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A approach of dispersion modeling to determine the impact of odor on the beef food industry.

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Abstract. The consequences due to the increase in the level of pollutants in the air occur in the most diverse areas, for example, environment and health. Among pollutants, the odor stands out for its greater perception capacity than the others. The evaluation of pollution by odor is still considered a difficult task, as bad smells are often caused by different chemical compounds. According to reports from the population that lives near a cattle confinement area, in the municipality of Capão do Leão, Rio Grande do Sul, Brazil, the animals, quarantined there for a certain period, give off a smell considered very strong, causing discomfort among the residents. This work aims to simulate odor dispersion using the advection-diffusion equation as a methodology, with a stochastic wind component. This stochastic formulation is necessary to consider the light wind scenario, in which wind disturbances play an important role.

Keywords: Mathematical modeling, odor dispersion, advection-diffusion equation

1 Introduction

Among the pollutants, by the immediate perception, the odor stands out in number of complaints among the population. Estimating the concentration of odors in the field is a complex task due to the homogeneity of the different emissions. Therefore, it is unnecessary to look for chemical tracers (SIRONI et al, 2010). This is one of the main reasons for using mathematical modeling as a method of assessing the impact of bad smell.

Due to the detection of odors in the environment of the Federal University of Pelotas, on the Campus of Capão do Leão, in a few days, it was possible to detect that the emitting source was from a confinement area for bovine animals, at a distance of approximately 2000m. With the use of meteorological data provided by the National Institute of Meteorology - INMET, applied to a transient three-dimensional equation solved analytically, solutions were obtained consistent with the reports and findings of the odor on specific days.

The methods used for the estimation of odors are usually numerical in character, which can have a high computational cost to the company or industry when using it to evaluate dispersion, estimate the causing source or to estimate maximum odor emissions. In this way, the use of an analytical model makes the process more accessible and with a lower computational cost.

The present work is focused on days with light wind conditions (wind speed below 2m/s) due to its specific characteristics, which cause a higher concentration of pollutants around the source. The main peculiarity of the light wind is the formation of meanders that are horizontal oscillations of the wind around the source, causing the diffusion of the pollutant in an irregular and indefinite way.

2 Dispersion Model

Considering the transient advection-diffusion equation, advective in the horizontal directions and diffusive in the vertical direction, which describes the concentration C of pollutants in the atmosphere, released by a source Q, at the initial time t=0, it is described by Businger [2] as :

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = \frac{\partial}{\partial z}\left(K_z \frac{\partial C}{\partial z}\right) \tag{1}$$

in which C(t,x,y,z) is a concentration function (Kg/m³), K_z is the vertical diffusion coefficient of turbulent transport (m²/s), u and v are average speeds (m/s) in the longitudinal directions and transversal respectively. The equation (1) is subject to the following boundary conditions, initial and source, respectively:

$$K_z \frac{\partial C}{\partial z} = 0\ em\ z = h\ e\ z = z_0 \tag{2}$$

$$uC(0,x,y,z) = Q(0)\delta(x)F(y)\delta(z - H_s) \tag{3}$$

$$uC(t,0,y,z) = Q(t)F(y)\delta(z - H_s) \tag{4}$$

where H_s(m) is the height and Q(g/m²s) is the source intensity F(y) is the average concentration of the pollutant on the y-axis.

the solution of the advection-diffusion equation is obtained by the joint use of the variable separation method with the GILTT (Generalized Integral Laplace Transform Technique) technique. Further details of the solution are found in Gonçalves et al. [3]. In this sequence, the concentration C is expressed by the product of the solutions below:

$$uC(t,x,y,z) = \ F(y - vt)Q(t - \tfrac{x}{u})\xi(x,z) \tag{5}$$

the function $\xi(x,z)$ represents the GILTT solution for a stationary two-dimensional problem. Assuming that F and Q are functions of the Dirac Delta, the plume concentration can be written as:

$$C(t,x,y,z) = \int_0^\infty H(t-\tau)C(t,\tau,x,y,z)d\tau = \frac{2\tau(x,t)}{\sqrt{16\pi^2 K_y K_x t^2}} \int_0^\infty uQ(\tau) e^{\frac{(z(t-\tau)-z)^2}{\frac{4K_y z}{z}}} e^{\frac{(v(t-\tau)-y)^2}{\frac{4K_y z}{z}}} \tag{6}$$

where $t_0 = 0$. The plume can still be decomposed into N segments C_j and, for each segment j that has an arbitrary time interval, the concentration is compatible with the meteorological conditions of the time interval in which the segment was emitted from the source. In this context, in each segment, the horizontal winds are represented by their average components added of their stochastic components. In this way,

$$C(t,x,y,z) = \sum_{j=1}^{N} \frac{Q_j u_j}{\sqrt{\pi D_j A_j}} e^{\frac{4C_j A_j + B_j^2}{4A_j D_j}} \left[\mathrm{erf}\left(\frac{2A_j t_j + B_j}{2\sqrt{A_j D_j}}\right) - erf\left(\frac{2A_j t_{j-1} + B_j}{2\sqrt{A_j D_j}}\right)\right] \xi(x,t) \tag{7}$$

on What $A = u^2 + v^2, B = 2u(x - ut) + 2v(y - vt), C = (x - ut)^2 + (y - vt)^2\ e\ D = 16(\frac{x}{u})^2 K_x K_y.$ The projected index *j* is the *j-th* interval. In this work, *u* (average wind) is presented as:

$$u(z) = \frac{u_*}{k}\left(ln\frac{z}{z_0} + 0{,}74\frac{z - z_0}{L}\right) \tag{8}$$

where z_0 is the roughness, L is the length of Monin-Obukhov, u^* is the speed of friction and k is the Von Karman constant. And a system of two Langevin coupled equations are used to simulate light wind conditions for horizontal winds:

$$u'(t + \Delta t) = -\big(pu'(t) + qv'(t)\big)\Delta t + \sigma_u\sqrt{2p\Delta t}\xi_u \tag{9}$$

$$v'(t + \Delta t) = -\big(qu'(t) + qp(t)\big)\Delta t + \sigma_v\sqrt{2p\Delta t}\xi_v \tag{10}$$

where *p* and *q* are parameters obtained theoretically and ξ are stochastic variables that obey a normal probability distribution function. The diffusion coefficients $K_x, K_y\ and\ K_z$ given by Sharan [4] and Sharan [5] respectively, are:

$$K_x = u[\cosh(\sigma_\theta^2) - 1]^{1/2} \tag{11}$$

$$K_y = u[\sinh(\sigma_\theta^2)]^{1/2} \tag{12}$$

$$K_z = 1{,}69 \left(\frac{u_*}{u}\right)^2 ux \tag{13}$$

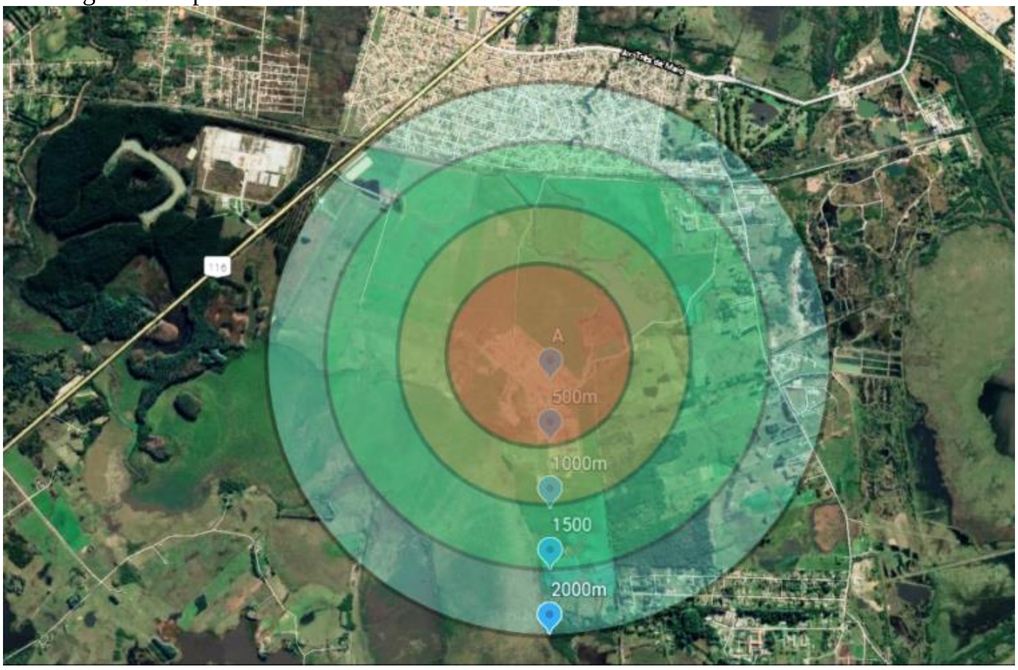
where x represents the distance from the source and σ_θ is the standard deviation of the wind speed direction.

3 Discussions and Results

As a case study, this work was motivated by the experience of witnessing the bad smell exhaled by the bovine confinement area, located in the municipality of Capão do Leão, Rio Grande do Sul, Brazil, close to approximately 2000m of the residential area from the Sítio São Marcos neighborhood and the Campus of the Federal University of Pelotas - UFPel. The solution most compatible with the situation witnessed was elaborated based on the studies by Schulte and Venkatram (2015) and Addullah et al. (2015) who used the planting of trees and vegetation on expressways with nearby residential areas, obtaining positive results, so the planting of vegetation around the cattle confinement area was added to the study.

For the analysis we considered a period of light wind of 1.1m / s, with data calculated for distances of 500m, 1000m, 1500m and 2000m, as shown in figure 1.

Figure1: Map of the location and affected area.



Source: Google Earth, Modified by the author

To perform the calculation, a low source, 1m high, was stipulated so that it could be compatible with the height of the animals, the receiver has a height of 1.70 m, considered the average height of an adult person. The meteorological data was provided by INMET (National Institute of Meteorology), which has a meteorological station nearby, generating data with greater reliability for the experiment.

On June 20 of this year, the presence of odor in the region was noticed at eleven in the morning. the meteorological data provided found that the average wind speed at this time was 1.1 m / s in the direction of 45º. Forty repetitions of the model were considered considering the maximum values of each repetition in real conditions and in illustrative conditions in which trees were planted around the animals' confinement area.The main characteristic of the light wind condition is the formation of meanders, which are oscillations of the wind in the horizontal direction with oscillatory behavior that makes dissipation more efficient.

Table 1. Comparison of pollutant concentration analyzes.

Radius	Without Vegetation	Standard Deviation	With Vegetation	Standard Deviation
500m	12.09	3.80	4.94	2.65
1000m	5.64	2.00	3.14	1.24

1500m	4.09	1.08	1.85	0.54
2000m	2.58	0.68	1.25	0.39

The data presented in the table show that the decrease in odor concentration would decrease in all distances that are being considered. Also pointing out a decrease in the standard deviation between the same radius distances and with the differentiation only the vegetation obstacle.

4 Conclusion:

The analytical solution presented by the model facilitates the understanding and description of the physical phenomena involved in the problem. With the GILTT technique applied to the advection-diffusion equation, the insertion of diffusive coefficients in horizontal directions is a desired adaptation for simulating dispersion in light wind conditions. In addition, the insertion of stochastic variables makes the mathematical representation closer to the phenomena that occur in nature.

The analysis of the data provided proved to be possible through the technique used and considering the characteristics of the wind, the understanding of the extent and dimension of the odor. These data can assist in decision making so that there is a solution to the problem, this solution can be estimated by means of computational mathematical modeling, generating less expenses for the company and a previously calculated answer, which will in fact have the expected results for the population.

The data verified by the pollutant dispersion model found that the planting of trees and vegetation may be an alternative solution to the issue of bad smell that affects the population and students at the University. This alternative has a low monetary cost and does not affect the territory of the animals, on the contrary it can be an ecological possibility.

The technique used has low computational cost due to its resolution being given in an analytical way, which makes the method differential since in the literature the materials use the numerical models to verify the odor.

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