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26-27 NOVEMBER 2019, SANTIAGO, CHILE**ODOROUS COMPOUNDS EMISSIONS IN AN URBAN AND INDUSTRIALIZED AREA**
EMISIONES DE COMPUESTOS OLOROSOS EN ÁREAS URBANAS E INDUSTRIALIZADAS**Authors**

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Keywords: Volatile Organic Compounds, Emissions inventory, Odorous compounds, Urban odour, VOC. / Compuestos Orgánicos Volátiles, Inventario de emisiones, Compuestos olorosos, Olor urbano, COV.

Abstract

In industrialized cities, there are many possible sources of odorous compounds, such as steel and pelletizing industries, wastewater treatment plants, landfills, and harbors. For most of these sources, limited data is available on odours emissions in inventories. To estimate odorous VOCs in gaseous emissions from industries it is necessary to identify which VOCs are emitted and are odorous. Although reasonably simple, there are few papers addressing this issue. Thus, this study aimed to categorize chemically the VOCs and TRS emissions from major activities in an industrialized urban area of Brazil, crossing references with U.S. EPA - AP 42 documents, SPECIATE 4.5 database, and literature available. The results provide key odorous compounds classified by potential nuisance, relation with emission activity and odour characteristics. This paper can assist further studies addressing industry odour emissions and dispersion modelling studies.

Resumen

En las ciudades industrializadas, existen muchas fuentes posibles de compuestos olorosos, como las industrias del acero y la peletización, las plantas de tratamiento de aguas residuales, los rellenos sanitarios, y los puertos. Para la mayoría de estas fuentes, se dispone de datos limitados sobre las emisiones de olores en los inventarios. Para estimar la presencia de gases olorosos en las emisiones de VOC de las industrias, es necesario identificar qué VOCs se emiten e son olorosos. Aunque es razonablemente simple, hay pocos artículos que abordan ambas áreas. Por lo tanto, este estudio tuvo como objetivo categorizar químicamente las emisiones de VOC and TRS de las principales actividades en un área urbana industrializada de Brasil,

cruzando las referencias con los documentos de USEPA - AP 42, la base de datos SPECIATE 4.5 y la literatura disponible. Los resultados proporcionan compuestos olorosos clave clasificados por daño potencial, en relación con la actividad de emisión y las características del olor. Este documento puede ayudar a otros estudios que aborden los modelos de dispersión y emisiones de olores de la industria.

1. Introduction

Odour nuisance in urban regions is a worldwide-recognized issue (Brancher et al., 2017; Nicell, 2009). At the city level, many case studies focus on dispersion modelling of specific sources of odorous compounds emissions (i.e. Abdul-Wahab et al., 2017; Çetin Doğruparmak et al., 2018; Luciano et al., 2017). In this sense, odour modelling proved to be a powerful tool integrated with urban planning (Badach et al., 2018). However, using dispersion models implies that emission inventories of the odorous compounds are known and, in fact, this information is not easily available.

According to Brancher et al. (2017) there are five key difficulties in odour emissions estimation, such as: (i) establishing concentrations for fugitive or diffusive sources, (ii) characterize temporal variations, (iii) sample variability, (iv) lack of equipment to monitor in real time and (v) uncertainties via dynamic olfactometry measurements.

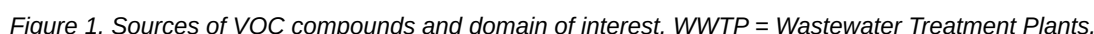
To overcome these drawbacks, we propose a methodology that integrates current estimation of Volatile Organic Compounds (VOC) and Total Reduced Sulphur compounds (TRS) in emission inventories and their chemical profile associated to odorous compounds. A vast literature on VOC and TRS odorous compounds is available (Abraham et al., 2012; Dravnieks and Forest, 2015; Jiang et al., 2017; Leonardos et al., 1969; Nagata, 2003; Rappert and Müller, 2005; Ruth, 1986; Talaiekhosani et al., 2016), which allow the development of this methodology.

2. Materials and methods

Methodological phases proposed are: (i) list a sufficient amount of odorous VOC and TRS compounds; (ii) establish emission sources of VOC/TRS for a case study in an urban industrialized area (or use current emission inventory); (iii) specify chemically VOC/TRS emitted by source and assess its data quality; (iv) quantify emission rate of odorous compounds by source and (v) summarize information on type of odour, smell and threshold.

For phase (i), the authors used available information described in Abraham et al. (2012); Dravnieks and Forest (2015); Jiang et al. (2017); Leonardos et al. (1969); Nagata (2003); Rappert and Müller (2005); Ruth (1986); Talaiekhosani et al. (2016) to create a list of common VOC and TRS odorous compounds. This list resulted in 472 different species. Additionally, later we present the major compounds emitted and their thresholds.

Phase (ii) derived from local VOC emissions inventory of the Metropolitan Region of Grande Vitória (MRGV), ES - Brazil (Figure 1). The authors investigated the emissions of 152 sources grouped into 33 industries. Sources were categorized according to relevance of VOC emissions rate and proximity to complaining districts in the region.



Phase (v) consists in summing odorous compounds estimated and categorizing chemical compounds according to their smell and odour threshold. Furthermore, the authors employed the Gaussian dispersion formula for limit scenarios to verify which compound could appear above its ambient threshold limit in order to select a focus for dispersion model studies.

A summary of the main references used in the construction of the odorous compounds emissions inventory is given in Table 1. The ten major compounds emitted in the region do not represent the prime concerns as other odorous VOC and TRS appear to exceed the odour threshold limit at a given condition of the atmosphere and pollutant release. Those that are found above the concentration limit are given in Table 2. Specific sources were grouped into ten categories that better fit the major industrial emission in MRGV. The total emission represents the sum of the particular compound release from all sources.

Table 1. Major emissions found.

Compound	Total emission	Emitted by ¹									
VOC/TRS/ Ammonia	(kg/h)	S.I. 2	L ³	A ⁴	WT ⁵	V.H ⁶	NGD ⁷	NGC ⁸	F.I ⁹	R/V ¹⁰	T ¹¹
Toluene	70.08	X	X	X	X	X	X	X		X	X
Benzene	52.46	X		X	X	X	X	X		X	X
Pentane	40.14	X						X			
Butane	32.42	X						X			
Dodecane	29.91					X					
Propane	25.03	X	X			X	X	X		X	X
Formaldehyde	14.24	X			X		X	X	X		
p-Xylene	8.80				X	X					
Isopentane	4.57	X		X						X	X
n-Butane	4.44	X	X	X		X				X	X
Ammonia	4.10	X									
Hydrogen Sulfide	3.84	X			X	X					

¹S.I = Steel industry; L = Landfills; A = Airports; WT = Wastewater Treatment; V.H = Vessels and Harbours; NGD = Natural Gas Distribution; NGC = Natural Gas Combustion; F.I = Food Industry (coffee); R/V = Refuelling/Vehicles; T = Thermal power; ²SPECIATE 2569, 0217, 0013; Li et al. (2018); USEPA (2008); ³SPECIATE 0202, ⁴SPECIATE 2571, ⁵SPECIATE 3003, Jiang et al. (2017); Talaiekhosani et al. (2016), ⁶Huang et al. (2018); Milazzo et al. (2017); Xiao et al. (2018), ⁷SPECIATE 7197, ⁸USEPA (2008b), ⁹Yeretzian et al. (2002), ¹⁰SPECIATE 2561; Chin and Batterman (2012), ¹¹Shi et al. (2015); Garcia et al. (1992).

To estimate odorous compounds that could potentially be affecting a given population the authors applied the well-known Gaussian-plume dispersion equation (Equation 1) and the peak-to-mean approach (Equation 2) under stable atmosphere conditions, assuming a release of near-ground emissions with low wind speed prevalence and within a 100m radius to neighbourhoods. This was done to estimate ambient concentrations of total VOC and TRS release on the worst-case scenario.

$$C(x, y, z) = \frac{q}{2\pi u \sigma_y \sigma_z} \exp\left(\frac{-y^2}{2\sigma_y^2}\right) \cdot \exp\left(\frac{-z^2}{2\sigma_z^2}\right)$$

$$\frac{C_1}{C_2} = \left(\frac{t_1}{t_2}\right)^p \text{ Equation 2}$$

The results of this analysis are given in Table 3. From major emissions found in Table 2 only Toluene, Formaldehyde and p-Xylene were considered important. Other odorous compounds that appeared to be relevant were Ethyl benzene, Hydrogen sulphide and Ammonia. Those gases are emitted majorly by Steel industry, Wastewater Treatment and Vessels and Harbours. References on odour threshold limits and smell are found in many studies (Abraham et al., 2012; Dravnieks and Forest, 2015; Jiang et al., 2017; Leonardos et al., 1969; Nagata, 2003; Ruth, 1986; Talaiekhozani et al., 2016; Verschueren, 2006).

Table 2. Pollutants of concern.

Compound	Total emission	Estimated concentration	Minimum Odour Threshold	Odour smell	Reference
VOC	(kg/h)	(mg/m³)	(mg/m³)	(type)	(author)
<i>Toluene</i>	70.08	1.24 ¹ -2.25 ²	0.4	<i>Rubbery, tarry, mothballs</i>	
<i>Formaldehyde</i>	14.24	0.25 ¹ -0.46 ²	0.06	<i>Unpleasant, strong, suffocating</i>	
<i>p-Xylene</i>	8.80	0.156 ¹ -0.28 ²	0.052	<i>Rubbery</i>	<i>(Jiang et al., 2017)³</i>
<i>Ethyl benzene</i>	4.01	0.07 ¹ -0.13 ²	0.01	<i>Sweet, solventy</i>	
<i>Hydrogen sulphide</i>	3.84	0.067 ¹ -0.12 ²	5.6E-5	<i>Rotten eggs</i>	
<i>Ammonia</i>	4.10	0.072 ¹ -0.13 ²	0.03	<i>Pungent, irritating</i>	

¹Using Equation 1. ²Using Equation 2. ³Reference used for all pollutants.

Comparing with Li et al. (2017); Liang et al. (2017); Shen et al. (2018) one can perceive resemblance with our results. For instance, in Li et al. (2017) the VOC profile of most sources under investigation correlated with this study. In Liang et al. (2017) and Shen et al. (2018) it is possible to verify that key odorous VOC compounds emitted in China and regions are similar to our study area. Furthermore, sources of concern and scents felt by population matched some indicated in Hayes et al. (2017) study. However, many aspects of odour estimations are still complex and scarce information for source profiles is available.

4. Conclusions

The authors provided a methodology to estimate the emission of odorous compounds to the atmosphere and applied it to an industrialized urban area. The main difficulty in our study was finding VOC and TRS chemical emissions profile for specific sources. This resulted in the qualitative estimation of unaccounted sources, which are known for emitting odours but could not be quantified. This study results proved to be correlated with odour estimation studies conducted in different regions of the planet.

Further dispersion and monitoring studies may be assisted by our results and establish stronger parallels with estimated odorous compounds and population perception.

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