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Human exposure to hydrogen sulphide concentrations near wastewater treatment plants

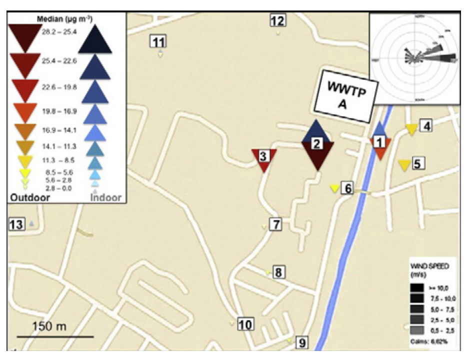
Ana Flavia Locateli Godoi [a], Anderson Marlon Grasel [a], Gabriela Polezer [a], Andrew Brown [b], Sanja Potgieter-Vermaak [b,c], Débora Camargo Scremim [a], Carlos I. Yamamoto [d], Ricardo Henrique Moreton Godoi [a,*]

[a] Environmental Engineering Department, Federal University of Parana, 210 Francisco H. dos Santos St., Curitiba, PR 81531-980, Brazil
[b] Division of Chemistry and Environmental Science, Manchester Metropolitan University, Manchester M1 5GD, UK
[c] Molecular Science Institute, University of the Witwatersrand, Johannesburg, South Africa
[d] Chemical Engineering Department, Federal University of Paraná/UFPR, Curitiba, PR, Brazil

HIGHLIGHTS

- First time quantification of hydrogen sulphide levels at wastewater treatment plants in Curitiba, Brazil.
- Indoor and outdoor levels above the WHO guideline values.
- Indoor/outdoor ratios pointing to H_2S accumulation inside residences.
- Life-time risk analysis indicates a significant non-carcinogenic risk.

GRAPHICAL ABSTRACT



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ABSTRACT

The hydrogen sulphide (H_2S) levels from wastewater treatment plants (WWTPs) in Curitiba, Brazil have been quantified for the first time. H_2S generated by anaerobic decomposition of organic matter in WWTPs is a cause for concern because it is an air pollutant, which can cause eye and respiratory irritation, headaches, and nausea. Considering the requirement for WWTPs in all communities, it is necessary to assess the concentrations and effects of gases such as H_2S on populations living and/or working near WWTPs. The primary objective of this study was to evaluate the indoor and outdoor concentration of H_2S in the neighbourhood of two WWTPs located in Curitiba, as well as its human health impacts. Between August 2013 and March 2014 eight sampling campaigns were performed using passive samplers and the analyses were carried out by spectrophotometry, presenting mean concentrations ranging from 0.14 to 32 $\mu g\ m^{-3}$. Eleven points at WWTP-A reported H_2S average concentrations above the WHO recommendation of 10 $\mu g\ m^{-3}$, and 15 points above the US EPA guideline of 2 $\mu g\ m^{-3}$. At WWTP-B the H_2S concentration was above US EPA guideline at all the sampling points. The I/O ratio on the different sampling sites showed accumulation of indoor H_2S in some instances and result in exacerbating the exposure of the residents. The highest H_2S concentrations were recorded during the summer in houses located closest to the sewage treatment stations, and towards the main wind direction, showing the importance of these factors when planning a WWTP. Lifetime risk assessments of hydrogen sulphide exposure showed a significant non-carcinogenic adverse health risk for local residents and workers, especially those close to anaerobic

* Corresponding author.
E-mail address: rhmgodoi@ufpr.br (R.H.M. Godoi).

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WWTPs. The data indicated that WWTPs operated under these conditions should be recognized as a significant air pollution source, putting local populations at risk.

1. Introduction

Human activities have contributed significantly to increased emissions of air pollutants at global, regional and local scales. It is important to know the source and concentration of pollutants for better pollution control and to assess the potential effects on human health.

H_2S is a colourless gas with a strong odour of rotten eggs produced under anaerobic conditions by organic matter decomposition from both natural (petroleum, volcanic) and anthropogenic sources (oil refining, wood pulp production, tanning industry) (WHO, 2000). Anaerobic wastewater treatment plants (WWTPs) and the degradation processes in landfills are significant sources of H_2S (Redondo et al., 2008; Capelli et al., 2009; Muñoz et al., 2010). Of the ten largest WWTPs existing in the world, eight are operational as anaerobic treatment facilities (Reynolds, 2012). Under anaerobic conditions, the biological reduction of sulphate to sulphide essentially occurs in the submerged part of sewers (Parande et al., 2006). Hydrogen sulphide emission is a physicochemical process involving both the water and air phases of sewer networks and is dependent on pH, temperature, hydraulic conditions of the water phase (Yongsiri et al., 2005). Only H_2S can be transferred to the air–water interface, resulting in an increase in the emission of H_2S from wastewater to the sewer atmosphere (Fu and Shen, 1990).

Unpleasant odours from WWTPs may cause acute social and economic conflicts due to poor quality of life and economic depreciation of the neighbouring real estate (Stellacci et al., 2010). Nuisance complaints about the odour emitted by WWTPs are registered in different parts of the world (Aristu, 2009; Billings, 2012; Wall, 2011). Besides the obvious unpleasant odour, the dominant cause for concern regarding H_2S pollution is its documented toxicity to humans. H_2S pollution effects are dose-related and can be detrimental to the nervous, cardiovascular and respiratory systems. Acute high-level concentration exposure can lead to eye damage, olfactory paralyzing perception, respiratory irritation, as well as pulmonary oedema, convulsions and even death (WHO, 2000). The long-term exposure to low-level concentrations also affects human health negatively, e.g., causing nausea, headaches and respiratory problems (Lebrero et al., 2011).

As the nuisance H_2S odour threshold has been reported to be in the ranges 0.7–200 $\mu g\ m^{-3}$, it is recommended to maintain levels at or below the lower limit to avoid community complaints (WHO, 1981). It has been established that daily inhalation exposure to H_2S has to be below 2.0 $\mu g\ m^{-3}$ to ensure lifetime risk abatement (USEPA, 2003). Having said that, the World Health Organisation recognises the fact that information on the affects that long-term low dosage exposure to ambient H_2S is scanty (WHO, 2000). It therefore remains of interest to evaluate the air quality in terms of its H_2S content close to WWTP's.

This paper aims to provide data on the indoor and outdoor concentration of H_2S in the neighbourhoods of two WWTPs in Curitiba, Brazil. This provided baseline data that could serve as a reference point for future research. The data obtained were used in a risk-assessment protocol to estimate the likely effect on human health of the residents over a lifetime of exposure. This information can be used to aid local governmental policies, provide baseline data that could inform future changes in operation, as well as assist in future planning for new plants.

2. Experimental

As there have been complaints regarding unpleasant odours at and around the plant, the investigators decided to start the analysis of the air quality by monitoring H_2S levels, as it is also the main pollutant from degradation processes causing nuisance odours.

2.1. Sampling methodology

To protect the identity of the WWTPs, they will be referred as WWTP "A" and WWTP "B". These plants treat wastewater volumes of 560 L s^{-1} and 1680 L s^{-1} for A and B, respectively. Both wastewater treatment plants (WWTP) process mainly domestic Municipal wastewater through a conventional setup. The preliminary treatment aims to remove bulky and large solids, thus preconditioning the effluent for the following treatment steps, including screening, flocculation, and flow equalization. In sequence, within the named primary treatment, sedimentation and/or flotation are employed to remove effluent's suspended and colloidal fractions. At the secondary treatment, the organic matter is removed through a biological process called Fluidized Bed Anaerobic Reactor (FBAR, or RALF in Portuguese), a Brazilian version of the Upflow Anaerobic Sludge Blanket - UASB. The hydraulic retention time at this step is only 8–10 h, resulting in 65–75% organic matter removal efficiency. With the tertiary treatment, using iron chloride, some nutrients such as nitrogen and phosphorous, residual suspended solids, inorganics, and refractory organics that may have escaped from previous stages, are removed. Finally, the disinfection removes pathogens by chlorination. The sludge produced at the secondary step is also treated through thickening, dewatering, drying, and digestion in order to reduce its volume as well as to biologically stabilize the final product, which is usually then sent to landfills (although it also may be used as fertilizer).

H_2S was sampled using radial diffusion passive samplers (Radiello®, Fondazione Salvatore Maugeri, Padova, Italy). This sampler comprises a zinc acetate impregnated polyethylene adsorbing cartridge, surrounded by a cylindrical microporous diffusive body mounted on a supporting plate. When H_2S contacts the zinc acetate, it is converted to stable zinc sulphide, which is later extracted and assayed by sulphide ion (Pavilonis et al., 2013). Sampling took place for seven consecutive days. The temperature was recorded every 20 min during the weekly sampling campaigns.

Sampling was performed in houses and schools near the two WWTPs, which are located in two different residential areas in Curitiba.

Eight sampling campaigns were carried out, as listed in Table 1. Samplings locations were assigned as A1 to A13 for WWTP "A", and B1 to B5 for WWTP "B". Besides point A1 that was assessed during all campaigns, locations of WWTP "A" were evaluated in campaigns 1 to 4, and points of WWTP "B" in campaigns 5 to 8. Residential accommodation near the WWTPs has little or no insulation between the roof and walls, allowing easy diffusion of H_2S into the house.

The sampling points were chosen based on three basic criteria: location with respect to the pollution source (WWTP) and the main wind direction, electrical support, and security against vandalism and theft. Table 2 presents the sampling points distances from the WWTP's.

Cartridges were installed at a height of 1.5 m inside residences, after permission was gained from residents. To enable a comparison between inside and outside air quality, samplers were positioned on the outside of the residences at an average height of 2.0 m. Radiello shelters (specifically designed for the diffusion tubes) were used to protect the samplers from precipitation. The Radiello samplers were exposed to air for a period of 15 days, after which the cartridge was removed from the diffusive body, sealed in its original tube and stored below 4 °C for analysis.