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Tool for Predicting and Monitoring the Impact of Wastewater Treatment Plants on Odour

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The SIAAP[1] has implemented a new specific tool called SYPROS based on analysing atmospheric dispersion for forecasting and monitoring the odour impact of wastewater treatment plants on the surrounding urban areas. Meteorological data and Total Reduced Sulphur concentrations monitored on-site are used in order to provide estimations of odour emissions generated by wastewater treatment facilities. The atmospheric dispersion of these odours is then assessed using a specific three-dimensional numerical model which provides information on the real-time odour impact of wastewater treatment plants. The weather forecast, the set-up of the facilities in use and data on wastewater quality are all used to assess the odour emissions generated. This method of evaluation is based on the results of a three-year on-site data analysis project. The odour impact of the wastewater treatment plants for the next two days is computed using forecasted odour emissions and weather forecast data with the help of another specific three-dimensional numerical model which is available for both internal purposes and public use.

1. Introduction

Over the last two decades, several combined factors led to an increase in odour monitoring around industrial and WasteWater Treatment Plants (WWTP):

- Cities are expanding and so the areas immediately surrounding plants became more urbanised;
- Wastewater discharges decreased while water savings increased, with pollutant concentrations remaining steady;
- Nuisance acceptance decreased.

The wastewater authority of the Paris area (SIAAP) anticipated these developments and implemented several tools designed to monitor odour impact in the urban areas surrounding the WWTPs. As part of its odour monitoring system, the SIAAP set up “odour observatories” in order to monitor odours in the urban areas surrounding 3

1 SIAAP: Syndicat Interdépartemental pour l’Assainissement de l’Agglomération Parisienne = the public body that manages sanitation systems around Paris.

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WWTPs. To monitor future changes in its odour impact, the SIAAP decided to introduce a new tool, called SYPROS[2], to be able to forecast and monitor odours generated.
This tool is innovative in several ways. Its implementation involved several one-year study campaigns and IT development. This paper will first look at the characteristics of the system and its main features, before providing details of the ways in which it is innovative and the methodology used for implementing the tool. Finally, the discussion section will describe the experimental data generated.

2. An Innovative Tool

2.1. Aim and objectives

The overall aim of SYPROS is to provide the SIAAP with a system for monitoring and predicting the odour impacts of three of its WWTPs in real time.
The objectives of the tool are:

- To provide continuous monitoring of the odour impact on the areas immediately surrounding the WWTP, with results updated every half an hour.
- To provide odour impact 48-hours predictions for the areas surrounding the WWTP.
- To help WWTP workers to assess the odour impact of on-site operations on the basis of the WWTP set ups and the weather conditions.
- To inform the public about odour nuisances.

2.2. Theoretical background

2.2.1. Real-time dispersion models coupled to CFD models

The literature survey on real-time dispersions shows that the real-time simulation tools are based on very simplified models of dispersion of particles, such as Gaussian or 2D models (Alhajraf et al, 2005; Davakis et al, 1998; Borysiewicz and Borysiewicz, 2006; Sorensen et al, 2007). Indeed a standard Gaussian or integral approach is very fast but tends to overestimate the concentrations and impact distances and is unable to predict correctly concentrations at close range.
On the other hand, more advanced models are able to take into account the specific configuration of a site in term of topography and/or obstacles. More specifically, the three-dimensional models, based on the resolution of the equations of fluid dynamics (termed as Computational Fluid Dynamics (CFD) models), make it possible to simulate the gas emissions by taking into account the influence of the ground roughness and the nature of the local environment. (Hill et al, 2007; Jenkinson et al, 2007; Mazzoldi et al, 2008). The drawback of CFD calculation is that it requires large CPU time. Therefore, the challenge of an innovative real-time numerical tool is to combine speed and precision for the calculation of the atmospheric flows and pollutant dispersion, in order to increase accuracy and dependability of real-time simulation results.
The methodology that will be described in this paper aims at providing such a numerical tool, by coupling the CFD models for local wind flows simulation with more classical Lagrangian models for dispersion modelling.

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[2] SYPROS : Système de Prévision des Odeurs du SIAAP = SIAAP odour forecasting system.

2.2.2. Wind modelling

A 3D CFD model, Fluidyn-PANEIA (Patil and Gupta, 2005; Nicolas et al, 2008) has been chosen to simulate the 3D wind field pattern on the WWTP, taking into account the details of the installations. This approach enables a precise simulation of the turbulence and flow around the buildings and near the ground; a crucial issue since short distance information are sought here.

2.2.3. Dispersion modelling

To obtain an odour real-time management system it is needed to couple the above quoted models (i.e. CFD model and Lagrangian puff model) to real-time adjustments of the source emission based on on-site continuous measurements. The so-called remapping process is then described in the following section.

2.3. Characteristics of SYPROS

2.3.1. Three different functions for three different aims

In order to fulfil the aim and objectives of the tool, three functions were identified and implemented: a "real time" function (to produce continuous odour concentrations), a "forecast" function (to predict odour concentrations) and a "diagnosis" function (to model odorous special events).

2.3.2. The architecture of the tool

The tool consists of an interface for data input, an atmospheric dispersion software with specific components and a graphical interface for displaying the results.

Inputs data includes (for the real-time function): weather forecast (wind direction, wind speed, atmospheric stability, and temperature), TRS concentrations measured at the monitoring stations and default odour and TRS emissions. For the prediction function, weather forecast and predicted odour and TRS emission data are needed.

The atmospheric dispersion software contains the WWTP numerical model, a database of pre-calculated wind fields, a component for remapping odour emissions (specific to the real time function), and a solver for atmospheric dispersion.

The results of the simulations are saved and displayed on an Intranet website. Tool operators check the results and validate them.

3. Real-Time Function

3.1. General functioning

Every half an hour, the system receives weather and TRS data, and calculations are made automatically. Emission estimations are produced and are then used for atmospheric dispersion simulation based on background concentrations (from the previous time period). Maps of the odour impact are generated from the results of these calculations and displayed on the Intranet validation tool.

3.2. A major innovation: Odour emissions remapping

Since there is no system in place for directly measuring odour emissions at the WWTP, the data available for estimating odour generation in real-time was based on the TRS concentrations measured at monitoring stations located in the vicinity of the processing facilities. Since TRS currently make up the main component of all odours generated by the WWTP, a good assessment of the TRS impact from the WWTP should help assess

the odour impact of the WWTP. An investigation was therefore carried out to evaluate the TRS generated by the processing facilities (81) from the TRS concentrations measured at monitoring stations (20) for various different weather conditions.
As a first step, theoretical contribution and dilution factors between odour sources and TRS monitors were calculated and analysed. Then contribution factors and the assumptions based on previous experiences in monitoring on-site parameters of this WWTP were analysed in order to identify which source(s) has/have the greatest impact on a given TRS sensor for each wind field in the weather database. Dilution factors were then adjusted so that simulated TRS levels compared with TRS levels measured at a sensor located in the vicinity of the WWTP.
TRS levels emitted from the main odour generating treating facilities were able to be evaluated from the remotely monitored TRS concentrations.

4. Predictive Function

4.1. General functioning

Being able to predict WWTP odour impact involves computing wastewater quality measurements and information on the facility set ups, as well as information on the operations schedule and weather forecast. This data is processed on day D-1 by the tool operator. On the following day D, the tool operator verifies the odour impact prediction maps and its validity.

4.2. A major innovation: Predicting odour emissions

An innovative system was developed for predicting odours generated by the main odour emitting processing facilities. During the first stage of development, parameters influencing odour emissions were studied using a dataset of on-site weather condition measurements taking data from a three-year period, records of on-site operations, and measurements of wastewater quality parameters. These investigations made it possible to identify the factors influencing TRS emissions (COD, levels and variations of dissolved oxygen, upstream/downstream redox potential in aeration tanks.
The purpose of the second stage was to determine whether these parameters could be predicted up to 72 hours in advance. Several could be predicted from the operations schedule, the others were assumed to remain steady over successive days.
Once the methodology for predicting the main influencing factors was defined, the combined influence of all these factors on odour emissions was investigated. Odour emissions from processing facilities are governed by two main factors: wastewater quality and the condition of equipment. Wastewater quality parameters were used to implement a scoring system that included both these factors for a given processing facility. For each score, the corresponding odour emission level was evaluated using three years' worth of on-site TRS data and the remapping matrix.

5. Calibration And Verification Of The Tool

The odour emissions levels used in SYPROS were first set to values based on the analysis of olfactometry measurements. Since odour flows are difficult to assess, particularly for non-aerated processing facilities, they were then adjusted on the basis of

the comparison between human observations in the WWTP surroundings and simulated odour impacts.
Observations came from different origins:

- Professionals trained to evaluate odour levels and recognise them. They carried out specific operations in the urban areas surrounding the WWTP in order to locate odour plumes generated by the WWTP;
- Residents who sometimes complain about odour nuisances from the WWTP;
- "Voluntary odour watchers", who live in the urban areas surrounding the WWTP and who record odour levels.

The TRS emissions levels were first set to mean levels based on the use of the remapping matrix and a dataset of TRS concentrations measured at the on-site monitoring stations gathered over a period of three years. Comparing the simulated TRS concentrations and the monitored TRS concentrations recorded in the WWTP surroundings helped adjust the TRS emission levels.
These adjustments enabled the global odour impact of the WWTP to be reasonably assessed.

6. Conclusions And Future Developments

The development of SYPROS has led to the existing tools being optimised, and is innovative in several ways:

- Given the weather conditions, the origin(s) of the TRS concentrations measured at some monitoring stations can be identified and the corresponding TRS emission(s) from processing facilities can be real-time evaluated.
- The main contributing factors governing odour emissions have been identified and used for predicting odour emissions associated with specific WWTP conditions.
- The model has been adjusted using experimental data.

The odour impacts generated by 3 WWTPs are monitored and predicted using SYPROS. It is integrated into the whole SIAAP monitoring system and is the component which links monitored parameters, scheduled site operations and weather forecast data with WWTP odour impacts on the surrounding areas. It is used on a daily basis by the tool operators to improve WWTP odour impact monitoring and understand on-site odour generation.
The first stage of the implementation of SYPROS has been successfully achieved during which, several steps were accomplished:

- A number of tool parameters has been validated: Results were analysed to verify and, if necessary, to modify certain parameters which could not have been adjusted over the 4-month experimental phase.
- SYPROS was progressively integrated into the information and decision-making system for WWTPs operations, as SYPROS results:

During the mid-term stage of the SYPROS implementation, actions were taken:

- Carry out constant improvement: through systematic analysis of the results generated by the tool, feedback were used to increase the accuracy of the prediction system as well as the accuracy of real time odour emissions estimates under specific on-site conditions.
- Ultimately SYPROS results were made available via a public-access website after on-site validation for the Seine aval WWTP and will be made for the other plants.

Improvement of the simulation tool will be done through new measuring campaigns in order to achieve better calibrations of the default odour emissions in the coming year.

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