CHEMICAL ENGINEERING TRANSACTIONS
VOL. 30, 2012
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at: www.aidic.it/cet
Guest Editor: Renato Del Rosso

ISBN 978-88-95608-21-1; **ISSN** 1974-9791
DOI: 10.3303/CET1230004

Evaluation of OEC Data for Preparation of the New VDI Guideline 3885/1

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Odour problems often arise from liquids that contain odorants. Depending upon circum stances like high turbulence etc., these odorants can be stripped off the liquid, generating nuisance in the environment. In order to assess a liquid concerning its ability to emit odorants, it is necessary to measure the total content of odorants in that liquid. The procedure to attain this goal it the Odour Emission Capacity (OEC) measurement method. Frechen and Köster (1998) presented this method for the first time international in the year 1998, although the methodology was established by them since 1993. Frechen (2009) reported on the method and gave a summary of ten years of using this measurement method, doing more than 800 OEC measurements. Also other researchers started to use the method, e.g. Zarra et al. (2010) who analysed 20 samples of 2 wwtps from March to December 2010. Nevertheless, the method was not subject to any standardization so far. Now the German VDI started a committee to standardize this method as VDI guideline 3885/1 “Olfactometry – Measurement of the Odour Emission Potential of Liquids” (in progress).
When setting up a standard, the method to be standardized must be very clearly described, using the experience of its application so far. This paper deals with the basic procedure of the OEC method and then presents some evaluation of the existing data that will be used for further elaboration of the draft guideline text, undertaken by Frechen.

1. Description of the method

1.1 Sampling

A 30 L sample of the respective liquid is required. It is essential that sampling is done avoiding any turbulence as far as possible. Preferably the sampling conditions and the conditions at the sampling point and during sampling are documented by photos and a sampling protocol including facts like weather, air temperature, water temperature, etc.. Conductivity, pH-Value, oxygen concentration etc. should be scanned onsite. The test should be undertaken as soon as possible after sampling, as a change of the liquid, e.g. due to biological activity, must be avoided. Basically, the liquid sample is much less stable than the air samples generated during the OEC test.

1.2 OEC test reactor

The OEC test reactor is shown in Figure 1. The test reactor should be round to avoid unaerated corners. Usually, a standard fine bubble aerator well known from wastewater treatment plant aeration can be used to fill the total bottom area of the test reactor.
The test reactor has a closure head. Headspace volume should be less than 15 L. The closure has a connector so that sampling bags can be connected to withdraw samples of the off gas periodically.

Please cite this article as: Frechen F.-B., 2012, Evaluation of oec data for preparation of the new vdi guideline 3885/1, Chemical Engineering Transactions, 30, 19-24 DOI: 10.3303/CET1230004

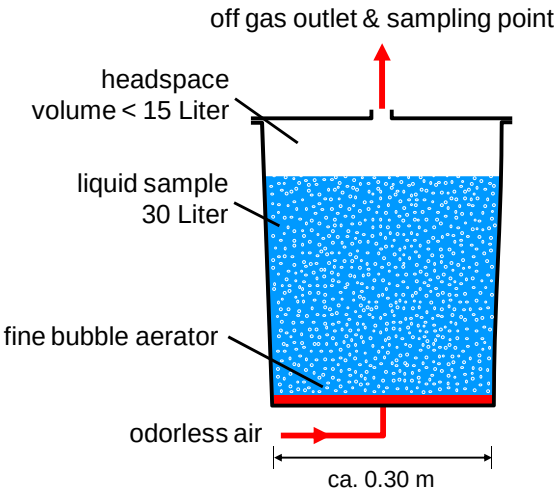

Figure 1: Sketch of the OEC test reactor

1.3 OEC test conduction

Before conducting each single OEC test, the respective test reactor has to be filled with drinking water. Then, aeration has to be started with the same airflow that will be used in the subsequent test. After an aeration time of 5 min a sample has to be withdrawn and analyzed via olfactometry concerning the odour concentration c_{od}.

The result should be below 100 ou_E/m^3. If not, the reason has to be identified and eliminated. A value of 100 ou_E/m^3 or less is accepted as the inherent smell of the test setting, especially the fine bubble diffuser, which usually is made of EPDM or similar. Thus, it is accepted by convention that a signal (i.e. an odour concentration c_{od}) is regarded as such if it is above 100 ou_E/m^3.

Immediately after sampling the sample should be filled into the test reactor avoiding any turbulence as far as possible. After filling, the test reactor is to be closed and aeration is switched on with the desired air flow.

From the measurements made by Frechen since 1994, the most common aeration flow rate is between 90 per h and 100 per h in relation to the sample volume of 30 L, resulting in an average airflow of 3,000 L/h. Although some tests were also undertaken with lower airflow down to below 10 $^1/_h$, more than 93 % were undertaken with an aeration flow rate between 90 $^1/_h$ and 110 $^1/_h$.

After start of aeration, off gas samples are taken after fixed time intervals. In the tests undertaken by Frechen since 1994, the most common times were 1.5 min, 8 min, 16 min, 32 min and 60 min. By doing so, for each test 5 samples are generated, that have to be analyzed via olfactometry and can of course also be analyzed analytically. Usually, the sample volume is about 10 L and the sample bag filling time is below 20 s.

1.4 OEC evaluation

Basis of the experimental data presented hereafter is the data pool measured by Frechen between April 1998 and June 2012. Older measurements undertaken in the years before 1998 were not taken into account. 835 OEC test were carried out in the period mentioned.

In general, the OEC is the area below the measurement curve and above a lower limit of integration which is accepted to be 100 ou_E/m^3 by convention, see section 1.3.

The basic formula of this integral is given in Figure 2. In fact the evaluation is done by simply calculating the area assuming a linear connection between the measured c_{od} values.

The simplest case of possible results of an OEC test, hereafter called *type a*, is shown in Figure 2. In the course of the test, the measured values c_{od} fall below 100 ou_E/m^3, which is accepted to be the lower limit of integration , see section 1.3.

The OEC is the area between the measurement curve and the lower limit of integration, thus the sum

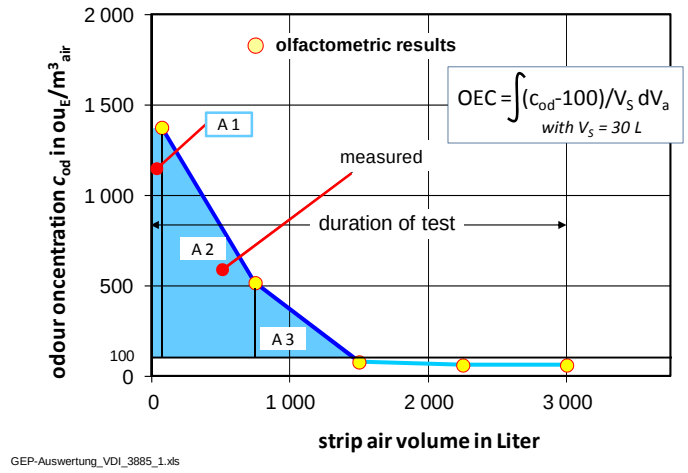

Figure 2: Evaluation of the test results type a

of areas A1, A2 and A3. 10.2 % of the total number of measurements mentioned were of *type a*.
Figure 3 shows the most likely *type b* of possible test results. 82.1 % of the total number of measurements mentioned followed *type b*.

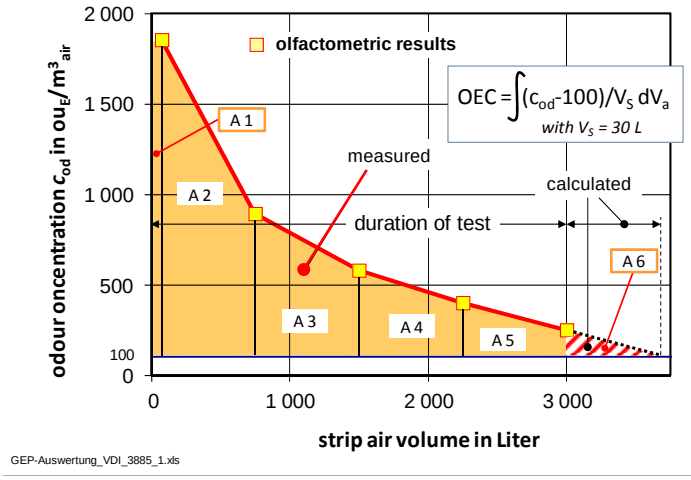

Figure 3: Evaluation of the test results type b

In the course of the test, the measured values c_{od} do not fall below 100 ou_E/m^3, (which becomes clear after olfactometric measurement, thus long after the test has ended). The last c_{od} value measured, however, is lower than the value second to last. In this case, the $OEC_{measured}$ is the area between the measurement curve and the lower limit of integration, thus the sum of areas A1 ... A5. The OEC_{total} is the $OEC_{measured}$ plus the area A6 which is calculated simply by linear extrapolation in linear scale.
Accordingly, with *type a*, $OEC_{measured}$ and OEC_{total} are identical.
An indicator of accuracy of the measurement might be the percentage of A6 related to the sum of areas A1...A6, thus to OEC_{total}, hereafter referred to as $\%OEC_{calc}$.
Besides these two types, there might be the result that OEC_{total} cannot be evaluated, see Figure 4. 7.7 % of all tests were of *type c*.
In this case, no extrapolation is possible. Either the last two c_{od} values are identical (1.5 % of all tests), or the last value is even higher than the value second to last as shown in Figure 4 (6.2 % of all tests).

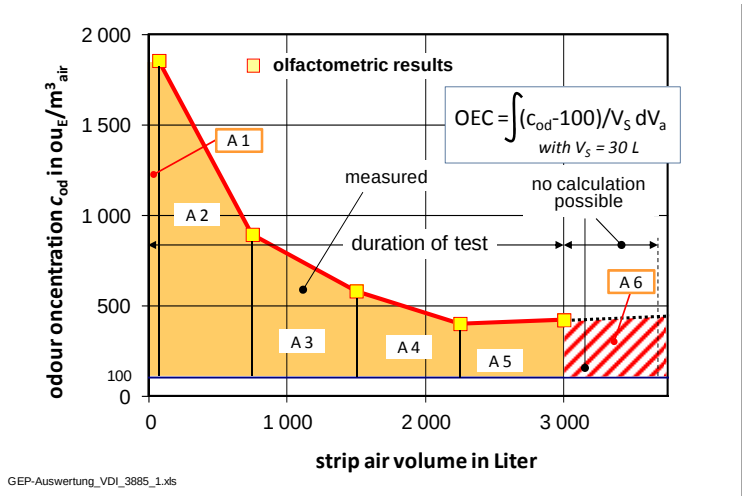

Figure 4: Evaluation of the test results type c

In case of *type c*, no OEC_{total} can be calculated. However, $OEC_{measured}$ can be calculated of course. Table 1 gives an overview over types of test and evaluation possibilities.

Table 1: types of tests and possible results; number of cases per types

Type of test	$OEC_{measured}$	OEC_{total}	$\%OEC_{calc}$	% of all tests
type a	Yes	**Yes** (=$OEC_{measured}$)	0 %	10.2 %
type b	Yes	**Yes**	>0 % - <100 %	82.1 %
type c	**Yes**	No	No	7.7 %

With test *type c*, it is not possible to give the OEC_{total} as the result of the test. In order to keep as much information as possible, today it is standard to give at least the $OEC_{measured}$ and add the information whether the last two c_{od} values were identical or the last c_{od} value was even higher that the second to last value.
Whenever OEC is mentioned without further specifications, OEC_{total} is meant. In general, it is recommended to report both the OEC_{total} (if possible) and the $OEC_{measured}$.

2. Further considerations

2.1 Influence of calculation of part of the OEC

As pointed out in section 1.4, in more than 4 out of 5 OEC tests, part of the OEC_{total} has to be calculated due to the circumstance that the last c_{od} value was not below the lower integration limit of 100 ou_E/m^3. Thus it is of interest which fraction of the result OEC_{total} is calculated. This is called $\%OEC_{calc}$ and is the ratio between the $OEC_{calculated}$ and OEC_{total}.
Figure 5 shows the distribution of the fraction of OEC_{total} that is calculated. The basis of this figure is that 771 OEC measurements gave a valid result (i.e. 92.3 %, see Table 1).
As can be seen, in more than 50 % of the cases the fraction of the calculated OEC is less than 5 % and in more than 75 % of the cases it is below 15 %.
So far no discussion is noticed whether the result might be subject to being discarded depending upon the fraction of the OEC that is calculated.

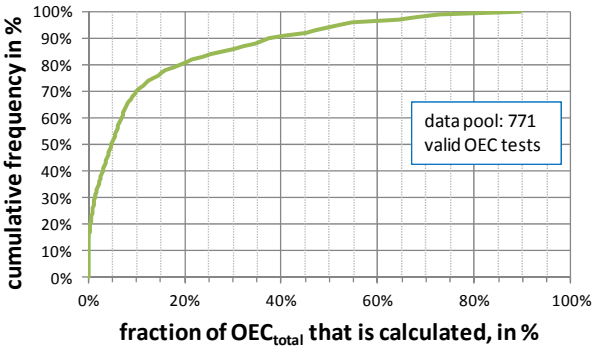

Figure 5: Distribution of the fraction of OEC_{total} that is calculated, in % (771 OEC test)

2.2 Test duration and number of gas samples

90 % of the test were conducted with a test time of 60 min, and even 93.3 % were carried out using a total air amount of between 90 % and 110 % of the "standard" value of 3,000 L.

Some of the liquids where it is of high interest to undertake OEC tests may contain organic load and also bacteria. Thus, it is possible that biological processes will take place during test, as the aeration is sufficient at all times to promote these processes.

Regarding this, a short test duration is favourable. In order to evaluate whether the OEC values of shorter tests are comparable to those evaluated with the "standard 1 hour test", the existing data were analyzed. For all tests, a second data set was created where the last out of n samples was omitted, resulting in tests with n-1 instead of n c_{od} values and of course also a shorter test duration.

Then the OEC calculation was done for the n-1 data set according to the evaluation described above.

Omitting test results for $OEC_{total,n}$ that were below 100 ou_E/m^3 or above 10,000,000 ou_E/m^3, and omitting tests where the total air volume for the test with n samples was not in the range of 3,000 L ± 10%, 601 pairs of results ($OEC_{total,n}$ and $OEC_{total,n-1}$), were left over for this evaluation.

Regarding aeration time, 98.8 % had a maximum aeration time for the test with n-1 samples that was 32 minutes or less. Regarding total air volume, 98.8 % of the tests used less than 1,600 Liter for the tests with n-1 samples.

Figure 6 shows the result. It can be stated that the $OEC_{total,n}$ is as an average 11.46 % higher than the $OEC_{total,n-1}$ would have been.

This means that shortening the test from 60 min duration down to 32 min duration and reducing the total amount of aeration air from 3,000 L down to 1,600 L gives a slight underestimation of the resulting OEC_{total}. Taking into account only tests where the fraction of OEC_{total} that is calculated is not above 5 %, 311 data pairs are left over indicating an underestimation of only 6 %.

These figures do not change significantly when taking into account the $OEC_{measured}$ instead of the OEC_{total}.

Another question is how many c_{od} values should be used for the determination of an OEC_{total} value. As Figure 7 reveals, nearly 100 % of all $OEC_{total,n}$ values were determined using 4 or 5 samples, and thus, nearly 100 % of all $OEC_{total,n-1}$ values were calculated from 3 or 4 samples.

2.3 Open questions

Tests with drinking water plus several defoaming agents that might be necessary to avoid unwanted foaming showed that the defoamers in usual quantity did not provoke significant more odour than the drinking water aeration. Research still has to be done concerning the mixture of real world samples with defoamers as well as the effect of using nitrogen for aeration instead of air.

Change of pH value due to stripping of CO_2 is not a concern as this also happens in real world stripping conditions.

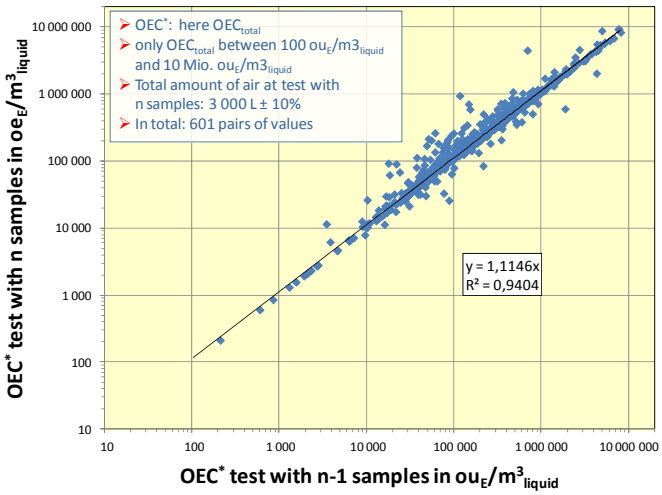

Figure 6: Comparison of $OEC_{total,n}$ with $OEC_{total,n-1}$

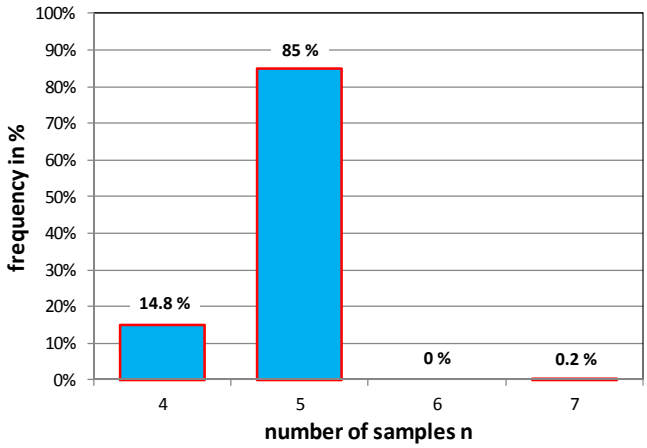

Figure 7: Distribution of number of samples for OEC determination (underlying data base as Figure 6)

3. Conclusions

In conclusion., it seems reasonable to shorten the test according to the above figures, i.e. test time should be 32 min minimum, amount of aeration air should be 1,600 L minimum.
Also, it can be recommended to set the number of samples to 4. This results in 5 samples per OEC test (1 with drinking water, see above) and allows for 3 OEC measurements per day and olfactometric team. Times for sampling are recommended to be 2, 6, 16 and 35 min, respectively.

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