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Implementation of a New Protocol of Odour Field Investigations for the Paris Wastewater Treatment Plants

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In the 90's, the wastewater management authority for the Paris area ('Syndicat interdépartemental pour l'assainissement de l'agglomération parisienne' - SIAAP) established various odour survey tools in order to understand the link between odours and significant operating events at its Waste Water Treatment Plant (WWTP) and in the sewage network. These tools include monitoring stations (weather stations, sulphur compounds analysed with stationary and mobile analytical instruments), human observers (daily odour patrols, voluntary citizens' panels and citizens' complaints logbook), and air dispersion modelling (three-dimensional numerical CFD (Computational Fluid Dynamics) dispersion allowing real-time and forecast odour dispersion).
Starting in 2017, some important changes were initiated in order to improve this monitoring system. Indeed, as a response to important redesign works of one of their WWTPs (Seine Aval), the SIAAP needed to demonstrate a monitoring tool with a high level of confidence, especially during the crucial commissioning period.
Because the previously operated daily patrols showed some limitations, one of the first steps was to implement a new protocol for field investigations and data treatment. The chosen method is, for the most part, inspired by the new standards: EN 16841-1 and EN 16841-2 - Determination of odour in ambient air by using field inspection - Grid method and Plume method. The originality of the new protocol implemented by SIAAP lies in the fact that both methods – Grid method and Plume method – are merged and adapted to needs and means of the SIAAP, in order to collect relevant data.

1. Introduction

1.1 The Seine Aval WWTP and its evolution

The SIAAP treats the waste water of 9 million inhabitants producing more than 2 500 000 m^3 a day, at six Waste Water Treatment Plants (WWTP) in the Paris area. The Seine Aval plant (SAV) is situated in the district of Saint Germain-en-Laye close to Paris. The plant occupies an area of 800 ha over a distance of several kilometres and has a potential impact on eight surrounding districts. The SAV WWTP treats 70% of the wastewater from the Paris area (1 700 000 m^3/day). Currently, important modernisation works are in progress at the plant. A new biological treatment unit was put into operation in 2017. This new facility is composed of two treatment units: a biofiltration unit to reinforce the treatment of carbon and nitrogen, and a membrane filtration unit for the production aiming to:

- substitute existing facilities with more efficient, modular and modern treatment units,
- propose an advanced water treatment in order to meet the requirements of the European Council Directive 91/271/EEC for protecting the adverse effects of urban waste water discharges,
- produce industrial water of drinking water quality,
- reduce consumption of methanol used in the denitrification process

To treat the sludge of its new equipment, a new sludge thickening unit has been installed. In addition, new chemical scrubber and activated carbon deodorization units have been built to treat foul air from the new buildings. Currently, the work focuses on the rehabilitation of primary settling, with the objectives of achieving

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a more efficient and more compact unit. A lamellar settling process in a closed building will replace the existing 20 open decanters, which will allow a considerable reduction in the environmental nuisances.

1.2 The monitoring network

The story of the odour monitoring at the SIAAP finds its origins at the beginning of the 1990's with the plan for the construction of 'Achères V' (the fifth part of SAV): this was when the first complaints due to the activities of the plant started. Public opinion led to the abandoning of the Achères V project and the creation of the "Environmental Observatories" which were imposed by a local authority order in 1991. These Environmental Observatories are monitoring centres which aim to:

- follow the evolution of odour and acoustic emissions of the facilities,
- simulate the movement in the atmosphere of the odour emissions, considering weather conditions and operating conditions,
- estimate the level of disturbance suffered by surrounding populations.

The SIAAP has a highly developed measuring network combining several measurement approaches designed to understand the odour nuisances around its facilities:

- a classic analytical approach with the installation of measurement stations to quantify odour emissions and to evaluate their propagation to bordering districts,
- a sensory or human approach with the appointment of a range of different members to a panel.

The complementarity of both approaches has allowed a range of different indicators to be established so that the SIAAP can qualify the odour situation around its plant.

1.3 Tracked criteria and indicators

The criteria gathered in the network are the followings:

- **Chemical measurements**. In order to track the odour of its plants, the Seine Aval WWTP owns 17 monitoring stations inside the plant and 2 stations outside the plant's boundaries. They measure specifically sulphur compounds through Total Reduced Sulphur (TRS) analyses. The use of UV-Fluorescence Technology allows the monitoring platform to measure the TRS concentration every 30 minutes, with a detection limit below 0.01 ppb. This data is used at different levels: (i) alarm mode to inform the plant operators; (ii) the data is used for the generation of statistics, allowing the indicators to be published on a weekly, monthly or yearly basis; (iii) the data is used for reverse-calculation modelling in order to adapt some odour emission rates to the real emission conditions.
- **Daily odour patrols**. Patrols are conducted by experts trained in the detection and recognition of odours from WWTPs. Each odour patrol is carried out by one odour inspector who tours the plant and bordering districts to establish an odour map. This sensory mapping is meant to warn the operating agents in case of any abnormal odours, and consequently to reduce its potential impact by immediate preventive or corrective actions. Furthermore, the results collected during these patrols are of great use when receiving complaints or spontaneous observations in order to identify the origin of the emissions, react and communicate with the complainants.
- **Citizens' panel members**. A citizen committee collaborates actively in monitoring odour problems. For SAV, 120 voluntary residents submit regular observations via the internet. During one week every month, the panel members are asked to fill in a form, on the internet, about their odour perceptions as well as their non-perceptions (this last data is important in order to be able to estimate an accurate odour exposition index). This all year round program has the advantage of covering the full annual climate cycle likely to affect the site.
- **Complaints logbook** (or spontaneous observations). Through different media (SIAAP website, phone, smartphone), every citizen is able to quickly inform SIAAP of any notable event.
- **Odour dispersion tool**. This tool (called SYPROS) is based on three-dimensional numerical CFD dispersion. It includes a real-time function to produce uninterrupted odour concentration maps and a forecast function to predict odorous events according to weather and operations conditions of the facilities.

The collection of these different parameters allows the development of a recurrent evaluation grid over time, as shown in Figure 1 below.

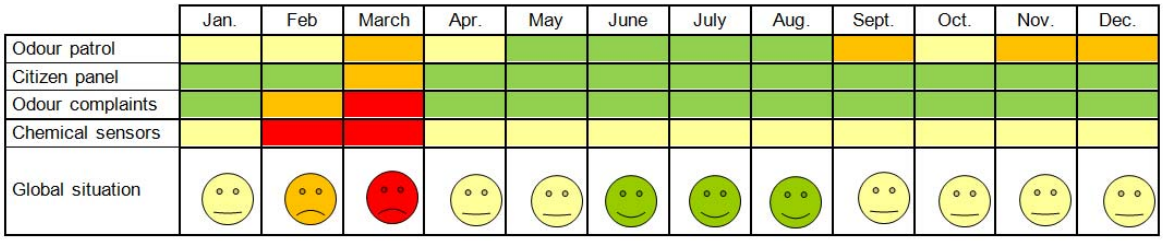

Figure 1: Indicator grid over time (SAV - 2017)

1.4 Regulation and guidelines

Generally, the impact of an odour results from a combination of interacting factors such as: the frequency of perception, the "odour concentration", the duration of perception, the offensiveness, the intensity, and the location (Freeman and Cudmore, 2002).
Most of the European guidelines are expressed as an odour limit such as an odour concentration, to be respected at a given frequency (Nicell JA, 2009):

- The frequency is a measure of how often an individual is exposed to an odour in the ambient environment. Many jurisdictions around the world have adopted regulatory limits for odours that restrict the frequency at which an odour impact should occur at or beyond the property boundary of a facility. The most common criteria state that a facility must be in compliance with a specified odour concentration limit (e.g., a maximum concentration) at frequencies of 98%, 99%, 99.5% or 99.9% (RWDI Air Inc., 2005).
- The odour concentration is a quantitative parameter based on the dilution-to-threshold principle. According to this principle, the odour concentration can be said to be equal to the number of dilutions of the original odour sample that are required to bring it to the sensory threshold level. The number of dilutions required is referred to as the odour concentration and are expressed as ''odour units'', abbreviated as OU, or, in Europe, as ou/m^3 (odour concentrations are assigned dimensions of ou/m^3, but are numerically equivalent to those expressed in OU). Also, an odour is said to have a concentration of one odour unit (1 OU) when it is at a level that corresponds to the threshold.

For the SAV facilities, the SIAAP chose to retain the value commonly used in France, namely the hourly mean approach, with a 98th percentile of hourly averages at 5 ou/m^3. This means that the odour threshold value (5 ou/m^3) can be exceeded for no more than 2% of the time over the year.

2. Weaknesses in the current monitoring system

While important redesign works at SAV are currently in progress, during which the need for an efficient monitoring system is highlighted, several weaknesses in the present tool have been identified.

Firstly, the daily odour patrols showed some limitations, such as:

- The previous daily patrols were carried out for a set of pre-identified points, chosen according to several patterns of weather conditions: six different circuits or rounds (for six wind direction patterns: NNE, SE, SSW, WSW, W, NW), each circuit including about 25 odour check points.
  The use of pre-identified points of control was historically chosen in order to save time for the odour inspectors. However, as the data collected from these field inspections was initially dedicated to developing an odour exposure index, it appears that this odour exposure index was overestimated, as the check points were systematically downwind.
- To facilitate the organization of work, the patrols were only carried out in the early morning. Although this is a favourable time for odour perception, this process lacks representatively over the course of the year.
- The patrols also aimed to collect qualitative information such as the odour descriptors, odour sources, odour offensiveness, etc. This objective was fully achieved. However, as the 6 pre-identified check point patterns do not take into account the wind speed or specific micrometeorological conditions that could occur, it is likely that the inspector can miss the odour peak in the plume.

Secondly, the predictive tool SYPROS, based on a real-time and forecast modelling platform, showed also some weakness such as:

- During the works of redesign SAV, various new and temporary operating conditions appeared, for which the modelling system were unable to predict the impact.

- The distribution of the chemical monitoring stations didn't anymore suit to the needs due to the important change of emissions sources.

3. New odour field investigations

3.1 Feasibility study

In order to improve the efficiency of the monitoring system, a feasibility study was carried out regarding the implementation of the new European Standard EN 16841, and taking into account of other feedback such as (Mannebeck, 2016). This standard is based on field inspections and describes two methods for direct assessment of odours in ambient air. The expected benefits of such implementation for the SIAAP were first evaluated as below (Table 1).

Table 1: Expected benefits regarding the implementation of EN 16841:2016

Standard	Description	SIAAP's benefits
EN 16841-1:2016	Grid method using direct assessment of ambient air by panel members to characterize odour exposure in a defined assessment area	Allows the estimation of an odour exposure index with a good degree of confidence Allows the verification of the compliance with the regulatory odour threshold (5 ou/m^3 to be respected at least 98% of the time)
EN 16841-2:2016	Plume method for determining the extent of the downwind odour plume of a source	Allows the evaluation of the odour plume during specific events, especially during the SAV's redesign works, events which are not fully appreciated using the modelling platform

As both methods are complementary, the SIAAP wished to implement both of them. Knowing that the previous patrols represented an important annual cost (representing about 550 $h.y^{-1}$ of odour patrols for SAV alone), the SIAAP's biggest constraint was to implement the new methods within the same budget. Therefore, the study aimed principally to evaluate the feasibility of the implementation of both standards within the SIAAP's means such as:

- a team of 2 inspectors,
- odour patrols with one inspector at a time for each daily round,
- a round with a duration no more than 2h30, only during day time and week days.

Table 2: Comparison between the standard's requirements and the SIAAP's means

Standard's requirements	Feasibility for the SIAAP monitoring platform
Qualification of the human panel members	
Selection to be conform with dynamic olfactometry EN 13725	To be implemented in the new process - **Feasible**
Team of at least 8 panel members	**Not feasible** (2 inspectors per site on average in the present configuration)
Each panel members cannot perform more than 20% of the measurements	**Not feasible** (2 inspectors per site doing each 50% of the measurements)
Supervision of a manager over 10% of the measurements	**Feasible (**1 to 2 days per month under close supervision)
Sizing of the grid	
Radius of the grid equal to at least 30 times of the highest stack or at least 600 m	**Feasible –** The size grid is set to 2 km x 2 km
Observation points every 250 m to 500m	**Feasible**. The final grid includes check points every 500 m except in the surroundings covered by woods
Planning	
Over one year, at least 26 measurements per observation points	**Feasible –** the number of observation points has been set in order to comply with this requirements
Even distribution of the observations over the time of the day and the day of the week	**Not feasible** – to be adapted to day time and week days

Twenty five criteria of both standards have been evaluated. Table 2 is an excerpt from this analysis for the grid method. The study showed that of the 25 studied criteria (the main requirements of the standard), only 8 criteria could not be respected considering the time allocated to each round and the number of panel members.
Finally, this first study concluded that in order to be in full compliance with all the requirements of the standard, the SIAAP would need to at least double the budget dedicated to the daily odour patrols. By applying the new standards, such as described in the next chapter, a compromise was found.

3.2 Main outcomes – Grid method

In order to suit the SIAAP's means and to ensure optimal benefits, the final protocol describes that the daily odour patrols are conducted as follows: according to the grid method during about 200 working days over the year, and according the plume method during about 50 working days over the year.
A detailed programme is done at the beginning of the year so as to be sure that the measurements of the grid method are evenly distributed over the season, the time of the week (here only week-days) and the time of the day (in this case: 7h-10h ; 10h-13h ; 13h-16h ; 16h-19h). The advanced planning also tried to avoid having two single measurement points of an assessment square evaluated on the same day. In order to save time during the patrols, 6 predetermined circuits have been defined, each of them having 9 to 11 observations points, for a total of 63 check-points (Figure 1a).

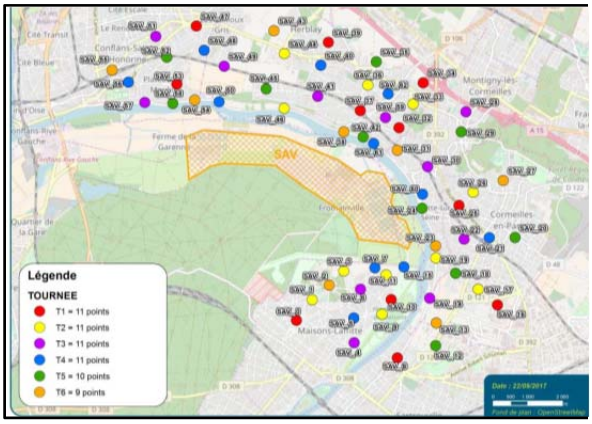

Figure 1b: Monthly Odour Exposure Index

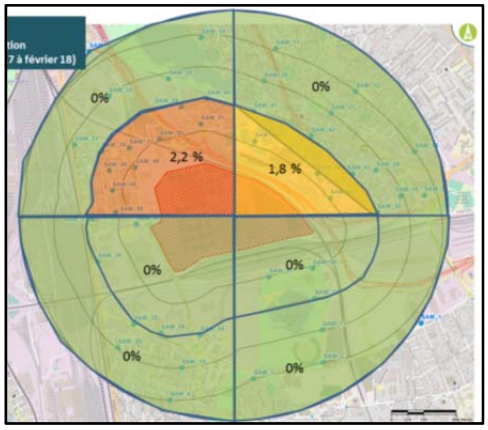

Figure 1a: Grid-Method – 9 predetermined circuits

Each single measurement is performed to determine whether the test result is an odour hour or not. According to the standard, the panel member conducts the single measurement at a measuring point for 10 minutes. He inhales ambient air every 10 seconds and evaluates the presence or absence of odour and the corresponding odour type. After the total measurement duration, 60 individual observations at the measurement point are obtained. When the SAV odour reaches or exceeds a percentage of time of 10 % (presence of odour is detected at six or more observations) the result is classified as an odour hour. However, for this protocol, the SIAAP proposed to change the duration of the measurement from 10 minutes to 5 minutes, in order that the SIAAP's conditions (a round to be done within 2h30) can be respected. Moreover, as the inspections take place in an urban environment, this duration reduces the chances of disruption. The number of individual observations is still 60, since the assessor evaluates the presence or absence of odour every 5 seconds.
Regarding the data treatment, the grid method describes the calculation of the odour exposure index, the odour hours of the four measurement points being summed up and the result is then divided by the amount of total measurements at this assessment square. The deliverable of the grid method is thus a yearly odour exposure indicator. However, the SIAAP wishes to have a monthly exposure index in order to be able to closely follow the environmental situation at the SAV. Since each check point is visited four times at best during one month, a monthly odour exposure index would have a very low degree of confidence. Consequently, the final indicators have been chosen as follow:

- Each month, the 12-month rolling odour exposure index is reappraised.
- Moreover, considering the chosen grid, with 63 checkpoints not located in a straight regular grid, it was not appropriate to evaluate the odour exposure index for assessment squares as described in the standard. Thus, the chosen method of visualisation of results was to estimate the odour exposure index for larger areas, as shown in the Figure 1b. The number of data points per zone is thus more important giving more confidence in the indicator.

- Another overall index is developed, based on the total number of odour hours reported over the month for the entire area. Represented on a chart, this monthly data, associated with the number of odour patrols, makes it possible to identify any drift.

3.3 Main outcomes – Plume method

As for the plume method, the odour patrols are carried out over about 50 days of the year, either:

- when odour complaints are signalled
- when unplanned events that could lead to odorous events are reported by the plant operators
- when the SYPROS tool forecasts an odour peak.

The rounds for the grid method are planned all year round, every working day (about 250 days), but the SIAAP evaluated that, during the year, around 50 odour patrols done according the grid method will be cancelled in order to do a round according to the plume method.
Each round triggers the generation of a summary report including information such as:

- general information (date, hour, duration of the round, weather conditions, reason why the round was done)
- results of the round, especially the plume outline, the odour origin, odour intensity,
- then a close comparison is done between the identified plume and the one estimated by the air dispersion modelling tool (real-time and forecast). This comparison is thus part of a continuous improvement process, each gap leading to a corrective action.

4. Conclusions

The SIAAP's odour monitoring system needed to be dusted off and updated with respect to its procedures for daily odour patrols. The implementation of both the 'Grid Method' and 'Plume Method' of odour field inspections, described in the new standards (EN 16841-1:2016 and EN 16841-2:2016), appeared to be the correct solution. However, as the implementation of these methods requires the use of considerable human means, even for an organisation such as the SIAAP, some compromises had to been found. Consequently, although the new protocol implemented by SIAAP is not in full compliance with the standards, the merging of both methods over the course of the year, in a new and original method, provides both a good degree of confidence in the odour exposure index and also allows the provision of extended information in case of an abnormal odorous event.

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