ENVIRONMENTAL IMPACT EVALUATION OF ODOR DISPERSION EMITTED FROM PIG FARMS: A CASE STUDY FROM ALBAN, CUNDINAMARCA, COLOMBIA

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ABSTRACT
The purpose of this research was to determinate the environmental impacts generated by the offensive odors coming from pig farming in the Alban municipality, located in Cundinamarca, Colombia. The main objective was to propose guidelines for the elaboration of a Plan for Offensive Odor Impact Reduction for the pig farms of the municipality. Initially an environmental impact evaluation was carried out. Then the application of the protocols established in Colombian regulations: NTC 6012-1 and Resolution 1543 of 2013 of the Ministry of Environment and Sustainable Development (MADS) resulted in a relevant impact on the air quality. This was ratified in the developed psychometric analysis that allowed us to identify a particular nuisance of offensive odors in the village of Pantanillo within the sector located on the right side of the road that communicates Albán and Guayabal de Siquima, taking into account that among the results obtained within the psychometric analysis the perception by odor level showed values between "Strong" (35.0%) and "Very strong", (20.0%) for the possible affected zone, while in the control area C, 72% considered it "very faint" and "no odor", finally proposing guidelines for the development of a program of reduction of offensive odors that fits the type of population existing in the study area and allow a reduction in the discomfort by offensive odors.
Keywords: environmental impacts, offensive odor, pig farming, reduction of offensive odors.

1 INTRODUCTION

Environmental odors represent a special air pollution problem that sometimes overrides the general air quality [1]. Odor-producing compounds like ammonia, aliphatic amines, hydrogen sulfide, carbon disulfide, mercaptans, BTEX, chlorobenzenes and chloroform originate from various activities like waste management plants, industrial production, and animal production facilities [2]. Odor from pig styes or pig production is a severe problem that causes substantial nuisance to neighbors and prevents the farmers from developing production [3], [4]. Ammonia emissions from intensive pig production are a major public concern due to their potential effects as a public nuisance [5].

In Colombia, pig farming is one of the economic sectors with the greatest growth in recent decades. Despite the world economic situation having harmful effects on the national economy, national pork production reached 46,888,080 tons [6], However, its production generates environmental impacts on water, soil and air. One of the main impacts of the sector is the generation of odors. Although such odors are not always harmful to people's health, they do generate nuisances for the communities surrounding pig husbandry. This type of nuisance causes displeasure and discomfort for the surrounding community and generates environmental impacts on the air quality. This affects the quality of life because it makes it uncomfortable to eat and sleep, and interrupts the daily life of the people who generally live


WIT Transactions on Ecology and the Environment, Vol 259, © 2022 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/AWP220061

in the immediate vicinity of the pig farms. Because of the above, it is necessary to look at this line of the economy that has great potential for improvement and development, hence the importance of proposing good practices for the management of offensive odors in this sector.

Quantitative and qualitative characterization of odors can be carried out by direct or indirect methods of odor control, and the following approaches are used: dynamic olfactometry, dispersion models, field inspection, electronic noses, and odor surveys [7]. The Resolution 1541 of 2013 [8] in Colombia, establishes ambient air quality standards and source emission assessment of offensive odors. The application of this resolution establishes the evaluation of a complaint using standardized surveys.

Colombian regulations establish permissible levels of air quality or emissions, for the case of offensive odors, and the standard peaks of reference conditions at 25°C and 760 mm Hg. Additionally, it provides procedures for the evaluation of activities that generate offensive odors, and it establishes measurement methods by analytical techniques and the prevention of odor generation through the odors impact reduction plans (OIRP). This paper evaluated a psychometric analysis based on the NTC 6012, for knowing the magnitude of the nuisance associated with offensive odors from this activity and generated guidelines for odors impacting reduction plans (OIRP).

2 ODOR'S ENVIRONMENTAL IMPACT

Air pollution from odor compounds is a significant problem for cities nowadays Odor emissions are a common source of complaints, affecting the quality of life for people. Odor is a property of a mixture of different volatile chemical species (sulfur, nitrogen, and volatile organic compounds) capable of stimulating olfaction sufficiently to trigger the sensation of odor [7]. Exposure to environmental odors is one of the major causes of complaints made by residents living near different kinds of industrial and agricultural settlements [12]. The harmful effects of odors are not related to their toxic effects on the body but result from people´s subjective reception and evaluation that has an adverse effect on the human psyche in the long run [13].

The most important pollutants that impact the environment that are emitted from livestock buildings used for the production of monogastric animals are odors and ammonia (NH_3). Odorous substances are more relevant on a local scale, causing annoyance to nearby residents [14]. The highest rate of odor emissions came mostly from pig farms [15] and represent one the most current topics in terms of industrial pig farming pollution effects, especially because of nearby settlements [16].

One of the first research projects found is the one carried out in the United States by Douglas Kreis [17] in which the author indicated that the main complaints of animal production industries in the United States were caused by odors emanating from them. He mentions in his research that controls to reduce the impact of offensive odors were costly and limited to the generation or quality of animal production, and he proposed land use planning and zoning for agricultural/animal feeding purposes as a tool to reduce offensive odors.

Nicell [18] carried out an evaluation of the environmental impact of odors and their regulation, measuring the impact of offensive odors according to measurable and objective criteria. In the existing regulation of odors, they took into account the annoyances generated by people according to their perception. The author indicated that the measurement of odors comes from a series of variables known as frequency, intensity, duration, offensive, and location, proposing an approach based on these variables.

At the Latin American level, important investigations were found, such as that of Murguía [19], where the economic repercussions of production and the nature of nuisances due to

offensive odors were discussed, as well as an analysis of the current state of Mexican legislation for the control and regulation of these odors. He initially indicated how the perception of odors can affect human senses and how they can compromise people's quality of life. He also proposed to legislate the impact of odors considering several variables, among them, the distance from the company that emits the odor, size, type of company, and the manufacturing practices of each one. He also mentioned the need to take into account two types of measurement, in any in-situ odor study using an atmospheric dispersion model, and a complementary one, through legislation based on complaints.

In Ecuador [20] an analysis of offensive odors was carried out and mitigation proposals were proposed for an area in Guayaquil. The methodology used for the analysis is the passive measurement of H_2S, sectoring the place with a measurement range of 0.2 to 200 ppm within 48 hours. It was concluded that the measurements exceed the threshold established at the international level, so it was proposed to specify the thresholds for the emission of offensive odors in the city, since they were not defined.

In most countries, environmental legislation covers most types of common air pollutants; and there is little variation between jurisdictions with such legislation. However, odor legislation tends to be much more varied and varies across a wide spectrum: from having little to no specific mentioning in environmental legislation to extensive and rigid detailing in odor source testing, odor dispersion modelling, ambient odor monitoring, setback distances, process operations, and odor control procedures. Odor legislation can be highly variable from one jurisdiction to the next [21].

3 MATERIALS AND METHODS

3.1 Study area

The possible impact area of this study is located in the Chimbe and Pantanillo villages of the Albán municipality in Cundinamarca province. The place where the activity took place was a rural area near the town, at the coordinates 4°54'49.78"N, 74°28'00.83"W (Fig. 1).

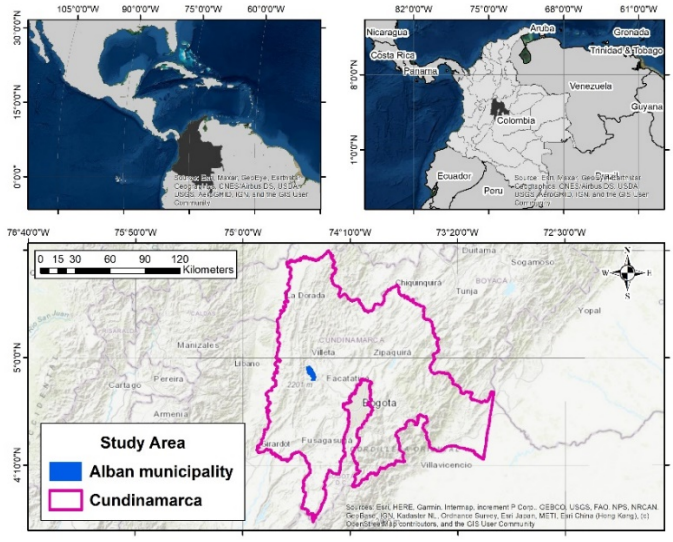

Figure 1: Study area – Alban, Cundinamarca.

3.2 Nuisance odor evaluation

This evaluation was carried out according to the protocols established in NTC 6012-1 and the guidelines required by resolution 1541 of 2013 [8] and the Protocol adopted by resolution 2087 of 2014 [22] as shown in Fig. 2.

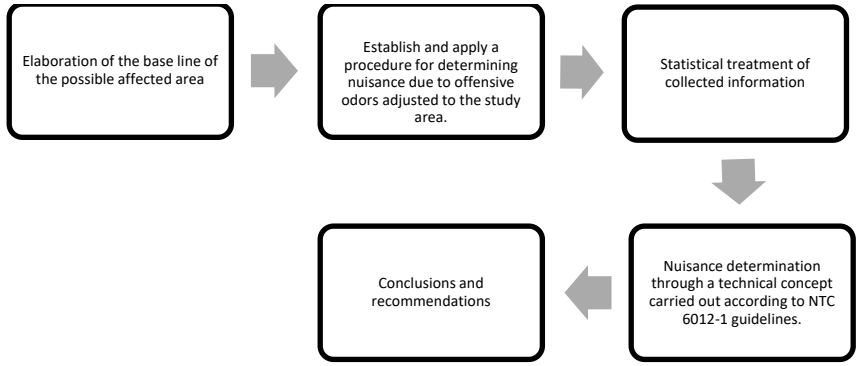

Figure 2: NTC 6012-1 Nuisance odor evaluation.

NTC 6012-1 standards were followed, selecting a possible effective zone (A) and a control zone (C) that must share similar characteristics of environmental, geographic, socioeconomic, housing infrastructure, and vehicular flow. Also, wind direction was taken into account. The data was retrieved from the Colombian "Instituto de Hidrología, Meteorología y Estudios Ambientales – IDEAM"; the nearest weather station was "Tibaitata [21205420]"; the data analysis period was 2017–2021 (Fig. 3). Therefore, in compliance with the technical standards, the possible impact area (A) was defined in the Chimbe village and the control area (C) in Pantanillo village in Albán (Fig. 4).

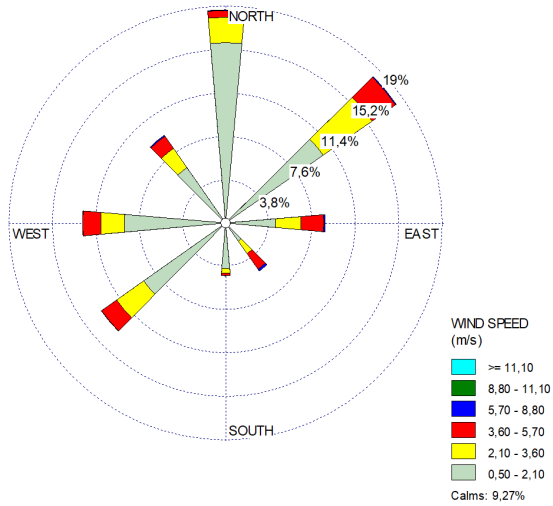

Figure 3: Wind rose study area.

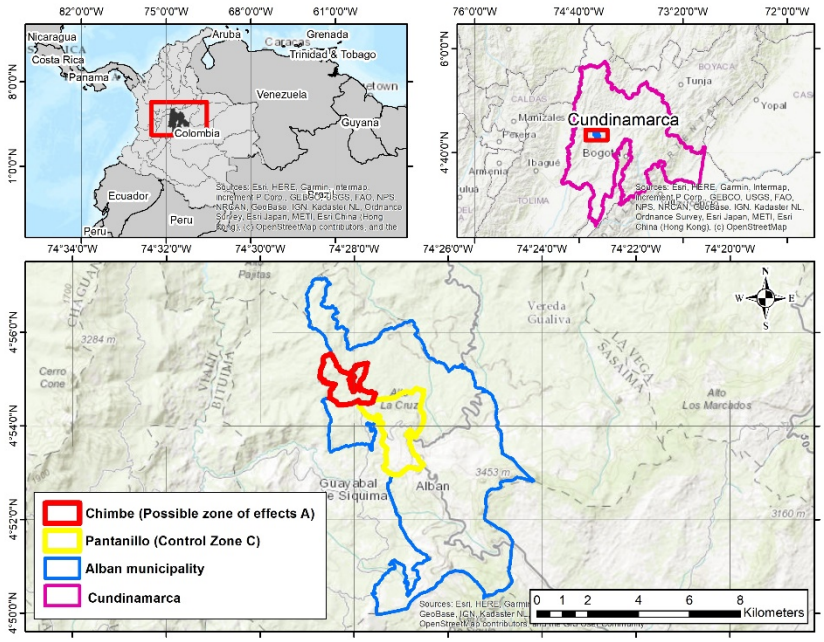

Figure 4: Possible impact area and control zone.

A psychometric analysis through the application of the surveys were applied to people older than 18 years in the possible zone of effects (A) and a control zone (C). The sample size was calculated by the SurveyMonkey sample size calculator [23] with a confidence level of 95% and a margin of error at 5%. The calculated sample size was 11 for Pantanillo and 20 for Chimbe.

The first section of the survey made it possible to characterize the people surveyed based on their spatial location in the area and sociodemographic conditions such as age, economic activity of the property, and how long they have lived in the area. The second part of the instrument presented the following questions: (1) How strong do you perceive odors in the area? (2) How often do you perceive odors in the area? (3) How would you rate the annoyance due to odor in the area where your property is located? (4) Do you consider that discomfort in this area is tolerable or intolerable?

To assess whether or not there were differences in the perception of odors between the control area and the possible affected area, a chi-square test of homogeneity ($\chi 2$) was performed. The results were obtained with the chisq.test package for the R platform [24].

4 RESULTS

4.1 Odor perception

According to those interviewed in the possible zone of effect (A), we found that 35.0% of the population considered that the level of odor was “Strong”, 25.0% “Very faint odor”, 20% as “Very strong”, 10% “Faint odor”, and finally 5% as “Distinct odor” and “No odor”. While for the control zone (C) the results were that the perception with the highest number of responses was “no odor” 36% and “very faint odor” 36%, followed by 27%, as “faint odor”,

as shown in Fig. 5. The results show that there were statistical differences in the perceptions of people between zone A and the control zone C ($\chi 2$=12.557, df = 5, p-value = 0.02791) where these odors were perceived much more in the affected zone.

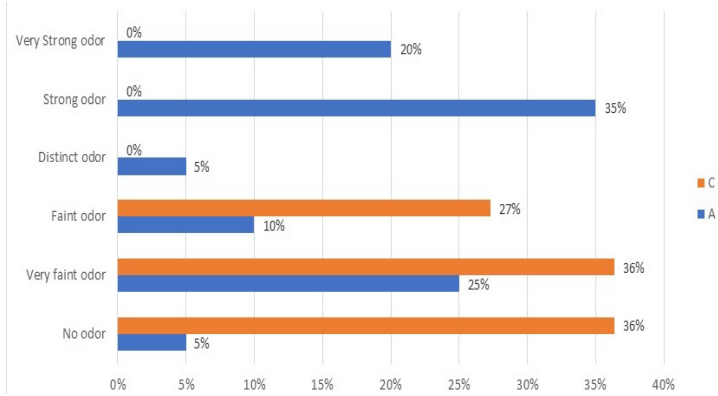

Figure 5: Odor perception.

4.2 Odor perception frequency

The relative frequencies of the data were calculated for the possible effect zone (A), we found that 40% have perceived the odors “Everyday”, 25% “2 or 3 times a week”, 15.0% “2 or 3 times a month”, 10% “1 day a week” and 5% “1 day a month”. The control zone (C) showed the odor frequencies that predominate are “Never” and “1 day a month” with 36% and 27% respectively, followed in equal proportion with 9%, the categories “2 or 3 times a month”, “1 day a month”, “2 or 3 times a week” and “Everyday” (Fig. 6).

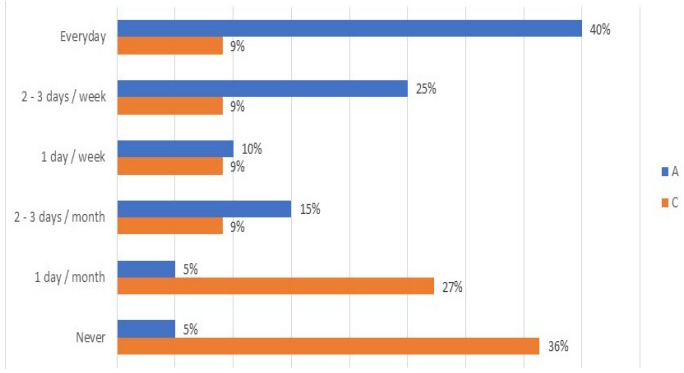

Figure 6: Odor perception frequency.

4.3 Odor nuisance levels

The responses obtained in a possible effect zone (A) for nuisance levels due to odors was level 10 with 35%, then level 9 with 15%, the same as level 5, followed by level 8, 7, and 0

with 10% and finally level 4 with 5%. For the control zone (C) nuisance levels due to odors were level 1 with 45%, followed by level 3 with 18%, and levels 0, 1, 4 and 8 with 9%, as shown in Fig. 7.

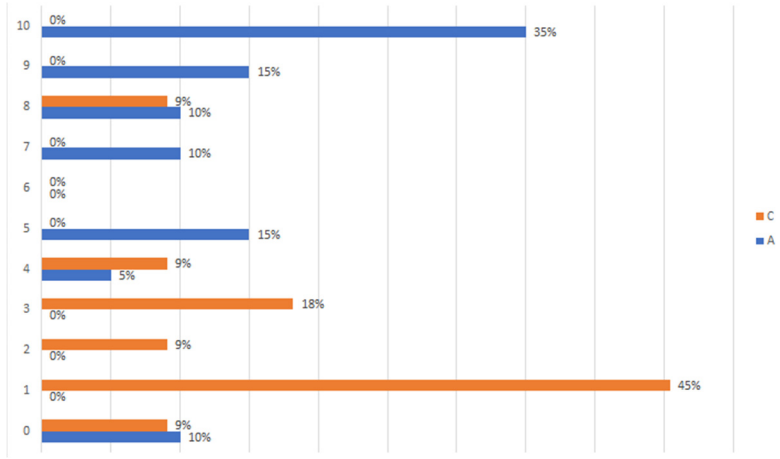

Figure 7: Odor nuisance levels.

4.4 Nuisance tolerance

For the possible zone of effect (A), 60% of the population considered the situation intolerable, and the remaining 40% say it was tolerable, while for control zone C, 100% of the population considered the odor nuisance tolerable.

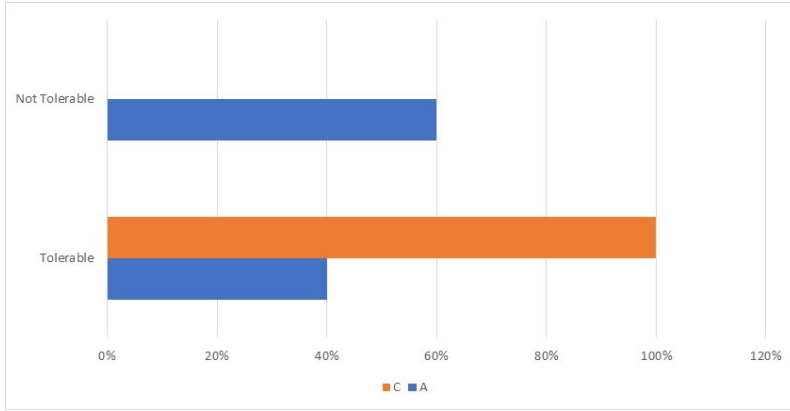

Figure 8: Nuisance tolerance.

4.5 Odors impact reduction plans (OIRP)

In the villages of Pantanillo and Chimbe selected as the study area the productive units that carry out the pig farm activity house a range of 1 to 400 pigs. According to the analysis, this

is an area of low economic income, so they will work with good practices as the main method of reduction, identifying that the main problem is odors [6]. For this, offensive odor reduction programs relating to the livestock sector were reviewed. We identified strong deficiencies in the social area that generated various effects divided between the effect of technical activities, whether good practices and/or best available techniques, and the perception of those possibly affected by offensive odors. Individual perception in many cases eliminates any positive effect on the community of the actions implemented by the possible odor generator [25]. Proposed techniques aim to prevent and reduce emissions of gases by intervening in the processes responsible for its formation and volatilization.

Initially, the installation of natural barriers was proposed that contributed to mitigate impacts and reduce the dispersal of odors that are inherent in production that can affect the communities near the pig farms [26]. Additionally, these barriers improved appreciation of the surrounding populations and the influence of subjective aspects in the perception of odors. Taking into account that according to where the wind arose, the general wind direction in the Albán municipality is north and northeast, this is the direction in which the planting of species should be prioritized that will be arranged approximately 20 m from the boundary of each unit. Planting should not be done at a shorter distance because it can generate an effect contrary to the expected effect, limiting the circulation of air inside the unit and giving rise to different odors. In addition to this condition, it should also be taken into account that these barriers will be formed mainly by three rows of trees. These trees should be scaled in height so that the first row is formed by shrubs, the second by species of medium height, and the third by deciduous trees, orienting the row of shrubs towards the odor-producing units and the taller trees towards the neighboring boundaries.

Reducing the temperature inside the housing and the airflow over the surface of the pig farm can reduce ammonia emissions. But it must be taken into account that guaranteeing an adequate temperature and air renewal are two essential premises both for the welfare of the animals and for the maintenance of their productive yields. Therefore, ventilation and air conditioning systems must always be adjusted according to the needs and comfort of the animals. The following management indicators are presented for the internal control of the air and the conditioning of the housing.

5 CONCLUSIONS

It was possible to identify that conflicts are generated by offensive odors due to poor operating practices. After reviewing existing regulations in Colombia, we determined that the techniques to be developed for the assessment of offensive odors could be validated through a survey in the sector.

Once reviewed the bibliography and the odors impact reduction plans (OIRP). So, we determined that in medium and small producers, typical producers of the study area did not have the technical expertise nor the financial capacity to carry out a OIRP.

It is necessary to use specific guidelines based on good technical practices that are adjusted to the budgets of medium and small producers, as well as an awareness of the activities and investments aimed at odor reduction known by the affected population and so allow changing the perceptions of offensive odors in the study area.

The results of these studies are important for the scientific community because there are very few studies in Latin America and Colombia on the perception of odors in communities near pig farms. This type of study allows assessment whether a community is being affected by offensive odors without the need for monitoring.

ACKNOWLEDGEMENT

The authors thank the University of Cundinamarca for all of their support and information they provided for the project.

REFERENCES

[1] Chunrong, J. et al., Identification of origins and influencing factors of environmental odor episodes using trajectory and proximity analyses. *J. Environ. Manage.*, **295**, 2021. DOI: 10.1016/j.jenvman.2021.113084.

[2] M.Piccardo, M., Geretto, M., Pulliero, A. & Izzotti, A., Odor emissions: A public health concern for health risk perception. *Environ. Res.*, 135907, 2021. DOI: 10.1016/j.envres.2021.112121.

[3] Hansen, M.J., Jonassen, K.E.N., Løkke, M.M., Adamsen, A.P.S. & Feilberg, A., Multivariate prediction of odor from pig production based on in-situ measurement of odorants. *Atmos. Environ.*, **135**, pp. 50–58, 2016. DOI: 10.1016/j.atmosenv.2016.03.060.

[4] Hove, N.C.Y., Van Langenhove, H., Van Weyenberg, S. & Demeyer, P., Comparative odour measurements according to EN 13725 using pig house odour and n-butanol reference gas. *Biosyst. Eng.*, **143**, pp. 119–127, 2016. DOI: 10.1016/j.biosystemseng.2016.01.002.

[5] Tabase, R.K. et al., Effect of ventilation control settings on ammonia and odour emissions from a pig rearing building. *Biosyst. Eng.*, **192**, pp. 215–231, 2020. DOI: 10.1016/j.biosystemseng.2020.01.022.

[6] PorkColombia, Economía porcícola 2020. *Rev. PorkColombia*, **257**, p. 60, 2021.

[7] Conti, C., Guarino, M. & Bacenetti, J., Measurements techniques and models to assess odor annoyance: A review. *Environ. Int.*, **134**, 105261, 2020. DOI: 10.1016/j.envint.2019.105261.

[8] Ministerio de Ambiente & Desarrollo Sostenible, Resolución 1541 del 12 de noviembre de 2013. Bogotá, DC, Colombia, p. 13, 2013.

[9] Brancher, M., Griffiths, K.D., Franco, D. & de Melo Lisboa, H., A review of odour impact criteria in selected countries around the world. *Chemosphere*, **168**, pp. 1531–1570, 2017. DOI: 10.1016/j.chemosphere.2016.11.160.

[10] Zarra, T., Galang, M.G., Ballesteros, F., Belgiorno, V. & Naddeo, V., Environmental odour management by artificial neural network: A review. *Environ. Int.*, **133**, 105189, 2019. DOI: 10.1016/j.envint.2019.105189.

[11] Brancher, M., Piringer, M., Franco, D., Belli Filho, P., De Melo Lisboa, H. & Schauberger, G., Assessing the inter-annual variability of separation distances around odour sources to protect the residents from odour annoyance. *J. Environ. Sci. (China)*, **79**, pp. 11–24, 2019. DOI: 10.1016/j.jes.2018.09.018.

[12] Invernizzi, M., Brancher, M., Sironi, S., Capelli, L., Piringer, M. & Schauberger, G., Odour impact assessment by considering short-term ambient concentrations: A multi-model and two-site comparison. *Environ. Int.*, **144**, 105990, 2020. DOI: 10.1016/j.envint.2020.105990.

[13] Wojnarowska, M., Plichta, G., Sagan, A., Plichta, J., Stobiecka, J. & Sołtysik, M., Odour nuisance and urban residents' quality of life: A case study in Kraków's in Plaszow district. *Urban Clim.*, **34**, 100704, 2020. DOI: 10.1016/j.uclim.2020.100704.

[14] Schauberger, G. et al., Impact of global warming on the odour and ammonia emissions of livestock buildings used for fattening pigs. *Biosyst. Eng.*, **175**, pp. 106–114, 2018. DOI: 10.1016/j.biosystemseng.2018.09.001.

[15] Calafat, C. & Gallego-Salguero, A., Livestock odour dispersion and its implications for rural tourism: Case study of valencian community (Spain). *Spanish J. Agric. Res.*, **18**(2), pp. 1–17, 2020. DOI: 10.5424/sjar/2020182-15819.
[16] Vasile, A., Gheorghita, T., Babeanu, N. & Popa, O., Odour assessment for a pig farm through dynamic olfactometry and air dispersion modelling in order to reduce the odour pollution using biotechnologies. *Rev. Chim.*, **71**(1), pp. 61–66, 2020. DOI: 10.37358/RC.20.1.7812.
[17] Douglas Kreis, R., Limiting the environmental impact of animal production odors. *Environ. Int.*, 1(5), pp. 247–275, 1978. DOI: 10.1016/0160-4120(78)90026-0.
[18] Nicell, J.A., Assessment and regulation of odour impacts. *Atmos. Environ.*, **43**(1), pp. 196–206, 2009. DOI: 10.1016/j.atmosenv.2008.09.033.
[19] Murguía, W., Contaminación por olores: el nuevo reto ambiental. *Gac. ecológica*, **82**, pp. 49–53, 2007. http://www2.inecc.gob.mx/publicaciones/gacetas/521/olores.pdf.
[20] Ortega Vélez, A.-F., Análisis De La Inmisión De Olores Ofensivos En El Ramal 'A' Del Estero Salado De La Ciudad De Guayaquil Y Propuesta De Mitigación, 2016.
[21] Bokowa, A. et al., Summary and overview of the odour regulations worldwide. **12**(2), 2021.
[22] Ministerio de Ambiente & Desarrollo Sostenible, Resolución 2087 del 16 de diciembre de 2014, **53**(9), pp. 1689–1699, 2014.
[23] SurveyMonkey, SurveyMonkey sample size calculator, 2020.
[24] R Core Team, R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, 2020. https://www.r-project.org.
[25] Urrego Ortiz, E.L., Propuesta De Una Guia Teórica Y Práctica Para El Diseño De La Planificación En Un Sistema De Gestión Ambiental Para Granjas Porcicolas En El Departamento De Cundinamarca, 2016.
[26] PorkColombia, Guía de mejores técnicas disponibles para el sector porcícola en Colombia, 2015. https://www.porkcolombia.co/wp-content/uploads/2018/07/Guia-MTD-en-la-Porcicultura-de-Colombia.pdf.