 1.6 % (with 1.4 % for pigs) suggesting little overall significance.

Effects on humans: Non-methane volatile organic compounds cause foul odor.

Environmental effects: Currently, data on NMVOC emissions from livestock do not allow for a direct estimate on emission factors for such compounds.

Particulate matter (PM)

The main source of PM emission is from buildings housing livestock, although outdoor yard areas may also be significant sources. These emissions originate mainly from feeding, which accounts for 80 to 90 % of total PM emissions. Bedding materials such as straw or wood shavings can also give rise to airborne particulates (AARNINK & ELLEN, 2008 [2]).

2. Materials and Methods

According to current legislation, the establishment of a livestock shelter may be made only by respecting the very strict rules, especially regarding the proximity, but also the conditions of storage of solid waste. Farmers who want to set up a farm should know that there are specific regulations that prohibit location of livestock farms near to inhabited areas. Under the legislation on hygiene and public health on the living environment of population (Ministry of Health Order no. 119/2014), the minimum distance between the territory

inhabited and an animal shelter with a number 50-100 heads must be at least 100 m. Given that the legislation requires a minimum distance of 100 m between animal shelter and inhabited area and in reality the distance is only 73 m, is required an impact study approved by the Institute of Public Health, who may approve reduce the distance according to effect pollutants on the environment.

In order to analyze pollutant dispersion it is necessary to calculate the amount of emissions from the process and to simulate the dispersion using a dispersion model.

A) Calculation of amount of emissions from process

The main pollutant to be taken into account in animal husbandry is ammonia. Emission calculation was made according to Order no. 3299/2012 (Methodology for reporting inventories and emission of pollutants in the atmosphere). In the section entitled "Activities in the Agriculture Group" the Order indicates the categories "Animal husbandry and manure management". The emission factors for the category of fattening cattle were used in accordance with EMEP / EEA 2009 [28].

Table 1: Default values for length of housing period, annual straw use in litter-based manure management systems and the N content of straw

Livestock	Housing period (days)	Straw (kg /animal/year)	N added in straw (kg/animal/year)
Beef cattle	180	500	2,0

Source: EMEP/EEA emission inventory guidebook 2009, updated June 2010 - 4.B Animal husbandry and manure management

Table 2: Default Tier 2 NH₃-N emission factors (EF) and associated parameters for the Tier 2 methodology for calculation of the NH₃-N emissions from manure management

Livestock	Housing period	Total annual N excretion	TAN (%)	Manure type	Emission factors housing	Emission factors yard	Emission factors storage	Emission factors spreading	Emission factors grazing/ outdoor
Beef cattle	180	41	0.6	Slurry	0.2	0.53	0.2	0.55	0.06
				Solid	0.19	0.53	0.27	0.79	0.06

Source: EMEP/EEA emission inventory guidebook 2009, updated June 2010 - 4.B Animal husbandry and manure management

Table 3: Default values for other losses needed in the mass-flow calculation

Specification	Proportion of TAN
EFstorage_slurry NO	0.0001
EFstorage_slurry N ₂	0.003
EFstorage_solid NO	0.010
EFstorage_solid N ₂	0.003

Source: EMEP/EEA emission inventory guidebook 2009, updated June 2010 - 4.B Animal husbandry and manure management

We used Apendixb computer software with the emission factors corresponding to the targeted animal category – beef cattle – and we took into account the existence of two pollution sources – the shelter and the solid manure platform; hence we obtained the following results:

a) at the shelter, the total ammonia emissions on location is given by: emissions generated by solid manure + ammonia emission from the liquid fraction + ammonia emission released when the animals are in the courtyard + ammonia emission from the two

urine storage pits at the end of the shelter = 50.04 + 47.54 + 101.48 + 95.236 = 294.295 kg (68.1g/h).

b) at the platform for solid manure storage the ammonia emission is 14.924 kg (3.5g/h)

Calculation of nitrogen oxides

The program has calculated the amount of NO_x released while storing liquid and solid manure as a result of nitrification.

Very little data are available on NO emissions from manure. NO emissions are estimated to quantify the nitrogen mass balance in Tier 2 methodology for calculating ammonia emissions.

a) at the shelter, in liquid manure storage, the total N₂O emission is 0.476 kg (0.11g/h), and the total emission of NO is 0.048 kg (0.01g/h).

b) at the solid manure storage platform the total N₂O emission is 4.422kg (1.02/h), and the total emission of NO is 0.442 kg (0.1g/h).

Calculation of NMVOC

Non-methane volatile organic compounds (NMVOC) generate odor. Currently, data referring to NMVOC emissions from animal husbandry do not allow a direct estimate of emission factors for these compounds. EMEP/EEA emission inventory guidebook does not indicate emission factors for NMVOC.

Calculation of powders

$$E_{PMi} = AAP_{animal} \cdot x_{house} \cdot \beta \cdot (x_{slurry} \cdot EF_{slurry} + (1-x_{solid_i}) \cdot EF_{solid})$$

where:

E_{PM} - PM₁₀ or PM_{2.5} emission for an animal category (in kg a⁻¹),

β - mass units conversion factor ($\beta = 1 \text{ kg kg}^{-1}$),

x_{house} - share of time the animals spend in the animal house (in a a⁻¹),

x_{slurry} - share of population kept in slurry based systems,

EF_{slurry} - PM₁₀ or PM_{2.5} EF for slurry based system (in kg AAP⁻¹ a⁻¹),

EF_{solid} - PM₁₀ or PM_{2.5} EF for solid manure based system (in kg AAP⁻¹ a⁻¹).

Table 4: Tier 2 emission factors for source category: manure management, cattle

Specification	EF PM ₁₀ (kg/ animal /year)	EF PM _{2.5} (kg/ animal / year)
Slurry	0.32	0.21
Solid	0.24	0.16

Source: EMEP/EEA emission inventory guidebook 2009, updated June 2010 - 4.B Animal husbandry and manure management

For:

$x_{house} = \text{half a year (180 days)}$

$x_{slurry} = 1$

$x_{solid} = 0.5$

We have:

$E_{PM10} = 55 \times 0.5 \times 1 \times ((1 \times 0.32 + (1 - 0.5) \times 0.24) = 12.1 \text{ kg/180 days} = 2.80 \text{ g/h}$

$E_{PM2.5} = 55 \times 0.5 \times 1 \times ((1 \times 0.21 + (1 - 0.5) \times 0.16) = 7.975 \text{ kg/180 days} = 1.84 \text{ g/h}$

B) Dispersion Modeling

Modeling pollutants in the air quality assessment is an important instrument for developing action programs to improve air quality. By means of modeling we can identify the contribution of various pollutant categories to exceeding the limit values. A major advantage is that the use of modeling pollutants leads to the identification of areas where the limit values are exceeded.

The determining factors are the wind direction and speed. Wind direction is measured at the height where the pollutant is discharged, and the average direction is the pollutant transporting path. The wind direction, as defined in meteorology, is the direction from which it blows and, therefore, a wind from the N-W will carry pollutants to the S-E.

Wind speed has a double effect, namely:

- wind speed will determine the travel time from source to receiver
- wind speed will affect dilution in the direction of the wind.

In general, the concentration of air pollutants in the direction of the wind is inversely proportional to the wind speed. Assessing atmospheric stability by measuring temperature differences has frequently been used as an indirect measurement method.

The description of the concentrations range can be performed with accuracy, but laboriously, by differential equations which model the turbulent diffusion process, or statistically, based on observations, by considering a distribution function, among which the most used is Gauss.

The distribution depends on two parameters:

- average deviation, which shows the position of the distribution center;
- standard deviation, which specifies the width of the Gaussian bell.

The most common set of dispersion coefficients is:

- Pasquill-Gifford coefficients, also called rural Pasquill coefficients;
- McElroy-Pooler coefficients, also called urban Briggs coefficients.

The standard deviations or the dispersion coefficients depend on the horizontal distance in the wind direction, on the land configuration (rural area with smooth land, open or urban areas with tall buildings), on atmospheric stability (tendency to vertical mix due to natural convection currents).

By convention, atmospheric stability has been divided into six classes by Pasquill, from A (extremely unstable) to F (the most stable), in order to represent the progressive growth of atmospheric stability which influences the lateral and vertical dispersion.

The characteristics of the stability classes are:

- A – highly unstable, temperature gradient $< -1.5^{\circ}\text{C}/100\text{ m}$, the trail of smoke shows a strong swing, describing loops;
- B – moderately unstable, temperature gradient between $-1.5\div-1.0^{\circ}\text{C}/100\text{ m}$, the trail of smoke oscillates powerfully, with turbulence;
- C – slightly unstable, temperature gradient between $-1.0\div-0.5^{\circ}\text{C}/100\text{ m}$, the trail of smoke is definitely conical, with an easy swing;
- D – neutral (adiabatic), temperature gradient between $-0.5\div+0.5^{\circ}\text{C}/100\text{ m}$, the trail of smoke is conical, without convective turbulence;
- E – isotherm, temperature gradient between $+0.5\div+1.5^{\circ}\text{C}/100\text{ m}$, the trail of smoke is conical, without convective turbulence;
- F – inversion, temperature gradient $>+1.5^{\circ}\text{C}/100\text{ m}$, the trail of smoke has a flag shape with a trend downwards.

3. Results and Conclusions

For the gaseous pollutant dispersion simulation the Meti-Lis modeling software developed by Japanese researchers was used. Scenarios with pollutants lighter or heavier than the air can be made at definite time intervals and at various gas concentrations in the dispersion trail. Dispersion calculations are based on atmospheric conditions (wind direction and speed, atmospheric stability, the level of solar radiation). Immission can be set for different receptors located at various distances from the source. Receptors position is selected so as to achieve pollutants concentration forecasts in the targets to be protected. The software uses a Gaussian distribution of the density of probable concentrations on the wind direction and vertically.

The pollutant dispersion modeling for the cattle breeding activity took into account several factors:

- The technological process of growth for beef cattle - the shelter is ventilated naturally by windows and doors, animals stay in the shelter 180 days / year;
- weather conditions in the area;
- the use of the emission factors in Minister Order no. 3299/2012 for bovine meat.

To simulate pollutant dispersion in areas adjacent to the location, a wide range of parameters were used. For the duration of the operation EMEP/EEA emission inventory guidebook 2009, updated June 2010 - 4.B Animal husbandry and manure management was used, and a period of 180 days - during which the animals live permanently in the shelter. A map scale of 1: 5000 was used. The receptor height at which imission measurement is made is 1.7 m.

The following classes of atmospheric stability were used for modeling:

- A – extremely unstable, the trail of pollutant strongly oscillates, describing loops;
- B – moderately unstable, the trail of pollutant strongly oscillates, with turbulence;
- C – slightly unstable, the trail of pollutant slightly oscillates.
- D – neutral, the trail of pollutant is conical, without convective turbulence.

Modeling was done for extreme conditions in the area, both in terms of weather and technology. It took into account weather data: the fact that the wind blows mainly from the west and North West and probable temperatures for the interval November to April.

Modeling was conducted for ammonia and particulate PM₁₀, for which the maximum permissible limits are set. Dispersion modeling was done for NH₃ which is the main pollutant. Whereas the program applies to stationary directed sources and our sources are fixed and undirected, in this model we considered as pollutant emission sources the cattle shelter and the solid manure storage platform. We used the calculated 68.1 g/h amount of ammonia for the cattle shelter and 3.5 g/h for the manure platform and then we compared the values obtained with the limits imposed by STAS 12574-87 - Air in protected areas; quality conditions.

Dispersion modeling for suspended particles PM₁₀ was made. It used the calculated particulate amount of 2.8 g/h and then the values obtained were compared to with the limit imposed by Law no. 104/2011 [29] on ambient air quality.

In the case of NO_x (NO and NO₂) modeling was made for NO, as NO₂ was not determined. We used the calculated NO amount of 0.01g/h for the cattle shelter and 0.1 g/h for the manure platform and afterwards we compared them to the value of 30 µg/mc – the annual critical level for vegetation protection provided by Law 104/2011.

Table 5: Modeling of the main pollutants from farming activity

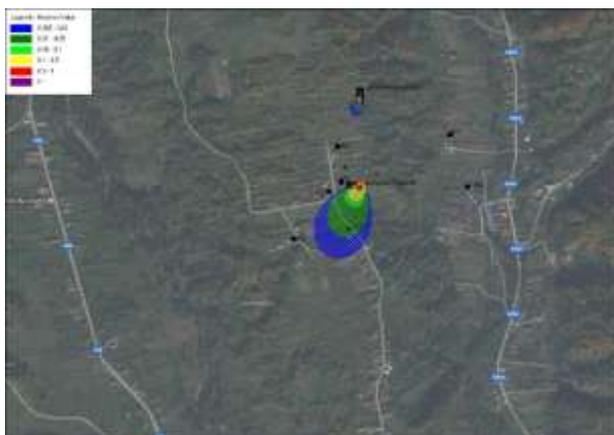
	Wind direction	Wind speed m/s	T ₀ C	Duration minutes	Atmospheric stability class.	Pollutant concentration at receiver						
						R1	R2	R3	R4	R5	R6	R7
Modeling ammonia emission						mg/mc						
1	NNE	1.5	15	30	A	0	0	0	0.006	0.001	0	0
2	N	2	15	1440	C	0	0	0	0.006	0	0	0
3	NE	3	-5	30	C	0	0	0	0	0.003	0	0
4	S	5	-10	30	B	0	0	0	0	0	0	0
5	SV	6	0	30	DD	0	0	0	0	0	0	0.002
6	V	6	20	1440	C	0	0	0	0	0	0	0
7	V	6	-5	30	C	0	0	0	0	0	0.001	0
8	E	2	0	30	C	0.031	0.019	0	0	0	0	0
9	NE	0	0	30	A	0.001	0	0	0	0	0	0
Powders emission modeling						µg/mc/day						
10	NNE	1.5	15	1440	A	0	0	0	0.135	0.033	0	0
11	NE	0	0	1440	A	0.054	0.013	0.003	0.003	0.001	0	0
Nitrogen oxides emission modeling						µg/mc/day						
12	N	3	-5	1440	C	0.003	0.002	0.004	0.002	0.001	0	0

As sensitive receptors we considered:

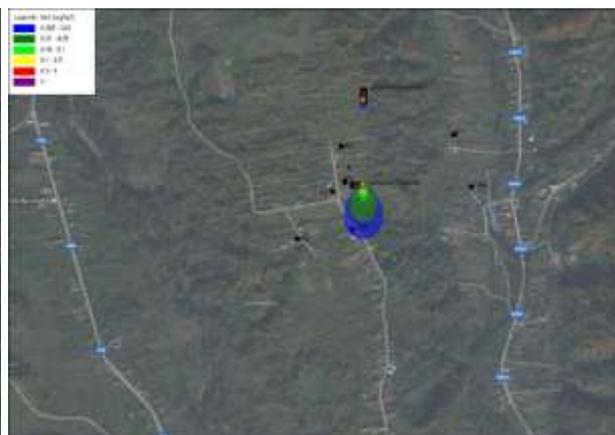
- R1 - the owner's house located 73 m away from shelter;
- R2 - neighbor to the west of the owner's house;
- R3 - neighbor north of the owner's house, 200 m away from the solid manure platform;
- R4 - neighbor south of the owner's house;
- R5 - house SW from the shelter;
- R6 - house E of the shelter;
- R7 - house NE of the shelter;

The figure below shows the results of modeling potential factors that contribute to the movement of pollutants in the region: wind direction, wind speed, air temperature, wind duration and atmospheric stability class.

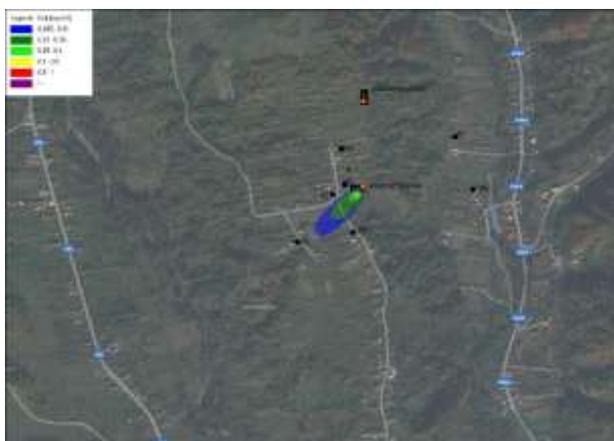
Each image shows the effect of two sources of pollution (animal shelter and storage platform) on the 7 receptors analyzed. According to variables analyzed we see that the effect of pollution on the environment and human health is below maximum levels allowed.



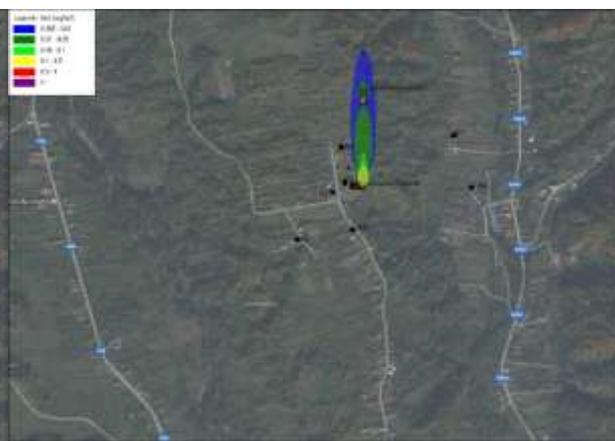
Modeling 1



Modeling 2



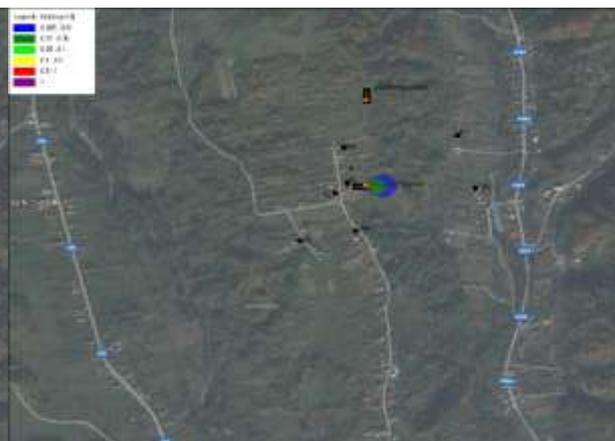
Modeling 3



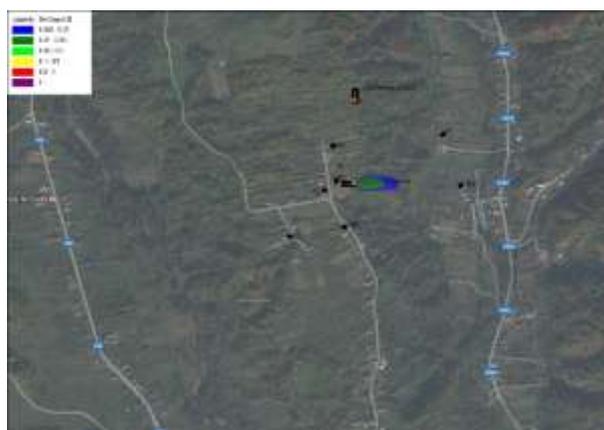
Modeling 4



Modeling 5



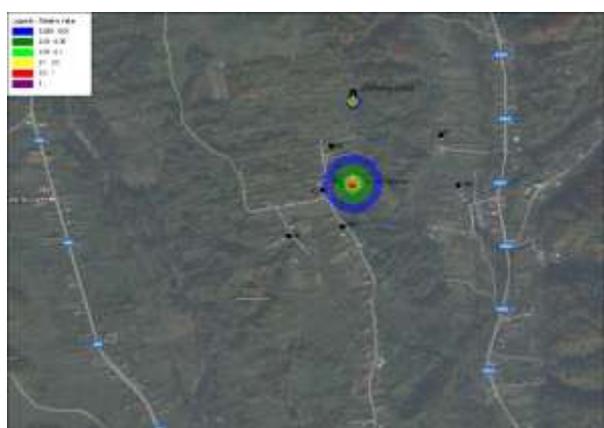
Modeling 6



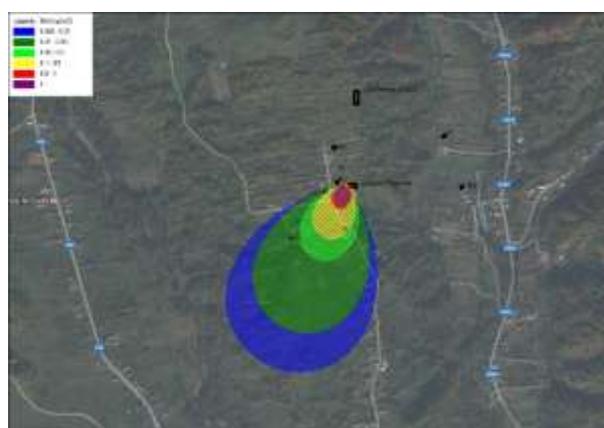
Modeling 7



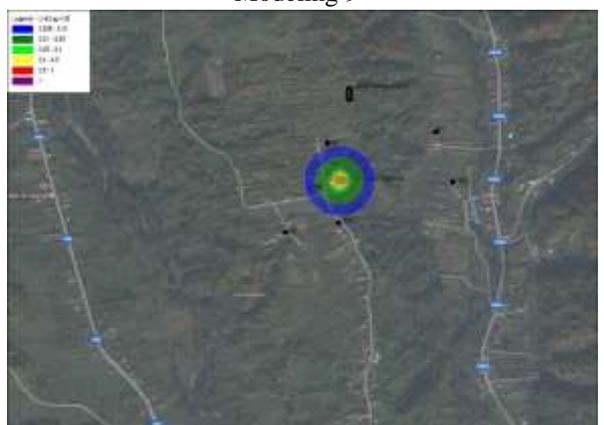
Modeling 8



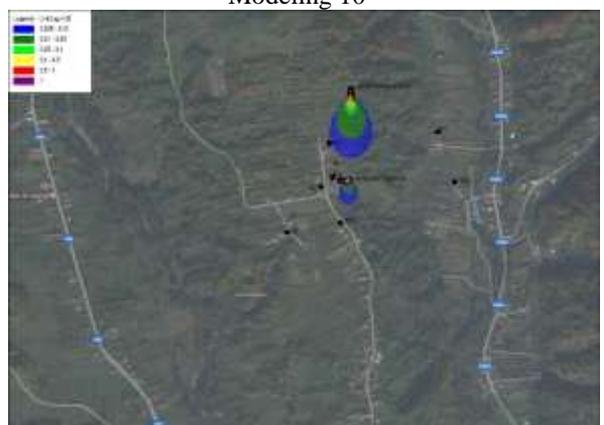
Modeling 9



Modeling 10



Modeling 11



Modeling 12

In the case of the mathematical modeling of pollutants emitted by sources in various weather conditions of temperature and atmospheric stability, wind direction and speed, we found:

a) for ammonia: ammonia concentrations in sensitive receptors are below the maximum admissible limit stipulated in STAS 12574-87 – Air in protected areas – quality conditions in all weather conditions from November to April.

b) for powders: concentrations of PM₁₀ powders in sensitive receptors are below the maximum admissible limit stipulated in Law 104/2011 on ambient air quality of 50 µg/mc/day.

c) for NO: NO concentrations in sensitive receptors are below 30 µg/mc - annual critical level for vegetation protection stipulated in Law 104/2011 on ambient air quality;

d) given the presence of ammonia, under certain atmospheric conditions, the smell may be discernible.

To prevent discomfort in the area, it is necessary:

- to maintain cleanliness inside the shelter by removing manure daily;
- the liquid manure fossa will be kept covered except when being emptied;
- to maintain cleanliness around the shelter;
- transporting to the solid manure storage platform will be made with appropriate means to avoid littering on the road.

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