Development of a diagnostic tool: the wastewater collection network odour wheel

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ABSTRACT

The assessment of nuisance odour problems and the application of an effective odour management programme for the associated industrial activity may be achieved using a representative odour wheel and Odour Profile Analysis methodology. The odour wheel is a very useful tool for conducting odour quality control monitoring and developing a constructive dialogue regarding nuisance odours with the public. Previously, odours from wastewater treatment plant activities have been identified and described with a dedicated odour wheel. The oxidation state of the organic chemicals responsible for a given odour depends on multiple parameters specific to the individual wastewater collection networks (residence time of wastewater, topographic disposition and network slope, aeration and on line chemical treatment processes). This is especially important for odorous nitrogen, sulfur and volatile fatty acids. Trained sensory odour panels combined with chemical analyses have been used to study wastewater collection network odours and to adapt the wastewater odour wheel accordingly. The wastewater collection network odour wheel has been produced using the results of five sampling campaigns; eight out of the 11 odour families constituting the wastewater odour wheel have been identified and consequently validated for sewer networks. Different groups of odours have been perceived according to the presence or absence of wastewater effluents at the various sampling points.

Key words | odour wheel, olfactory nuisances, sewer networks

INTRODUCTION

Flow stagnation and sedimentation within wastewater collection networks, as may occur in zones having a low slope, frequently result in the production of odorous compounds, particularly in the absence of oxygen. As a consequence, volatile compounds produced in sewer systems may be stripped from the aqueous phase and are likely to induce discomfort within the local resident population and subsequent complaints to the local authorities.

The diagnosis and control of nuisance odours requires the use of a common language as a basis for a constructive dialogue between residents and network operators. A successful method to achieve this goal is the development of a dedicated odour wheel which serves to assist with the identification of olfactory nuisances and the associated compounds responsible for residents’ discomfort. An odour wheel consists of two concentric circles: the inner indicates the primary odour groups or categories representing the different odour families of an industrial activity while the outer circle corresponds to more precise descriptors of odours, the secondary odours.

In wastewater collection networks, efforts are primarily focussed on H₂S production and behaviour both for economic and safety reasons (Zhang et al. 2008). However, all odour problems cannot be solely attributed to H₂S as other kinds of compounds, such as mercaptans, sulfides, nitrogen compounds or volatile fatty acids, may be responsible for olfactory nuisance. Burlingame et al. (2004) developed an odour wheel for wastewater activities, however, at the present time, no published study has been conducted in order to validate or adapt the wastewater odour wheel for improved management of wastewater collection networks.

This paper describes the development of an odour wheel specifically adapted to wastewater collection networks, based on chemical and sensory characterizations of samples from different locations within various sewer systems.

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MATERIALS AND METHODS

Five field campaigns were carried out near Paris and in the south of France. In total 16 sampling points were considered (two to four per campaign) and selected at different locations along the sewer network where odour issues are typically encountered: pumping stations, manholes and ventilation grids. Chemical and sensory analyses were carried out on the gaseous samples taken at each location. The odorous compounds measured by chemical analysis cover a wide range of chemical families commonly found in gaseous emissions from different environmental activities and described in the wastewater odour wheel. The sensory and chemical parameters chosen for odour characterization are:

- Odour Profile Analysis (OPA), with gas sampled in Tedlar bags;
- sulfur compounds, with gas sampled in Tedlar bags;
- ammonia and amines, with gas sampled in impingers;
- volatile fatty acids, with gas sampling conducted by adsorption of compounds on charcoal cartridges;
- aldehydes and ketones, with gas sampled by adsorption on silica cartridges impregnated with DNPH;
- volatile organic compounds (VOCs), with gas sampled by adsorption on charcoal cartridges.

Chemical analysis

The sulfur compounds (H₂S, mercaptans, sulfides) were determined on the MEDÔR system from the CHROMATOSUD company, which is a chromatograph coupled to an electronic cell filled with chromic acid. This detection mode is specific for the analysis of sulfur compounds and is the most sensitive technique which allows detection levels in the ppb range. Ammonia was analysed by colorimetric assay of the ammonium ion in a H₂SO₄ solution at 0.1 N. The analysis of amines (methylamine, ethylamine, dimethylamine, trimethylamine) trapped in the same solution (pH = 2) as ammonia was realized by chromatography with a NPD (specific detector for nitrogenous and phosphorous compounds) after pH equilibrium with sodium hydroxide in sealed vials. Volatile fatty acids, trapped on a charcoal cartridge ORBO 32 during on-site sampling, were analysed by gas chromatograph-flame ionization detector (GC-FID) after two consecutive elutions with 1 mL ethanol solution. Aldehydes and ketones were trapped on DNPH cartridges during on-site sampling and after reaction with DNPH to produce hydrazones; they were further eluted with acetonitrile in the laboratory and analysed by high-performance liquid chromatography-ultraviolet (HPLC-UV). VOC screening was realized after two consecutive solvent elutions (1 mL) on ORBO 32 cartridges and the analysis on a GC coupled with a mass spectrometry (MS) detection.

Principle of OPA: the odour wheel

OPA allows the characterization of odorant mixtures in a qualitative and quantitative manner, with a trained panel. In order to qualify precisely the odours, the panellists use the wastewater odour wheel as described by Suffet et al. (2004) as a technical tool. The panellists are trained regularly to recognize and describe odorant mixtures; panel trainings have been organized before the campaign and on site in order to develop continuing odour evaluations. For each identified odour, panellists determine an intensity referring to a standard of sugar solution scale. The sugar scale used for the odour intensity corresponds to a uniform method of quantifying odour intensity. Panellists transfer their calibrated taste sensation to the intensity of the perceived odour. The standard scale is made up of seven levels (1 (threshold), 2, 4, 6, 8, 10 and 12) which correspond to solutions of water with successively higher amounts of sugar. This scale is used in Standard Methods for the Examination of Water and Wastewater for evaluation of off-odours in drinking water (AWWA 1993; APHA 2000).

The methodology of training and learning is based on the recognition of the different categories of odour descriptors presented in the odour wheel. The panel is trained via blind testing to recognize each category and each descriptor within a category. During the odour profile measurements, the panellists characterize the odour qualities and provide an intensity rating for each odour. Data are then statistically treated in order to obtain the primary odours with their associated intensity at each point of evaluation or for each sample. The basic data treatment consists of:

- calculating the means of intensity for each odour characteristic by at least 50% of the panellists – these descriptors are called primary odour notes;
- listing the other secondary descriptors not identified by at least 50% of the panel as another odour note, without assigning them an intensity.

Within the framework of the campaigns on wastewater collection networks, 11 gas samples have been analysed by OPA, in the CIRSEE laboratory with at least six trained panellists and 13 odour characterizations performed on-site, directly at the sampling points, with and without the manhole cover.
DEVELOPMENT OF AN ODOUR WHEEL - METHODOLOGY

The development of an odour wheel requires information on the industrial activity concerned, sensory data on gas emissions in order to identify and quantify the odours released, as well as chemical data to complete the sensory information on the identification of compounds responsible for the odours. The characterization of odours is based on a combination of two complementary analysis modes: the chemical analysis and the olfactory analysis.

With the chemical analysis, the presence of the odorous compounds in the gas samples can be detected with the level of concentration. This allows the assessment of whether the typical odour of each compound could be detected and also to confirm the odours identified by other analyses. In complex mixtures of odours, the identification of a specific odour can be difficult and even impossible for the panellists, due to the masking effect of other dominant odours. In this case, the chemical analysis of the corresponding compound can help to complete the characterization of the gas sample.

The olfactory analysis allows the identification of odours along with their level of intensity in order to classify the odour families and to prepare the odour wheel categories. Some odorous compounds can only be detected by their specific odours and not by chemical analysis, especially when they have an odour threshold below the detection limit of the analytical technique and when some volatile organic compounds could only be measured by specific and expensive analytical techniques. In the case of olfactory measurements, OPA have been performed directly on-site and in the laboratory with panellists. The on-site measurements were realized by two persons during the campaigns and some visits at different points of sewer networks for the campaigns’ preparation. For subsequent analyses in the laboratory, odour emissions have been sampled in Tedlar bags and analysed with at least six trained panellists. Both these measurements are complementary, because fugitive odour emissions can only be characterized by direct measurements at the source and not by measurements on an integrative gas sample. However, OPA performed in the laboratory is realized with a sufficient number of panelists in order to guarantee a good quantification of the odour intensities; moreover, OPA results on gas samples can be linked with chemical analyses as the sampling times are in the same order of magnitude.

RESULTS AND DISCUSSION

Results of chemical analysis

The chemical analyses reveal, as expected, that the main odour families present within wastewater collection network samples include the sulfur compounds (sulfide/cabbage/garlic odour), the nitrogenous compounds with ammonia and trimethylamine (ammonia/fishy odour), and the volatile fatty acids, especially propionic acid (rancid/putrid odour). An example of results is presented in Table 1; the analytical results correspond to the ratios of the chemical concentrations divided by the odour thresholds for each compound. These ratios are indicated if they are above or around one which means that the level of chemical concentration of the compound is above its odour threshold and the specific odour of the compound can be perceived. At several sampling points, the ratios for sulfur compounds are very high, as the concentrations measured are several orders of magnitude above the odour threshold and in some cases, above the exposition limit value of 7.6 mg/Nm³. Concerning the frequency of detection on the 16 gas samples analysed, sulfur compounds, especially hydrogen sulfide and methylmercaptan, have been detected at sufficient concentrations to be responsible for odours in 15 samples, ammonia and trimethylamine at four sampling points, acetaldehyde at two points and propionic acid at one sampling point. This confirms the predominance of the sulfur odours and proves the presence of other kinds of perceptions such as irritant and pungent (ammonia), rotten fishy (trimethylamine), sweet fermentation (acetaldehyde) and rancid (propionic acid). With the chemical analysis results, five odour categories of the wastewater odour wheel (Suffet et al. 2004) have been confirmed for the wastewater collection networks.

From the results of VOCs screening, only the compounds present in significant concentration levels and with sufficient confidence in the identification of compounds by GC-MS have been taken into account. With such conditions, only six sampling points present interesting results for VOC identification; the chemical compounds identified include alkanes, cycloalkanes, BTEX, halogenated solvents, terpenes and sulfides. The concentration levels were never above the corresponding odour threshold except for the sulfides (dimethyltrisulfide and dimethyltrisulfide) which were detected at concentrations 10 times above the odour perception level. The results of VOC screening did not help in the completion of other odour categories in addition
## Table 1 | Example of chemical analysis and OPA results for a campaign at several points of a wastewater collection network

<table>
<thead>
<tr>
<th>Chemical compounds</th>
<th>Point 1</th>
<th>Point 2</th>
<th>Point 3</th>
<th>Point 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chemical conc. (mg/Nm³)</td>
<td>Conc/olfactory threshold ratios</td>
<td>Chemical conc. (mg/Nm³)</td>
<td>Conc/olfactory threshold ratios</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>0.66</td>
<td>55</td>
<td>0.10</td>
<td>8</td>
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<tr>
<td>Methylmercaptan</td>
<td>0.27</td>
<td>79</td>
<td>0.06</td>
<td>18</td>
</tr>
<tr>
<td>Ethylmercaptan</td>
<td>&lt;0.06</td>
<td>&lt;0.06</td>
<td>&lt;0.06</td>
<td>&lt;0.06</td>
</tr>
<tr>
<td>Dimethylsulfide</td>
<td>&lt;0.06</td>
<td>&lt;0.06</td>
<td>&lt;0.06</td>
<td>&lt;0.06</td>
</tr>
<tr>
<td>Dimethyldisulfide</td>
<td>&lt;0.06</td>
<td>&lt;0.06</td>
<td>&lt;0.06</td>
<td>&lt;0.06</td>
</tr>
<tr>
<td>Ammonia</td>
<td>2.12</td>
<td>5</td>
<td>0.06</td>
<td>&lt;1</td>
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<tr>
<td>Methylamine</td>
<td>&lt;0.020</td>
<td>&lt;0.020</td>
<td>&lt;0.020</td>
<td>&lt;0.020</td>
</tr>
<tr>
<td>Trichloroethane</td>
<td>&lt;0.04</td>
<td>31</td>
<td>&lt;0.020</td>
<td>&lt;0.020</td>
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<tr>
<td>Acetic acid</td>
<td>&lt;0.21</td>
<td>&lt;0.22</td>
<td>&lt;0.22</td>
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<tr>
<td>Propionic acid</td>
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<td>&lt;0.33</td>
<td>&lt;0.33</td>
<td>&lt;0.33</td>
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<tr>
<td>Isobutyric acid</td>
<td>&lt;0.30</td>
<td>&lt;0.33</td>
<td>&lt;0.33</td>
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<tr>
<td>Butyric acid</td>
<td>&lt;0.09</td>
<td>&lt;0.11</td>
<td>&lt;0.11</td>
<td>&lt;0.11</td>
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<tr>
<td>Isovaleric acid</td>
<td>&lt;0.10</td>
<td>&lt;0.11</td>
<td>&lt;0.11</td>
<td>&lt;0.11</td>
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<tr>
<td>Valeric acid</td>
<td>&lt;0.10</td>
<td>&lt;0.11</td>
<td>&lt;0.11</td>
<td>&lt;0.11</td>
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<tr>
<td>Formaldehyde</td>
<td>&lt;0.07</td>
<td>&lt;0.06</td>
<td>&lt;0.06</td>
<td>&lt;0.06</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>0.07</td>
<td>1</td>
<td>0.06</td>
<td>1</td>
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<tr>
<td>Acroleine</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>Acetone</td>
<td>0.13</td>
<td>&lt;1</td>
<td>0.08</td>
<td>&lt;1</td>
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<tr>
<td>Propionaldehyde</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
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<tr>
<td>Crotonaldehyde</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
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<tr>
<td>Methacroleine</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
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<tr>
<td>2-butanone</td>
<td>1.10</td>
<td>&lt;1</td>
<td>0.90</td>
<td>&lt;1</td>
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<tr>
<td>Butyraldehyde</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
<td>&lt;0.03</td>
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</table>

### Odour notes

<table>
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<tr>
<th>Odour notes</th>
<th>Notes</th>
<th>Intensities</th>
<th>Notes</th>
<th>Intensities</th>
<th>Notes</th>
<th>Intensities</th>
<th>Notes</th>
<th>Intensities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary notes</td>
<td>Rotten cabbage/garlic</td>
<td>7.7</td>
<td>Smokey</td>
<td>3.5</td>
<td>Rotten cabbage/garlic</td>
<td>8.8</td>
<td>Rotten cabbage/garlic</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Faecal</td>
<td>3.5</td>
<td></td>
<td></td>
<td>Sewery</td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary notes</td>
<td>Rotten vegetable</td>
<td>–</td>
<td>Rancid</td>
<td>–</td>
<td>Rancid</td>
<td>–</td>
<td>Rotten vegetable</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>Rotten eggs</td>
<td>–</td>
<td>Manure</td>
<td>–</td>
<td>Manure</td>
<td>–</td>
<td>Sewery</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>Sewery</td>
<td>–</td>
<td>Putrid</td>
<td>–</td>
<td>Putrid</td>
<td>–</td>
<td>Smokey</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Smokey</td>
<td>–</td>
<td>Sewery</td>
<td>–</td>
<td>Sewery</td>
<td>–</td>
<td>Smokey</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Faecal</td>
<td>–</td>
<td>Rancid</td>
<td>–</td>
<td>Rancid</td>
<td>–</td>
<td>Faecal</td>
<td>–</td>
</tr>
</tbody>
</table>

*aINRS (2005); Van Gemert (1999).

n/a: not available.
to the five identified by other chemical analyses; they only confirmed the predominance of sulfur compounds with the presence of dimethyltrisulfide, at two sampling points. This chemical compound presents a very low odour threshold (0.0075 mg/Nm³) similar to the other sulfur compounds (mercaptans and sulfides) and is responsible for the rotten vegetable odour as the dimethylsulfide and the dimethyldisulfide.

Results of odour profile analysis

The frequencies of perception obtained for the descriptors identified by OPA are presented in Figure 1 for the on-site measurements and in Figure 2 for the analyses conducted subsequently on gas samples in the laboratory.

In both series of measurements, nine odours have been identified:

- rotten egg, rotten cabbage, rotten vegetable corresponding to sulfur compounds and the sulfide/cabbage/garlic category;
- rotten fish, which is characteristic of the trimethylamine odour and classified in the ammonia/fishy category;
- rancid, which corresponds to some volatile fatty acid odours and to the rancid/putrid family on the wastewater odour wheel;
- sewery and faecal, which are found in the same category of odours.

The soapy/detergenty and putrid descriptors have only been identified on-site, at sampling locations both with
and without the presence of wastewater effluents. Alternatively, the rubber and smoky odours have only been measured via OPA conducted on gas samples in the laboratory.

Using both the OPA methodology on-site and analytical characterization of gas samples in the laboratory, six odour categories of the wastewater odour wheel have been confirmed; the irritant nose feel has also been detected as secondary perception.

The frequencies of perception obtained by the OPA measurements on-site are slightly higher than those realized on gas samples in the laboratory. Some odours such as sewery, rancid and rotten egg are perceived more frequently on-site than in the laboratory. This difference is mainly due to the dilution effect on gas samples; the sampling for olfactory measurements is an integrative method which lasts around 30 min, whereas odour emissions from the sewer network are often very fugitive and dependent upon the associated wastewater effluent flow. This emission behaviour is not compatible with an integrative sampling which dilutes each odour peak during the time of sampling. However, this remains the only reliable means of collecting a gas sample for OPA measurements in the laboratory.

On-site, the main odours perceived were soapy/detergenty, sewery, putrid and rotten vegetable (Figure 1) when OPA in the laboratory shows mostly the rotten vegetable, rotten cabbage and rubber odours (Figure 2). Sulfur compound odours (rotten vegetable for sulfides, rotten cabbage for mercaptans and rotten egg for H₂S) have always been perceived most of the time in both cases.

The intensity levels measured for the descriptors identified by OPA on-site are presented in Figure 3 and by OPA in the laboratory in Figure 4. Each figure indicates the minimum and maximum values measured and the mean calculated on the overall intensity values obtained for all the campaigns. The maximum values of intensity observed in both cases lay between 8 and 12 and always measured for the sulfur compounds odours: mainly for rotten egg (H₂S) and in a second level, for rotten vegetable (sulfides) and rotten cabbage (mercaptans). The soapy/detergenty odour has been also measured as a blast of high intensity (of 8), at some sampling points on the sewer and at certain times of the day (essentially in the morning and at the beginning of the afternoon); this odour has never been measured by OPA on samples even if the sewer gas emissions have been sampled when the odour was smelt. It is probably due to the dilution effect of sampling over time and the fact that the soapy/detergenty odour is not persistent (high odour threshold) and perceived only during fugitive emissions. Mean values of intensities observed on-site are all centred between 4 and 6 (Figure 3), which correspond to

![Levels of intensity measured by OPA on-site at sampling points](https://iwaponline.com/wst/article-pdf/68/4/839/439960/839.pdf)
the middle of the intensity scale; this means that when these odours are present in sewer gas emissions, they are always well perceived, at an intensity level considered as a possible olfactory nuisance. The means of intensities calculated for OPA on gas samples (Figure 4) are more widely spread, between 3 and 9, most likely due to the dilution effect of the integrative sampling.

Construction of the wastewater collection network odour wheel

Eight of 11 odour families from the wastewater odour wheel (Suffet et al. 2004) were identified and validated with the results of chemical analyses and OPA conducted directly on-site and on gas samples from 16 points within various sewer networks:

- sulfide/cabbage/garlic with the characteristic rotten egg, rotten cabbage and rotten vegetable odours and the chemicals detected, H₂S, dimethylsulfide and dimethyldisulfide, methylmercaptan;
- faecal/sewery with both odours detected;
- ammonia/fishy with the irritant feeling of ammonia, the rotten fishy odour and the analysis of trimethylamine and ammonia;
- rancid/putrid with both odours detected by OPA and the presence of propionic acid confirmed by chemical analysis;
- fragrant/fruity with the soapy/detergenty odour;
- earthy/musty/moldy with the earthy odour slightly detected at some sampling points;
- solventy/hydrocarbon with the rubber and burnt smoky odours and some hydrocarbons and VOCs identified by screening (toluene, xylene and dichlorobenzene, tetrachloroethylene);
- nose feel especially with the irritant and pungent perceptions due to ammonia and high concentrations of sulfur compounds sometimes met at sampling points.

For a defined wastewater network exhaust to atmosphere, the perception of odours changes with time throughout the day depending on the wastewater collection network operation. During each sampling campaign, different groups of odours were perceived according to the presence or absence of wastewater effluents at the sampling points. Some odour families were detected only when the effluents flowed out: sulfide/cabbage/garlic, rancid/putrid, ammonia/fishy and the nose feel of irritant and pungent. These families are marked with a pink square on the proposed Wastewater Collection Network Odour Wheel (Figure 5; the full colour version of this figure is available online at http://www.iwaponline.com/wst/toc.htm). Two groups of odours (earthy/musty/moldy and solventy/hydrocarbon) were never detected with the presence of effluents and only when the wastewater flow stopped (with the yellow circle on the odour wheel – Figure 5); these odours are not so pronounced as sulfide, rancid and fishy.
odours and they could be masked by these dominant odours when the effluents flow out. Two groups of odours, faecal/sewery and soapy/detergenty, have always been perceived, with and without wastewater effluents; these families are marked on the odour wheel, with both legends (pink square and yellow circle).

Three odour families from the wastewater odour wheel were not detected during the present measurement campaigns: grassy/woody, oxidant/chlorinous and medicinal/alcohol; consequently, they could not be confirmed for the application on sewer networks. Despite this fact, these families were maintained, with non-coloured segments, on the proposed Wastewater Collection Network Odour Wheel as the present study will be completed with complementary data since five campaigns is not considered to be sufficiently representative to cover all the possible odours which can be released from sewer networks.

The odour wheel, based on associating a perceived odour to a known and recognized odour, is an essential tool for the training of resident panels because this common 'language' not only enables the establishment of a constructive dialogue among all parties and the improved integration of sewer networks within the local social and environmental contexts, but also the diagnosis and
resolution of the root causes contributing to the generation of nuisance odours.

CONCLUSIONS

Five campaigns have been conducted at different locations within five sewer networks managed by Suez Environment affiliate companies. Chemical and sensory measurements have been performed both on-site and on gaseous samples; with eight of the 11 odour families constituting the wastewater odour wheel of Suffet et al. (2004) identified by chemical analysis and OPA and consequently validated for wastewater collection networks. This allowed for the creation of an odour wheel specifically adapted to sewer systems. The perception of odours changes with time throughout the day depending on the wastewater flow and activities at the discharge point on the network. Only four odour categories (sulphide/cabbage/garlic, rancid/putrid, ammonia/fishy and the nose feel of irritant and pungent) were perceived when the effluents flow out; while two groups of odours (earthy/musty/moldy and solventy/hydrocarbon) were never detected with the presence of effluents. Finally, two categories, faecal/sewery and soapy/detergenty, have always been perceived at sewer network exhausts, with and without wastewater effluents.

The results of both chemical analyses and the OPA methodology demonstrate the predomination of sulphurous odours within wastewater collection network samples, either in terms of chemical concentrations or the perception frequency of odours, which is not surprising. However, even though hydrogen sulphide (H₂S) has been detected on multiple occasions, sulphides were more present, at high intensities, and perceived with their specific odour of rotten vegetables. The three compounds most often detected were dimethylsulfide, dimethyldisulfide and dimethyltrisulfide, and are therefore likely to be just as responsible as hydrogen sulfide for olfactory nuisances associated with wastewater collection networks. Additionally, three other categories were found to contribute to the production of odours within sewer systems: rancid/putrid, faecal/sewery and ammonia/fishy. These categories presented equivalent perception frequencies as the sulphide/cabbage/garlic category, during the OPA measurements on-site. In cases where sulfides are reduced via chemical treatment, these three odour groups may be largely perceived and can cause serious olfactory nuisance. Therefore, such families have to be taken into account in addition to the sulphide odour group, in a global odour management plan for sewer networks.

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