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Estimation of hydrogen sulphide emissions at several wastewater treatment plants through experimental measurements by using passive samplers

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Multiple processes are responsible for hydrogen sulphide (H_2S) emissions in a WWTP, such as settling tanks, manholes or sludge thickeners among others, and these are not usually controlled (fugitive emissions), so it is difficult to assess and experimentally measure H_2S emission rates *a priori*, thus resulting interesting the use of indirect methods of estimation. Several intensive field campaigns were carried out using passive samplers for exposure periods of about five days. A meteorological tower of 15 m height provided in situ continuous measurements of wind and temperature. The potential field of concentrations around the plant was modelled by using a dispersion diagnostic code.
Different emission rates were obtained by comparing between simulated and experimental values obtained with diffusive samplers.
The results show a temporal variability of emissions as response to changing environmental and operational conditions. The average H_2S emissions for the studied WWTP range between 0.50 and 1.87 g/s. Differences between these plants are plausible since the volume of wastewater treated in each one is different.

1. Introduction

Routine activity in wastewater treatment plants (WWTP) usually involves the atmospheric release of odour-causing substances, with a potential impact on life quality for the surrounding population. This olfactory impact (Coll-Lozano et al., 2006), which is caused by the substances emitted into the atmosphere, is basically a problem of atmospheric dispersion since these compounds are transported and spread from the emission area to the potential recipient by means of atmospheric dynamic processes. The smell derived from wastewater treatment processes presents several especially complex aspects: a great variety of compounds, in very diverse concentrations, are capable of producing olfactory stimuli and sensory responses which do not vary linearly

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with concentrations (Stuetz and Frechen., 2001); the emissions are largely fugitive or unchanneled, and they are generated by different processes within the plant, although they are usually produced at ambient temperatures and at surface level. Other human activities (particularly agriculture and livestock farming) and natural processes also contribute to additional emission sources, thus complicating the problem (Kjeld and Bo, 1981). Hydrogen sulphide is often present in higher concentrations than other odorants in WWTP emissions, as result of anaerobic degradation processes. Therefore it can be considered a good indicator of the presence and intensity of olfactory impact.

Within a large experimental programme carried out in several WWTP in the Valencian Community (Spain), some intensive field campaigns were carried out using passive samplers for exposure periods of about five days. A meteorological tower of 15 m height provided in situ continuous measurements of wind and temperature. A dispersion diagnostic code was used to simulate the potential field of concentrations around the plant. Different emission rates were obtained by comparing between simulated and experimental values obtained with the diffusive samplers. This communication presents an approach followed to calculate the effective H_2S emission rates estimated for several WWTP.

2. Methodology

2.1 Available measurements

Meteorological measures A meteorological tower placed in each studied WWTP provided precise meteorological information. This infrastructure usually consisted of a 15 m-tall mast with wind measures (velocity and direction) at the highest level and temperature measures at two heights (3 and 15 m, thus providing a direct measure of the surface thermal gradient).

Ground-level concentration measures Palmes-type diffusion tubes were used to sample H_2S. They consisted of hollow acrylic tubes with length of 70 mm and internal diameter of 10 mm, fitted on one end with a polypropylene cap containing 2 stainless-steel meshes impregnated with a solution of $AgNO_3$ (Shooter et al., 1995). At each sampling point, 3 dosimeters and 1 blank were exposed for five days, analyzing two of them and using the mean value as the concentration estimator; the third sampler was analyzed only when discrepancy between the other two ones existed. All the sampler concentrations were temperature-corrected and normalized to 20 ºC, on the basis of measurements from the meteorological station.

Dispersion model Previous experiments with accumulated concentration measurements around different wastewater treatment plants showed a rapid decay in the concentrations with the distance from the facility; thus, the simulation window was focused to the immediate surroundings of the plant, on a 4 km square.

The model used to simulate dispersion is based on the adaptation and integration of two independent codes: a diagnostic non-divergent meteorological model coupled to a puff diffusion model. The meteorological module incorporates the Lawrence Livermore National Laboratory MATHEW base model. This is a regional, three-dimensional wind-field. It considers complex topography explicitly, it is site-independent, it usually employs available surface and in height meteorological measures, and it is computationally stable (Espinós et al., 2008). The diffusion model is a modification of the EPA-INPUFF model (Petersen and Lavdas, 1986). It incorporates Pasquill-Gifford's formula to describe the dispersion and Briggs's algorithms to estimate the plume rise (Briggs and Haugen, 1975). The numerical runs were performed for the same periods of time in which the dosimeters were exposed.

2.2 Procedure

Eight dispersive scenarios were sampled for obtaining H_2S concentration measures between 2002 and 2005 at two wastewater treatment plants, La Vila Joiosa and Rincón de León placed both in the Valencian Community (Spain). It provides a broad enough collection of meteorological conditions in which H_2S emission rates were calculated.

On the one hand average simulated concentrations were obtained in each of the measurement points of the external network, which coincide with the sampling period, and both sets of values (simulated and experimental) were linearly adjusted. These averages were then adjusted to the averages provided by the dosimeters to obtain corrected ground-level concentration maps.

The proportionality factor can be considered an indirect measure of the average emission rate of the WWTP. For each simulated period, an estimated value for the emission of the plant was obtained by this procedure.

3. Results

The Rincón de León WWTP is located relatively close to both the city of Alicante (Spain) and the coast. It is a large facility with an inflow higher than 80000 m^3 per day, and it presents a markedly urban profile. The wind rose distribution (Figure 1 left) shows a clear arrowhead along an axis approximately ESE-WNW. Weaker winds come from the second quadrant, thus resulting in major impacts on the west of the plant. The surface H_2S concentrations (Figure 1 right) show a characteristic “butterfly wings” distribution, with a major impact onshore, due to predominant sea advection. As can be seen, the highest concentrations occur very close to the plant.

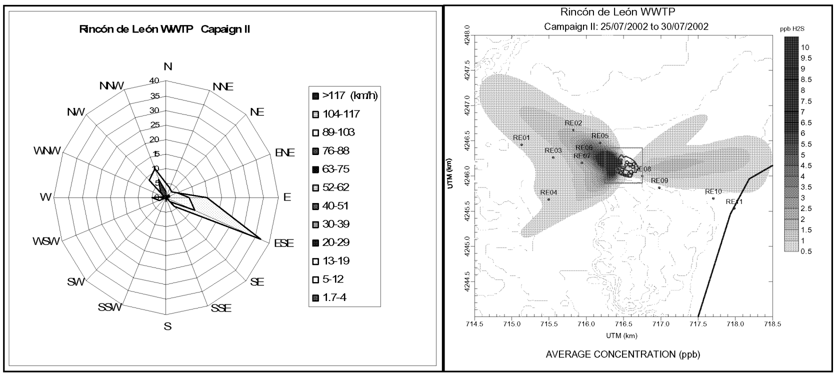

Figure 1: Wind rose (left) and average concentration map (right) for the Rincón de León WWTP (Campaign 25/07/2002 to 30/07/2002).

On the other hand, the Vila Joiosa WWTP is an intermediate-scale facility, which receives and treats wastewater from a population of 45755 inhabitants approximately. It presents an average inflow of 6761 m^3/day, which increases in summer periods. It has a seasonal profile, since two seasonal tourist municipalities discharge their wastewater to the WWTP due to its proximity to the coast. The wind rose presents an arrowhead form (Figure 2 left). Strong winds produced the cleaning of the concentration levels on the northwest part of the treatment plant. The surface concentrations map (Figure 2 right) shows the dilution and the transport of the concentrations produced in the south-eastern part of this WWTP.

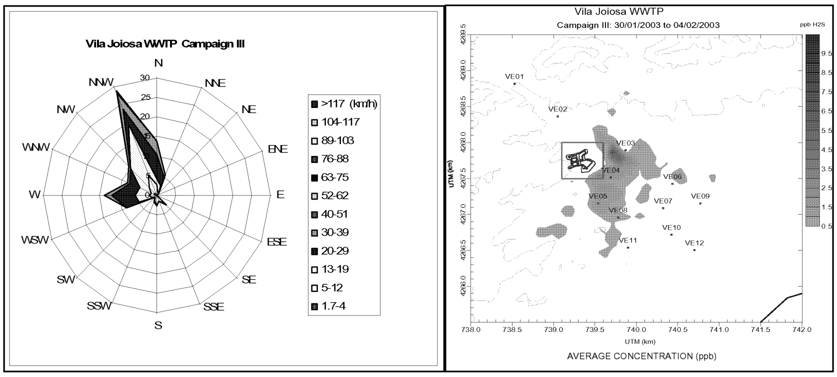

Figure 2: Wind rose (left) and average concentration map (right) for the Vila Joiosa WWTP (Campaign 30/01/2003 to 04/02/2003).

Figure 3 shows the adjustment between the experimental measurements provided by the passive samplers and the values obtained by the model for the two campaigns. The correlation between the passive sampler measurements and the model is quite good in both cases (R^2 = 0.89 for the Rincón de León campaign and R^2 = 0.65 for the Vila Joiosa campaign).

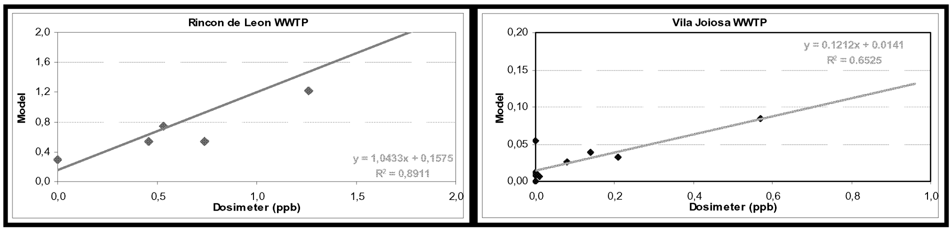

Figure 3: Adjustment between experimental measurements .vs. model for the Rincón de León campaign (left) and the Vila Joiosa campaign.

The calculated average emission rates are shown in the Table 1. Information about environmental parameters (velocity and temperature) and plant operation factors (volume, pH, BOD) is also included. According to the Table 1, it can be seen that the average H_2S emissions for the two WWTP range between 0.50 and 1.87 g/s. This fact implies differences lower than a 4 factor, which is less, for example, that differences between the volumes of wastewater treated in each plant.

Therefore, 43-162 kg of hydrogen sulphide is released per day into atmosphere. This amount is about 10% of incoming sulphur in a plant, according to the standard values on urban wastewater quality.

The possibility of applying this methodology for estimating emission rates is sometimes limited by environmental conditions during the sampling periods. It is possible that emissions do not impact enough on the sampling net and, therefore, the comparison between the model and the experimental measurements could not provide a relation (identified on the table 1 as "l/m").

Table 1: Average rates at the different wastewater treatment plants, plant operation factors and environmental parameters.

WWTP	Camp	Start Date	Exp Days	Volume (m^3/day)	pH influent	BOD (mg/l)	Temp (ºC)	Speed (m/s)	Average Emission (g/s)
LVJ	I	23/05/2002	5.2	4304	7.6	800	20.0	3.1	0.409
	II	18/07/2002	5.2	5034	7.7	360	25.5	2.6	I/m
	III	30/01/2003	5.1	5071	7.8	620	11.5	5.1	0.048
	IV	08/05/2003	4.9	6564	7.9	200	18.1	2.5	0.446
	V	29/05/2003	5.2	6670	7.8	420	21.0	2.2	1.484
	VI	10/07/2003	5.1	6348	7.6	500	26.3	3.1	0.753
	VII	15/01/2004	5.1	5516	7.7	440	12.1	3.6	0.786
	VIII	19/02/2004	7.1	6325	7.8	460	11.7	2.8	0.089
		Average		***5729***	***7.7***	***475***	***18.3***	***3.1***	***0.50***
		Stand.	***Desv***						***0.49***
RL	I	17/05/2002	4.3	77235	7.7	420	18.8	3.3	1.515
	II	25/07/2002	5.0	79992	7.4	550	24.8	2.7	1.958
	III	23/01/2003	5.0	75814	7.9	380	11.9	3.1	1.804
	IV	15/05/2003	5.1	86381	7.6	330	20.1	2.9	1.310
	V	22/05/2003	5.2	78299	7.5	520	19.3	3.6	2.616
	VI	17/07/2003	5.2	81653	7.4	570	26.5	2.8	1.868
	VII	08/01/2004	4.3	82063	7.8	310	17.4	5.3	2.074
	VIII	12/02/2004	5.2	82965	7.4	470	11.0	2.3	1.809
		Average		***80550***	***7.6***	***444***	***18.6***	***3.3***	***1.87***
		Stand.	***Desv***						***0.39***

DOP: Denia-Ondara-Pedreguer; **LVJ**: La Vila Joiosa; **RL**: Rincon de Leon; **I/m**: Inadequate passive measurements; **Camp**: Campaign; **Temp**: Temperature; **Exp Days**: Exposure days of the passive samplers **Stand.Desv**: Standard Deviation

4. Conclusions

This work provides H_2S emission values at several WWTP over different periods of the year, which are based on an inverse estimation procedure from the comparison between passive sampler measurements and numerical dispersion simulations.

This methodology has the advantage of providing a complete evaluation of emissions from the plant as a whole, including diffuse sources and channelled, which exhibit a difficult individualized treatment. It also presents clear implementation advantages over olfactometric measurements, such as simplicity and cost of the measures.

Some situations can not be satisfactory solved using the proposed method. It indicates a lack on the sampling net, that inhibit the capture of the dispersive processes of the plant under certain weather conditions. In this sense, this could be resolved in future works with using greater spatial coverage of the sampling net, or by increasing the exposure time of the samplers (and thus incorporating a greater variety of weather conditions during exposure periods).

The usual alternating day / night regimes of local breezes at this latitudes makes possible temporal variations in emissions, which lead to substantial changes in the spatial pattern of impacts. In this way, our group is working on the introduction of a temporal modulation in the emission rates, in order to enhance the adjustment of the modelling with the experimental values.

5. Acknowledgements

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