CHEMICAL ENGINEERING TRANSACTIONS

VOL. 30, 2012

Guest Editor: Renato Del Rosso
Copyright © 2012, AIDIC Servizi S.r.l.,
ISBN 978-88-95608-21-1; **ISSN** 1974-9791

A publication of

AIDIC

The Italian Association
of Chemical Engineering
Online at: www.aidic.it/cet

DOI: 10.3303/CET1230049

Design of a Specific Apparatus to Evaluate Odour Reduction Efficiency of a Nebulizing System Applied on Odorous Liquid Surfaces

Licinia Dentoni*[a], Matteo Bascelli[b], Laura Capelli[a], Selena Sironi[a], Renato Del Rosso[a], Marco Buccolini[b]

[a]Politecnico di Milano, Department of Chemistry, Materials and Chemical Engineering "Giulio Natta", Piazza Leonardo da Vinci 32, 20133 Milano
[b]Chimec S.p.A., via delle Ande 19, 00144 Roma
*corresponding author: ldentoni@chem.polimi.it

In recent years an increase of population complaints about odour emissions from industrials occurred. For this reason several abatement systems have been developed in order to reduce odour emissions that could impact on the surrounding territory. The evaluation of the odour reduction efficiency of such systems is a crucial aspect and therefore methods to evaluate it have been developed.
This work focuses on the development of an experimental apparatus in order to evaluate the odour reduction efficiency of nebulization systems on odorous surfaces. This apparatus was designed in order to simulate field conditions, such as the wind flow on the odorous surface. The designed apparatus was used to evaluate the odour abatement efficiency of deodorizing products from Chimec S.p.A. on API liquid, taken form a refinery API tank. Olfactometric analyses were carried out on samples relevant to API solution without any treatment and after product nebulization. The efficiency was evaluated at different wind speeds inside the apparatus, in order to simulate different conditions that may occur on field. Moreover, tests were carried out in order to evaluate the influence of the product concentration in water on the odour abatement efficiency. Tests show that by nebulizing the product with an optimized dosage an odour abatement efficiency of 80% can be reached. Further tests could be performed by using other odour emitting surfaces or to compare the efficiency of different products designed for odour abatement.

1. Introduction

Odour nuisance from industrial sites and complaints from population are becoming more and more frequent (Shukla 1991). For this reason several abatement systems have been developed in order to reduce odour emissions that could impact on the surrounding territory (Sironi et al., 2007; Kennes and Veiga 2010). Such systems often require a specific set up to achieve good odour reduction efficiencies, and, as a consequence, odour measurements at the considered emission are fundamental. When the involved emission is a point source and the odour abatement system is placed before the emission, the evaluation of odour reduction efficiency is easily obtained by comparing the odour concentration values obtained with and without the abatement system (Munoz et al. 2010). When considering area sources, it is possible to evaluate the odour emission rate and odour concentration by using specific equipment (i.e. wind tunnel for liquid surfaces) (Capelli et al. 2009), but the evaluation of odour abatement systems efficiency is more complex. In the case of abatement systems by nebulization of deodorizing

Please cite this article as: Dentoni L., Bascelli M., Capelli L., Sironi S., Del Rosso R. and Buccolini M., 2012, Design of a specific apparatus to evaluate odour reduction efficiency of a nebulizing system applied on odorous liquid surfaces, Chemical Engineering Transactions, 30, 289-294 DOI: 10.3303/CET1230049

products on the odorous surface, representative gas samples of the treated odour source are difficult to be obtained. For this reason, at the Politecnico di Milano, in collaboration with Chimec S.p.A., a specific apparatus was designed and realized, in order to evaluate the odour abatement efficiency of nebulized products on an odorous liquid surface. More in detail this apparatus, designed to simulate the wind flow on odorous surfaces, was used to evaluate the odour abatement efficiency of a specific product by Chimec S.p.A., composed by surfactant compounds and essential oils, named CH 9176 Star, on API liquid, withdrawn directly form a refinery API tank. The samples collected on the API solution without any treatment and after product nebulization were analyzed by dynamic olfactometry (EN 13725, 2003). This analytical technique allows to evaluate odour concentration (Gouronnec and Tomasso, 2000). The odour abatement efficiency was evaluated at different wind speeds inside the apparatus, in order to evaluate the influence of different conditions, that could be found on field, on the product efficiency. Moreover, tests were carried out in order to evaluate how different concentrations of the aqueous solution of CH 9176 Star affect the odour abatement efficiency.

2. Materials and methods

2.1 Apparatus design

The apparatus was designed to reproduce field conditions. More in detail, a real application of a nebulizing system on the surface of an API tank was taken into account. Some operational parameters, such as the ratio between the nebulized liquid flow and the area of the odorous surface treated and the air flow on the liquid surface were kept constant between the real system and the laboratory apparatus. The apparatus design is reported in Figure 1.

The apparatus is composed by two different sections (A and B) in order to evaluate the odour reduction due both to the physical absorption of odorous molecules into drops and the effect of the nebulization of surfactant compounds on the odorous liquid surface. These sections are divided by an empty septum in order to avoid the drag of the nebulized product from the first to the second section. In order to evaluate the contribution of physical absorption in odour reduction, the API liquid was placed in the basin behind the section A, and the aqueous solution of CH 9176 was nebulized inside section B. This way, odorous compounds coming from the API liquid were kept in contact with the deodorizing product in the gaseous phase, thus allowing to evaluate solely the absorption effect.

To evaluate the combined effect of the physical absorption and of the surfactant on the API liquid, the deodorizing product was nebulized inside section A, on the basin containing the API liquid.

Moreover, the presence of the two different sections allowed the investigation of the odour abatement efficiency at different wind conditions. Indeed, nebulizing the deodorizing product inside section A over the API liquid, allows to evaluate the efficiency of the system with low wind speeds, whereas nebulizing the CH 9176 Star in section B is representative of high wind speed conditions, when the nebulized product is dragged away from the odorous liquid surface.

The apparatus was designed in order to guarantee, inside the chamber, flow speeds between 0.1 and 1 m/s, which is a range considered to be representative of the conditions that can be found on flat land, at the level of an API tank. The nebulization system and the apparatus dimensions were chosen in order to keep the ratio between nebulized liquid flow and area of the odorous liquid surface treated equal to real conditions (field conditions), at 0.144 L m^{-2} min^{-1}.

Moreover, the height of the chamber was fixed in order to guarantee the complete development of the sprinkle coming from the nebulization system, which consists in an atomizing nozzle and all connected devices (i.e. peristaltic pump for the liquid injection and compressed air flux).

In order to guarantee a good distribution of the air flow a divergent section was placed between the fan and section A. This divergent section was sized in order to minimize the presence of turbulence into the apparatus. After section B a convergent section was placed, to facilitate sample collection.

The whole apparatus was constructed using Polyethylene terephtalate (PET), in order to obtain gaseous samples not polluted by odours coming from the apparatus (EN 13725, 2003).

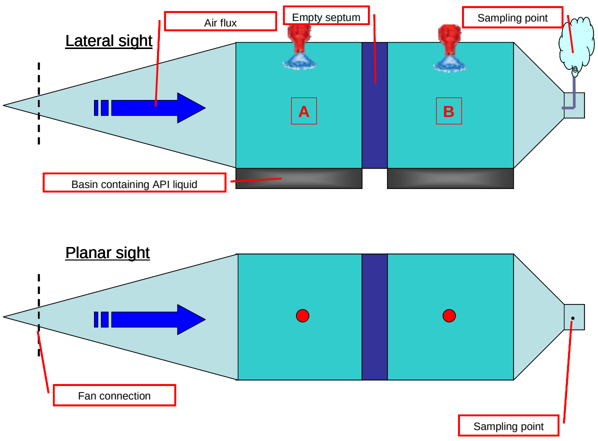

Figure 1. Apparatus design

Figure 2. The experimental apparatus

2.2 Preliminary tests
In order to verify the air flow velocity distribution inside the experimental apparatus, some preliminary tests were conducted using a hot wire anemometer. Air speed was measured inside the experimental apparatus at different heights from the odorous liquid surface. During the analyses, the basins at the bottom of the two sections were filled with water, in order to reproduce the operating conditions and to avoid losses of air from the bottom of the chamber. The instrument registered a speed value every 5 seconds. A minimum of 120 values were measured at each height, and their median was then calculated.

2.3 Test method
Analyses were carried out in order to evaluate the odour abatement efficiency of the aqueous solution of the CH 9176 Star product.

2.3.1. Sampling
Gaseous samples relevant to the non-treated API liquid were collected at the beginning of all tests. During each test gaseous samples were collected after 5, 10, 30 and 45 minutes from the switching on of the nebulizing system, in order to reproduce real conditions of start up of the system and the stationary functioning.
In addition, samples relevant to the nebulized product at the optimized concentration were collected with the aim of evaluating the characteristic odour of the CH 9176 Star product.
All samples were collected by using a depression pump in order to fill Nalophan^{TM} sampling bags with the gas to be analyzed.

2.3.2. Odour concentration measurement
The collected samples were analyzed by dynamic olfactometry. All samples were analyzed within 2 hours from their collection. Dynamic olfactometry allows to determine the odour concentration (c_{od}) of an odorous air sample, which is expressed in European odour units per cubic metre (ou_E m^{-3}), and represents the number of dilutions with neutral air that are necessary to bring the odorous sample to its odour detection threshold concentration (EN 13725, 2003).

2.4 Additional tests
Additional tests were conducted in order to evaluate the odour reduction that can be reached by nebulizing water instead of the deodorizing product.
Moreover, in order to evaluate the contribution of the presence of surfactant compounds on the odorous liquid surface, some specific analyses were conducted. More in detail, the same amount of deodorizing product that would have been nebulized in 45 minutes was poured on the surface of the API liquid, gaseous samples were then collected and thus the odour removal efficiency was verified.

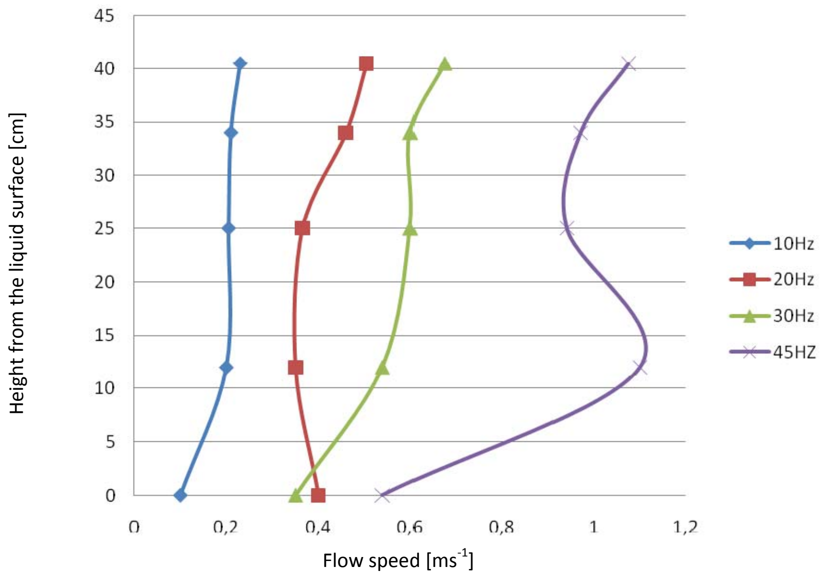

Figure 3. Flow speed at different heights form the liquid surface and at different inverter frequencies

3. Results and discussion

3.1 Air flow speed

Tests were performed setting different frequencies to the inverter connected with the fan. Median values obtained at the different frequencies and at different heights from the liquid surface are shown in Figure 3.

The results show that at an inverter frequency of 45 Hz the speed profile inside the experimental apparatus is not uniform, and therefore tests were not performed in these conditions.

3.2 Odour measurements

3.2.1. Odour of the non-treated API liquid and of the CH 9176 Star

Odour concentration values of gaseous samples relevant to the non-treated API liquid at different air flow speeds are listed in Table 1. For each flow speed some measurements were repeated in different days in order to account for the variability of the API liquid. The odour concentration values listed in Table 1 represent the mean values of those results.

Tests were also performed to evaluate the CH 9176 Star odour. Results obtained using a water solution containing 1% of CH 9176 Star at different air flow speeds are listed in Table 2.

The measured odour concentration values are between 20 and 30 ou_E/m^3. These values are comparable with typical non-odorous ambient air odour concentration values, thus proving that the water solution of CH 9176 Star does not have an odour that could mask the odour of the API liquid.

Table 1: Odour concentration of gaseous samples relevant to non-treated API liquid

Flow speed [m/s]	0.2	0.4	0.5
ou_E/m^3	520	590	540

Table 2: Odour concentration of gaseous samples relevant to the CH 9176 Star product

Flow speed [m/s]	0.2	0.4	0.5
ou_E/m^3	27	29	20

3.2.2. Odour abatement efficiency of the aqueous solution of CH 9176 Star

Tests were performed in order to evaluate the odour reduction efficiency of a water solution of CH 9176 Star nebulized on the API liquid surface.

Several tests were carried out in order to evaluate the influence of the CH 9176 Star concentration on the odour reduction efficiency. Results listed in Table 3 were obtained by meaning the odour concentration values of three repetitions of each measurement.

The results show that there is the odour concentration reduction increases with the nebulization time. Moreover, increasing the CH 9176 Star concentration entails an odour reduction efficiency decrease. More in detail, using a solution with 5% CH 9176 Star, the odour reduction is less than 50%, whereas using a solution with 1% CH 9176 Star at 1%, the odour reduction is more than 85%. These results highlight the importance of the optimization of the CH 9176 Star concentration in order to reach a satisfactory odour reduction.

Other tests where conducted using a water solution containing 1% of CH 9176 Star to evaluate the odour reduction efficiency of the system at different air flow speeds. Results, obtained by meaning three values for each measure, are listed in Table 4.

The results obtained show that the odour reduction efficiency increases when the air flow speed decreases, due to the increased residence time.

Table 3: Odour concentration reductions obtained nebulizing CH 9176 Star at different concentrations

CH 9176 Star concentration [v/v in water solution]	**t [min]**	**ou_E/m^3**	**Odour reduction %**
1%	0	650	--
	5	140	78.3
	10	91	85.9
	30	85	86.8
	45	77	88.2
2%	0	410	--
	5	110	72.9
	30	110	72.9
	45	68	83.3
5%	0	580	--
	5	460	20.0
	10	290	49.6
	30	360	37.4

Table 4: Odour concentration reductions at different air flow speeds

Air flow speed [m/s]	t [min]	ou_E/m^3	Odour reduction %
0.2	0	650	
	5	140	78.3
	30	85	86.8
	45	77	88.2
0.4	0	380	
	5	100	74.0
	30	68	82.3
	45	57	85.2
0.5	0	540	
	5	160	70.5
	45	120	77.9

3.2.3. Additional tests

Additional tests show that an odour abatement efficiency of 70% can be reached by nebulizing pure water. Furthermore other tests were conducted by pouring the CH 9176 Star directly on the API liquid, and the odour abatement efficiency turned out to be around 35%.

These data suggest that the odour abatement is primarily due to the physical absorption of odorous molecules and that the presence of CH 9176 Star in the nebulized mixture guarantees a greater odour abatement efficiency relative to pure water, probably due to the presence of surfactant compounds in the nebulized mixture.

References

Capelli L., Sironi S., Del Rosso R., Centola P., 2009, Design and validation of a wind tunnel system for odour sampling on liquid area sources, Water Sci Technol, 59, 8, 1611-1620.

Gouronnec A., Tomasso V., 2000, Measurement of odours by sensory analysis or "olfactometry", Analusis, 28, 3, 188-199.

Kennes C., Veiga M.C., 2010, Technologies for the abatement of odours and volatile organic and inorganic compounds, Chemical Engineering Transactions 23, 1-6, DOI: 10.3303/CET1023052.

Munoz R., Sivret E.C., Parcsi G., Lebrero R., Wang X., Suffet I.H., Stuetz R.M., 2010, Monitoring techniques for odour abatement assessment RID E-6493-2010, Water res, 44, 18, 5129-5149.

Shukla N.P., 1991, Air pollution by odour--sources, identification and control, Rev Environ Health, 9, 4, 239-244.

Sironi S., Capelli L., Céntola P., Del Rosso R., Il Grande M., 2007, Odour emission factors for assessment and prediction of Italian rendering plants odour impact, Chem Eng J, 131, 1-3, 225-231.