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RESEARCH ARTICLE OPEN ACCESS

ATMOSPHERIC DISPERSION STUDY OF AIR POLLUTANT PM10 GENERATED IN ALUMINUM RECYCLING

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ABSTRACT

Despite all the progress made in reducing air pollutant emissions over the last decades, air pollution still represents one of the major environmental problems in urban centers. Air quality can be assessed at local, regional, national and international levels by estimating emissions, using mathematical models and measuring the environmental concentrations of major pollutants using physicochemical methods. Through such measures, it is possible to verify whether standards and limit values for air pollutant concentrations, established or recommended by national governments. Possible effects depend not only on the concentration and duration of the impact, but also on many different factors such as climate, nutritional status, predisposition, age, the simultaneous impact of other pollutants and others that play an important role. From these considerations, the objective of this work is to conduct a study of the concentrations of isokinetic monitored atmospheric pollutants at the chimney outlet, the production process of the Alutech Aluminio LTDA Company, with the pollutants monitored at the stations of the Duque City Quality Telemetric Network. de Caxias, correlating them with the meteorological variables, proposing control measures and procedures to mitigate the impacts on the surrounding population. Crossing this data will allow modeling of each source, dispersion, coverage and distance from the source. It will be possible to analyze the behavior of the dispersion plumes with the variation of the source height, seeking the minimum variation for better dispersion of the pollutants. It will be possible to plan actions on days of thermal inversion, such as feed ratio / production capacity, retention time and fugitive emissions from the control system, so that there is better dispersion of pollutants.

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INTRODUCTION

The demographic growth and the economic development marked by the Industrial Revolution, in the 18th and 19th centuries, led to an increase in the demand for natural resources, and, consequently, the environmental impacts started to grow at an accelerated pace, even causing an imbalance not only locally, but also on a global scale (Conceição, 2017). The intensifications of this development, added to the population agglomeration in urban centers, made atmospheric pollution not only an environmental problem, but also a public health problem. In addition to the deterioration of air quality and soil and water pollution, exposure to air pollutants is associated with cardiovascular and respiratory diseases and cancer (RIBEIRO, 2010). In view of this, with the growing concern of society in search of commitment to environmental causes as well as the minimization of impacts caused to health, combined with the strengthening of inspection by the competent inspection bodies, it was necessary to use and improve processes environmental monitoring, specifically that of Air Quality. According to Bitar; Ortega (1998), the monitoring of air quality consists of data collection, study and continuous and systematic monitoring of parameters, with the objective of identifying and evaluating - qualitatively and quantitatively - the atmospheric air conditions at a given moment, as well as trends over time, allowing the development of strategies and regulations for the control of air pollution. The municipality of Duque de Caxias spans 467,271 km² and had 914,383 inhabitants in the last census (IBGE, 2018). The demographic density is 1,956.86 inhabitants per km² in the territory of the municipality. The municipality is limited to the north with Petrópolis and Miguel Pereira; to the east, with Guanabara and Magé Bay; to the south, with the city of Rio de Janeiro and, to the west, with São João de Meriti, Belford Roxo and Nova Iguaçu. Caxias has a warm climate, but the third and fourth districts (Imbariê and Xerém) have a mild temperature due to the green area and the proximity to the Serra dos Órgãos.

This urban and industrial development, despite generating several benefits, has increased the levels of air pollutant emissions in the region. In order to quantify and evaluate these emissions, the municipality has a Telemetric Air Quality Network comprising stations that continuously monitor, in real time, the concentrations of particulate materials (MP1, MP2.5 and MP10), total suspended particles (PTS), sulfur dioxide (SO2), hydrogen sulphide (H2S), carbon monoxide (CO), ozone (O3) and nitrogen oxides (NOX, NO and NO2). It is also noteworthy that this monitoring network is an important control mechanism in the context of not only the degradation of air quality, but also in the preparation of inventories, in the evaluation of health effects and in the dissemination of data for the knowledge of population, as these are the most affected (CARVALHO et al., 2015).

The lack of studies on air quality in the Duque de Caxias region as well as the current spatial distribution of sources of emissions, make this work an important source of information on the concentration of air pollutants in the region and on air quality standards. Based on these considerations, the objective of this work is to carry out a dispersion study of atmospheric pollutant PM 10 monitored by isokinetics at the chimney outlet, of the production process of Empresa Alutech Aluminio LTDA, established in the city of Duque de Caxias, Rio de Janeiro, correlating it with meteorological variables, proposing control measures and procedures to mitigate the impacts on the population surrounding the company.

METHODOLOGY

Isokinetic Monitoring: This evaluation consisted of the insertion of a sampler for particulate material in the chimney outlet duct. The sampling was carried out by the company WS Engenharia Ambiental Ltda, specialized in this type of analysis. With the results of the analysis it was possible to measure the efficiency of the atmospheric control system. The measurements were carried out in accordance with the methods of the State Institute of the Environment - INEA, environmental agency of the State of Rio de Janeiro and U.S Environmental Protection Agency (USEPA):

- MF-511 - Determination of points for sampling in chimneys and ducts from stationary sources.
- MF-512 - Determination of the average gas velocity in chimneys.
- MF-514 - Determination of gas humidity in chimneys.
- “Method 3A - Determination of Oxygen and Carbon Dioxide Concentrations in Emissions From Stationary Soucers (Instrumental Analyzer Procedure)”.
- “Method 17 - Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration Method)”.

Air Quality Data: The meteorological data used were real, taken from the monitoring station of the International Airport of Galeão, for the period from January 1 to December 31, 2017, totaling 8,760 hours of information, where the following parameters were used: direction (degrees) and wind speed (m / s), ambient temperature (C °), cloud cover (tenth) and barometric pressure that were inserted in AERMET, responsible for processing and preparing meteorological files in formats (* .sfc and * .pfl) , which were used as input data, in SAMSON format, in AERMOD View.

The file with the extension (*.sfc) presented the surface meteorological data, while the file (*.pfl) contained information related to the parameters of the boundary layer, calculated by AERMET.

The air quality data were obtained from the Jardim Primavera telemetric air quality station, operated by INEA, from the time series, for the period from January 2017 to December 2017, available on the website, for the oxide parameters of nitrogen (NOx), ozone (O3), carbon monoxide (CO), sulfur dioxide (SO2) and particulate matter (MP10), relative humidity (ur), as well as meteorological data such as wind speed and direction.

Pollutant Dispersion Modeling: The dispersion model used in this study was the AERMOD View software version 9.6 from Lakes Environmental Consultants, Inc. Ontario-Canada. The technical characteristics selected in the software for the modeling of this research were:

- Receivers; Area of influence of industrial activity represented by a Cartesian coordinate system (x, y), considering the elevation of each point of the receiver, in relation to sea level;
- Meteorological data; actual data for the year 2017;
- Results of pollutant concentrations: First Maximum for periods of 24 hours and annually; and
- Pollutant: Particulate Material (MP10).

As a source of atmospheric pollutants, 01 (one) chimney was selected. The technical variables that characterize the emitting source (chimney) used as input data in AERMOD View were as follows: geographic coordinates of the source; altitude at the base of the source; physical height of the source; internal diameter of the source at the chimney outlet; concentration data monitored by isokinetics.

RESULTS

Isokinetic Monitoring: The results of isokinetic monitoring are shown in table 1. The result obtained for the Particulate Material parameter was compared by similarity with the Resolution of the National Environment Council (CONAMA) 382/2006, for Portland Cement activity in which the limit for Particulate Material is 50 mg / Nm³. The INEA directive that establishes the limit for this pollutant has been revoked. It is noted that the average value found is well below the limit, in accordance with current legislation.

Pollutant Dispersion Modeling: The selection of sources of emissions of atmospheric pollutants, the quantification of emissions, constitute a fundamental subsidy for the development of the intended dispersion simulations. The dispersion mathematical model was used to determine the impact (contributions) of these sources on the air quality of the region of interest. The dispersion modeling was performed considering the fixed source (chimney) located after the atmospheric control system using bag filters. The height of the chimney was 10 meters. Emissions dispersion was evaluated in a grid of receivers, with a coverage equivalent to 500 km2 for the simulated area. The basic variables that characterized the chimney and used as input data in the AERMOD View software were: geographic coordinates of the emission source; altitude at the base of the emission source; physical height of the emission source; and internal diameter of the emission source at the chimney outlet, with a unit of measurement in meters. Table 2 shows the physical characteristics of the fixed emitting source used in the simulations.

The properties of atmospheric emissions used in the simulations were estimated from emission factors characteristic of the production activity. Only fixed (isokinetic) sources were considered for the modeling, disregarding mobile sources and fugitive sources. The choice of the pollutant (MP10) is justified by the significance of its emissions in the typologies of sources of the productive activities existing in the studied region. As well as being considered conventional and / or regulated by CONAMA resolution 03/1990 (which establishes primary and secondary air quality standards to be obeyed in the study region), in addition to being precursors to the formation of secondary pollutants in the atmosphere. The main meteorological variables in the study area that contributed directly to the dispersion of air pollutants were temperature, speed, wind direction and precipitation. The plume of pollutants resulting from the 24-hour simulation had an approximate perimeter of 30 km, dispersing mainly in the Northeast (NE), Southwest (SE) and West (W) directions, as can be seen in the isolines of figures 01, 02 and 03. The displacement of the plume in the Southwest orientation, in a straight line, from the emitting sources, with concentrations varying from 4.48 to 3.03 µg / m3 (close to the sources, with height variation from 10 to 14 m) and, from 0.04 to 0.03 µg / m3 (at the most distant points) as shown by the concentration isolines. Table 3 shows the minimum and maximum concentrations for each height simulation. The data reported in table 3, compared to the isolation profile of figures 01, 02 and 03, show that the base height of 10 meters, has a reduction of 13% when increased by 2 meters, 25% when increased by 4 meters. In these figures, it can be seen that Vila Maria Helena and Parque Santa Lucia were the places affected by the dispersion of simulated air pollutants.

Table 1. Results of isokinetic monitoring after the atmospheric control system

	Values					
	Symbols	unity	sample 1	sample 2	sample 3	Average
Sampling date	-	-	03/07/2018	03/07/2018	03/07/2018	-
Sampling duration	t	min	60	60	60	-
Chimney temperature	Tc	°C	57	57	58	57
Volume measured at CNTP	VgN	Nm³	0,9940	1,0421	0,9882	1,0081
Gas humidity	Bag	%	1,32	1,26	1,07	1,22
Gas speed	v	m / seg	8,85	9,22	8,66	8,98
Normal dry flow	Qnbs	Nm³ / h	81.994	85.436	82.037	83.156
Isokinetic	I	%	99,21	99,85	98,60	-
Concentration of particulate material	C	mg / Nm³	6,84	2,69	7,69	5,74
Emission rate of particulate matter	Te	Kg / h	0,561	0,230	0,631	0,474

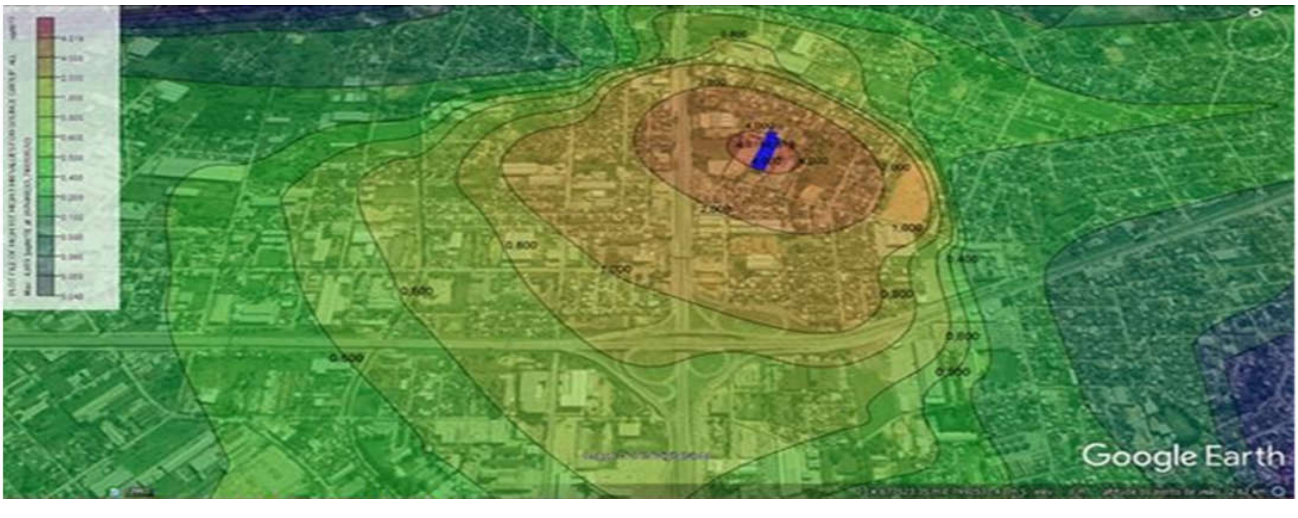

Figure 01. Modeling of PM10 with the AERMOD model - isolines of plume concentrations over inhabited areas, for a chimney with a height of 10 meters. Annual simulation

Table 2. Physical characteristics of the emitting fixed source

Source	Characterization of sources				Emission fee
description	Chimney height (m)	Gas temperature (k)	Gas velocity (m / s)	Chimney diameter (m)	Particulate material (kg/h)
Chimney	10	33	8,98	2	0,474

Table 3 . Variation of the minimum and maximum concentrations of PM10, with variation in the height of the chimney

Altura da Chaminé (m)	Concentração Máxima (µg/m3)	Concentração Mínima (µg/m3)
10	0,048	4,81
12	0,04	4,22
14	0,04	3,58

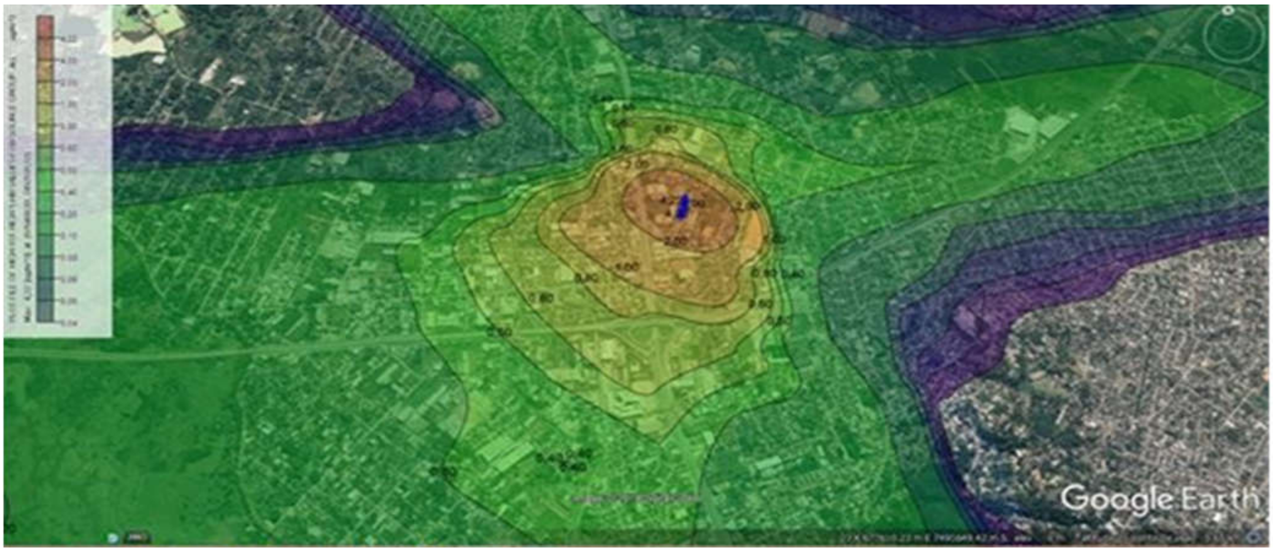

Figure 02. Modeling of PM10 with the AERMOD model - isolines of plume concentrations over inhabited areas, for a chimney with a height of 12 meters. Annual simulation

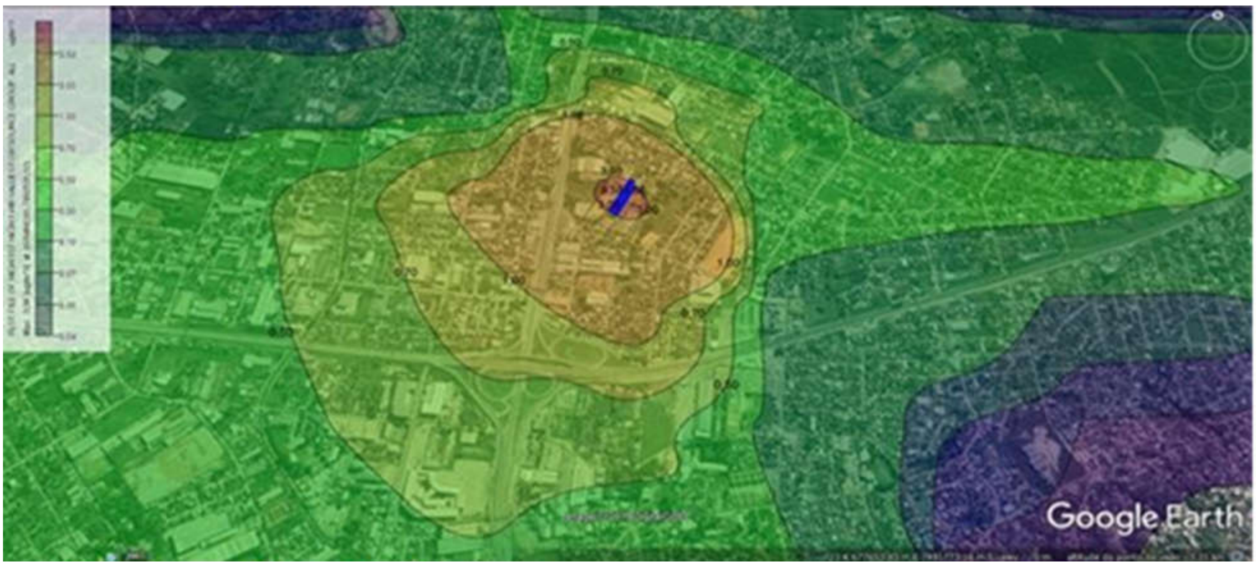

Figura 03. Modelagem de PM10 com o modelo AERMOD - isolinhas de concentrações da pluma sobre áreas habitadas, para uma chaminé com altura de 14 metros Simulação anual

The evaluated areas presented heterogeneity of economic activities such as commerce, services, leisure and industries, offering a better offer of public services, among others, water supply networks, electricity distribution network and health care service. Most of the properties lacked domestic waste collection, water and sewage treatment services. The distribution of electricity and water extended to all households. Regarding the constructive typology and the existence or not of infrastructure (basic sanitation, energy supply, health service, community organization, etc.), it was noticed that the forms of occupation existing in the communities are reflected in a spatial organization with great disparity between Vila Maria Helena and Parque Santa Lucia. It is important to note that in the communities reported there was no evidence of the effects of exposure to particulate matter, which would suggest an association with adverse effects on respiratory health. The increase in the chimney by 04 meters was sufficient for the dispersion of particulate material, not affecting the population in the surroundings, given the 25% reduction in concentrations. Corroborated by the efficiency of the installed control system, since the results of the isokinetic sampling showed that the concentration at the entrance was measured at 266.32 mg / Nm3 and after exit 5.74 mg / Nm3.

Conclusion

The modeling demonstrated the possibility of using the AERMOD View model to verify the spatial distribution of the receivers, the range and distribution of the pollutant plumes, in the estimation of the concentrations of pollutants emitted and comparisons between concentrations of simulated pollutants and air quality. The plume of pollutants resulting from the 24-hour simulation had an approximate perimeter of 30 km, dispersing mainly in the Northeast (NE) and Southwest (SE) directions, the identification of the areas affected by atmospheric pollution, through the subposition of the pollutant concentration isolines in the aerial image of the research target region. Vila Maria Helena and Parque Santa Lucia were the places affected by the dispersion of simulated air pollutants and there was no evidence of the effects of exposure to particulate matter, that they were associated with adverse effects on respiratory health. It is considered that the increase of the chimney in 04 meters is sufficient for the dispersion of the particulate material, not affecting the population in the surroundings, considering the reduction in 25% of the concentrations.

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REFERENCES

Allen, A.G. et al. Influence of sources and meteorology on surface concentrations of gases and aerosols in a coastal industrial complex. Journal of the Brazilian Chemical Society. Vol.20. p.214-221. 2009.

Baird, C., Cann, M. Environmental chemistry. Translation: Marcos Tadeu Grassi et al. Bookman Publisher, 4th ed. Porto Alegre. 2011.

Baldasano, J.M. et al. Air quality data from large cities. The Science of the Total Environment. v. 307. n.1. P. 141–165. 2003.

Barbon, A; Gomes, J. Simulation of atmospheric emissions over the municipality of Araucária using the AERMOD model. Environmental Sanitary Engineering. v.15 n.2. P. 129-140. 2010.

Bezerra, A.C.N. Cavalcanti, E.P. Static energy over the north and northeast of Brazil related to sea surface temperature. Brazilian Journal of Meteorology. v.23. n.2. p.239-263. 2008.

Botelho, C. et al. Environmental factors and hospitalizations in children under five with acute respiratory infection. Public Health Notebooks. v.19. n.6. p.1771–1780. 2003.

Bakonyi, S.M.C. et al. Air pollution and respiratory diseases in children in the city of Curitiba, PR. Public Health Magazine. v.38. n 5. p 695. 2004.

Brazil Federal Law No. 6,938, of August 31, 1981. Provides for the National Environment Policy, its purposes and application mechanisms and provides other measures. Brasília, DF, 1981.

Brazil. Ministry of the Environment. National Environment Council - CONAMA. Resolution nº 18. Provides for the creation of the Air Pollution Control Program by Motor Vehicles - PROCONVE. Brasília, DF, May 6, 1986.

Brazil. Constitution (1988). Constitution of the Federative Republic of Brazil. Brasília, DF, Senate, 1988.

Brazil. Ministry of the Environment. National Environment Council - CONAMA. Resolution 05. Deals with the creation of the National Air Quality Control Program - PRONAR. Brasília, DF, June 15, 1989.

Resolution No. 03. Provides for air quality standards provided for in PRONAR. Brasília, DF, June 28, 1990a.

Resolution No. 08. Provides for the establishment of maximum limits for the emission of pollutants in the air for processes of external combustion of fixed sources of pollution. Brasília, DF, December 6, 1990b.

Resolution No. 382. Provides for maximum emission limits for air pollutants from fixed sources, Brasília, DF, December 26, 2006.

Resolution No. 418. Provides for criteria for the elaboration of Vehicle Pollution Control Plans - PCPV and for the implementation of Inspection and Maintenance Programs for Vehicles in Use - I / M by the state and municipal environment agencies and determines new limits of emission and procedures for assessing the maintenance status of vehicles in use. Brasília, DF, November 25, 2009.

Cançado, J.E. et al. The impact of sugar cane-burning emissions on the respiratory system of children and the elderly. Environmental Health Perspectives. v.114. n.5. p.725-729. 2006.

Carmo, CN. et al. Association between particulate matter from fires and respiratory diseases in the southern region of the Brazilian Amazon. Panamerican journal of public health. v.27. n.1. p.10-6. 2010.

Carvalho JR, J.A., Lacava, P.T., Emissions in Combustion Processes. Editora UNESP, São Paulo, 2003.

Cavalcanti, P.M.S. Evaluation of the impacts caused on the air quality by the thermoelectric generation. 2003. 100f. Dissertation (master's degree), COPPE / UFRJ, Rio de Janeiro, RJ, 2003.

Cerqueira, L. Air Pollutants, Free Forum. Available in: <http://www.unilivre.org.br/centro/textos/polar.htm. 2010>. Accessed on: February 15, 2019.

Clancy, L. et al. Effect of air-pollution control in deaths rates in Dublin, Ireland: an intervention study. The Lancet. v. 360, n. 9341, p. 1210-1214, 2002.

Technological Company OF Environmental Sanitation (CETESB). 1st Emissions Inventory direct and indirect anthropogenic greenhouse gas emissions in the state of São Paulo; Sao Paulo; 1 CD: il. Color; CETESB, 2011a.

Vehicle pollution control plan for the State of São Paulo - 2011 - 2013, São Paulo, CETESB, 2011b.

Conceição, G.M.S. et al. Mlg and MAG models to analyze the association between air pollution and morbidity and mortality markers: an introduction based on data from the city of São Paulo. Brazilian Journal of Epidemiology, v. 4, n. 3, p. 206-219, 2001.

Cortez, L.A.B ., Lora, E.E.S ., Olivares Gómez, E. Biomass for energy. Campinas. SP. Unicamp Publisher. 2009.

Costa, A.C.L. Hydrometeorological studies in a rainy rainforest in the Amazon - Project ESECAFLOR. Brazilian Journal of Meteorology. v. 21. n.3b. P. 283 - 290. 2006.

Christofoletti, A. Modeling of environmental systems. São Paulo: Editora Edgard Blücher Ltda, 236p.1999.

Cimorelli, A. J ., Perry, S. G ., Venkatran, A ., Weil, J. C ., Paine, R. J ., Wilson, R. B ., LEE, R. F .,

Peters, W. D ., Brode, R. W. Aermod: A. Dispersion Model for Industrial Source Applications Part I: General Model Formulation and Boundary Layer Characterization. Journal of Applied Meteorology. v. 44. p. 682 - 693. 2004a.

Cimorelli, A.J. et al. Aermod description of model formulation. EPA-454 / R- 03-004. 2004b.

Cunha, R.M.P. Pollutant transport in the region of the petrochemical pole of triumph. 2002. 155f. Dissertation (master's degree) - Federal University of Rio Grande do Sul, State Center for Research in Remote Sensing and Meteorology, Porto Alegre, 2002.

Daumas, R.P ., Mendonça, G.A.S ., León, A.P. Air pollution and mortality in the elderly in the city of Rio de Janeiro: time series analysis. Public Health Notebooks, Vol. 20, n.1, pp. 311-319, 2004.

Derisio, J.C. Introduction to environmental pollution control. 2nd ed. - São Paulo: Signus Editora. 2000.

Duarte, A.F. Aspects of climatology in Acre, Brazil, based on the 1971 - 2000 interval. Revista Brasileira de Meteorologia. v.21. n.3b. p.308-317. 2006.

Environmental Protection Agency (EPA). AERMOD description of model formulation. EPA- 454 / R-03-004. 2004a. Available at: <http://www.epa.gov>. Accessed on: February 15, 2012.

Users guide for the AERMOD meteorological preprocessor (AERMET). EPA-454 / B-03-002. 2004b. Available at: <http://www.epa.gov>. Accessed on: January 12, 2012.

Users guide for the AMS / EPA Regulatory Model - AERMOD. EPA-454 / B- 03-001. 2004c. Available at: <http://www.epa.gov>. Accessed on: January 15, 2012.

Users guide for the AERMOD terrain preprocessor (AERMAP). EPA- 454 / B-03-003. 2004d. Available at: <http://www.epa.gov>. Accessed on: January 15, 2012.

Esquivel, G.A.R. et al. Evaluation of the correlation between concentrations of air pollutants and mortality in the elderly in the city of Curitiba. Environmental Sanitary Engineering. v.16. n.4. p.387- 394. 2011.

Fedorova, N ., Carvalho, M. H. Synoptic processes in La Niña and El Niño years: convective cloudiness in the equatorial and tropical regions of South America and adjacent oceans. Brazilian Journal of Meteorology. v.21. n.1. P. 1-14. 2006.

Freitas, C. et al. Hospitalizations and deaths and their relationship with air pollution in São Paulo, 1993 to 1997. Revista Saúde Pública. v.38. n.6. p.751–757. 2004.

Freitas, M. K. Investigation of the production and dispersion of air pollutants in the urban environment: empirical determination and modeling in neural network of CO concentration. 2003. 242f. Thesis (doctorate) - USP / São Carlos-SP, 2003.

Fruehauf, G.L.C. Deterioration of air quality and climate in the metropolitan region of São Paulo. 1998. 210f. Thesis (doctorate) - Federal University of São Paulo, Institute of Physics, 1998.

Google Earth. Image of the industrial area of Barcarena - Pa. Available at:<www.earth.google.com>. Accessed on: September 15, 2018.

Hanna, S.R. et al. Evaluation of the ADMS, AERMOD and ISC3 dispersion models with from Optex, Duke, Forest, Kinkaid, Indianapolis and Lovett Field data sets. International Journal of Environment and Pollution, vol. 16, n. 1-6, p. 301-314. 2001.

Ignotti E, et al. Effects of burning in the Amazon: method of selecting municipalities according to health indicators. Revista Brasileira Epidemiológica. V.10. n.4. p.453–64. 2007.

Lora, E.E.S. Pollution prevention and control in the energy, industrial and transportation sectors. 2.ed. Rio de Janeiro: Interciência, 2002.

Marengo, J. et al. On the onset and end of the rainy season in the Brazilian Amazon Basin. Journal of Climate. v.14. P. 833-852. 2001.

Martins, L.C, et al. Air pollution and care for pneumonia and flu in São Paulo, Brazil. Public Health Magazine. v.36. n.1. p.88-94. 2002.

Mascarenhas, M.D.M. et al. Air pollution due to the burning of forest biomass and emergency care for respiratory disease in Rio Branco, Brazil - September 2005. Jornal Brasileiro de Pneumologia. v.34. n.1. p.42–46. 2008.

Melo, G.C. B ., Mitkiewicz, G.F. M. Atmospheric dispersion of pollutants in a steel industry complex. In: Inter-American Congress Of Ingenieria Sanitaria Y Ambiental, 28.,

Cancun, Mexico. Proceeding. Cancun, Mexico. p.08. 2002.

Menezes, C.R.C, Monteiro, M.A., Galvão, I.M.F. Ecological-economic zoning of the eastern and southern channels of the state of Pará. Belém, PA: Management Center for the Pará Rural Program, 2010. 2v.

Monteiro, M.A. Half a century of industrial mining in the Amazon and its implications for regional development. Advanced Studies Magazine, v.19, n. 53, p.187-208. 2005.

Moraes, B.C. et al. Spatial and temporal variation of precipitation in the state of Pará. Acta Amazônica. v. 35. n.2. P. 207-214. 2005.

Moreira, D ., Tirabassi, T. Mathematical model for the dispersion of pollutants in the atmosphere: a technical instrument for environmental management. Environment & Society. vol. VII. no. 2. Jul./Dec. 2004.

Munhoz, F. C ., Garcia, A. Characterization of the prevailing wind speed and direction for the location of Ituverava – SP. Brazilian magazine of meteorology.v. 23. n. 1. p. 30-34. 2008.

Oliveira, F. E. M. de. Statistics and probability: exercises solved and proposed. 2. ed. São Paulo: Atlas, 1999.

Ostro, B. et al. Fine particulate air pollution and mortality in nine California counties: results from CALFINE. Environmental Health Perspectives, v. 114, n. 1, p. 29-33, 2006.

Porto, M.F. MILANEZ, B. Axes of economic development and the generation of socio-environmental conflicts in Brazil: challenges for sustainability and social justice. Revista Ciência e Saúde Coletiva. v.14, n.6. p.1983-1994. 2009.

Pagliuso, J. D. et al. Development of an artificial neural red model for the prediction of the concentration of CO in urban areas. In: CONGRESO DE INGENIERÍA DEL TRANSPORTE, 5., 2002, Santander - Catabria, Spain.

Proceeding. Santander - Catabria, España, 2002. p.370-380.

For. Environmental Law of the State of Pará No. 5,887, of May 9, 1995. Provides for the State Environmental Policy and provides other measures. State Secretariat for the Environment, Belém, 2005.

For. State Secretariat for Planning, Budget and Finance. Pará Institute of Economic, Social and Environmental Development. Municipal statistics of Barcarena. Belém, PA, 2011.

Philippi JR. et al. Municipalities and the Environment: Perspectives for the Municipalization of Environmental Management in Brazil. São Paulo: National Association of Municipalities and Environment, 1999. 201 p.

Pires, D.O. Inventory of atmospheric emissions from stationary sources and their contribution to air pollution in the Metropolitan Region of Rio de Janeiro. 2005. 188 f. Dissertation (master's degree) - COPPE / UFRJ, Rio de Janeiro - RJ., 2005.

Quiterio, S.L. et al. 2004. Metals in airborne particulate matter in the industrial district of Santa Cruz, Rio de Janeiro, in an annual period. Atmospheric Environment. v.38, p.321–331.

Quiterio, S.L. et al. Evaluation of levels, sources and distribution of airborne trace metals in seven districts of the Baixada Fluminense, Rio de Janeiro, Brazil. Atmospheric Environment. v.35, p.3503– 3512. 2005.

Ramos, V.P., Falaguasta. M.C.R. Technical report - atmospheric dispersion study of pollutant emissions from Alcoa, Juruti Unit, PA. Alcoa World Alumina Brasil LTDA, São Paulo, 2010.

Rendeiro, G. et al. Combustion and gasification of solid biomass - energy solutions for the Amazon. Ministry of Mines and Energy, Brasília. 192p, 2008.

Ribeiro, L. E. Structural aspects of the urban form: its influences on the concentration of air pollutants and receptive impacts - alternatives for urban planning for the case of São Paulo-SP. 1993. 413f. Thesis (doctorate) - Escola Politécnica-USP. 1993.

Ribeiro, S.K ., Costa, C.V ., David, E.G ., Real, M.V ., Dágosto, M.A. Transport and climate change. 1st ed. Rio de Janeiro, Mauad Ed.Ltda., 2000.

Rodrigues, J.E.C. Technological risk: an analysis of the port of Vila do Conde as a potential threat to oil spills for vulnerable communities. 2008, 97f. Dissertation (master in geography). Federal University of Pará, Belém, 2008.

Santos, L.M.M. Environmental assessment of industrial processes. Sao Paulo-SP. Signus Editora, 2006.

Santos, A.R ., Varejão, A.S., Silva, K.G. Modeling the impact of the expansion of Avenida Fernando Ferrari (Vitória - ES) on the air quality in its surroundings. UFES - Vitória / ES - Brazil. 2011.

Santos, S.R.Q. et al. Soil thermal and water regime for tropical forest area in El Niño and La Niña years, Caxiuanã-PA: case study. Brazilian Journal of Meteorology. v.26. n.3. p.367 - 374. 2011.

Seinfeld, J. H ., PANDIS, S. N. Atmospheric chemistry and physics: from air pollution to climate change. [S.l.]: Ed. John Wiley & Sons, 1326p.1998.

Soares, P.S.M, Santos, M.D.C, Possa, M.V. Brazilian coal: technology and environment. Rio de Janeiro, CETEM / MCT, 2008.

Souza, E. B. et al. On the influences of the El Niño, La Niña and atlantic dipole pattern on the Amazonian rainfall during 1960-1988. Amazon Acta. v. 30. n. 2. p. 305-318. 2000.

Sicard, P. et al. Air quality trends and potential health effects: development of an aggregate risk index. Atmospheric Environment, v. 45, n. 5, p. 1145-1153, 2011.

Silva Junior, J. A. et al. Seasonal variation of meteorological variables in mangrove ecosystem in the Bragantina Region - PA .. In: Brazilian Meteorological Congress, XIII, 2004, Fortaleza, Annals of the XIII Brazilian Meteorological Congress, Fortaleza, 2004.

Thé, J. L. Aermod Course gaussian plume air dispersion model. Air dispersion modeling. Workshop, São Paulo, SP, 2011a. (Class notes)

Thé, J. L. Air dispersion modeling. Workshop. Ontario: Lakes Environmental software Inc. 2011b. (Course Notes).

Tresmondi, A.C.C.L. et al. Concentration of inhaled particulate matter MP10 in Espírito Santo do Pinhal - SP. Environmental Engineering Magazine, v. 5, n. 1, p. 133-144, 2008.

Velloso, M.F.A. 2007. Evaluation of Gaussian models for regulatory purposes - a study for Aerial Basin III of the Metropolitan Region of Rio de Janeiro, Dissertation - Federal University of Rio de Janeiro, COPPE / UFRJ, Rio de Janeiro.

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