IMPEL GUIDELINES ON DIFFUSE VOC EMISSIONS

- **emission estimation methods**
- **emission reduction measures**
- **licensing and enforcement practice**

IMPEL NETWORK

European Union Network for the Implementation and Enforcement of Environmental Law

AUTHOR
Reinoud J. K. van der Auweraert – Tebodin Consultants and Engineers

ABSTRACT

IMPEL, the environmental inspectors network for the EU, developed guidelines on diffuse VOC (volatile organic Compounds) emissions. The objective of the guidelines is to improve the monitoring, licensing and inspection of industrial activities. The guideline report includes a review of the emission estimation methods and a review of the emission reduction methods. The report is based on an EU wide inventory, hands-on experience with emission measurements and a comparison with the US EPA-guidelines and practice in the USA.

The guidelines are focused on the VOC emissions of diffuse sources of large process installations, both fugitive emissions (leakage from equipment) and emissions from storage tanks and loading/unloading. The installations & emissions are common in refineries and (petro-) chemical plants. Excluded are emissions resulting from the use of solvents which are regulated by the EC Directive 1999/13/EC.

Although the targeted activities are restricted to the process industry it should be clear that various of the presented measuring methods, reduction techniques and licensing&enforcement practice are also applicable to other activities such as (off-shore) gas&oil exploration/production and military activities. Some of the remote sensing methods are well suited for measuring the diffuse emissions of landfill sites (e.g. methane leakage) .

The paper highlights the essential aspects of diffuse VOC emission estimation methods in relation to environmental licensing&enforcement.

NOTE ON IMPEL

The European Union Network for the Implementation and Enforcement of Environmental Law is an informal network of the environmental authorities of EU Member States. The network is commonly known as the IMPEL Network. The European Commission is also a member of IMPEL and shares the chairmanship of management meetings.

The expertise and experience of the participants within IMPEL make the network uniquely qualified to work on certain of the technical and regulatory aspects of EU environmental legislation. The Network's objective is to create the necessary impetus in the European Community to make progress on ensuring a more effective application of environmental legislation. It promotes the exchange of information and experience and the development of greater consistency of approach in the implementation, application and enforcement of environmental legislation, with special emphasis on Community environmental legislation. It provides a framework for policy makers, environmental inspectors and enforcement officers to exchange ideas, and encourages the development of enforcement structures and best practices.

Information on the IMPEL Network is also available through its web site at http://europa.eu.int/comm/environment/impel.

1. INTRODUCTION

1.1 Background

Establishing an environmental policy for industrial sources usually commences with a regulation of the large point sources. Attention is then focused on piped emissions, e.g. exhaust gases directed via a stack and wastewater through a discharge pipe. In general these piped emissions are well regulated and have been reduced substantially, to such an extent that the other emissions have become more and more dominating. With respect to atmospheric emissions of volatile organic emissions (VOC) these ‘other emissions’ comprise mainly leakage from equipment (fugitive emissions) and evaporation losses of storage, loading and unloading. These emissions are called ‘diffuse’ emissions. Monitoring of diffuse emissions is more complex compared with monitoring of piped emission sources. Abatement and regulation of diffuse emissions is a relatively new issue in some member states of the European Union (EU). It is however not common practice in all EU member states, this contrary to the USA where it is common practice for about 10-20 years.

The main environmental effect of VOC in general is their role in the formation of smog and ozone in the presence of nitrogen oxides. VOC in the ambient air are precursors to the formation of ground level (tropospheric) ozone, the primary constituent of smog. Smog and ozone cause respiratory damage, damage to property and vegetation (agriculture and ecosystems). Individual components of VOC are known for other negative effects such as toxic effects on health and ozone layer depletion in the stratosphere. Reduction of VOC emissions is not only beneficiary to the environment but also can lead to better workplace conditions, can reduce risks of fire, can reduce nuisance (odours) and can save money.

IMPEL, the environmental inspectors network for the EU, developed guidelines for implementing diffuse emissions regulations, both for licensing of industrial plants and for enforcement. The Netherlands’ Inspectorate for the Environment was in charge of the development project and commissioned Tebodin to assist as consultant. IMPEL adopted the guidelines in December 2000.

1.2 Objective and scope

The objective of the guidelines is improving the monitoring, licensing and inspection of industrial activities. The guidelines are focused on the VOC emissions of diffuse sources of large process installations, both fugitive emissions (leakage from equipment) and emissions from storage tanks and loading/unloading. The installations & emissions are common in refineries and (petro-) chemical plants. Excluded are emissions resulting from the use of solvents which are regulated by the EC Directive 1999/13/EC.

Although the targeted activities are restricted to the process industry it should be clear that various of the presented measuring methods, reduction techniques and licensing&enforcement practice are also applicable to other activities such as (off-shore) gas&oil exploration/production and military activities. Some of the remote sensing methods are well suited for measuring the diffuse emissions of landfill sites (e.g. methane leakage).

The guidelines are based on an EU wide inventory, executed in close co-operation with the members of the IMPEL working group on diffuse VOC emissions. The findings are summarised in this document..

1.3 European policy

Permit requirements are subject of the IPPC Directive (96/61/EC). The application of Best Available Techniques (BAT) is a cornerstone of the Directive and diffuse emissions are a subject that needs to be addressed in the environmental permit. It is the intention of the European IPPC Bureau in Sevilla to develop BAT reference documents for about 30 industrial sectors and a few general subjects. Of interest are the sectors ‘refineries’, ‘large volume organic chemicals’ and 'storage' and the subject ‘monitoring’. These sectors BAT reference documents are being prepared.

The Technical Working Group on monitoring will cover the monitoring of fugitive emissions. It is however not their intention to provide a BAT reference document as it is not intended to specify the best monitoring techniques but it is their intention to provide an exchange of views and practices [1] to enhance the licensing. Furthermore it should be noted that a significant VOC emission reduction in Europe is the objective of several protocols and policy plans.

2 EMISSION ESTIMATION METHODS

Estimation of diffuse emissions is more difficult and complex than estimating piped emissions (e.g. by stack measurement). A variety of methods have been developed. The methods range from calculation to measurement, point measuring to remote sensing. Some are suited for leak detection, others for estimation of the annual emission or both. The presented overview is focused on methods to identify leaks and methods to estimate the annual emission.

It should be realised that the guidelines of the United States Environmental Protection Agency (EPA) are widely used in the EU member states. Also the methods that are developed within a member state are often based on the EPA guidelines and the emission estimating equations that are developed by the American Petroleum Institute (API).

2.1 Equipment, storage tanks, loading & unloading and utilities

The United States Environmental Protection Agency (EPA) issued the Protocol for Equipment Leak Emission Estimates [2]. According to this protocol, different approaches can be used to estimate emissions. These approaches are, in order of increasing refinement:

1. Average emission factor,
2. Screening ranges / stratified factors,
3. EPA correlation and
4. Unit-specific correlation approach.

Except for the average emission factor approach, all of the approaches require screening data. Screening data are collected by using a portable monitoring instrument to sample air from potential leak interfaces on individual pieces of equipment. A screening value is a measure of the concentration of leaking compounds in the ambient air that provides an indication of the leak rate from an equipment piece, and is measured in units of parts per million by volume (ppmv.). In addition to equipment counts and screening data, the Unit-specific correlation approach requires bagging data. Bagging data consist of screening values and their associated measured leak rates. A leak rate is measured by enclosing an equipment piece in a bag to determine the actual mass emission rate of the leak. The screening values and measured leak rates from several pieces of equipment are used to develop a unit-specific correlation. The resulting leak rate/screening value correlation predicts the mass emission rate as a function of the screening value.

Emissions of storage tanks and loading&unloading. are usually calculated based on general emission factors. Emissions from the utilities (wastewater treatment and cooling water system) are not always considered but can also calculated by general emission factors. Calculation methodologies are published by EPA and Concawe.

2.2 Remote sensing and other leak detection methods

The annual emissions are calculated by extrapolation of the measurement time. Measuring times are relatively short. Hence attention should be paid to take into account the operational and meteorological conditions during the measuring versus annual average. Measuring in several periods of a year or during several years can increase accuracy in this respect.

- *Distributed point sources*: with the help a ‘reverse’ atmospheric dispersion model it is possible to calculate the emission from down-wind measured air quality data and meteorological data. In order to cover all potential emission sources it is common practice to monitor at several points. The method enables an estimation of the total emissions. The measuring may not cover high plume emissions. The (exact) location of a leakage is hard to indicate with this method.
- *Fixed beam (open-path) optical absorption methods*: the basic principle of a fixed beam (open-path) optical absorption method consists of absorption of an electromagnetic beam (IR and UV) by gases present in ambient air. Specific gases will absorb light from known parts of the spectrum, both in the UV, visible and IR wavelength ranges. From the absorption between the beam source and the detector coupled to a spectrometer and computer it is possible to calculate (the integrated) amount of VOC. High plume emissions may not be covered by the measuring. The (exact) location of a leakage is hard to indicate with this method.
- *Differential Absorption Lidar (DIAL):* The optical methods have been further developed in the late nineties to overcome the main limitations (i.e. leakage localisation and non-detection of high leaking sources). The

developed method is named DIAL (differential absorption LIDAR; LIDAR being light detection and ranging). The infrared laser beam source and the detector are located at the same end of the beam. The detector picks up the signal from the small amount of light scattered from aerosol droplets or particles in the atmosphere. The main advantages of DIAL over fixed beam methods are that gas concentration is measured at all points along the path and no height limitations exist. This allows building up 2/3-D maps of gas concentration. It is possible to localise the emissions within large industrial complexes. In other words DIAL enables both estimation of the total emission flux and localisation of (unexpected) leakage sources. It covers all potential emission sources (equipment, storage, loading/unloading, waste water system, etc.). However it has its limitations in the accuracy of the localisation and in the differentiation into different chemical compounds. Nevertheless DIAL is an outstanding technology complementary to standard point by point leak detection (screening ranges or correlation method).

- *Tracer gas:* The tracer gas method consists of releasing a tracer gas (usually SF_6) at different identified release areas and at various heights above the surface in the factory area and of measuring the VOC & tracer gas concentrations downwind of the factory by portable syringe-based samplers or portable gas chromatographs. The emission rates of specific hydrocarbons can be estimated from simple flux assumptions with near stationary wind conditions and with no significant atmospheric reactions or deposition of hydrocarbons or other release gases between the leakage points and the sampling points.

2.3 Leak detection and repair (LDAR)

The main objective of the EPA fugitive emission estimation methods is to assist the leak detection and repair programme (LDAR). LDAR is compulsory for the process industry. It consists of checking the components for leakage and of repairing the identified leaking components. The check on leakage is performed by the EPA reference method 21 [2] and has to be executed quarterly or annually.It should be noticed that in practice the inaccessible components are not monitored (e.g. for reasons of insulation, height).

Trained sniffer dogs can optimise LDAR. Monitoring is only performed at components, which the dog points out as leaking. The detection by dogs has been verified by a certification institute.
Other possibilities to enhance detection have developed, such as VOC-sensitive tubes and tapes.

2.4 Practice in the EU member states

The most widely used estimation method for the first estimation of the emissions, is the average emission factor method. The default emission factors are often EPA's, the German set of emission factors [3] and the Netherlands' set of emission factors [4].

Significant product leakage from process components may cause hazardous situations leading to fire, explosion or intoxication of the personnel. Hence occupational safety considerations imply that all industrial process plants inspect process components on a regular basis. In this sense, all large chemical industries and refineries have a leak detection and repair programme.
However, this does not mean that these companies have a LDAR which is comparable to the EPA standards (monitoring of all components quarterly or annually). Only in some of the companies does a LDAR include measuring of a substantial part of equipment components annually.

The commonly used method to identify leaks and to estimate annual emissions is the EPA method 21. As only a small number of components are leaking (less than 1%) several methods are applied to screen more cost-effectively, i.e. restricting the measurements to those components that are more vulnerable to leaking. More and more (international) companies assist the detection programme by remote sensing techniques. Leak detection assisted by trained sniffer dogs is also becoming more common.

The most widely used estimation methods for estimations of the emissions of storage tanks and loading and unloading are the EPA AP42 [5] and similar methods (e.g. [3], [6]).

Remote sensing techniques are applied increasingly and DIAL has become common practise in some of the countries for estimation of the annual VOC emission. Also the tracer gas method is used on regular basis in some member states.

2.5 Discussion of the emission estimation methods

The features of the presented methods differ considerably. The ideal method in the context of licensing and enforcement should have at least the following features:

- suitable for equipment, storage tanks and loading&unloading
- suitable for leak detection (all compounds, all locations)
- suitable for estimation of the annual emission
- real time estimation
- easy inspection for enforcement
- inexpensive .

None of the reported available methods comes close to the ideal method. Hence a combination of methods is required to manage diffuse emissions. The main features of the methods are presented in table 1.

The costs and the accuracy of the monitoring methods are discussed in paragraph 2.6.1-2.6.2.

Table 1 – Features of the diffuse emission estimation methods and leak detection.

Method	**Equipment**	**Storage tanks, loading&unloading**	**Leak detection** (suitable for LDAR)	**Annual emission estimation**	**Accuracy**	**Real time emission estimation**	**Enforcement**
Average emission factor	+	+	-	+	low	-	Data check is possible but tends to be time consuming
Screening ranges	+	-	+	+	medium	compo-nent	Check of documentation easy; field spot-check of repairs on identified leaks possible; complete inventory data check is almost impossible
Correlation	+	-	+	+	high	compo-nent	Check of documentation possible; field spot-check of repairs on identified leaks possible; complete inventory data check is almost impossible
Trained sniffer dogs	+	-	+	-	-	unit	Check of monitoring documents; could be used to check a part of installation during inspection visit
VOC-sensitive materials	+	-	+	-	-	compo-nent	Check of monitoring documents.
Distributed point sources, tracer gas	+	+	-	+	high	site	Check of monitoring documents and real time check
Fixed beam optical absorption	+	+	-	+	high	site	Check of monitoring documents and real time check
DIAL	+	+	+	+	very high	site	Check of monitoring documents and real time check

+ suitable; - not suitable.

2.5.1 Cost of the measurements

The magnitude of the costs depends on the size and type of the process installation. Three cases of imaginary factories have been worked out (table 2) in order to give an impression of the typical costs (table 3).

Table 2–Three typical configurations.

	Petroleum refinery unit	Fine chemicals factory	Storage tank terminal
No. of equipment components	30000	3000	2500
No. of storage tanks	50	10	50
No. of products	10	50	50

An emission inventory/monitoring is often coupled to a LDAR (leak detection and repair programme), resulting in emission *reduction.* The monitoring costs have therefore also to be considered in combination with a LDAR. An indication of the costs to monitor the emissions is given in table 3, making distinction between methods suited for an emission inventory only, LDAR and LDAR supporting methods.

Table 3 – Cost indication (order of magnitude) of the emission estimation methods (€; 1999).

Method	Cost per unit	Petroleum refinery unit	Fine chemicals factory	Storage tank terminal
Emission inventory only				
Average emission factor	1)	5,000-15,000	2,500-5,000	2,500-7,500
Screening ranges or correlation (remark: not suited for storage tanks)2)	(see emission inventory being part of a LDAR)			
Distributed point sources	12,500 €/measurement	12,500	12,500	12,500
Fixed beam optical absorption	25,000 €/measurement	25,000	25,000	25,000
Differential absorption Lidar (DIAL)	10,000 €/day	150,000	50,000	30,000
Emission inventory being part of a LDAR (leak detection and repair)				
> once-only: component inventory	3 €/component	90,000	9,000	8,000
> annual3) : leak measuring	2 €/component	60,000	6,000	5,000
LDAR supporting methods				
Trained sniffer dogs	Methods will lower costs by improved leak detection.			
VOC-sensitive materials				
Differential absorption Lidar (DIAL)4)	10,000 €/day	150,000	50,000	30,000

1) Inventory required with type of source, phase, product; simple calculations for components; quite complicate calculation for storage tanks and loading&unloading.
2) Storage tanks and loading&unloading are not measured; have to be estimated otherwise (usually by average emission factors).
3) Annual or other frequency; the costs of the initial phase will amount to 3+2=5€/component as both component inventory and measurement are required.
4) First survey costs; following surveys and combining several factories tend to lower the costs.

2.5.2 Accuracy of the emission estimation

First of all it should be clear that it is practically impossible to measure the exact amount of diffuse emissions released during a year. The amount has to be estimated. The described methods will usually lead to considerably different results. Comparison the results of different methods it is in most cases not straightforward. However it may be crucial to judge a claimed emission reduction. The following discussion is intended to assist in this respect.

<u>Average emission factors versus measurements</u>
Estimation based measurement should be considered more reliable than based on average emission factors only. Nevertheless an average emission factors estimation will provide the right order of magnitude. Comparison studies differ in their conclusions but remarkably often it has been found that the average emission factors provide indeed the right order of magnitude.

In case the estimated magnitude based on measurements differs considerably (more than factor 2) it is worth to look or ask for underlying reasons.

<u>Component measurements</u>
The component measurements consist of measuring the hydrocarbon concentration nearby the component. From the measured concentration, the annual emission can be estimated by calculation according to different equations. The correlation equation is considered the most accurate estimation but screening ranges/stratified

factors method is more widely used in the EU.

Three situations are compared for a hypothetical plant to illustrate the impact of the method, i.e.:

- no leaking sources (hypothetical)
- average leaking sources
- severe leaking sources (higher emission rates than average).

The results are summarised in table 4.

Table 4 - Comparison of emission calculation methods for a hypothetical plant (as fraction of the correlation method result for the average leaking situation).

Calculation method	No leaking sources	Average leaking sources	Severe leaking sources
Average emission factor	10	10	10
Screening range method	1.2	8.5	23
Stratified factor method	0.49	10	25
Correlation method	0.0025	1	3.7

The comparison illustrates the following conclusions:

- the emission estimation may differ significantly from one calculation method to another (difference in order of magnitude);
- the average emission method does not reflect the emission in accordance with the condition of the plant but will reflect the average condition only;
- either the screening range or the stratified method will result in a slightly higher estimated emission;
- the correlation method will result in a considerable lower estimated emission.

The latter conclusion can be deduced by comparing the equations (figure 1) for a compressor.

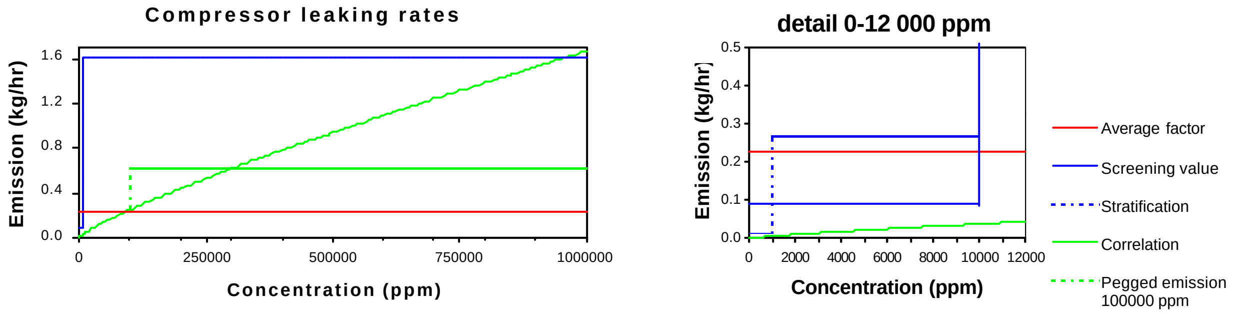

Figure 1 – Graphic comparison of the different equations to calculate the emission rate based on an average emission factor and based on screening values (= concentration within 1 cm of the seal) of a compressor (SOCMI factors of [2]).

The calculated emission is presented in the Y-axis; the measured hydrocarbons concentration in the X-axis. As the average factor method (red horizontal line) does not take any measurement into account, the calculated emission is fixed. The emission calculated according to the screening ranges / stratification method (blue horizontal lines with one/two leaps) varies stepwise with the measured concentration (respectively one and two leaps).

As the *high* emission factor of the screening ranges / stratification method corresponds to a high leaking situation, the calculated emissions tend to be overestimated. Furthermore the screening ranges / stratification method is not suitable to reflect *low* emission rates and will overestimate such situation. The emission calculated by the correlation method (green line) varies about linear with the measured concentration. As not all measuring devices are capable of measuring concentrations above 100,000 ppmv a fixed emission factor may be used (pegged emission; green horizontal line).

Component measurements versus remote sensing measurements
The results of component measurements (paragraph 2.3) and calculations of all other sources (hereafter called 'traditional' methods) may differ considerably with the results of remote sensing measurements (paragraph 2.4). The studies that compared both methods ('traditional' and remote sensing) differ in their conclusions. On one hand studies of Concawe [7], IVL [8] and TNO [9] conclude that the results of remote sensing are consistent with the results of 'traditional' methods. On the other hand, the DIAL surveys lead consistently to higher results than the 'traditional' methods. A company that executes the DIAL measurements reports differences ranging from factor 3 to 18 for different refineries and loading & unloading facilities.

Differences in the results of component measurements and remote sensing measurements need to be investigated. It is important to note that remote sensing techniques cover all emissions, not diffuse emissions only. Hence the emissions of all potential emission sources should be estimated.

A considerably higher amount of emissions measured by remote sensing is often caused by a few leaks with a very high emission rate. Important errors of the 'traditional' methods are unknown emission sources (e.g. contaminated soil or surface water, cooling water system), non-applicability of equations due to different products or processes.

3 MEASURES TO REDUCE VOC EMISSIONS

Diffuse emissions are originated by intrinsic leakage of equipment and of ‘leaking’ equipment. The latter may be related to inadequate design, installation, handling & maintenance of the equipment and external impact. An example of inadequate design is the choice of a material that is not suited for operational conditions (e.g. corrosion, pressure, temperature), either at the designed process conditions or following changes in process conditions. An example of inadequate handling is the non-tight closing of valves, flanges, drains, etc. Good maintenance should prevent the occurrence of equipment failure. An example of external impact is an object falling on process equipment.

It is clear that only good management and a good maintenance programme can guarantee the lowest emissions of an installation. As these programmes are not specific for diffuse emissions, management systems and maintenance programmes are not further discussed. In addition to these general measures a leak detection and repair programme is important.

A *leak detection and repair programme* (LDAR) aims to reduce emissions by regularly checking the equipment for any abnormal leak and repairing if necessary. Measuring techniques and a measuring strategy are given in the EPA protocol for equipment leak emission estimates [1].

3.1 Equipment

A variety of ‘low emission’ components exists, especially for toxic, flammable and odious substances. Whether a component is a relevant or irrelevant fugitive emission source, depends on a lot of parameters, such as process conditions, investment and operational cost, resistance, reliability, maintenance capabilities, etc. There is no rigid rule. As previously explained the selection of equipment is complex. No specific guidelines exist for the selection of equipment with respect to diffuse emissions. General guidance documents however do exist, e.g. the German guidelines [3, 10, 11]. Low emission components are presented in the annex B.

3.2 Storage tanks, loading & unloading and utilities

The three technical items that are related to the emission of a storage tank are tank design, sealing and vapour handling. In general fixed roofs tanks are characterised with larger emissions than floating roof tanks for a given product. However as volatile products now often are stored in floating roof tanks, the VOC emissions of these floating roof tanks tend to be higher than the emissions of a fixed roof containing a non-volatile product like e.g. fuel oil.

The emissions of a fixed roof tank can be reduced by a large extent, using a vapour treatment system, such as:

- vapour balancing
- vapour recovery (e.g. by condensation or adsorption)
- vapour incineration.

The common requirements on the storage of large volume liquids such as motor fuels are floating roof tanks, vapour balancing system or vapour treatment system. Requirements for loading & unloading vessels are given in e.g. IMO guidelines. For crude receipt, the change over to segregated ballast with tanker fleet renewal over time (prescribed in the MARPOL 73/78 Convention) has the side effect of reducing hydrocarbon emissions at crude oil discharge locations. The gasoline loading & unloading of rail way and truck containers is regulated by the EU Council Directive 94/63/EC (VOC vapours at the dispatch stations to be recovered in a vapour recovery unit). The publication of an EU Directive on barge loading regulation is announced.

3.3 Practice in the EU member states

Specific standards for process equipment with respect to diffuse emissions do not exist. A few general guidance documents are used, such as the German TA-Luft & VDI-3479/3790 and the British ETBPP documents. More information is referenced in paragraph 4.2. The VOC Stage 1 Council Directive 94/63/EC specifies special requirements for the storage of large volume liquids such as motor fuels. Floating roof tanks or vapour balancing systems are required in most countries or considered as BAT.

4. LICENSING AND ENFORCEMENT PRACTICE

As clearly stated in the IPPC Directive (96/61/EC) large industrial installations must have an environmental permit. The permit must include requirements in accordance with the standards of Best Available Techniques (BAT), also related to diffuse emission. The permit must include requirements on monitoring of emissions and reporting to the authorities.

Technical requirements are mostly specified in fairly general definitions, which gives the permit holder the freedom of choosing between a range of apparatus according to BAT (e.g. [13]).

General requirements related to diffuse emissions are:
- Annual emission estimation
- Measuring programme
- Leak detection and repair programme
- ‘Low emission’ techniques
- Emission target (absolute value or relative value)

Furthermore the competent authority might supplement its enforcement program with technical assistance:
- Eco-audit
- Training programme, seminar or other educational forum
- Reliance on third parties.

Several options exist to check compliance of the permit requirements. The most common options are:
- Site inspection by the Competent Authority
- Inspection of company data by the Competent Authority
- Validation of company data by third party.

5. RECOMMENDATIONS

The review revealed that emission monitoring and reporting of the diffuse VOC emission to the competent authorities is not yet common practice in all EU member states. Also requirements with respect to diffuse emissions are either missing in permits or are prescribed in rather vague terms. Diffuse emissions have actually not yet caught the attention in all member states.

The IPPC Directive stipulates that the permit shall include emission limit values (amongst others for VOC). Emissions include diffuse sources in the installation into the air. The Directive also requires the operator to supply the competent authority with data required for checking compliance with the permit and requires the operator to inform the competent authority on the results of the monitoring. Results must also be made available to the Public.

This report may provide valuable input to the development of several BAT reference notes with respect to diffuse emissions. New measuring and low emissions techniques have emerged recently and are being applied successfully.

From these and their own observations the members of the IMPEL Working Group on diffuse emission draw the conclusion that a clear need exits for a licensing and enforcement guidance note with respect to diffuse emissions. Recommendations are given in the following paragraphs. An example of a diffuse emissions action plan is presented as annex.

5.1 Identification of industries with potential relevant emissions

In order to identify industries with relevant emissions it is recommended that:

- Process industry handling organic liquids or gases in large volumes are investigated for their VOC emissions. The tank terminals, petroleum refineries and the organic chemical industry are most concerned. Total VOC emissions are typically above of 10-100 ton/a. The organic compounds may include toxic and/or smelly substances.

5.2 Target or limit value

The IPPC Directive stipulates that the permit conditions shall include emission limit value for pollutants. It is recommended to distinguish diffuse emissions separately. Examples are:

- setting a target on the total emissions; feasible reduction percentages depends on the initial situation.
- setting a target on the admissible number of leaking equipment. An example is given annex C.

The former requirement is of course more relevant for judgement of the environmental impact but exact quantification of the emission tends to be difficult. The latter requirement is easier to verify by enforcement authorities. Whatever the basis, a clear definition of the reference situation and limit is paramount. The emission calculation method and definition of a "leaking" component should be unambiguous.

5.3 Procedural measures

It is recommended that the environmental permit may include the following procedural measures:

- a leak detection and repair programme (LDAR) based on regular measuring of all accessible components, storage tanks and loading&unloading facilities; records of the detected leaks shall be maintained and reported regularly for checking of the compliance by the authorities.
- the monitoring results should be reported to the authorities (IPPC), e.g. the estimated total emission, the number of detected leaking components, the number of repaired/ replaced components and comparison with previous measurements.
- Maintenance should be geared to emission prevention.

The enforcement authorities can verify the execution of a LDAR by:

- checking the existence and regular updating of component measurements.
- checking just repaired units by measuring at the components.

5.4 Emission estimation

Emission estimation of all atmospheric emissions, including diffuse VOC emissions is laid down in the IPPC, as well as reporting to the competent authorities. It is recommended that the licensing Authorities take the following requirements into account:

- Companies indicate their monitoring methods.
- All identified industries provide a report on the atmospheric emissions covering all diffuse emissions sources regularly, e.g. on an annual basis. The concerned company is able to specify the emission calculation method for every single source at request of the competent authority.
- The emission monitoring (and control) should be approved by the competent authorities. An example of an appropriate emission monitoring plan is presented in annex D.

As the emission estimation may vary by order of magnitude according to the used calculation method it is paramount that emission calculation method is defined and that the definition is unambiguous. Also the monitoring and reporting frequency should be defined.

The enforcement authorities can verify the emission estimation by checking:

- the methodologies used and the applied emission factors
- if the estimation covers all relevant emission sources
- the use of remote sensing techniques (especially DIAL).

5.5 Technical measures

The application of BAT is laid down in the IPPC. Examples of good practice are presented in [12]. It is recommended that the licensing Authorities should require:

- In case of new installations, companies to justify their technology choice in relation to BAT; in case of existing installations, companies should agree an action plan to upgrade the installation to BAT standards.
- The requirements for the storage, loading & unloading of gasoline (-like products) should be based on the VOC stage I Council Directive 94/63/EC.

The enforcement authorities can verify the application of BAT by:

- checking the relevant documents (e.g. the ETBPP publications, German standards).
- site visit and checking of the installation and provisions (e.g. presence of cap or plug on open-ended lines) and proper operation (e.g. use of vapour recovery system or the execution of the repair programme)

It should be noticed that proper installation, operation and maintenance of the equipment are paramount. It has to be recognised that in all installations some components will leak to some extent. Notwithstanding that this situation is accepted, large uncontrolled leaks should not be acceptable. Different levels of response (e.g. immediate, short term, long term) could be defined for different leak sizes.

5.6 Non-compliance

In case of non-compliance the authority may decide to:

- have the plant audited resulting in additional permit conditions;
- initiate a leak detection and programme by a contractor at the cost of the plant.
- actively inform the public about the non-compliance.

It is emphasised that the permit requirements should be ‘measurable’ in order to provide unambiguous proof of compliance or non-compliance. Examples of measurable requirements related to diffuse emissions are:

- the annual emission reporting with a break-down of all emission sources;
- the presence and operation of technical measures (e.g. vapour recovery system);
- a leak detection programme by measurements through the check of the measuring data;
- a target on the admissible number of leaking components.

5.7 Supporting activities

Supporting activities may be considered by the authorities, such as:

- organising an information & training programme in regions where the subject is relatively new (targeting both companies and licensing & enforcing bodies)
- establishing national guidelines
- performing an eco-audit of the industrial plant
- establishing a helpdesk to assist both companies and licensing & enforcing bodies .

REFERENCES

1 Technical Working Group on monitoring of the European BAT reference project; Draft reference document on monitoring; January 1999.

2 US EPA; Protocol for equipment leak emission estimates (The protocol includes the measuring protocol 'Reference Method 21'); EPA–453/R-95-017; November 1995.

3 VDI-3479; Emissionsverminderung Mineralölvertriebsläger/ Emission control, Marketing installation tank farms ; VDI, July 1985 (revision expected!).

4 KWS2000 programme: Diffuse procesbronnen, Raffinaderijen&terminals; KWS2000, Fact sheet 18; The Hague, December 1994.

5 EPA -AP42; Compilation of Air Pollutant Emission Factors, AP 42 – Chapter 5, Petroleum industry (1995); Section 7.1 Organic liquid storage tanks; US EPA; September 1997 (updated regularly).

6 NL Ministry of the Environment; Emissiefactoren, Lekverliezen van apparaten en verliezen bij op- en overslag; VROM, Publicatiereeks Emissieregistratie nr. 8; The Hague, April 1993.

7 Concawe; 95/52 VOC emissions from external floating roof tanks: comparison of remote measurements by laser with calculation methods; Concawe 95/52.

8 IVL; Measurements of industrial fugitive emissions by the FTIR-tracer method (FTM); IVL – Institutet för vatten- och luftvårdsforkning/Swedish environmental research institute; Report nr. B1214, January 1996.

9 TNO; Development and demonstration of a method to monitor the effects of measures to reduce VOC emissions in the EU; LIFE & VROM; TNO-MEP report no. R 98/028, January 1998.

10 VDI-2440: Emissionsminderung Mineralölraffinerien/Emission control mineral oil refineries (Entwurf/draft); VDI, July 1999.

11 VDI-3790; Emissionen von Gasen, Gerüchen und Stäuben aus diffusen Quellendeponien (Entwurf/draft); VDI, March 1997.

12 ETBPP; Cost-effective reduction of fugitive solvent emissions; Environmental Technology Best Practice Programme; GG71; March 1997.

13 TA-Luft: Erste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz (Technische Anleitung zur Reinhaltung der Luft - TALuft), Nach § 48 des Bundes-Immissionsschutzgesetzes (BimSchG) vom 15. März 1974 (BGBl. IS. 721); 1986.

14 Cost-effectiveness of hydrocarbon emission controls in refineries from crude oil receipt to product dispatch; Concawe report 87/52; 1987.

ANNEX: PROPOSAL FOR AN ACTION PLAN FOR DIFFUSE EMISSIONS CONTROL

Why ?

The aim of the action plan for diffuse emissions control consists of three subjects:
1. prevent and reduce emissions;
2. manage the operations with respect to the emissions;
3. estimate, monitor and report the emission.

Ad 1: Preventing and reducing emissions is what it is all about. At the same time the acceptable emission level should be clear. Acceptable will be related to acceptable from an air quality point of view (occupational and environmental), acceptable from a technical and economic point of view. The latter is illustrated by the definition of BAT (Best Available Technique), which addresses both. Hence it is important to take the cost-efficiency into consideration.
Ad 2: Managing the operations requires an insight in the correlation between emissions and maintenance and equipment. Emission monitoring will provide the information in order to find an efficient strategy for maintenance, to identify the major leaking sources and to optimise monitoring itself. The information is valuable for considerations for replacement & new investments.

Ad 3: Regular emission reporting is required by the IPPC. It is an important communication tool with the Authorities and the public. In order to be convincing the emission monitoring should be based on good practice methods and be consistent over a range of years.

What ?

The action plan consists of following phases:
1. *gaining insight* in the contribution of different installations of a plant and in the order of magnitude; based on this insight an monitoring approach can be developed.
2. *initial monitoring*: the initial monitoring should cover all potential emission sources.
3. *first evaluation* of the initial monitoring results
4. *first reporting*
5. *regular monitoring*
6. *regular reporting*

How ?

Gaining insight

1. Prepare an inventory of all components within the installations. To be inventoried are the number of tanks (fixed roof, floating roof, …), pumps, compressors, agitators, valves, pressure relief devices, flanges, open-ended lines. Examples of installations are loading&unloading of raw material (e.g. crude oil), loading&unloading of product, storage tanks, process unit 1, process unit 2, waste water treatment and cooling water system.

2. . Estimate diffuse VOC emissions according to the average emission factors. Choose the method that is best suited for the plant. Suitable methods are:
   - fugitive emissions: EPA's [2],
   - storage, loading&unloading: [5]
   - waste water treatment [5, 14]
   - cooling water system [5, 14].
3. Present the estimated emissions per logical installations/operations and per group of components.
4. Develop the measuring approach. The recommended approach consists of measuring all components (screening according EPA method 21) and of measuring the total VOC flux by a remote sensing technique. Remote sensing using the DIAL technique gives the best results by covering all emissions and by pinpointing the major emission source. The screening may be contracted or may executed by own personnel. Remote sensing is in most cases performed by a contractor because of the expensive equipment.

5. Discuss the strategy for diffuse emission control with the authorities. Both the methods and the costs to monitor emissions can be discussed.

Initial monitoring

1. Set up an inventory database of all components. Several companies have developed database applications which will calculate the emissions based on the screening values and which can be used to generate the overviews that are necessary for an in-depth analysis and for the reporting. It is also possible to have a similar database application developed by own personnel.
2. Measure all components and enter all screening data in the database, which can be executed by a mobile computer coupled to the measuring device. The preferred method for calculating emissions based on the screening value is the correlation method [2]. The correlation method is more accurate than the screening range (stratification) method and requires equal measuring effort.
3. Execute the possible repairs (e.g. fastening of bolts to fasten the seal) and measure the component after the repair; small repairs can be done during the measurements.
4. Mark the components that couldn't be repaired for repair during shut-down and inform the maintenance department.
5. Execute the remote sensing.

First evaluation

1. Analyse the results of the initial monitoring with respect to the contribution of the various emission sources to the (total) VOC emissions, the reliability of the components, the costs of maintenance & replacement. Special attention should be paid to significant difference in results between the emission estimation according to the average emission factor, according to the screening and according to the remote sensing.
2. Set priorities for emission reduction items (e.g. in three categories: urgent, high and medium priority) and define suitable measures to reduce/prevent emission. The appendix on 'low emission components and techniques' may be of help for finding suitable measures. The measures should cover the system design, installation and maintenance
3. Develop a strategy and action plan for maintenance and monitoring, taking into consideration other environmental priorities also. The strategy and action plan should include the timing of the measures, e.g. measures during normal operations, during cleaning or revamp or recommendations for new investments. System design includes not only suitable low emission equipment but should also include minimisation of potential leakages (e.g. weld pipes rather than using flange connections). The choice of fittings and sealing materials is paramount, as is the careful installation.

First reporting

1. Communicate the results to the authorities and discuss the strategy for diffuse emission control and discuss the reporting format. Both the magnitude of the emissions and the costs to monitor and reduce emissions can be discussed.
2. Report the emissions, the strategy and the short-term action plan in the annual environmental report (both to the authorities and to the public).

Regular monitoring

1. Measure all components and enter all screening data in the database; execute the repairs if possible (e.g. fastening of bolts to fasten the seal) and measure the component after the repair; mark the components that couldn't be repaired for repair during shut-down and inform the maintenance department.
2. The monitoring can be assisted by methods such as sniffer dogs and VOC sensitive tubes/tapes.

Regular evaluation and reporting

1. Analyse the results of the monitoring from the initial monitoring on (trend analysis). Special attention should be paid to significant differences in results

between different years and between results according to the screening and according to the remote sensing.

2. Review the set priorities for emission reduction items and measures to reduce/prevent emission.
3. Reconsider the strategy and action plan for maintenance and monitoring, taking into consideration other environmental priorities also.
4. Communicate the results to the authorities and discuss the changes in strategy. Both the magnitude of the emissions and the costs to monitor and reduce emissions can be discussed.
5. Report the emissions, the strategy and the short-term action plan in the annual environmental report (both to the authorities and to the public).

AUTHOR

Reinoud J. K. van der Auweraert
Tebodin Consultants & Engineers
P.O. Box 16029
2500 BA The Hague
The Netherlands

Tel.: +31 71 3480204
Fax: +31 70 3480591
E-mail: r.vanderauweraert@tebodin.nl

Mr. Van der Auweraert has worked fourteen years as environmental consultant and is specialised in environmental monitoring. During four years he was the project leader of the Netherlands' Industrial Emission Registration. The project covered the collection and validation of information on industrial emissions, database management and the reporting on the national monitoring of emissions to air and water. He contributed to various monitoring methodology projects (IPCC guidelines; SME; diffuse VOC emissions). He co-ordinates the environmental aspects in various Activities Implemented Jointly. He actually is involved in the compliance monitoring of petrol stations, authorities (communities, provinces) and hazardous industrious installations.