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Comparison of Predicted Versus Real Odour Impacts in a Rendering plant with PrOlor

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PrOlor is the first commercial software (Cartelle et. al 2014) that is able to predict odour emission episodes two days beforehand, using prediction meteorological data instead of real time data. This way the plant operator has a time frame to take actions to control the odour emission and prevent odour incidents, before they actually happen. PrOlor is based on CALPUFF and WRF at very high resolutions. The system is run in a Linux cluster with supercomputing capabilities.
In this experiment, PrOlor was used in an animal by-product rendering plant with a previous record of odour complaints. In a village nearby to this plant, a register of complaints from the residents was set for a year. Each volunteer had an application in its mobile to register a complaint every time they detected odours from the animal by-product processing plant. The first results were not very promising and it was necessary to increase the resolution of the model. Later it was necessary to apply a peak to mean ratio to further improve the results. In addition, it was necessary to run the model several times a day, to better tune the prediction of odour episodes. After 10 months, the results showed that the optimum level to consider a forecasted result as an odour incident is 2.1 ou_E/m^3. Also, PrOlor was able to forecast adequately in a 41.2% of the incidents and 99.1% of the hours where no incident was recorded. Finally, the results showed that there is a trend to over-predict odour incidents.

1. Introduction

Traditionally, animal by-products processing plants (or rendering plants) have processes that are known to produce odour emissions (Sironi et al. 2007). This odour emission is linked to a process of evaporation of the water contained in the material processed. During this evaporation process, there is a release of non-condensable gases to the atmosphere with a high odour concentration.In some cases the odorants emitted may cause an odour impact.
In Europe this type of activities have a very special environmental regulation under the Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control). This Directive regulates among other things the emissions to the atmosphere of the rendering plants including the odour emission.
The Reference Document on Best Available Techniques (BATs) in the Slaughterhouses and Animal By-products Industries (May 2005) is a guideline that sets different ways of achieving a better control of odour emissions. However, although most of the plants release odours to the atmosphere, not all of them produce an odour impact in villages and towns nearby.
There are many BATs that allow a decrease in the odour emission with not much cost involved. In other cases the BATs are expensive in terms of installation, operation or maintenance. An olfactometric assessment is the most adequate method to know which is the best BAT to control odour emissions in a rendering plant with problems of odour impacts.
After an olfactometric assessment, odour dispersion modelling is nowadays a routine method in environmental odour management to calculate an odour impact. The calculation of the impact of the odours released by a rendering plant is usually based on a previous set of meteorological data. This evaluation gives a good idea of

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the yearly odour impact of plant, provided that the met data are representative. However this odour assessment is not quite useful for a day by day operation of the factory.
In the last years the calculation capacity of the computers grew and it was possible to calculate and follow the odour plume in real-time with the help of a weather station. This made possible to the industrial activities to see on a screen when there was an impact in the neighbourhood at the same time that it was happening. This “online” or “real time” odour monitoring has a philosophical problem in itself: once the impact is observed at a real time, it is already too late to take actions to correct it.
That is, there is no way to prevent the odour impact.
It is important to know well in advance if there is going to be an odour impact because many industrial activities can control their emission by means of operative actions. For example, the operator can turn on or delay a process involving a high odour release. Also the plant manager could take other actions, as regulating the chemical-dosing, the temperature or the fan speed of the odour abatement system.
If the industrial operator knows well in advance when, where and which is going to be the odour impact in a town or city nearby, operative actions can be taken in order to prevent it such as stopping or delaying a process known to generate odours.
In addition, many of these factories have a *Thermal Oxidizer*(TO).The cost of running a TO can go up to several hundreds of euro every year just burning fuel or natural gas. This expense can be greatly reduced if the industrial operator just burn fuel in the TO when is able to foresee that there will be an odour impact.
PROLOR is the first commercially available software tool that is able to forecast an odour impact 2 days before it actually happens. PROLOR is available through a web service or an android app.
PROLOR was first presented worldwide at the NOSE conference in Venice in 2014 (Cartelle et. al. 2014) as the first commercial software that was able to forecast an odour incident two days beforehand. At that time, an experiment to check the performance of PrOlor was already set with an animal by-products industry, but no results were given in that conference.
The aim of this paper is to present the results of a case study of an animal by-product processing plant that used the software PROLOR comparing the odour and no-odour alerts with a record of complaints. In addition, the second aim of this paper is to present the influence of an increase in the resolution of the meteorological data and the application of a peak to mean factor on the overall prediction.

2. Methodology

The animal by-product processing plant set in this case study had a previous record of complaints from some villages nearby since its opening in 1992. The owners of the plant also pointed out that there were other potentially odour emitting activities in the area. In addition, the owners commented that they had no idea about when, where and which type of odour the residents were complaining about, as the environmental complaint forms filled did not specify these data.
After some meetings with the owners of the rendering plant and the residents, a mechanism was set in order to register automatically every complaint. Some residents living nearby were part of this project. They had a link to a website where they could register an odour complaint form. This was made with their mobiles.
In this complaint form, the residents would register an odour incident with an intensity scale. Once this form was filled, automatically an alert was sent by e-mail to a group of people, which comprised the coordinator of the plant and the environmental responsible of the plant among many others.
The database recorded 91 and 68 "odour incidents" from the volunteers in the years 2013 and 2014, respectively. Although there was a decrease of odour incidents along the years, the factory decided to use PROLOR to predict the odour impact 2 days before they happened. With these data, the plant began to program production delays and to redirect the production to hours with no prevision of odour impact.
In this study we have considered the period August 2014 -June 2015.
In this case PrOlor was set to forecast the odour incidents of this plant in order to prevent the odour impacts. The odour emission rate was obtained from various olfactometric campaigns performed along the years in the six sources that the plant had in two separate processing buildings.
In all cases the measurements consisted of triplicates for each source. Some sources had a high temperature and they had to be diluted in order to avoid condensations of the samples. The analysis of all the samples were made before 30 hours in labs accredited under EN ISO/IEC 17025 for the determination of odour concentration according to the norm EN 13725. The worst operational conditions were selected.
PrOlor is based on an advanced Lagrangian model system, built and installed in a cluster of Linux platforms with supercomputing capabilities (Cartelle et. al. 2014). The system is formed by a meteorological model (WRF) whose results are used as an input for a Lagrangian model (CALPUFF) (Scire et. al. 2006). The results are shown in a website and with an android app.

In September 2014 a peak to mean ratio (NSW 2005; Piringer et. al. 2014) was implemented in order to consider the short-term impacts that might occur in the village nearby, however, although an improvement of the results was shown, a need for further improvement was detected.
In February 2015 the resolution of the meteorological model WRF was also improved in order to reach a better correlation between predicted and real incidents.
In this analysis, the whole set of data was split in different subsets. In the first subset, the coincidence of the real and the predicted data was compared regarding the time coincidence of the two data in the following manner:

1.If there was a correspondence between the hour predicted and the hour of the incident

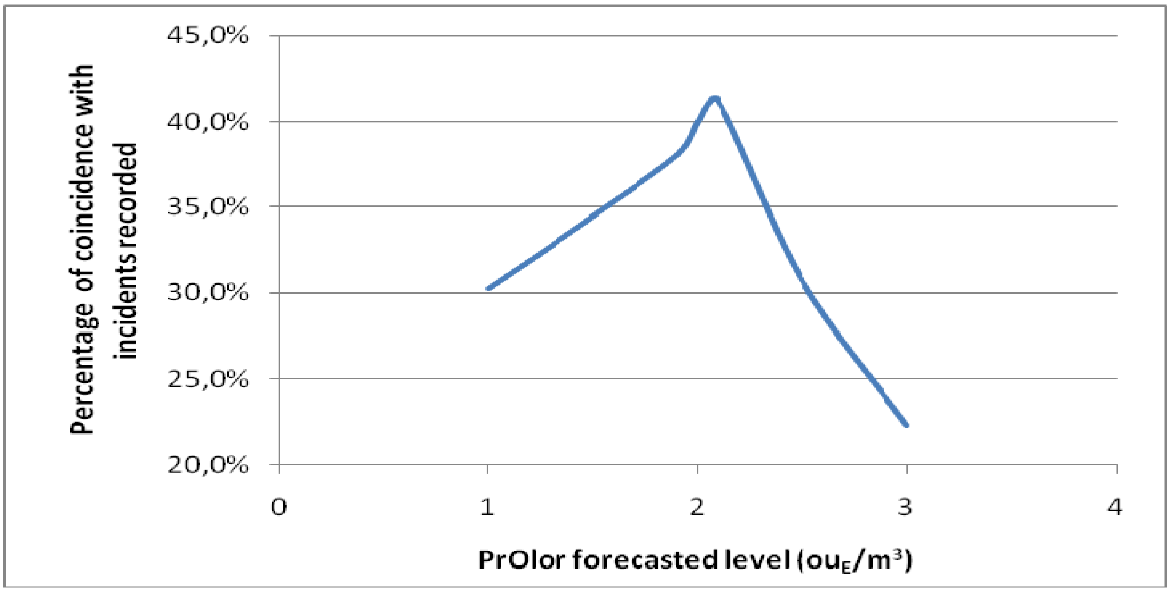
2.If there was a correspondence between the hour predicted and one hour before or after the incident (deviation of ± 1 h)

3.If there was a correspondence between the hour predicted and two hours before or after the incident (deviation of ± 2 h)

Another subset was considered considering the correlation between predicted and real odour impacts. Hours at which the residents were not in the village or were sleeping were discarded in order to have a valid set of odour- and no-odour- hours.

3. Results

A set of 49 validated incidents have been recorded along the time-study of 10 months.
The following step was to determine which level of calculated odour concentration was the right one to be considered an "odour incident". To this effect, the optimal percentage of odour concentration was calculated regarding the different ambient air odour levels predicted by the software. The following graph shows that the optimum odour level to consider that an odour incident predicted by PROLOR is real, is 2.1 ou_E/m^3.



Graph 1: Graphic representation of the percentages of odour coincidence, regarding different predicted levels of PrOlor.

Taking into account the level of 2.1 ou_E/m^3_in the period of study, PROLOR forecasted 73 incidents.
Then, the performance of PROLOR was calculated considering each of the complaints sent by the volunteers 1) prediction at the very same hour of the incident 2) prediction in the interval of ± 1 hour of the incident and 3) prediction in the interval of ± 2 hours of the incident. The results are shown on the first column of the table 1.

Table 1: Performance of PrOlor predictions at different hourly intervals regarding the incidents recorded.

	Odour Coincidence	Non-odour Coincidence	Odour + Non-odour Coincidence
At the exact time of the incident recorded	23.5 %	97.7 %	96.6 %
Deviation of ±1 hour	35.3 %	100 %	99.0 %
Deviation of ±2 hours	41.2 %	100 %	99.1 %

In addition, the number of coincidences of "non-odour hours" was also studied, that is, the hours where no odour impact was neither recorded nor predicted. The results are shown in the second column of the table 1.
Last, the number of coincidences of "odour hours" was compared, that is the hours where there was an odour impact recorded and predicted. The results are shown in the second column of the table 1.
The results show that PROLOR get an accurate prediction of 96.6 % of non-odour hours. It is possible to improve the result considering an interval of ± 2 h, as the percentage increases to a 99.1 %.
PROLOR is able to predict 100 % of the incidents when it was considered the interval of ± 1 h or ± 2 h. However, PROLOR only predicted a 41.2 % of the odour incidents, when the interval considered was the optimum of ± 2 h.
Finally, the impact of the increment of the spatial resolution of the WRF model on the predictions of PROLOR was studied. The WRF resolution was increased in February 2015 from 9 km to 3 km. The aim was to try to improve the percentage of successful forecasted events.

Table 2: Results of the comparison of the PrOlor forecasted results with the incidents recorded with a deviation of ±2h, with and without WRF improvement.

	Odour Coincidence	Non-odour Coincidence	Odour + Non-odour Coincidence	Number of incidents
Initial phase of PrOlor	41.2%	100%	99.1%	37
Phase after the WRF increased resolution	12.5%	100%	98.6%	12

The results showed that the increment of the resolution of the WRF did not improve the performance of PROLOR, but on the contrary resulted in a decrease of the results forecasted.

4. Discussion

The use of a dispersion model to forecast an odour incident is a valid tool to be used by a plant that is receiving odour complaints. Even if there is regulatory odour requirement in the facility, an appropriate odour management will lead to a good image of the industrial plant, less obstacles with environmental regulators and a good relationship with the neighbours. In addition, any regulatory procedure with the environmental regulator will not be slowed down.
For example, when a plant applies to include a new process of its activity, there is a need for the plant manager to speed up the processing of the application. Months of delay in the concession of the permit, means major economic losses and sometimes cancellation of the whole project. With PrOlor, the plant manager will avoid conflicts with the communities nearby and the corporate image of the plant will improve.
Many of the original subsidy and incentive programs have started to come to an end, which means that the industry as a whole has become more reliant on the overall business case and economics behind building and operating new plants. The demand for innovative, cost effective, reliable and sustainable plant components has never been greater as plant builders, owners and operators look to do their job in the most efficient manner possible.
Allocate resources to abate odours at all time is a very inefficient way to control the environmental costs of an industrial facility. With PrOlor the plant will need to abate odours only when there is a risk that the community around it will be affected.
There is no need to spend thousands of euro every year in odour abatement if there is no risk to have an odour incident with the community around a plant.

If the industrial facility decreases their environmental costs, the price of their final product will be lower and their total revenue will therefore increase. This situation happens when the plant have optimized labour cost and other costs related to chemical reagents, fuel, electricity, waste management, etc that will affect the overall environmental cost. With PrOlor the plant will be able to tight the cost of a product, which will make it more attractive and competitive in the market. This way the revenue will increase without affecting the community around the plant.

5. Conclusions

In 2014, PrOlor, the first odour forecasting service in the world based on Lagrangian model coupled with the meteorological model WRF was presented in the NOSE conference that took place in Venice in 2014 (Cartelle et al.). To date, we have not found yet any publication on the available scientific literature about the use of a Lagrangian dispersion model to forecast odour events.We have selected a Lagrangian model instead of a Gaussian model because Lagrangian models such as CALPUFF are usually better suited to model Odours (Barclay J. 2013).

To test this tool, we took this theoretical forecasting model and we compared the results predicted with real odour incidents.

A rendering plant implemented the software PROLOR in August 2014 in order to forecast the odour incidents in the populations nearby 2 days before they happened. PROLOR is a program based on a Lagrangian dispersion model run on a daily basis with a cluster of Linux machines with supercomputing capabilities. We have decided to brand this product with the name PROLOR, that stands for *Pro*gnosis of Odour (*Olor*in Spanish).

After 10 months, the results showed that the optimum level to consider a forecasted result as an odour incident is 2.1 ou_E/m^3.

Also, PROLOR was able to forecast adequately in a 41.2% of the incidents and 99.1% of the hours where no incident was recorded.

As the prediction of odour results was not satisfactory we decided to increase the resolution of the WRF model.

The results showed that an increase in the resolution of WRF model did not improve the results forecasted.

It must be taken into account several aspects that may affect the results such as that the olfactometric campaign was made with the worst possible conditions. Some other aspects that might affect the low forecasted percentage are also the uncertainties of the prognostic Met data, of the olfactometric analysis and that of the model. In addition a higher resolution spatial and temporal may improve the results.

Finally, the application of a Peak to Mean ratio did improve the results forecasted.

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