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**Integrated Pollution
Prevention and Control (IPPC)**

**Reference Document on the
General Principles of Monitoring**

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EXECUTIVE SUMMARY

This reference document on “The General Principles of Monitoring” reflects an information exchange carried out under Article 16(2) of Council Directive 96/61/EC. The executive summary - which is intended to be read in conjunction with the preface's explanations of objectives, usage and legal terms - describes the main findings and the principal conclusions. It can be read and understood as a stand-alone document but, as a summary, it does not present all the complexities of the full text. It is therefore not intended as a substitute for the full document text as a tool in decision making.

This document provides information to guide IPPC permit writers and operators of IPPC installations in meeting their obligations under the Directive with regard to monitoring requirements of industrial emissions at source.

Permit writers are recommended to take into account the following seven considerations when establishing optimised permit monitoring conditions:

1. **"Why" monitor?** There are two main reasons why monitoring is included in IPPC requirements: (1) for compliance assessment, and (2) for the environmental reporting of industrial emissions. However, monitoring data can often be used for many other reasons and objectives and indeed it is often more cost effective when monitoring data obtained for one purpose can serve other purposes. In all cases it is important that the objectives for undertaking the monitoring are clear for all the parties involved.
2. **"Who" carries out the monitoring?** The responsibility for monitoring is generally divided between the competent authorities and the operators, although competent authorities usually rely to a large extent on “self monitoring” by the operator, and/or third party contractors. It is highly important that monitoring responsibilities are clearly assigned to all relevant parties (operators, authorities, third party contractors) so that they are all aware of how the work is divided and what their own duties and responsibilities are. It is also essential that all parties have appropriate quality requirements in place.
3. **"What" and "How" to monitor.** The parameters to be monitored depend on the production processes, raw materials and chemicals used in the installation. It is advantageous if the parameters chosen to be monitored also serve the plant operation control needs. A risk-based approach can be used to match various levels of potential risk of environmental damage with an appropriate monitoring regime. To determine the risk the main elements to assess are the likelihood of exceeding the emission limit value (ELV) and the severity of the consequences (i.e. harm to the environment). An example of a risk-based approach is presented in Section 2.3.
4. **How to express ELVs and monitoring results.** The way ELVs, or equivalent parameters, are expressed depends on the objective for monitoring these emissions. Different types of units can be applied: concentration units, units of load over time, specific units and emission factors, etc. In all cases, the units to be used for compliance monitoring purposes should be clearly stated, they should preferably be internationally recognised and they should match the relevant parameter, application and context.
5. **Monitoring timing considerations.** Several timing considerations are relevant for setting monitoring requirements in permits, including the time when samples and/or measurements are taken, the averaging time, and the frequency.

The determination of monitoring timing requirements depend on the type of process and more specifically on the emission patterns, as discussed in Section 2.5., and should be such that the data obtained are representative of what is intended to be monitored and comparable with data from other plants. Any timing requirement of the ELV and associated compliance monitoring must be clearly defined in the permit so as to avoid ambiguity.

6. **How to deal with uncertainties.** When monitoring is applied for compliance checking it is particularly important to be aware of measurement uncertainties during the whole monitoring process. Uncertainties need to be estimated and reported together with the result so that compliance assessment can be carried out thoroughly.
7. **Monitoring requirements to be included with ELVs in permits.** These requirements should cover all relevant aspects of the ELV. To this end it is good practice to take into account the issues specified in Section 2.7, i.e. with regard to the:
 - legal and enforceable status of the monitoring requirement
 - pollutant or parameter being limited
 - location for sampling and measurements
 - timing requirements of sampling and measurements
 - feasibility of limits with regard to available measurement methods
 - general approach to the monitoring available for relevant needs
 - technical details of particular measurement methods
 - self-monitoring arrangements
 - operational conditions under which the monitoring is to be performed
 - compliance assessment procedures
 - reporting requirements
 - quality assurance and control requirements
 - arrangements for the assessment and reporting of exceptional emissions.

The production of monitoring data follows several consecutive steps that all need to be performed according to either standards or method-specific instructions to ensure good quality results and harmonisation between different laboratories and measurers. This **data production chain** consists of the following seven steps, described in Section 4.2:

1. Flow measurement.
2. Sampling.
3. Storage, transport and preservation of the sample.
4. Sample treatment.
5. Sample analysis.
6. Data processing.
7. Reporting of data.

The practical value of the measurements and the monitoring data depends on the degree of confidence, i.e. reliability, that can be placed on the results, and their validity when compared to other results from other plants, i.e. comparability. Therefore, it is important to ensure the appropriate **reliability and comparability** of the data. In order to allow a proper comparison of the data, it should be ensured that all relevant information is indicated together with the data. Data that have been derived under different conditions should not be directly compared, in these cases a more elaborate consideration may be necessary.

The **total emissions** of an installation, or unit, are given not only by the normal emissions arising from the stacks and pipes, but also by taking into account diffuse, fugitive and exceptional emissions. It is therefore recommended that IPPC permits, where appropriate and reasonable, include provisions to properly monitor these emissions.

As progress has been made in reducing channelled emissions then the relative importance of other emissions have become increasingly important, for instance more attention is now paid to the relative importance of **diffuse and fugitive emissions**. It is recognised that these emissions can potentially cause damage to health or the environment, and that sometimes their losses may also have economic significance for a plant. Similarly, the relative importance of **exceptional emissions** has also increased. These are classed as occurring under foreseeable conditions or unforeseeable conditions.

The handling of **values under the limit of detection** and **outliers** values can affect comparability and also require agreement in practice. Five different possibilities for handling values below the detection limit are presented in Section 3.3, however, none of them have been singled out as the preferred option. Outliers are generally identified by expert judgement on the basis of a statistical test (e.g. Dixon test) together with other considerations, such as an abnormal emission pattern in the particular facility.

Several **approaches to monitoring** a parameter are listed and briefly described below and in greater detail in Chapter 5:

- direct measurements
- surrogate parameters
- mass balances
- calculations
- emission factors.

In principle, it is more straightforward, but not necessarily more accurate, to use a method involving direct measurements (specific quantitative determination of the emitted compounds at the source); however, in cases where this method is complex, costly and/or impractical other methods should be assessed to find the best option. Whenever direct measurements are not used the relationship between the method used and the parameter of interest should be demonstrated and well documented.

When deciding whether to approve the use of an approach in a relevant regulatory situation the competent authority is generally responsible for deciding whether the method is acceptable, based on considerations of fitness for purpose, legal requirements, and available facilities and expertise.

Monitoring techniques for **direct measurements** can be divided mainly into continuous and discontinuous techniques. Continuous monitoring techniques have the advantage that they provide a greater number of data points, however, they may have also some drawbacks, e.g. their higher costs, they are not much use for very stable processes, and the accuracy of on-line process analysers can be lower than laboratory measurements. When considering the use of continuous monitoring for a particular case it is good practice to take into account the relevant issues listed in the Chapter 5.1.

The use of **surrogate parameters** may offer several advantages, including greater cost-effectiveness, reduced complexity, and a larger number of data. However, it may also lead to several disadvantages, including the need for calibration against direct measurements, they may only be valid over part of the entire emissions range and they may not be valid for legal purposes.

Mass balances consist of accounting for inputs, accumulations, outputs and the generation or destruction of the substance of interest, and account for the difference by classifying it as a release to the environment. The result of a mass balance is usually a small difference between a large input and a large output, also taking into account the uncertainties involved. Therefore, mass balances are only applicable in practice when accurate input, output and uncertainties quantities can be determined.

The use of **calculations** to estimate emissions requires detailed inputs and is a more complex and more time consuming process than emission factors. On the other hand they provide a more accurate estimate given that they are based on specific conditions of the facility. In any emission estimation calculations, the **emission factors** need reviewing and prior approval by the authorities.

Compliance assessments generally involve a statistical comparison between the measurements, or a summary statistics estimated from the measurements, the uncertainty of the measurements and the emission limit value or equivalent requirements. Some assessments may not involve a numerical comparison, for example they may just involve a check of whether a condition is complied with. The measured value can be compared with the limit, taking account of the associated uncertainty in measurements, and determined as belonging in one of three zones: (a)compliant, (b)borderline or (c)non-compliant, as described in Chapter 6.

The reporting of monitoring results involves summarising and presenting monitoring results, related information and compliance findings in an effective way. Good practice is based on consideration of: the requirements and audiences for reports, responsibilities for producing reports, the categories of reports, scope of reports, good reporting practices, legal aspects of reporting and quality considerations, as described in Chapter 7.

In carrying out the monitoring, optimisation of the **monitoring costs** should be undertaken whenever possible, but always without losing sight of the monitoring objectives. Cost-effectiveness of the monitoring may be improved by applying some actions including: selecting appropriate quality performance requirements, optimising the number of parameters and the monitoring frequency, complementing routine monitoring by special studies, etc.

The EC is launching and supporting, through its RTD programmes, a series of projects dealing with clean technologies, emerging effluent treatment and recycling technologies and management strategies. Potentially these projects could provide a useful contribution to future BREF reviews. Readers are therefore invited to inform the EIPPCB of any research results which are relevant to the scope of this document (see also the preface of this document).

PREFACE

1. Status of this document

Unless otherwise stated, references to “the Directive” in this document means the Council Directive 96/61/EC on integrated pollution prevention and control. As the Directive applies without prejudice to Community provisions on health and safety at the workplace, so does this document.

This document forms part of a series presenting the results of an exchange of information between EU Member States and industries concerned on best available technique (BAT), associated monitoring, and developments in them. *[It is published by the European Commission pursuant to Article 16(2) of the Directive, and must therefore be taken into account in accordance with Annex IV of the Directive when determining “best available techniques”].

* Note: brackets will be removed once the procedure of publication by the Commission is completed.

2. Relevant legal obligations of the IPPC Directive

In order to help the reader understand the legal context in which this document has been drafted, some of the most relevant provisions of the IPPC Directive, are described in this preface. This description is inevitably incomplete and is given for information only. It has no legal value and does not in any way alter or prejudice the actual provisions of the Directive.

The purpose of the Directive is to achieve integrated prevention and control of pollution arising from the activities listed in its Annex I, leading to a high level of protection of the environment as a whole. The legal basis of the Directive relates to environmental protection. Its implementation should also take account of other Community objectives such as the competitiveness of the Community’s industry thereby contributing to sustainable development.

More specifically, it provides for a permitting system for certain categories of industrial installations requiring both operators and regulators to take an integrated, overall look at the polluting and consuming potential of the installation. The overall aim of such an integrated approach must be to improve the management and control of industrial processes so as to ensure a high level of protection for the environment as a whole. Central to this approach is the general principle given in Article 3 that operators should take all appropriate preventative measures against pollution, in particular through the application of best available techniques enabling them to improve their environmental performance.

Competent authorities responsible for issuing permits are required to take account of the general principles set out in Article 3 when determining the conditions of the permit. These conditions must include emission limit values, supplemented or replaced where appropriate by equivalent parameters or technical measures. The competent authorities are also required to ensure that the permit contains suitable release monitoring requirements, specifying measurement methodology and frequency, evaluation procedure and an obligation to supply the competent authority with data required for checking compliance with the permit.

3. Objective of this Document

Article 16(2) of the Directive requires the Commission to organise “an exchange of information between Member States and the industries concerned on best available techniques, associated monitoring and developments in them”, and to publish the results of the exchange.

The purpose of the information exchange is given in recital 25 of the Directive, which states that “the development and exchange of information at Community level about best available techniques will help to redress the technological imbalances in the Community, will promote the worldwide dissemination of limit values and techniques used in the Community and will help the Member States in the efficient implementation of this Directive.”

The Commission (Environment DG) established an information exchange forum (IEF) to assist the work under Article 16(2) and a number of technical working groups have been established under the umbrella of the IEF. Both IEF and the technical working groups include representation from Member States and industry as required in Article 16(2).

The aim of this series of documents is to reflect accurately the exchange of information which has taken place as required by Article 16(2) and to provide reference information for the permitting authority to take into account when determining permit conditions. By providing relevant information concerning best available techniques and associated monitoring, these documents should act as valuable tools to drive environmental performance.

4. Information Sources

This document represents a summary of information collected from a number of sources, including in particular the expertise of the groups established to assist the Commission in its work, and verified by the Commission services. All contributions are gratefully acknowledged.

Since the best available techniques and monitoring practices change over time, this document will be reviewed and updated as appropriate. All comments and suggestions should be made to the European IPPC Bureau at the Institute for Prospective Technological Studies at the following address:

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Draft Reference Document on The General Principles of Monitoring

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SCOPE OF THIS DOCUMENT

IPPC permits are required to include emission limit values (ELVs) for pollutants emitted in significant quantities; where appropriate, ELVs may be supplemented or replaced by equivalent parameters or technical measures (Article 9.3). Associated with these ELVs are monitoring requirements to which the IPPC Directive refers in Article 9.5.

Article 9.5 states that the permit shall contain suitable release monitoring requirements, specifying a suitable measurement methodology and frequency, evaluation procedure and an obligation to supply the competent authority with data required for assessing compliance with the permit.

Article 15.3 states that an inventory of the principal emissions and sources shall be published by the Commission on the basis of data supplied by the Member States. This inventory is known as the European Pollutant Emission Register (EPER), and to meet this requirement, industries need to supply monitoring data (including estimated data) to national authorities (See Commission Decision 2000/479/EC of 17 of July 2000. The European Commission has produced a special guidance document for the purpose of EPER reporting).

It can be seen from these articles that an IPPC permit writer needs to set permit conditions and appropriate monitoring requirements bearing in mind the future need for compliance assessment. Moreover, industrial operators are obliged to propose monitoring measures in their application for a permit.

The aim of this document is therefore to provide information to guide IPPC permit writers and operators of IPPC installations in meeting their obligations under the Directive with regard to the monitoring requirements of industrial emissions at source. This also helps promote comparability and reliability of monitoring data.

There are three main types of industrial monitoring:

- Emission monitoring: monitoring of industrial emissions at source, i.e. monitoring releases from the plant to the environment.
- Process monitoring: monitoring the physical and chemical parameters (e.g. pressure, temperature, stream flow rate) of the process in order to confirm, using process control and optimisation techniques, that the plant performance is within the range considered appropriate for its correct operation.
- Impact monitoring: monitoring pollutant levels within the environs of the plant and its area of influence, and the effects on ecosystems.

This document focuses on the monitoring of industrial emissions at source; therefore, process monitoring and impact monitoring of the quality of the environment are not covered in this document.

This document does not cover any monitoring considerations that are specific to certain types of activities included in Annex 1 of the Directive. For such industry-specific aspects, the reader is referred to the relevant "vertical" (sectoral) BREF(s).

Where appropriate, it refers to available CEN standards in the field of monitoring (see list in Annex 2), but it does not in any way evaluate any standard.

For greenhouse gases, special monitoring guidance has been developed by the Intergovernmental Panel on Climate Change (IPCC).

Scope

Parallel to the work of developing this document, a project with an overlapping scope was carried out in the framework of IMPEL (European Union Network for the Implementation and Enforcement of Environmental Law). That project was called “Best practice in compliance monitoring” and there was a certain degree of co-ordination with the work that resulted in this document.

This document does not in general cover issues relating to inspections. However, an important document of significant relevance to monitoring in the framework of the IPPC Directive is the Recommendation of the European Parliament and of the Council of 4 April 2001 providing for minimum criteria for environmental inspections in the Member States.

1 INTRODUCTION

When emission limit values (ELVs), equivalent parameters, technical measures, and monitoring requirements are laid down in IPPC permits, the permit writer and the operators should be aware of how, in future, compliance assessment and environmental reporting of industrial emissions can be achieved, bearing in mind the costs involved.

There are two reasons why monitoring is included in IPPC requirements:

- Compliance assessment: monitoring is needed to identify and quantify the plant performance, thereby allowing the authorities to check compliance with the conditions in the permit.
- The Environmental reporting of industrial emissions: monitoring is needed to generate information for reports on the environmental performance of industries, e.g. to meet the reporting obligation under the IPPC Directive or the European Pollutant Emission Register (EPER). In some cases this information is also applicable for the assessment of financial charges, taxation or emission trading.

Chapter 2 sets out seven considerations that a permit writer can take into account in order to establish optimised permit monitoring conditions. These considerations address the following issues:

1. "Why" monitor?
2. "Who" carries out the monitoring?
3. "What" and "how" to monitor
4. How to express ELVs and monitoring results
5. Monitoring timing considerations
6. How to deal with uncertainties, and
7. Monitoring requirements to be included with ELVs in permits.

A secondary aim of this document is to promote comparability and reliability of monitoring data across Europe. This is especially important when comparing performances of different plants from the same sector, or total loads from different sectors. Current approaches to monitoring vary across Europe, and these different approaches produce data that are often not comparable, as they may refer to different methods of measurement, periods, frequencies, emission sources, etc. Attempting a direct comparison of data from different plants that have been obtained under different conditions can lead to wrong conclusions or decisions.

A good understanding of the process to be monitored is essential for obtaining results that are reliable and comparable. Given the complexity, cost, and the fact that subsequent decisions are made based on the monitoring data, an effort should be made to ensure that the data obtained are appropriately reliable and comparable.

Monitoring in this document means a systematic surveillance of the variations of a certain chemical or physical characteristic of an emission, discharge, consumption, equivalent parameter or technical measure, etc. The monitoring is based on repeated measurements or observations, at an appropriate frequency in accordance with documented and agreed procedures, and is done to provide useful information. This information may range from simple visual observations to precise numerical data. The information can be used for several different purposes, the main aim being to verify compliance with emission limit values but it can also be useful for a surveillance of the correct operation of the plant processes, as well as for allowing better decision-making about industrial operations.

The terms measuring and monitoring are often interchanged in common usage. In this report they have the following scopes:

- measuring involves a set of operations to determine the value of a quantity, and therefore implies that an individual quantitative result is obtained
- monitoring includes the measurement of the value of a particular parameter and also the follow-up into variations in its value (so as to allow the true value of the parameter to be controlled within a required range). Occasionally, monitoring may refer to the simple surveillance of a parameter without numerical values, i.e. without measuring.

2 MONITORING ISSUES TO CONSIDER IN SETTING IPPC PERMITS

When laying down ELVs (Emission Limit Values) in permits, the permit writer should consider how the environmental reporting and compliance assessment will be carried out and how the most relevant information can be obtained with the requisite quality of, and confidence in, the results, without losing sight of the cost-effectiveness.

In this chapter, it is recommended that the permit writer takes into account the seven considerations covered in Sections 2.1 to 2.7 when establishing appropriate permit conditions. These considerations should not be taken in isolation but are interdependent and together form a "quality chain", whereby the quality achieved at each step affects what can be achieved at all later stages. This means that any weaknesses in the early stages could have a major adverse effect on the quality and usefulness of the final results.

The IPPC Directive expects permit writers to set ELVs for emissions and discharges, and to set other requirements for waste management, use of energy, noise, odour and possibly use of raw and auxiliary materials. For reasons of simplicity, in the remainder of this chapter these environmental items will all be referred to as "emissions".

2.1 "Why" monitor?

[Mon/tm/64]

The IPPC Directive requires all ELVs in permits to be based on the application of Best Available Techniques (BAT). Monitoring the performance of these BAT-based techniques may be necessary for two main reasons:

- to check that the emissions are within ELVs, e.g. compliance assessment
- to establish the contribution of a particular installation to environmental pollution in general, e.g. periodic environmental reporting to the competent authorities.

It is often the case that monitoring data obtained for one purpose may well serve other purposes, although occasionally the data may need some prior treatment. For example, compliance monitoring data could be used for the EPER reporting obligation. Therefore, monitoring is a valuable source of information, not only for assessing whether industrial installations are operating in compliance with IPPC permits but also for understanding and managing their interactions with the environment and society.

Some examples of additional reasons and objectives for undertaking monitoring are (apart from the two main reasons already stated above):

- reporting for emissions inventories (e.g. local, national and international)
- assessing Best Available Techniques (e.g. at company, sector and EU levels)
- assessing environmental impacts (e.g. for input to models, pollutant load maps)
- undertaking negotiations (e.g. of emission quotas, improvement programmes)
- investigating possible surrogate parameters with practical and/or cost advantages
- making decisions on feedstock and fuel, plant life and investment strategies
- setting or levying environmental charges and/or taxes
- planning and managing increases in efficiency
- setting appropriate scope and frequency of inspections and corrective actions in co-operation with competent authorities
- optimising the process with regard to emissions
- establishing taxation on behalf of emission trading.

Operators and authorities should have a clear understanding of the objectives before monitoring begins. The objectives and the monitoring system should also be clear for any third party involved, including external contractors and other possible users of the measurement data (e.g. land-use planners, public interest groups and central government).

Good practice is to document the objectives at the start, and to keep them under systematic review. This information may include consideration of the aims, obligations, uses and users of the data collected during a monitoring programme.

A systematic review process should be in place to ensure that technical developments that might improve the quality and effectiveness of a programme are taken into account, but bearing in mind that a stable and consistent monitoring regime is always maintained. The data obtained can be regularly compared with the objectives over time to check that they are being met.

Monitoring is therefore a useful investment with wide practical benefits. These benefits can only be fully achievable, however, when the data are reliable and comparable and when they have been obtained from an appropriate quality monitoring programme.

2.2 “Who” carries out the monitoring?

[Mon/tm/64]

Compliance monitoring can be carried out by competent authorities, operators, or by third-party contractors acting on their behalf. Both the authorities and operators are increasingly making use of external contractors to undertake monitoring work on their behalf. However, even when using contractors the ultimate responsibility for the monitoring and its quality remains with the relevant authority or operator and cannot be contracted out.

In EU Member States there is no consistent division between “authority responsibilities” and “operator responsibilities”. Some tasks are always appropriate to the competent authorities (e.g. making regulations, studying operators’ proposals) and others to the operators (e.g. self-monitoring).

The IPPC Directive provides for requirements for operators’ monitoring to be specified in the permit. Usually, competent authorities rely to a large extent, on “self monitoring” by operators. They audit the operator arrangements and carry out more limited monitoring programmes themselves to provide independent checks where necessary. These programmes may be subcontracted to a third party contractor, at the operator expense, and may be performed without notice.

Self-monitoring has potential advantages because it can use the operator's own knowledge of their processes, it encourages operators to take responsibility for their emissions and it can be relatively cost-efficient. However, it is critically important for the regulator to confirm the quality of the data, in order to increase the public confidence, by the use of appropriate quality assurance procedures. See Section 2.7 point 8 for information on the requirements in permits on self-monitoring arrangements.

Monitoring carried out by the authorities may command higher public confidence, but typically their resources may be limited. It is also usually less cost-effective for the authority to carry out the monitoring, particularly with regard to the use of continuous monitoring systems, since their knowledge of the processes is unlikely to be as detailed as that of the operator and, de facto, the personnel engaged in monitoring will not be present on the site at all times.

It is highly important that monitoring responsibilities are clearly assigned to relevant parties (operators, authorities, contractors) so that they are all aware of how the work is divided and what their own duties and responsibilities are. Details of such assignments and of the methods to be used may be specified in monitoring programmes, schemes, permits, legislation or other relevant documents, such as applicable standards.

For good practice, such specifications would include details of:

- the monitoring for which the operator is responsible, including any monitoring that external contractors do when acting on their behalf
- the monitoring for which the competent authority is responsible, including any monitoring that external contractors do when acting on their behalf
- the strategy and the role of each participant
- the methods and safeguards that are required in each case
- the reporting requirements.

It is essential that the users of monitoring results have confidence in the **quality** of such results. This means that whoever does the work needs to achieve a high level of quality, i.e. by doing the work in an objective and rigorous manner and to a appropriate standard, and also needs to be able to demonstrate this to data users.

Chapter 2

It is the responsibility of the competent authority to establish and set appropriate quality requirements, and to consider a range of safeguards. For the purpose of compliance assessment use of the following is good practice:

- standard methods of measurement, where available
- certified instruments
- certification of personnel
- accredited laboratories.

See Section 2.7 point 12 for more information on the quality considerations in IPPC permits.

For self-monitoring activities the use of recognised quality management systems and periodic check by an external accredited laboratory instead of formal own accreditation can be appropriate.

2.3 “What” and “How” to monitor

In principle there are various approaches that can be taken to monitor a parameter, although some of them may not be appropriate for particular applications:

- direct measurements
- surrogate parameters
- mass balances
- other calculations
- emission factors.

When choosing one of these approaches for monitoring there must be a balance between the availability of the method, reliability, level of confidence, costs and the environmental benefits. Further information on these different approaches can be found in Chapter 5.

Selection of the parameter(s) to be monitored depends on the production processes, raw material and the chemicals used in the plant. It is useful if the parameter chosen to be monitored also serves the plant operation control needs. The frequency at which the parameter is monitored varies widely according to the needs and risks to the environment and according to the monitoring approach taken (see Section 2.5.)

Since emission monitoring must provide authorities with adequate information on the emissions and their variations in time, the parameters to be monitored usually exceed the number of parameters listed in the permit or monitoring programme [Mon/tm/39].

Various levels of potential risk of environmental damage can be distinguished, and matched with an appropriate monitoring regime. When determining the monitoring regime, or intensity, the main elements influencing the risk of having an actual emission higher than the ELV are:

- (a) the likelihood of exceeding the ELV
- (b) the consequences of exceeding the ELV (i.e. harm to the environment).

Items to consider when assessing the likelihood of exceeding the ELV include:

- number of sources contributing to the emission
- stability of process conditions
- buffer capacity of effluent treatment available
- treatment capacity of the source for excess emissions
- potential for mechanical failure caused by corrosion
- flexibility in product output
- capacity of the industrial operator to react when a failure happens
- age of equipment in service
- operating regime
- inventory of hazardous substances that might be released during normal or abnormal conditions
- importance of load (high concentrations, high flowrate)
- fluctuations in the composition of the effluent.

Items to consider when assessing the consequences of exceeding the ELV include:

- duration of a potential failure
- acute effects of the substance, i.e. the hazard characteristics of the substance handled
- location of the installation (proximity of neighbourhoods,...)
- dilution ratio in the receiving media
- meteorological conditions.

The remainder of this Section shows an **example** of how some of the items of the previous lists can be classified into different levels of risk.

In this example the main elements influencing the risk of having an actual emission higher than the ELV are listed in Table 2.3.1 and classified into different levels of risk, corresponding to a low up to a high level of risk. The risk evaluation should take local conditions into consideration, including items that may not be reflected in this table. The final assessment of likelihood or consequences should be based on the combination of all items, not on a single item.

Items to consider and corresponding risk scoring level	LOW LEVEL 1	MEDIUM LEVEL 2 – 3	HIGH LEVEL 4
Items influencing the likelihood of exceeding the ELV			
(a) number of individual sources contributing to the emission	Single	Several (1 - 5)	Numerous (> 5)
(b) stability of operating process conditions	Stable	Stable	Unstable
(c) buffer capacity of effluent treatment	Sufficient to cope with upsets	limited	none
(d) treatment capacity of the source for excess emissions	Able to cope with peaks (by dilution, stoichiometric reaction, oversize, spare treatment)	Limited capabilities	No capabilities
(e) potential for mechanical failure caused by corrosion	No or limited corrosion	Normal corrosion, covered by design	Corrosion conditions still present
(f) flexibility in product output	Single dedicated production unit	Limited number of grades	Many grades, multipurpose plant
(g) inventory of hazardous substance	Not present or production dependent	Significant (compared to ELV limits)	Large inventory
(h) maximum possible emission load (concentration x flowrate)	Significantly below the ELV	Around the ELV	Significantly above the ELV
Items for assessing the consequences of exceeding the ELV			
(i) duration of potential failure	short (< 1hour)	Medium (1hour to 1 day)	Long (> 1 day)
(j) acute effect of the substance	No	Potential	Likely
(k) location of the installation	Industrial area	Safe distance between residential area	Residential area nearby
(l) dilution ratio in the receiving media	High (e.g. above 1000)	Normal	Low (e.g. less than 10)

Table 2.3.1: Items influencing the likelihood of exceeding the ELV and the consequences of exceeding the ELV

The results of the assessments of these items can then be combined and represented in a simple diagram plotting the likelihood of exceeding the ELV against the consequences of exceeding that ELV, see Figure 2.3.1. The combinations of these items can be decided on a case by case basis and can be done in such a way that more weight may be given to the most relevant items. The location of the result on risk-based grid, as shown in Figure 2.3.1 determines the appropriate monitoring regime conditions for routine process operation.

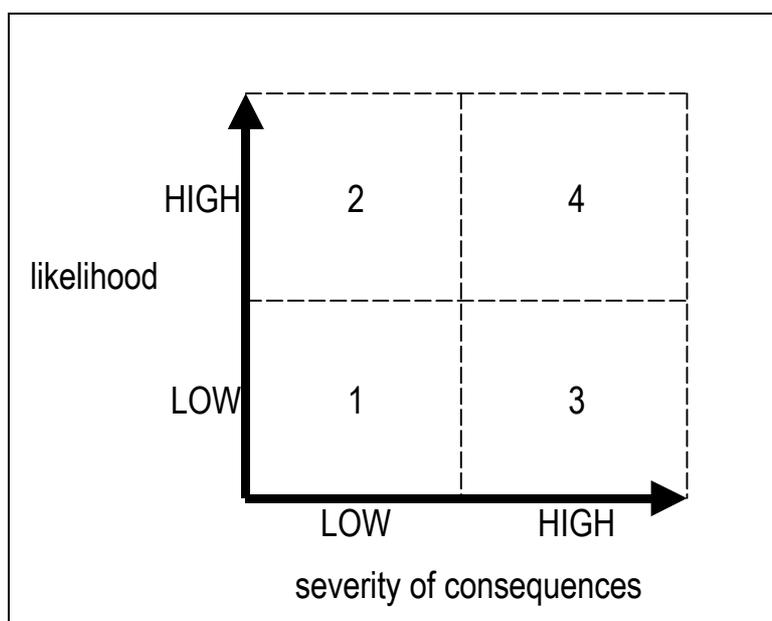


Figure 2.3.1: Monitoring Regime according to the risk of exceeding the ELV

The corresponding monitoring regimes are:

1. Occasional - (once per month to once per year): the main purpose is to check the actual level of emissions with predicted or usual conditions.

2. Regular to frequent (once to three times per day to once per week): frequency needs to be high in order to detect unusual conditions or an incipient decrease of performance and to rapidly initiate corrective actions (diagnostic, repair, maintenance,...). Here, time proportional sampling may be appropriate.

3. Regular to frequent (once per day to once per week): accuracy needs to be high and uncertainties of the monitoring chain minimised in order to ensure no harm of the receiving environment. Here flow proportional sampling may be appropriate.

4. Intensive (continuous or high frequency sequential sampling is appropriate, 3 to 24 per day): this is used when, for instance, unstable conditions are likely to lead to an exceedance of the ELV. The purpose is to determine emissions in real time and/or at the exact period of time and at the level of emission reached.

An example of an existing approach, consistent with the philosophy of the risk-based approach, for assigning a monitoring regime to any source according to the risk of environmental damage can be found in the Netherlands Emissions Guidelines for Air [Mon/tm/74].

2.4 “How” to express ELVs and monitoring results

There is a relationship between the way ELVs are expressed and the objective for monitoring these emissions.

The following types of units can be applied, either singly or in combination:

- concentration units
- units of load over time
- specific units and emission factors
- thermal effect units
- other emission value units
- normalised units.

Concentration units

- expressed as mass per unit of volume (e.g. mg/m^3 , mg/l) or volume per unit of volume (e.g. ppm). These units (frequently quoted with an averaging time, e.g. hourly or daily value, see Section 2.5) are applied as ELVs to check for the correct performance of a process or an end-of-pipe abatement technology as prescribed in the permit (e.g. compliance checking of an installation). Note that volumes can be expressed in different ways: volume as such, normal volume, dry, wet, related to a certain oxygen concentration, etc.
- in some permits, ELVs are expressed both as concentration and load units to prevent the ELV (in mg/m^3) being met by diluting the emission.

Units of load over time

The choice of time period for unit load over time is related to the type of impact of the emission to the environment:

- a short time base is applied to express a short-term burden to the environment and is often used for individual installations for e.g. impact assessment
 - kg/s is usually used in the consequence assessment of hazardous release scenarios or exceptional events or with health effects (safety studies)
 - kg/h is usually used for emissions from continuous process operations
 - kg/d or kg/week are usually used for the impact assessment of emissions that need to be closely followed
- a long time base, for example t/yr , is mainly applied when the long-term burden to the environment is relevant, for example with acidifying emissions (such as SO_2 and NO_x) and for periodic environmental reporting, e.g. EPER.

Specific units and emission factors

- based on the unit of product, for example kg/t of product. They can be used to compare different processes to each other independently of actual production, thus also allowing the opportunity to evaluate trends; the value thereby acting as a benchmark, which can be used to select the best technique. When an installation produces only one or a small number of products, specific units can be used as permit limits to allow for varying production levels
- based on the unit of input, for example g/GJ (thermal input), they can be used especially for combustion processes and are often independent of the size of the process. They can also be used for assessing the efficiency of abatement equipment (e.g. mass balance g(in)/g(out)).

The unit bases must be clearly and unambiguously indicated together with the result. For example it is necessary to indicate whether they relate to actual production or nameplate/nominal capacity. The same units used in ELVs must be used when reporting compliance monitoring results.

Thermal effect units

- expressed as temperature (i.e. °C, K, e.g. for assessing the destruction performance of an incinerator), or as unit of heat per unit of time (e.g. W, to assess the thermal effects in receiving waters).

Other emission value units

- expressed as: velocity in e.g. m/s, to assess compliance with minimum stack gas efflux velocity; or units of volume per unit of time e.g. m³/s to assess the discharge rate of effluent to receiving water; residence time, e.g. s to assess completeness of combustion in an incinerator
- dilution or mixing rate (used for odour control in some permits).

Normalised units

- these units take into account auxiliary parameters to express the data at normalised conditions. For example, in gases it is usual to give the results in concentration expressed as mass per normal cubic metre, where “normal” means at a standard temperature, pressure, water content (dry/humid) and a reference oxygen concentration. The reference conditions used should always be indicated together with the result. Note that there is a difference between "normal" and "standard" conditions (see Section 4.3.1).

In all cases, the units to be used for compliance monitoring purposes should be clearly stated, preferably be internationally recognised (e.g. based on the *Système Internationale*) and match the relevant parameter, application and context.

2.5 Monitoring timing considerations

[Mon/tm/64]

Several timing considerations are relevant for setting monitoring requirements in permits, the main ones being:

- time when samples and/or measurements are taken
 - averaging time
 - frequency.
- The **time** when samples and/or measurements are taken refers to the point in time (e.g. the hour, the day, week, etc.) at which the sampling and/or measurements are performed. The time may be crucial to obtaining a result that is relevant to the ELV, and the estimation of loads, and may depend on plant processing conditions, such as:
- when specified feedstock or fuels are being used
 - when a process is operating at a specified load or capacity
 - when a process is operating in upset or abnormal conditions. A different monitoring approach may then be required because the pollutant concentrations may then exceed the range of the method used in normal conditions. Upset and abnormal operations include start-up, leaks, malfunctions, momentary stoppages and terminal shutdown. Further information on this issue can be found in Section 3.2.
- Most commonly in permits, (and in this document) **averaging time** refers to the time over which a monitoring result is taken as representative of the average load or concentration of the emission. This may be for example hourly, daily, yearly, etc.

An average value can be obtained in a number of different ways, including:

- in continuous monitoring, calculating an average value from all the results produced during the period. A continuous monitor is typically set to calculate an average result over contiguous short periods of time, say every 10 or 15 seconds. This can be referred to as the averaging time of the monitoring equipment. For example, if one result was produced every 15 seconds the average over 24 hours is the mathematical average of 5760 values
- sampling over the whole period (continuous or composite sample) to produce a single measurement result
- taking a number of spot samples over the period and averaging the results obtained.

Note that some pollutants may need a minimum sample period, long enough to collect a measurable amount of the pollutant, and the result is the average value over the sample period. For example, measurement of dioxins in gaseous emissions may typically need a sample period of 6 to 8 hours.

- The **frequency** refers to the time between individual samples and/or measurements or groups of measurements of a process emission. It can vary widely between different situations (e.g. from one sample/year to on-line measurements covering 24 hours/day) and it is generally divided into continuous and discontinuous monitoring. Among discontinuous monitoring, campaign monitoring is a special application (see Section 5.1).

When determining the frequency, it is very important to balance the requirements for the measurements with emissions characteristics, risk to the environment, practicalities of sampling and the costs. For instance, a high frequency may be chosen for simple and economical parameters, e.g. surrogate parameters (see Section 5.2 for information on surrogates), the emission for which the parameter has been used can then be monitored at a lower frequency.

Good practice entails matching the monitoring frequency to the time-frames over which harmful effects or potentially harmful trends may occur. For example, if harmful effects may occur due to short-term pollutant impacts, then it is best to monitor frequently (conversely, if they are due to long-term exposure). The monitoring frequency should be reviewed and if necessary revised as more information becomes available (e.g. updates on the time-frames of harmful effects).

There are different types of approaches available for determining the frequency. Risk based approaches are commonly used for this purpose, see Section 2.3 for an example of a risk-based approach, although there are other possible procedures for determining the frequency, such as the Capability Index.

Other applications of monitoring may need different considerations for determining the frequency, for example campaign monitoring, which involves measurements made in response to a need or interest to obtain more fundamental information than that which routine/conventional monitoring provides (see Section 5.1).

In general, the description of the ELV in the permit (in terms of e.g. total amount and peaks), is the basis to set up the monitoring timing requirements. These requirements and associated compliance monitoring must be clearly defined and indicated in the permit so as to avoid ambiguity.

The monitoring timing requirements expressed in the permit mostly depend on the type of process and more specifically on the emission patterns. When the emission is subject to random or systematic variations, statistical parameters including means, standard deviations, maxima and minima provide only estimates of the true values. In general, the uncertainty decreases as the number of samples increases. The magnitude and duration of changes may determine the monitoring timing requirements, as described below.

The philosophy behind determining timing requirements can be illustrated by the following examples (A, B, C and D) in Figure 2.5. The figures show how emissions (vertical axis, i.e. Y-axis) can vary over time (horizontal axis, i.e. X-axis).

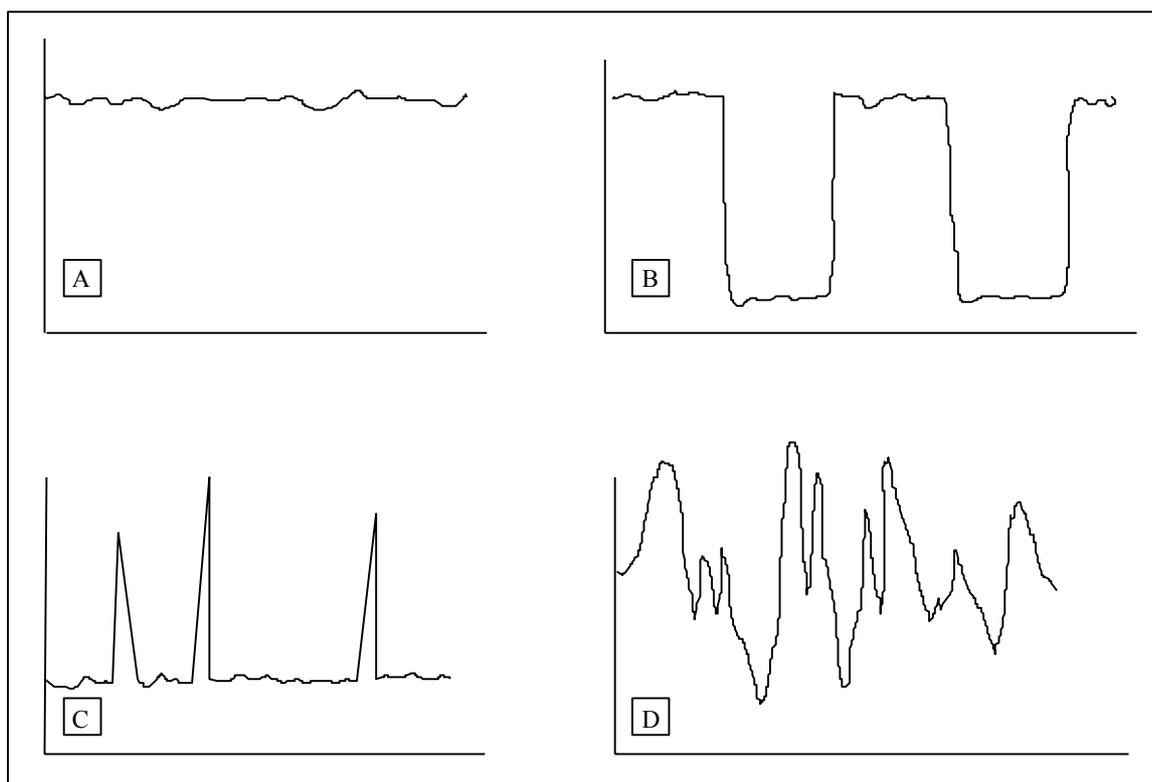


Figure 2.5: Examples of how emissions can vary over time and their implications on determining monitoring time requirements

In the examples given in Figure 2.5 the determination of the time, averaging time and the frequency depends on the emission pattern as follows:

- **Process A** represents a very stable process.
 The time when samples are taken is not important since the results are very similar irrespective of when the samples are taken (i.e. in the morning, on Thursdays, etc.).
 The averaging time is also not so important since whatever time we choose (e.g. half-hour, 2 hours, etc.) the mean values are also very similar.
 The frequency could therefore be discontinuous because the results would be very similar, independent of the time between them.
- **Process B** represents a typical example of a cyclic or a batch process.
 The time when samples are taken and the averaging time can be restricted to the periods when the batch process is in operation; although average emissions during the whole cycle, including downtime, might also be of interest, especially for estimation of loads.
 The frequency could be either discontinuous or continuous.
- **Process C** represents a relatively stable process with occasional short but high peaks, which contribute very little to the cumulative total emissions.
 Whether the ELV should focus on the peaks or on the total amount depends entirely on the nature/potential hazard of the emissions. If harmful effects can occur due to short-term pollutant impacts then it is important to control the peaks rather than the cumulative load.
 A very short averaging time is used for controlling the peaks, and a longer averaging time for controlling the total amount.
 A high frequency (e.g. continuous) is more suitable for controlling peaks.
 Similarly the time when samples are taken is also important for controlling the peaks, since short averaging times are used. However, it is not so important for controlling the cumulative load, as long as a sufficiently long averaging time is taken to avoid the result being too influenced by the occasional short peak.

- **Process D** represents a highly variable process.
Again, the nature/potential hazard of the emissions will dictate whether an ELV is to be set for the peaks or for the total amount of emissions.
In this case, the time when samples are taken is very important because, due to the variability of the process, samples taken at different times can give very different results.
A very short averaging time is used for controlling the peaks, and a longer averaging time is used for controlling the total amount.
In either case a high frequency (e.g. continuous) is likely to be necessary, since a lower frequency is likely to produce non-reliable results.

The determination of the timing requirements (time, averaging time, frequency, etc.) for ELVs and related monitoring also needs to take into account the following factors:

- the time during which harm may occur to the environment (e.g. 15 - 60 minutes for breathing of air pollutants, annual deposition for acid rain, 1 minute to 8 hours for noise, 1 hour to 24 hours for waste water)
- the variations of the process, i.e. how long it runs in different modes
- the time needed to obtain statistically representative information
- the response time of any instrument involved
- the data obtained should be representative of what is intended to be monitored and comparable with data from other plants
- environmental objectives.

The total duration of a monitoring programme is often aligned to the operating life of a process, particularly when the time-frame of any harmful effect is short compared to the operating life.

2.6 How to deal with uncertainties

[Mon/tm/64]

When monitoring is applied for compliance assessment it is particularly important to be aware of measurement uncertainties during the whole monitoring process.

The uncertainty of a measurement is a parameter, associated with the measurement result, that characterises the dispersion of the values that could reasonably be attributed to the measurand (i.e. the extent to which measured values can actually differ from the real value).

In general, the uncertainty is expressed as a plus or minus interval around the measurement result with a 95 % statistical confidence. Two dispersions are of practical interest for uncertainties:

- the "external dispersion" - this expresses how different (“reproducible”) the results of different laboratories performing the considered measurement according to the applicable standard(s) are
- the "internal dispersion" - this expresses how “repeatable” the results obtained by a laboratory performing measurements according to the same applicable standard(s) are.

The "internal dispersion" is only used to compare different measurement results obtained by a given laboratory from the same measurement process for the same measurand. In all other situations the "external dispersion" is to be considered when estimating the uncertainty.

When the permit explicitly specifies (or implicitly by reference to national regulation) an applicable standard method for the regulated parameter, the "external dispersion" corresponds to the uncertainty of such standard method of measurement.

When the permit leaves open the choice of a standard method for the regulated parameter, the “external dispersion” corresponds to the uncertainty of a measurement result. This includes the systematic differences (i.e. “bias”) that may exist between the results obtained with different applicable standard measurement methods for the same regulated parameter.

Theoretically, such systematic differences are not significant, provided that all the applicable standard measurement methods are made traceable to SI units in the same way. In practice, this traceability can be done by using Certified Reference Materials (CRMs). However, CRMs, when available, can be applied for the analytical steps, but rarely in the sampling steps of the data production chain.

To avoid ambiguity the arrangements foreseen for dealing with uncertainties need to be clearly stated in the permit. For this purpose, concise agreed procedures (e.g. stated as "the result minus the uncertainty should be below the ELV", "the average of N measurements should be below the ELV") are a better option than general statements that are open to wide interpretation (e.g. statements such as “as low as reasonably practicable”).

The statistical conditions attached to the compliance assessment procedure may dictate practical aspects of the monitoring, such as the number of samples or measurements required to reach a certain level of confidence. If the permit uses examples to explain the compliance assessment procedure, then it is important to explain that the examples are not meant to constrain the application of the method, only to illustrate it.

Identification of the uncertainty sources can be useful to reduce the total uncertainty, this can be especially important in those cases when the measurement results are close to the ELV. The main sources of uncertainties are those associated with the measurement steps of the monitoring data production chain, such as:

- sampling plan
- taking of the sample
- sample pretreatment, (e.g. enrichment/extraction in the field)
- transport/storage/preservation of the sample
- sample treatment (e.g. extraction/conditioning, etc.)
- analysis/quantification.

However, other external sources of uncertainties also need to be considered, such as:

- uncertainties in flow measurements when loads are calculated
- uncertainties in data handling, e.g. the uncertainties related to missing values when calculating a daily or other average
- uncertainties due to the dispersion of results associated with systematic differences (“bias”) that may exist between results obtained with different applicable standard measurement methods for the same regulated parameter
- uncertainties due to the use of secondary method or of surrogates
- uncertainties due to inherent variability (e.g. of a process or weather conditions).

The total uncertainty for a particular application is difficult to calculate. During the preparation of standards (e.g. CEN standards, see Annex 2.) the uncertainty may have been experimentally determined by interlaboratory tests and then indicated in the standards.

2.7 Monitoring requirements to be included with Emission Limit Values (ELVs) in permits

[Mon/tm/64]

It is recommended that the permit writer consider the items addressed in the previous sections (Sections 2.1 – 2.6) before deciding on how to formulate the ELV in the permit.

When setting ELVs in a permit there are three key elements:

- the ELVs must be capable of being monitored in practice
- monitoring requirements must be specified together with the ELVs
- compliance assessment procedures must also be specified together with the ELVs so that they can be readily understood.

The different types of ELVs, or equivalent parameters that may be used, may include:

- conditions within a process (e.g. temperature of combustion)
- equipment performance within a process (e.g. efficiency of abatement equipment)
- emissions from a process (e.g. pollutant release rates or concentrations)
- flow characteristics (e.g. exit temperature, exit velocity or flow)
- resource usage (e.g. energy used or pollution emitted/unit of production)
- percentage capture of monitoring data (i.e. the minimum percentage of the monitoring data needed to make averages).

Clarity about the relationship between the ELVs and the monitoring programme is essential. The specified monitoring requirements should cover all relevant aspects of the ELV. To this end it is good practice to take into account the following points:

1. Make it clear in the permit that monitoring is an inherent and **legally enforceable** requirement and that it is as necessary to comply with the monitoring obligation as with the limit value/equivalent parameter.
2. Specify clearly and unambiguously the **pollutant or parameter being limited**. This may include specifying details such as, for instance:
 - if a volatile substance is to be monitored, it should be clear whether this refers to the gaseous component and/or to the solid component attached to particulates
 - if oxygen demand in water is to be monitored, it should be clear which test is to be used, e.g. Biochemical Oxygen Demand 5 days test (BOD₅)
 - if particulates are to be monitored the size range should be specified, e.g. total, <10 µm, etc.
3. State clearly the **location** where samples and measurements are to be taken. These should match the positions where the limits are applied. It is necessary to have suitable sampling measurement sections and/or measurement sites available. To this end, relevant requirements for space and technical facilities, such as safe measurement platforms and sampling ports, should also be stated in the permit.
4. Specify the monitoring **timing requirements** (time, averaging time, frequency, etc.) of sampling and measurements, as explained in Section 2.5.

5. Consider the **feasibility of limits** with regard to available measurement methods. Limits must be set so that the monitoring required in order to determine compliance is within the capability of available measurement methods. For example, in order to obtain detectable quantities of dioxins from stack emissions it is usually necessary to sample over several hours. In this case the averaging time should correspond to this practical sampling duration. The limit setting process must therefore take into account the technical limitations of the relevant monitoring methods which will include consideration of detection limits, response times, sampling times, possible interferences, general availability of the methods and possible use of surrogates.
6. Consider the **general approach to the monitoring** available for relevant needs (e.g. the scale). It is useful if the monitoring programme for a limit first describes the general type of monitoring required, before giving details of specific methods. The general approach will suit the considerations of location, timing, time-scale and feasibility, and take into account the options of direct measurement, surrogate parameters, mass balances, other calculations, and the use of emission factors. These general approaches are described in Chapter 5.
7. Specify the **technical details of particular measurement methods**, i.e. the associated standard (or alternative) measurement method, and the units of measurement. Choosing measurement methods in accordance with the following priorities will lead to better reliability and comparability, provided they are reasonably practicable:
 - standard methods required by relevant EU Directives (normally CEN standards)
 - CEN standard for the relevant pollutant or parameter
 - ISO standards
 - other international standards
 - national standards
 - alternative methods, with the prior approval of the competent authority, who may also impose extra requirements.

The measuring method should be validated, i.e. the performance criteria should be known and documented. Where appropriate the permit may specify performance criteria for the method (uncertainty, limit of detection, specificity, etc.)

8. In cases of **self-monitoring**, either performed by the operator or by a contractor, clearly state the procedure for periodically checking the traceability of the self-monitoring. An accredited third party testing laboratory should be used for this work.
9. State the **operational conditions** (e.g. production load) under which the monitoring is to be performed. If normal or maximum production at the facility is required, this should be quantitatively defined.
10. Clearly state the **compliance assessment procedures**, i.e. how will the monitoring data be interpreted to assess compliance with the relevant limit (as shown in Chapter 6), also taking into account the uncertainty of the monitoring result as explained in Section 2.6.
11. Specify the **reporting requirements**, e.g. what results and other information are to be reported; when, how, and to whom. Reporting aspects of compliance monitoring are considered further in Chapter 7.

12. Include appropriate **quality assurance and control requirements**, so that the measurements are reliable, comparable, consistent and auditable. The main quality considerations may include:

- *Traceability* of the measurements' results to a reference specified by the competent authorities, this includes calibration of the monitoring system when relevant.
- *Maintenance* of the monitoring system.
- For self-monitoring, the use of recognised *Quality Management Systems* and periodic checks by an external *Accredited* laboratory.
- *Certification* of instruments and personnel under recognised certification schemes.
- *Updating of monitoring requirements* to regularly check opportunities for simplification or improvement, taking account of:
 - changes in limits
 - the latest compliance situation of the process
 - new monitoring techniques.

The local situation may result in specific requirements complementing the quality requirements specified in the national approval schemes existing in several Member States. Such procedures of "approval" rely for technical matters on a valid accreditation of the regulatory measurements being performed.

13. Make arrangements for the assessment and reporting of **exceptional emissions**, both foreseeable (e.g. shutdowns, stoppages, maintenance) and unforeseeable (e.g. disturbances in the process input, or in abatement technique). The approach to these emissions is discussed in Section 3.2.

This "full approach" to defining the monitoring requirements associated to the ELV may sometimes however result in a simple expressed obligation.

3 ACCOUNTING FOR TOTAL EMISSIONS

[Mon/tm/67]

Information on the total emissions of an industrial installation may be needed when:

- reviewing compliance with environmental permits
- reporting emissions (e.g. EPER register)
- comparing environmental performance with the relevant BAT Reference document (BREF) or with that of another installation (whether in the same or another industrial sector).

The total picture of the emissions is not only given by the normal emissions arising from the stacks and pipes, but also by taking into account diffuse and fugitive, and exceptional emissions (described in Sections 3.1 and 3.2). Monitoring systems can be developed, when necessary, so that the total load on the environment is accounted for. The following box summarises this statement:

TOTAL EMISSIONS =	END-OF-PIPE EMISSIONS (normal operation) + DIFFUSE and FUGITIVE EMISSIONS (normal operation) + EXCEPTIONAL EMISSIONS
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To facilitate the management of total emissions from a plant, the number of emission discharging points may be minimised, e.g. by closing minor discharging points and conducting the effluent to the main pipes. This helps to limit and minimise diffuse and fugitive sources. However, in many cases (e.g. flammable vapours, dust), the collection and grouping of emission points cannot be achieved for safety reasons (e.g. explosion and fire risks).

This chapter also discusses values under the limit of detection (Section 3.3) and outlier values (Section 3.4).

3.1 Monitoring of Fugitive and Diffuse Emissions (DFE)

[Mon/tm/50],[Mon/tm/65],[Mon/tm/66]

As progress has been made in reducing channelled emissions then the relative importance of other emissions have become increasingly important, for instance more attention is now paid to the relative importance of **diffuse and fugitive emissions (DFE)**. It is recognised that these emissions can potentially cause damage to health or the environment, and that sometimes their losses may also have economic significance for a plant. It is therefore recommended that IPPC permits, where appropriate and reasonable, include provisions to properly monitor these emissions.

DFE quantification is labour and cost intensive. Measurement techniques are available, but the level of confidence in results is low and, due to the extended number of potential sources, the assessment of the total amount of DFE may be more costly than point source emission measurements. However, it is believed that future developments will improve the knowledge and surveillance of DFE.

Before any discussion on DFE it is important to be clear on the **definitions** when dealing with DFE:

- *Channelled emissions* - Emission of pollutants into the environment through any kind of pipe, regardless of the shape of its cross-section. The practicality of measuring flowrates and concentrations is important to decide whether an emission is channelled.
- *Fugitive emissions* - Emissions into the environment resulting from a gradual loss of tightness of a piece of equipment designed to contain an enclosed fluid (gaseous or liquid), typically this could be caused by a pressure difference and a resulting leak. Examples of fugitive emissions include leakages from a flange, a pump or a piece of equipment and losses from the storage facilities of gaseous or liquid products.
- *Diffuse emissions* - Emissions arising from a direct contact of volatile or light dusty substances with the environment under normal operating circumstances. These can result from:
 - inherent design of the equipment (e.g. filters, dryers ...)
 - operating conditions (e.g. during transfer of material between containers)
 - type of operation (e.g. maintenance activities)
 - or from a gradual release to other media (e.g. to cooling water or waste water).

Diffuse emission sources can be point, linear, surface or volume sources. Multiple emissions inside a building are normally considered as diffuse emissions, whereas the general ventilation-system exhaust is a channelled emission.

Examples of diffuse emissions include venting from storage facilities during loading and unloading, storage of solid matter in the open air, separation pools in oil refineries, vents, doors in coke plants, mercury emission from electrolysis cells, processes involving solvents, etc.

Note, fugitive emissions are a subset of diffuse emissions.

Quantification of DFE

Some examples of techniques for quantifying DFE are listed here and briefly described below:

- analogy with channelled emissions
- assessment of equipment leaks
- emissions from storage tanks, loading and unloading, and utilities
- long path optical monitors
- mass balances
- tracers
- similitude assessment
- assessment of wet and dry depositions downwind of the plant.

Analogy with channelled emissions

This method consists of defining a “reference surface” through which a flux of matter is measured. For a channeled emission, this reference surface is the cross-section of the pipe; for DFE however the reference surface is sometimes complex to define. For instance, such a surface could be a lantern, a theoretical surface more or less perpendicular to the plume of pollutants downwind of the source, the surface of a liquid, etc.

Assessment of equipment leaks

The Protocol for Equipment Leak Emission Estimates issued by the USEPA provides details on several different approaches, listed below, which can be used to estimate these emissions:

- average emission factor
- screening ranges/stratified factors
- EPA correlation
- unit-specific correlation approach.

All the approaches require screening data except for the average emission factor approach. A screening value is a measure of the concentration of leaking substance in the ambient air close to the equipment. It provides an indication of the leak rate from a piece of equipment. Measurements can be obtained by using a portable monitoring instrument, sampling air from the potential leak points of individual pieces of equipment.

The unit-specific correlation approach also uses measured leak rates associated to screening values. In this approach the leak rate is measured by enclosing a piece of equipment 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.

The main objective of the USEPA fugitive emission estimation methods is to assist in a Leak Detection And Repair programme (LDAR). A LDAR programme consists of checking components for leaks and then repairing any identified leaking components. The leakage check is performed according to the US EPA reference method EPA 21, at a pre-defined sampling frequency. Inaccessible components are in practice not monitored (e.g. for reasons of insulation, height).

Trained sniffer dogs can optimise LDAR, since monitoring is only performed at components that the dog has pointed out (i.e. “sniffed out”) as leaking. Other possibilities to enhance leak detection have been developed, such as sensitive tubes and tapes.

Emissions from storage tanks, loading and unloading and utilities

Emissions from storage tanks, loading/unloading operations, waste water treatment and cooling water systems are usually calculated based on general emission factors. Calculation methodologies are published by API (American Petrol Institute), US EPA and CEFIC/EVCM (European Council of Vinyl Manufacturers).

Long path optical monitors

This approach detects and quantifies downwind concentrations by using electromagnetic radiation, which is absorbed and/or diffused by pollutants. A simple way to use electromagnetic radiation is through using light properties (i.e. ultraviolet, visible or infrared). The travel path of a light beam of a certain wavelength can be modified by contact with emission substances, e.g. particulates, gaseous molecules.

The following are two examples of existing operational techniques:

- active technique: a pulse of lights (e.g. about one per microsecond) with a very well defined wavelength is diffused and absorbed by molecules and by dust. The time analysis of the “echo” observed with an optical device makes it possible to measure pollutant concentration and location in the ambient atmosphere. With the additional use of diffusion modeling techniques a rough indication of the area of emission can be achieved.
An example of an active technique is DIAL (Differential Infrared Absorption Laser), which is regularly used in some countries (e.g. Sweden) as common practice for campaign monitoring of VOC emissions from refineries and oil harbours.
- passive technique: the intensity of a continuous light beam is partially absorbed by the pollutants, and the remainder of the light beam is measured by the detector behind. An example of a passive technique is DOAS (Differential Optical Absorption Spectrometry).

Mass balances

This procedure normally accounts for inputs, accumulations, outputs, generation or destruction of the substance of interest, and accounts for the difference by classifying it as a release to the environment. If materials are transformed in the process, for instance by incineration, it is in principle possible to achieve a balance, not in terms of actual mass of product, but in terms of an element (for example carbon in the combustion processes).

The result of a mass balance is usually a small difference between a large input and a large output, also taking into account the uncertainties involved. Therefore, mass balances are only applicable in practice when accurate input, output and uncertainty quantities can be determined.

Tracers

This method consists of releasing a tracer gas in different identified points or areas of the factory site and at various heights above the surface of the factory site. Then the pollutant (e.g. VOC) and tracer gas concentration are measured downwind of the factory by portable samplers or portable gas chromatographs. The emission rates can be estimated from simple flux assumptions with near stationary conditions and assuming insignificant atmospheric reactions or deposition of gases between the leakage points and the sampling points.

Similitude assessment

With the help of a ‘reverse’ atmospheric dispersion model it is possible to estimate the emissions from down-wind measured air quality data and meteorological data. To cover all potential emission sources it is common practice to monitor at several points. High plume emissions may not be covered by this approach. However, the (exact) location of a leak is difficult to indicate with this method.

Assessment of wet and dry depositions downwind of the plant

A qualitative monitoring of DFE may be performed by analyses of wet and dry depositions downwind of the plant, which then allows an estimation of the evolution of DFE in time (month or year basis). Other measurements methods may be used near to the plants (e.g. bio-monitoring, etc.). This method is used for stable compounds likely to accumulate (e.g. heavy metals and dioxins) provided that the source of emission can be distinguished unambiguously from background ambient concentration.

3.2 Exceptional emissions

[Mon/tm/39],[Mon/tm/66],[Mon/tm/67]

Exceptional emissions can be defined as the emissions arising when there is an event that deviates from regular operation. Examples include: varying input or changing process conditions, start-ups or shutdowns, temporary stoppages, by-passes of treatment units due to malfunctioning of the installation, incidents, etc.

Exceptional emissions can occur under both foreseeable and unforeseeable conditions. There are, at the moment, no formal generic rules for identifying, handling, and reporting of exceptional emissions in European Member State countries.

The relative importance of exceptional emissions has increased as normal process emissions have been reduced to low levels. Exceptional emissions form an integral part of the monitoring requirements in IPPC permits.

Permits may include particular requirements for controlling these emissions, including a plan for monitoring in upset conditions prepared and proposed by the operator and approved by the authority. Information including data and estimates of the amounts, quality, duration and rate of the exceptional emissions may be required to be included in the reported emissions.

Permits normally require all situations, under both foreseeable and unforeseeable conditions, that significantly affect the normal emissions be promptly reported to the authority, including quantified figures and details about the corrective actions taken or going on.

3.2.1 Exceptional emissions under foreseeable conditions

Overall these emissions should be prevented or minimised through control of the process and operation of the installation concerned. The emissions may include the following types:

1. Emissions during planned start-ups and shutdowns due to temporary stoppages, repair work, turn-arounds or similar situations; often carried out according to planned schedules.

For air, emission rates can usually be estimated or calculated by emission factors or by a mass balance (see Section 5.3 and Section 5.5). In other cases they need to be estimated on the basis of measurement campaigns. Some pollutants can be estimated only if measurement data from previous similar situations at the plant are available.

For waste water, the estimation of the emissions may be difficult; for instance, the operation and control of a biological waste water treatment during start up and shutdown requires careful precautions, and this might lead to a greater or lesser extent to unpredictable emission rates. However, in most cases even during such periods permanent flow proportional measurements of relevant parameters are still carried out, so there is no loss of information and corresponding emissions can still be determined.

2. Emissions due to maintenance works can depend on the procedure used for such works. For batch processes these can be planned at regular intervals, which may result in periodic peak emissions. For continuous processes, maintenance will in most cases require a shutdown of the installation.
3. Discontinuous conditions in the process. These happen, for example, when changing product type or grade, or where integrated plants cannot operate simultaneously (e.g. if a process gas, normally used as an energy source in another unit is out of service, it might be flared or vented with or without treatment).

4. Composition of raw material in some processes may greatly vary if specifications are not properly defined or monitored and therefore the emissions can also vary considerably (e.g. melting of scrap).
5. Biological waste water systems (activated sludge) may not work properly due to a sudden exceptional effluent from the process, e.g. toxic substances or exceptionally high concentrations of substances in raw waste water. This triggers a chain reaction that can lead to a lower performance of treatment for a longer period, until the activity of the sludge rises again and achieves the normal treatment efficiency level.

3.2.2 Exceptional emissions under unforeseeable conditions

Unforeseeable conditions are those that are not meant to happen during operation, start-up or shutdown of the installation. They are caused by disturbances, e.g. unexpected and random variations in the input to the process, in the process itself or in the abatement techniques.

These conditions lead to situations where the concentration or volume of the emission is not in the anticipated range or pattern or period of time. Disturbances are not regarded as accidents as long as the deviation from normal emission is not remarkable and the actual emission can be estimated at an adequate certainty. Accidental emissions tend to have human, environmental and economical consequences.

Examples of these unforeseeable situations include:

- equipment malfunction
- process upsets caused by abnormal circumstances such as plugging, excessive temperature, equipment failure, anomalies
- unforeseen changes in feedstock for installations for which feedstock quality cannot be controlled (e.g. waste treatment)
- human error.

Monitoring of exceptional emissions under unforeseeable conditions is possible when continuous measurements are used and the emission concentration remains in the measurement range of the equipment used. It is good practice, when feasible and justified on a risk-basis, to have a procedure to take a sample during exceptional emissions conditions in order to compare it with continuous monitoring results taken at the same time.

Nevertheless, exceptional emission concentrations often exceed the measurement range of the equipment, or they may not be monitored if the source is being monitored discontinuously. In these cases the levels need to be calculated/estimated so that they can be taken into account when summing up the total emissions.

When exceptional emissions are assumed to be of significant importance, the monitoring system should be set up to be able to gather enough data to allow an estimation of those emissions. Operators may establish substitute calculation procedures, with prior approval by the authorities, for estimating these emissions.

Operational control in these situations plays an important role in providing information before, during and after the event. By careful examination of the process and abatement conditions, it may be possible to limit the undesirable effects of the event.

If process control or estimation methods do not provide sufficient information, the frequency of monitoring may be intensified under unforeseeable circumstances. In many cases however, these unforeseeable circumstances correspond to rare events and these emissions cannot be monitored. These emissions will then have to be determined after the event by calculation or estimation based on sound engineering judgement. The basis used in assessing the emission should then be reviewed and approved by the authority.

The following paragraphs present approaches that can be applied where appropriate and that can be considered as good practice in the monitoring of exceptional emissions. In all situations the risk and the cost/benefit ratio needs to be assessed with regard to the potential impact of the emission. Four situations are considered:

1. Monitoring of emissions during disturbances in process conditions or process control

The following approaches are used, alone or in combination:

- use of continuous emission measurements that may include alarm and back-up systems. In critical cases two measurement systems can be installed at the same point but working at different measurement ranges that are calibrated according to the concentration ranges predicted under normal conditions and exceptional circumstances
- periodic/single emission measurements
- estimation with the help of operational control parameters, such as temperature difference, conductivity, pH, pressure, valve position etc. These may specifically provide an early indication of abnormal process conditions. Calculations based on these parameters need to be reviewed and approved by the authority
- reference data from other plants may be used when no measurements or data for plant specific calculations are available
- emission factors available from national or international databases or literature.

Some examples of situations where these approaches are applied include:

- in many processes where chemical and/or thermal oxidation are involved (furnace, kilns, incinerators, boilers, etc) the concentration of carbon monoxide (CO) is an useful parameter to monitor during disturbances because of its correlation to other pollutant concentrations. For example, in the pulp and paper industry the concentration of CO is known to correlate (under certain conditions) with the concentration of total reduced Sulphur (TRS)
- the cumulative flow from a leak (which can be assessed by several methods, including level records, orifice size calculations, pump revolutions, pump movements or pump power consumption over time, etc.) correlates to the total leak amount or flow
- conductivity measurements can be used in waste water as an alarm for other parameters (dissolved salts, metals) during an incident
- for combustion processes under known and stable conditions fuel sulphur content and fuel feed data can be used to calculate SO₂ emissions
- emission factors related to the fuel feed and type (e.g. gas, coal, oil) can be used to calculate the CO₂ emission.

2. Monitoring of emissions during disturbances in abatement technique

The following approaches can be applied:

- continuous emission measurements before an abatement technique. Measurement systems that are calibrated at the raw untreated concentration level, can be installed before the abatement technique, e.g. sulphur removal plant or waste water treatment plant, to monitor emissions during by-pass situations of the abatement system or when only part of the abatement technique is working. During a by-pass of treatment, the record before the abatement equipment is to be used as an actual emission. Routine measurement systems for incoming and outgoing flows and concentrations are usual at plants where the efficiency of the abatement technique is to be monitored for optimisation of performance. At a waste water treatment plant, monitoring of both incoming and outgoing waste water may need to be intensified when exceptional emissions occur
- measurement campaigns and/or periodic measurements
- operational control parameters, as previously explained
- estimations by mass balances or engineering calculations
- data from previous measurements of exceptional emissions can also be used in cases where the volume and concentration of the emission were measured in a similar situation. Default values for volume and concentration may be established for cases of by-pass of each piece of abatement equipment used, so that emissions can even be estimated in cases where one or more of them are inoperative
- reference plant data from other plants may be used for the calculations when no specific measurements data are available
- calculation of emissions with emission factors available from national or international databases or literature. No flow information is normally needed for an estimation of the emission since these emission factors are often related to the production rate.

3. Monitoring of emissions during disturbances or break-downs in the measurement system

In cases where the process and abatement techniques are working under normal conditions but the emissions cannot be measured because of a disturbance or breakdown of the measuring system, then the average measurement results can be used as default emission factors to calculate the emissions. If the performance of the abatement treatment technique is time dependent then the latest result can be used to calculate the emissions.

Operational control parameters, surrogate parameters, mass balances and other estimation techniques may also be applied here.

4. Monitoring of emissions during disturbances or break-downs in the measurement system, process and abatement techniques

Disturbances in process and/or abatement techniques may also, but not necessarily, affect the measurement technique as the measurement is calibrated according to a range at normal conditions. In these cases expert judgement based on mass balances, reference plant data or relevant emission factors may be applied. The expert judgement can be supported by information of previous similar situations at the plant or at reference plants.

3.3 Values under the limit of detection

[Mon/tm/66]

Measuring methods normally have limitations with regard to the lowest concentration that can be detected. Clarity on the handling and reporting of these situations is essential. In many cases the problem can be minimised by using a more sensitive measuring method. Therefore, a proper monitoring strategy should attempt to avoid results under the limit of detection, so that only for less interesting low concentrations do values under the limit of detection occur.

In general, it is good practise to use a measurement method with detection limits of not more than 10 % of the ELV set for the process. Therefore, when setting ELVs, the limits of detection of the available measurement methods need to be taken into account.

It is important to distinguish between the limit of detection (LOD - the lowest detectable amount of a compound) and the limit of quantification (LOQ - the lowest quantifiable amount of a compound). The LOQ is usually significantly larger than the LOD (2 - 4 times). The LOQ is sometimes used to assign a numeric value when handling values under the limit of detection, however the use of the LOD as a reference value is widely spread.

Problems with values of concentrations below the LOD are primarily connected to the calculation of averages. Particularly, when the LOD is close to the emission limit value, the handling of these values has a significant importance. There are only a few written rules in the field, and as a consequence the handling varies between and even within different sectors.

There are principally five different possibilities for handling values below the detection limit:

1. The measured value is used in the calculations, even if it is unreliable. This possibility is only available for certain measuring methods.
2. The limit of detection is used in the calculations. In this case the resulting mean value is normally stated as <(less than). This approach tends to overestimate the result.
3. Half of the detection limit is applied in the calculations (or, possibly, another predefined fraction). This approach may over or underestimate the result.
4. The following estimation:

Estimation = (100 %-A)*LOD,
where A = percentage of samples below the LOD

Therefore if, for instance, 6 samples out of 20 are below the LOD the value that would be used for the calculations would be (100 - 30) * LOD, which is 70 % of the LOD.

5. Zero is used in the calculations. This approach tends to underestimate the result.

Sometimes the value is reported to be between two values. The first value is obtained by using zero for all measurements below the LOD, and the second by using the LOD for all measurements below the LOD.

It is good practice to always report the approach taken together with the results.

It is useful if the permit clearly states the appropriate arrangements to deal with these values under the limit of detection. Where possible, the choice should be consistent with that applied throughout the sector or within the own country so that fair comparisons of the data are possible.

Examples are available in Annex 4 that show the difference in results when using different approaches.

3.4 Outliers

[Mon/tm/66]

An outlier can be defined as a result deviating significantly from the others in a measurement series (typically a series of monitoring data), and which cannot be directly assigned to the operation of a facility or process. Outliers are generally identified by expert judgement on the basis of a statistical test (such as the Dixon tests) together with other considerations, such as an abnormal emission pattern in the particular facility.

The only difference between an outlier and an exceptional emission is whether a reason has been identified in the operating conditions of the plant. A close analysis of these operating conditions is always an important condition for the identification of an outlier.

Other actions for identifying potential outliers may include:

- checking all concentrations against preceding and following observations and permits
- checking all observations exceeding a defined level based on statistical analysis
- checking extreme observations with production units
- checking past outliers in previous monitoring periods.

This checking is generally done by skilled staff, although automated procedures may also be in place. However, strong variations in observations need examination by a skilled database operator.

Errors in sampling or analysis performance are a common cause of deviating results when an operational cause of an outlier cannot be identified. In this case the performing laboratory can be notified with reference to a critical revision of their performance and monitoring data. If self-monitoring has been carried out with continuous reading instruments, the performance should be investigated.

If no cause can be identified, and a critical examination of the measurements does not lead to a correction of the results, the outlier may be left out from the calculation of average concentrations, etc. and should be indicated when reporting.

The basis for the identification of an outlier, as well as all actual data, should always be reported to the authority.

Further information on handling of outliers can be found in the ISO Standard - ISO 5725.

4 DATA PRODUCTION CHAIN

4.1 Comparability and reliability of data through the data production chain

[Mon/tm/62],[Mon/tm/39],[Mon/tm/64],[Mon/tm/78]

The practical value of the measurements and the monitoring data depends on two main features:

- their reliability, i.e. the degree of confidence that can be placed on the results
- their comparability, i.e. their validity to be compared to other results from other plants, sectors, regions or countries.

The actual production of reliable and comparable measurements and monitoring data requires following several consecutive steps, which form a data production chain. Each step needs to be performed according to either standards or method-specific instructions to ensure good quality results and harmonisation between different laboratories and measurers. These steps of the data production chain are explained in Section 4.2.

A good understanding of the process to be monitored is essential for obtaining results that are reliable and comparable. Given the complexity, cost, and subsequent decisions based on the monitoring data, an effort should be made to ensure that the data obtained are appropriately reliable and comparable.

Reliability of the data may be defined as the correctness, or the closeness, of the data to the true value, and should be appropriate for the intended use of the data. Certain applications need extremely accurate data, i.e. very close to the true value, however, in other situations, rough or estimated data may suffice.

To assure the quality of the whole data production chain, attention should be paid at every step to all quality aspects. Information about the uncertainty associated with the data, the accuracy of the systems, the errors, the validation of the data, etc. should be available together with the data.

The sampling stage is very important, and should ensure that measurands subjected to analysis are fully representative of the substance of interest. It is thought that the largest part of the uncertainty of a measurement is due to this stage.

Situations where the reliability is poor and the results are far from the true value can mislead important decisions, such as penalties, fines, prosecutions or legal actions. Therefore it is important that the results have the appropriate level of reliability.

Comparability is a measure of the confidence with which one data set can be compared to another. When the results are to be compared with other results from different plants and/or different sectors, they need to have been obtained in a way that enables them to be compared so as to avoid wrong decisions.

Data that have been derived under different conditions should not be directly compared and a more differentiated consideration may be necessary. The following measures can be taken to ensure the comparability of the data:

- use of standard written sampling and analysis procedures, preferably European CEN standards when available
- use of standard handling and shipping procedures for all collected samples
- use of skilled personnel throughout the programme
- use of consistent units when reporting the results.

The availability of relevant information concerning the production of the monitoring data is important in order to allow a fair comparison of the data. For that reason it should be assured that the following information, when relevant, is indicated together with the data:

- method of measurement, including sampling
- uncertainty
- traceability to the specified reference for secondary methods or surrogates
- averaging time
- frequency
- calculation of the average
- units (e.g. mg/m³)
- source that has been measured
- prevailing process conditions during the acquisition of the data
- auxiliary measures.

For better comparability of data in the long term, emission monitoring should be harmonised across European Member States. However, in practice at present, emission data from various sources, either at national or international level, are often difficult to compare, since there are differences in the way the data is obtained and even how they are processed and turned into reported data results. In addition, the reporting form, auxiliary measures and averaging times are often too different to provide a good basis for a proper comparison.

4.2 Steps in the data production chain

[Mon/tm/39],[Mon/tm/78]

Generally, for the majority of situations the production of data can be broken down into seven consecutive steps. Some general aspects of each step are described below in Sections 4.2.1 – 4.2.7. However, note that some determinations may need only some of the steps.

Since the results are as inaccurate as the most inaccurate step of the chain, knowledge of the uncertainty of each step of the data production chain leads to a knowledge of the uncertainty of the whole production chain. This also means that care must be taken with every step of the chain as it is worthless having an extremely accurate analysis of the sample if the sample itself is not representative of what is to be monitored or if it was badly preserved.

In order to improve the comparability and reliability of the monitoring data, all the information from one step that could be relevant for the other steps (e.g. information on the timing considerations, sampling arrangements, handling, etc.) should be clearly indicated when passing the sample to the following steps.

Some specific factors affecting the data production chain in air, waste water and waste are presented in Section 4.3.

4.2.1 Flow/amount measurement

The accuracy of the flow measurement has a major impact on the total load emission results. The determination of concentrations in a sample can be very accurate, however accuracy of the determination of the flow at the time of sampling may vary widely. Small fluctuations in flow measurements can potentially lead to large differences in load calculations.

In some situations flow can, more easily and accurately, be calculated instead of measured.

Better accuracy and repeatability for the flow measurements could be achieved by including in the detailed report of the monitoring programme a description of how the measurements, checking, calibration and maintenance are to be carried out.

4.2.2 Sampling

Sampling is a complex operation consisting of two main steps: establishment of a sampling plan and taking of the sample. The latter may influence (e.g. by lack of cleanliness) the analytical results. Both steps strongly affect the measurement results and the conclusions derived from them. It is therefore necessary that sampling is representative and properly performed; this means that both sampling steps are carried out according to relevant standards or agreed procedures. Generally, sampling should comply with two requirements:

1. The sample must be representative in time and space. This means that when monitoring the releases from an industry, the sample taken to the laboratory should represent all that it is discharged during the period of interest, for example, a working day (time representativeness).

Equally, when monitoring a substance, the sample should represent the whole amount being released from the plant (space representativeness). If the material is homogeneous, sampling at a single point may be enough, however for heterogeneous materials several samples from different points may be required in order to have a spatially representative sample.

2. The sampling should be carried out with no change in the composition of the sample, or to an intended and more stable form. In fact, there are parameters in a sample that should be determined, or somehow preserved, in situ as their value may change with time, for example the pH and the oxygen content of a waste water sample.

Generally samples are labelled and identified with a sample code number. This should be a unique sample identification number assigned from a sequentially numbered register. Further information necessary for defining the sampling plan and further interpretation of the results should consider the following items (which may be indicated in a label attached to the sample):

- the location at which the samples are taken. The location should be such that the material is well mixed and sufficiently far away from the mixing points to be representative of the overall emission. It is important to select a sampling point that is practical to reach and where the flow can also be measured or is known. The samples should always be taken from the same defined locations. Appropriate safeguards should be considered with regard to the sampling point (e.g. good access, clear procedures and instructions, work permits, sampling loops, interlocks, use of protective equipment) in order to ensure that any risk for sampling personnel and the environment are minimised
- the frequency at which the samples are taken and other timing considerations, such as the averaging time and the duration of sampling. The frequency is usually decided on a risk basis, taking into account the variability of the flow, its composition, and the magnitude of the variability with respect to unacceptable limit values. See Section 2.3 for further information on monitoring timing considerations
- the sampling method and/or equipment
- the type of sampling, e.g. automatic (time or flow proportional), manual spot, etc.
- the size of individual samples and bulking arrangements to provide composite samples
- the type of sample, e.g. a sample for a single or multiple parameters analysis
- the personnel in charge of taking the samples; they should have appropriate skills.

To improve reliability and traceability of the sampling, a number of parameters may be included on the label with the sample code number, for example:

- date and time of sampling
- sample preservation details (if applicable)
- process relevant details
- references to measurements made at the time when the sample was taken.

Most of these details are already considered in standards or norms.

4.2.3 Sample storage, transport and preservation

In order to preserve the parameters that are to be measured during any storage and transporting of the sample, a time-proof pretreatment will generally be needed. Any pretreatment of the sample should be carried out according to the measurement programme.

For waste water, this pretreatment generally consists of keeping the sample in the darkness, at a suitable temperature, typically 4 °C, adding certain chemicals to fix the composition of the parameters of interest, and not exceeding a maximum time before analysis.

Any arrangement for chemically preserving, storing and transporting the samples should be clearly documented, and indicated, when possible, on the sample label.

4.2.4 Sample treatment

Before analysing the laboratory sample, some specific treatment may be needed. This treatment strongly depends on the analysis method being used and the component being analysed. Any treatment of the sample should be carried out according to the analysis programme.

Some of the reasons for the application of a specific sample treatment are given below:

- concentration of the sample may be carried out when the level of the compound of interest is too low to be detected by the analysis method
- elimination of impurities that have been added to the sample during the sampling procedure. For example a non-metallic sample may become contaminated with metal components from the extraction tools, or a metallic sample may be contaminated by oils from the extraction equipment
- elimination of water, both humidity and chemically combined. In this respect it is very important to indicate if the resulting data refer to dry or wet basis
- homogenisation: When analysing waste water, the sample must be totally homogenous, since analysis of a non-sedimented waste water sample gives totally different results from the results of a sedimented sample. Composite samples should also be well mixed when taking a sample for the analysis
- dilution of samples is occasionally carried out to improve the performance of the analytical method
- elimination of interferences are often necessary, as there may be compounds present that can increase or decrease the reading of the determinant of interest.

Any specific treatments applied to the samples should be clearly documented when reporting, and indicated, when possible, on the sample label.

4.2.5 Sample analysis

There are many analysis methods that are available for many determinations. The complexity of the methods may range from those requiring only basic laboratory apparatus or analytical instruments commonly found in laboratories, to methods requiring advanced analytical instruments.

There will normally be several analytical methods available to determine a parameter. Selection of the appropriate method is always made in accordance with the specific needs of the sampling (i.e. the specified performance criteria) and depends on a number of factors, including the suitability, availability and the cost.

As different methods can give variable results from the same sample it is important to indicate with the results the method used. In addition, the accuracy of the methods and matters affecting the results, such as interferences, should be known and indicated together with the results.

When an external laboratory is used for the analysis of the samples, it is very important that the selection of the sampling and analytical methods are carried out in close co-operation with the external laboratory. This ensures that all relevant aspects such as method specificity and other limitations are considered before the sampling is performed.

Close co-operation between the personnel responsible for sampling and the personnel responsible for laboratory analysis is very important. When the samples are transferred to the

laboratory, sufficient information to perform a correct analysis is needed (i.e. expected parameters and concentration, possible interferences, specific needs, etc.). When the results are transferred from the laboratory, it is very important that sufficient information to handle the results in a proper way is available together with the results (i.e. analytical uncertainties limitations, etc.).

4.2.6 Data processing

Once measurements' results are produced, the data generated need to be processed and evaluated. All data handling and reporting procedures should be determined and agreed by the operators and authorities before the testing begins.

Part of the data processing involves the validation of emission data. This is usually done by skilled personnel in the laboratory, who check that all the procedures have been properly followed.

Validation may include the use of a thorough knowledge of monitoring methods and national and international (CEN, ISO) standardisation procedures, and may also involve quality guarantees for certification methods and procedures. An effective system of controls and supervision, in which calibration of equipment and intra- and inter-laboratory checks are involved, may also be a standard requirement in the validation process.

A considerable amount of data may be generated when carrying out monitoring, particularly when continuous monitors are applied. **Data reduction** is often necessary in order to produce the information in a format suitable for reporting. Data handling systems, mostly electronic devices, are available which can be configured to provide information in a variety of forms and which take a variety of inputs.

Statistical reductions may include calculations from the data of means, maxima, minima and standard deviations over appropriate intervals. When data are from continuous monitoring, they can be reduced to 10-second, 3-minute, hourly, or other relevant intervals, as means, maxima and minima, standard deviations or variances.

Data loggers, chart recorders, or both, are used to record continuous data. Sometimes an integrator is used to average the data as it is collected and the time-weighted average (e.g. hourly) is recorded. Minimum data requirements may include taking a value every minute by recording the measured value or updating the rolling average (e.g. a one-minute rolling hourly average). The recording system can also be capable of storing other values that may be of interest, such as the minima and maxima.

4.2.7 Reporting

From the large amount of data generated when a parameter is monitored, a summary of the results over a certain period of time is usually generated and presented to the relevant stakeholders (authorities, operators, public, etc.). Standardisation of reporting formats facilitates the electronic transfer and subsequent use of data and reports.

Depending on the medium and the monitoring method, the report may include averages (e.g. hourly, calendar day, monthly or annual averages), peaks or values at a specific time or at times when the ELVs are exceeded.

Due to the importance of this step, information on reporting is given in further detail in Chapter 7. However, it should be borne in mind that reporting is not a separate chapter matter but an essential and irremovable step of the Data Production Chain.

4.3 The data production chain for different media

The next sections discuss, for air emissions, waste water and wastes, some relevant issues such as volume measurements, sampling issues, data handling and processing, etc.

4.3.1 Air emissions

[Mon/tm/53],[Mon/tm/02],[Mon/tm/78]

ELVs for air are generally laid down as a mass concentration (e.g. mg/m³) or, together with the volumetric flow emitted, as a mass flow (e.g. kg/h), although specific emission limits are also sometimes used (e.g. kg/t of product). The mass concentration of an emission is the concentration of the measured component averaged, if necessary, over the cross-section of the waste gas channel of the emission source over a defined averaging time.

For spot-checking or for compliance verification by external parties, for facilities with operating conditions that primarily remain constant with time, a number of individual measurements (e.g. three) are made during undisturbed continuous operation at periods of representative level of emissions. In facilities whose operating conditions vary with time, measurements are made in sufficient number (e.g. a minimum of six) at periods of representative level of emissions.

The duration of individual measurements depends on several factors, e.g. on gathering enough material to be able to give it a weighting, whether it is a batch process, etc. The results of individual measurements are assessed and indicated as mean values. Usually it is necessary to determine a minimum number of individual values (e.g. 3 half-hour values) to calculate a daily mean.

The sampling of particles in a flowing exhaust gas must take place isokinetically (i.e. at the same velocity as that of the gas) to prevent segregation or disturbance of the particle-size distribution due to inertia of the particles, which can lead to a false analysis of the measured solids content. If the sampling rate is too high, the measured dust content will be too low, and vice versa. This mechanism depends on the particle size distribution. For particles of aerodynamic diameter <5 - 10 µm, the effect of this inertia is practically negligible. Applicable standards require isokinetic particle sampling.

Continuous monitoring is a legal requirement in several Member States for processes whose emissions exceed a certain threshold value. Parallel continuous determination of operational parameters, e.g. waste gas temperature, waste gas volume flow, moisture content, pressure, or oxygen content, allows the evaluation and assessment of continuous measurements. The continuous measurement of these parameters may sometimes be waived if these, from experience, show only slight deviations which are negligible for emission assessment or if they can be determined by other methods with sufficient certainty.

Conversion to reference standard conditions

Monitoring data for air emissions are typically presented in terms of either actual flow or a 'normalised' flow.

Actual conditions, which refer to actual temperature and pressure at the source, are ambiguous and should be avoided in permits.

Normalised data are standardised to a particular temperature and pressure, typically 0 °C and 1 atm respectively, although sometimes they may be referenced to 25 °C and 1 atm.

The following conditions may be used when presenting data:

- m³ - actual cubic metre (at actual temperature and pressure)
- Nm³ - normal cubic metre (typically at 0 °C and 1 atm). Note that this notation is widely used although quite incorrect
- scm - standard cubic metre (typically at 25 °C and 1 atm, although sometimes it may be at 20 °C). This unit is mainly used in USA.

It is essential to ascertain under what conditions the source test data are presented before determining annual emission estimates.

Two examples of the use of sampling data to characterise annual emissions are presented in Annex 4.

Conversion to Reference Oxygen Concentration

In combustion processes, the emission data are generally expressed at a given percentage of oxygen. The oxygen content is an important reference value from which the measured concentrations can be calculated according to the equation:

$$E_B = \frac{21 - O_B}{21 - O_M} * E_M$$

Where:

E_B = emission expressed at reference oxygen content

E_M = measured emission

O_B = reference oxygen content (expressed in percentage)

O_M = measured oxygen content (expressed in percentage)

Calculation of means

Daily means are generally calculated on the basis of half-hourly means. For example, the new Dutch regulations (NeR, [Mon/tm/74]) uses the average of three half hour means.

4.3.2 Waste water

Sampling methods for waste water [Mon/tm/56]

There are basically two sampling methods for waste water:

- (a) composite sampling, and
- (b) spot sampling.

- (a) Composite sampling. There are two types of composite samples: flow-proportional and time-proportional. For the flow-proportional sample, a fixed amount of sample is taken for each pre-defined volume (e.g. every 10 m³). For time-proportional samples, a fixed amount of sample is taken for each time unit (e.g. every 5 minutes). Because of the desired representativity, flow-proportional samples are generally preferred.

The analysis of a composite sample gives an average value of the parameter during the period over which the sample has been collected. It is normal to collect composite samples over 24 hours to give a daily mean value. Shorter times are also used, for example 2 hours, or half an hour. Composite sampling is usually automatic; instruments automatically withdraw a portion of sample at the appropriate volume discharged or time.

Duplicates of composite samples can be kept frozen, and then mixed together to calculate the weekly, monthly or annual mean concentration, although this may cause a change of the composition and lead to the storage of large amounts.

For annual load calculations, composite samples are generally preferred.

(b) *Spot sampling*. These are taken at random moments and are not related to the volume discharged. Spot samples are used, for example, in the following situations:

- if the composition of the waste water is constant
- when a daily sample is not suitable (for example, when the water contains mineral oil or volatile substances, or when, due to decomposition, evaporation or coagulation, lower percentages were measured in daily samples than are actually discharged)
- to check the quality of the discharged waste water at a particular moment, normally to assess compliance with the discharge conditions
- for inspection purposes
- when separate phases are present (for example an oil layer floating on water).

If there are enough composite samples, they can be used to determine a representative annual load. Spot samples can then be used to support and/or verify the results. If not enough composite samples have been determined, the results of the spot samples can be included.

In principle, separate annual loads are calculated for both the composite samples and the spot samples. Only then are the annual loads compared with each other and, if necessary, corrected.

Calculation of average concentrations and loads for waste water

[Mon/tm/56]

The annual average concentration may be determined as follows:

$$C = \Sigma (C_{\text{sample}} \text{ or } C_{\text{day}}) / \text{number of samples}$$

Where:

C_{sample} = measured concentration over a period shorter than 24 hours (usually a spot sample)

C_{day} = measured day concentration in a 24-hour composite sample.

Depending on the available information the load may be calculated in different ways:

- the concentrations measured per day are multiplied by the discharged amount of waste water over the same day period. The average of the daily loads is determined and multiplied by the number of discharge days in the relevant year, i.e.:

Step 1: daily load = concentration x daily flow

Step 2: annual load = average daily load x number of discharge days

- if there are no daily measurements or discharges, a particular day or number of days can be defined as being representative for a particular period. This would be the case, for example, for seasonal companies that discharge the most during a short period in the year (e.g. the harvest period).

This method can be applied for daily loads, but also where relevant for daily concentrations and/or daily flows, i.e.

Step 1: daily load = representative daily concentration x representative daily flow

Step 2: annual load = sum of the daily loads (where relevant, sum of weekly loads)

- the concentration may be averaged out over all the measurements in the relevant year and multiplied by the annual flow, which can be determined as the average of a number of daily flow measurements, or can be determined in another way (for example, with pump capacity and operational hours or in accordance with the licence)
- when the discharge is largely fluctuating then the actual annual flow multiplied by the annual average concentration should be used
- in some cases, a company or the authority can also determine a reliable annual load by means of a calculation. This might be used for substances added in known amounts but for which analysis is not possible or is disproportionately expensive
- for relatively small discharges by particular sectors, the load of oxygen-bonding substances (e.g. BOD, COD, TKN, ...) and metals (often the basis for the charge) is determined using coefficients based on production figures or on the discharged/consumed amount of water.

4.3.3 Wastes

For the waste received at or produced by the permitted installation, the operators should record, and retain the following records for an appropriate period:

- a) its composition
- b) the best estimate of the quantity produced
- c) its disposal routes
- d) a best estimate of the amount sent to recovery
- e) registration/licenses for carriers and waste disposal sites.

5 DIFFERENT APPROACHES TO MONITORING

[Mon/tm/15] [Mon/tm/64]

There are several approaches to monitoring a parameter. These include:

- direct measurements
- surrogate parameters
- mass balances
- calculations
- emission factors.

However, some of these possibilities may not be available for the parameter of interest. The choice depends on several factors, including the likelihood of exceeding the ELV, the consequences of exceeding the ELV (as explained in Section 2.3), the required accuracy, costs, simplicity, rapidity, reliability, etc., and should also be suited to the form in which the components may be emitted.

In principle, it is more straightforward, but not necessarily more accurate, to use direct measurements (specific quantitative determination of the emitted compounds at the source). However, in cases where this method is complex, costly and/or impractical other methods should be assessed to find the best option. For instance, in those cases in which the use of surrogate parameters provides an equally good description of the actual emission as a direct emission measurement, these methods may be preferred for their simplicity and economy. In each situation the necessity for, and the added value of, direct measurements should be weighed against the possibility of simpler verification using surrogate parameters.

Whenever direct measurements are not used, the relationship between the method used and the parameter of interest should be demonstrated and well documented.

National and international regulations often impose requirements on the approach that can be used for a particular application, e.g. EC Directive 94/67/EC on the incineration of hazardous waste requires the use of relevant CEN standard methods. The choice may also be indicated or recommended in published technical guidance, e.g. the Reference Documents on Best Available Techniques.

The monitoring approach to be adopted in a compliance monitoring programme may be chosen, proposed or specified for use by:

- the competent authority - the usual procedure
- the operators –usually a proposal which still needs approval by the authority
- an expert –usually an independent consultant who may propose on behalf of the operators; this proposal still needs approval by the authority.

When deciding whether to approve the use of an approach in a relevant regulatory situation the competent authority is generally responsible for deciding whether the method is acceptable, based on the following considerations:

- fitness for purpose, i.e. is the method suited to the original reason for monitoring as shown, for example, by the limits and performance criteria for an installation?
- legal requirements, i.e. is the method in line with EU or national law?
- facilities and expertise, i.e. are the facilities and expertise available for monitoring adequate for the proposed method, e.g. technical equipment, staff experience?

The use of surrogate parameters, mass balances and emission factors transfer the burden of uncertainty and traceability (to the specified reference) to the measurement of several other parameters and to the validation of a model. This model could be a simple linear relationship, similar to that used with mass balances or emission factors.

5.1 Direct measurements

[Mon/rm/02], [Mon/tm/15], [Mon/tm/14], [Mon/tm/64]

Monitoring techniques for direct measurements (specific quantitative determination of the emitted compounds at the source) vary with the applications and can be divided mainly into two types:

- (a) continuous monitoring
 - (b) discontinuous monitoring.
- (a) Two types of continuous monitoring techniques can be considered:
- fixed in-situ (or in-line) continuous reading instruments. Here the measuring cell is placed in the duct, pipe or stream itself. These instruments do not need to withdraw any sample to analyse it and are usually based on optical properties. Regular maintenance and calibration of these instruments is essential
 - fixed on-line (or extractive) continuous reading instruments. This type of instrumentation continuously extracts samples of the emission along a sampling line, transport them to an on-line measurement station, where the samples are analysed continuously. The measurement station may be remote from the duct, and therefore care must be taken so that the sample integrity is maintained along the line. This type of equipment often requires certain pretreatment of the sample.
- (b) The following types of discontinuous monitoring techniques can be considered:
- instruments used for periodic campaigns. These instruments are portable and are carried to and set up at the measurement location. Normally a probe is introduced at an appropriate measurement port to sample the stream and analyse it in situ. They are appropriate for checking and also for calibration. Further information regarding campaign monitoring is given later in this section
 - laboratory analysis of samples taken by fixed, in-situ, on-line samplers. These samplers withdraw the sample continuously and collect it in a container. From this container a portion is then analysed, giving a mean concentration over the total volume accumulated in the container. The amount of sample withdrawn can be proportional to time or to flow
 - laboratory analysis of spot samples. A spot sample is an instantaneous sample taken from the sampling point, the quantity of sample taken must be enough to provide a detectable amount of the emission parameter. The sample is then analysed in the laboratory providing a spot result, which is representative only of the time at which the sample was taken.

Continuous monitoring techniques have the advantage over discontinuous measurement techniques that they provide a greater number of data points. They therefore provide data that is statistically more reliable and can highlight periods of adverse operating conditions for both control and evaluation purposes.

Continuous monitoring techniques may also have some drawbacks:

- costs
- they may not be of much use for very stable processes
- the accuracy of on-line process analysers may be lower than discontinuous laboratory analyses
- retrofitting an existing continuous monitoring may be difficult or even unpractical.

When considering the use of continuous monitoring in a particular case it is good practice to take into account the following issues, although this list may not be exhaustive:

- continuous monitoring may be a legal requirement for the sector
- continuous monitoring may be given as part of a BAT technique for the sector
- the required level of uncertainty
- local issues may prompt the use of continuous monitoring (e.g. is this plant the source of higher emission levels? Is it heavily contributing to reduced local air quality?)
- public confidence tends to be higher when using continuous monitoring
- sometimes continuous monitoring is the most economical option (e.g. if continuous monitoring is needed for process control)
- extent of the environmental risk associated to the emission
- likelihood of periodic upsets
- ability to control or mitigate excessive emission
- availability of continuous measurement equipment
- the requirements for the determination of total loads
- applicability of IPPC Directive Article 10 (monitoring for air quality assessment) may be a criterion for continuous monitoring
- reliability of continuous measurement equipment
- the requirements for emission trading
- availability of a system to promptly act according to the continuous data.

Direct measurements should be carried out in accordance with the standards indicated for discontinuous or continuous measurements since ELVs and associated compliance assessment arrangements are normally based on the standard method.

In respect of those components for which no standardised measurement methods yet exist for the determination of emissions, measurements can be carried out where possible in accordance with draft standards and guidelines in practice or in accordance with the generally accepted measurement practice.

If the continuous measurement of the emission of a specific substance is considered necessary, but continuous measurement techniques suitable for the purpose are not available or cannot be used for technical reasons, then continuous monitoring for the substance class or category should be considered.

A special type of monitoring is campaign monitoring, which is made in response to a need or an interest in obtaining more fundamental information than that available from routine, day-by-day monitoring. Campaign monitoring usually involves relatively detailed and sometimes extensive and expensive measurements which are not usually justified on a regular basis.

Some situations in which campaign monitoring might be carried out are when:

- a new measurement technique is to be introduced and needs to be validated
- a fluctuating parameter is to be investigated in order to identify the root causes of the fluctuation or to assess opportunities to reduce the range of the fluctuations
- a surrogate parameter is to be defined and correlated with process parameters or other emission values
- the actual compounds/substances in an emission are to be determined or evaluated
- the ecological impact of an emission is to be determined or assessed by eco-toxicological analytical analyses
- volatile organic compounds are to be determined for odour
- uncertainties are to be evaluated
- more conventional measurements are to be verified
- a new process is to be started without previous experience about emission patterns
- a preliminary study is necessary to design or improve a treatment scheme
- a cause-effect relationship is to be investigated.

5.2 Surrogate parameters

[Mon/tm/64], [Mon/tm/71]

Surrogate parameters are measurable or calculable quantities which can be closely related, directly or indirectly, to conventional direct measurements of pollutants, and which may therefore be monitored and used instead of the direct pollutant values for some practical purposes. The use of surrogates, used either individually or in combination with other surrogates, may provide a sufficiently reliable picture of the nature and proportions of the emission.

The surrogate is normally an easily and reliably measured or calculated parameter that indicates various aspects of operation such as throughput, energy production, temperatures, residue volumes or continuous gas concentration data. The surrogate may provide an indication of whether the ELV can be satisfied if the surrogate parameter is maintained within a certain range.

Whenever a surrogate parameter is proposed to determine the value of another parameter of interest, the relationship between the surrogate and the parameter of interest must be demonstrated, clearly identified and documented. In addition, traceability of the parameter's evaluation on the basis of the surrogate is needed.

A surrogate is only likely to be useful for compliance monitoring purposes if:

- it is closely and consistently related to a required direct value (several examples are shown below)
- it is more economical or easier to monitor than a direct value, or if it can provide more frequent information
- it is capable of being related to specified limits
- the process conditions when surrogates are available match the conditions when direct measurements are required
- the permit allows use of a surrogate for monitoring and prescribes the type/form of the surrogate
- it is approved for use (e.g. in permit or by competent authority). This implies that any extra uncertainty due to the surrogate must be insignificant for regulatory decisions
- it is properly described, including periodic evaluation and follow-up.

Key advantages of the use of surrogates may include:

- cost savings thus greater cost effectiveness
- more continuous information can be possible than with direct measurements
- more discharge points can be monitored for the same or less resource
- sometimes more accurate than direct values
- give an early warning of possible upset conditions or abnormal emissions, e.g. combustion temperature changes warn of a possible increase in dioxin emissions
- less disruption to the process operation than direct measurements
- information from several direct measurements may be combined, thereby giving a more complete and useful picture of process performance e.g. a measurement of temperature may be useful for energy efficiency, pollutant emissions, process control and feedstock blending
- recovery of corrupted monitoring data.

Key disadvantages of the use of surrogates may include:

- resources needed for calibration against direct measurements
- may provide a relative measurement only rather than an absolute value
- may only be valid for a restricted range of process conditions
- may not command as much public confidence as direct measurements
- sometimes less accurate than direct measurements.
- sometimes may not be used for legal purposes.

Some national regulations include provisions for the use of surrogate parameters. For example, when polluting substances in waste gas are in a constant relation to each other then continuous measurement of the leading component can be used as a surrogate for the rest of the pollutant substances.

Similarly continuous emission measurements of a compound may be waived if the attainment of emission standards can be sufficiently proven by applying other tests as surrogates, e.g. the continuous measurement of efficiency of the emission control facilities, composition of fuels or raw materials, or processing conditions.

There are a series of practices that support good use of surrogate parameters, these include:

- a well operated maintenance system
- an environmental management system
- a good history of measurements
- limitation of production or load.

Different categories of surrogate parameters

Three categories of surrogates may be distinguished on the basis of the strength of the relationship between the emission and surrogate, these are listed below and some examples are also provided. Combinations of surrogates may result in a stronger relationship and a stronger surrogate.

- (a) quantitative surrogates
- (b) qualitative surrogates
- (c) indicative surrogates.

(a) Quantitative surrogates - these give a reliable quantitative picture of the emission and can substitute for direct measurements. Examples of their use may include:

- the assessment of the total VOC instead of the individual components when the composition of the gas flow is constant
- calculation of the waste gas concentration from the composition and throughput of fuel, raw materials and additives and from the flow rates
- continuous dust measurements as a good indication for heavy metal emissions
- the assessment of the total TOC/COD (total organic content/chemical oxygen demand) instead of the individual organic components
- the assessment of the total AOX (active carbon adsorbable halogens) instead of the individual halogen organic components.

(b) Qualitative surrogates - these give reliable qualitative information of the composition of the emission. Examples may include:

- the temperature of the combustion chamber of a thermal incinerator and the residence time (or flow rate)
- the temperature of the catalyst in a catalytic incinerator
- the measurement of CO or total VOC of the flue gas from an incinerator
- the temperature of the gas from a cooling unit
- the conductivity instead of the measurement of individual metal components in precipitation and sedimentation processes
- the turbidity instead of the measurement of individual metal components or suspended/unsuspended solids in precipitation, sedimentation and flotation processes.

- (c) Indicative surrogates – these give information about the operation of an installation or process and therefore give an indicative impression of the emission. Examples may include:
- temperature of the gas flow from a condenser
 - pressure drop, flow rate, pH and humidity of a compost filtration unit
 - pressure drop and visual inspection of a fabric filter
 - pH in precipitation and sedimentation processes.

Examples of installations using surrogates as monitors

The following paragraphs give a series of examples of installations that use different surrogates and give an indication of the surrogate type:

Furnaces

1. Calculation of the content of SO₂ (quantitative).

Thermal Incinerators

1. Temperature of the combustion chamber (qualitative).
2. Residence time (or flow rate) (Indicative).

Catalytic incinerators

1. Residence time (or flow rate) (Indicative).
2. Temperature of the catalyst (Indicative).

Electrostatic Precipitators

1. Flow rate (Indicative).
2. Voltage (Indicative).
3. Dust removal (Indicative).

Wet Dust Separators

1. Air flow (Indicative).
2. Pressure in the pipe system for washing liquid (Indicative).
3. Functioning of the pump/flow washing liquid (Indicative).
4. Temperature of the treated gas (Indicative).
5. Pressure drop over the scrubber (Indicative).
6. Visual inspection of the treated gas (Indicative).

Precipitation and sedimentation reactors

1. pH (Indicative).
2. Conductivity (qualitative).
3. Turbidity (qualitative).

Anaerobic/aerobic biological treatment

1. TOC/COD/BOD (quantitative).

Toxicity parameters – a special group of surrogate parameters

During the last few years biological test methods/systems have raised more and more interest. Fish/fish egg test, daphnia test, algae test and luminescent bacteria test are all common test methods for the toxicity assessment of complex waste water streams. They are often used to obtain additional information to the information that can be gained from sum parameter measurements (COD, BOD, AOX, EOX...).

With toxicity tests it is possible to assess the possible hazardous character of waste water in an integrated manner and to assess all synergistic effects which may occur because of the presence of a lot of different single pollutants. Apart from the possibility of using the toxicity tests to estimate potential hazardous effects on the ecosystem/surface water these tests can help to protect or to optimise biological waste water treatment plants.

Toxicity tests, when used in combination with direct measurements of specific substances and with the measurements of sum parameters, are increasingly becoming a set part of any Whole Effluent Assessment strategy (WEA).

5.3 Mass balances

[Mon/tm/53]

Mass balances can be used for an estimation of the emissions to the environment from a site, process, or piece of equipment. The procedure normally accounts for inputs, accumulations, outputs and generation or destruction of the substance of interest, and the difference is accounted for as a release to the environment. They are particularly useful when the input and output streams can be readily characterised, as is often the case for small processes and operations.

For example, in combustion processes the emissions of SO₂ are directly related to the amount of sulphur in the fuel and in some cases it might be simpler to monitor the sulphur in the fuel instead of the emission of SO₂.

When part of the input is transformed (e.g. the feedstock in a chemical process) the mass balance method is difficult to apply, in these cases a balance by chemical elements is needed instead.

The following simple equation can be applied when estimating emissions by a mass balance:

$\text{Total mass into process} = \text{accumulations} + \text{total mass out of process} + \text{uncertainties}$

Applying this equation to the context of a site, process or a piece of equipment, this equation could be rewritten as:

$\text{Inputs} = \text{products} + \text{transfers} + \text{accumulations} + \text{emissions} + \text{uncertainties}$

Where:

Inputs =	All incoming material used in the process
Products =	Products and materials (eg. by-products) exported from the facility
Transfers =	Include substances discharged to sewer, substances deposited into landfill and substances removed from a facility for destruction, treatment, recycling, reprocessing, recovery or purification
Accumulations =	Material accumulated in the process
Emissions =	Releases to air, water and land. Emissions include both routine and accidental releases as well as spills.

Care must be taken when using mass balances, since although they seem a straightforward method of emission estimation, they usually represent a small difference between a large input and a large output number, with the uncertainties involved. Therefore, mass balances are only applicable in practice when accurate input, output and uncertainties quantities can be determined. Inaccuracies associated with individual material tracking, or other activities inherent in each material handling stage, can result in large deviations for total facility emissions. A slight error in any one step of the operation can significantly affect emission estimates.

For example, small errors in data or calculation parameters including those used to calculate the mass elements for the mass balance equation (e.g. pressure, temperature, steam concentration, flow, and control efficiency) can result in potentially large errors in the final estimates.

In addition, when sampling of input and/or output materials is conducted, the failure to use representative samples will also contribute to the uncertainty. In some cases, the combined uncertainty is quantifiable, if so this is useful in determining whether the values are suitable for their intended use.

Overall Facility mass balance

Mass balances can be used to estimate emissions from a facility, providing that sufficient data are available pertaining to the process and relevant input and output streams. This involves the consideration of material inputs to the facility (i.e. purchases) and materials exported from the facility in products and wastes. The remainder is considered as a 'loss' (or a release to the environment).

As an example, applying the mass balance to an individual substance (substance 'i'), the equation may be written as:

Input of substance 'i' =	Amount of substance 'i' in product + amount of substance 'i' in waste + amount of substance 'i' transformed/consumed in process - amount of substance 'i' generated in process + accumulation of substance 'i' + emissions of substance 'i'
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The use of mass balances has the greatest potential when:

- emissions are the same order of magnitude as inputs or outputs
- the amounts of the substance (input, output, transfer, accumulation) can be readily quantified over a defined period of time.

A simple example of the application of a mass balance can be found in Annex 6.

5.4 Calculations

[Mon/tm/53]

Theoretical and complex equations, or models, can be used for estimating emissions from industrial processes. Estimations can be made by calculations based on physical/chemical properties of the substance (e.g. vapour pressure) and on mathematical relationships (e.g. ideal gas law).

The use of models and related calculations require available corresponding input data. They provide usually a reasonable estimate if the model is based on valid assumptions and demonstrated by previous validations, if the scope of the model is corresponding to the case studied and if input data are reliable and specific to the conditions of the facility

Fuel analysis is an example of an engineering calculation. It can be used to predict SO₂, metals and other emissions based on the application of conservation laws, if the fuel mass flow rate is available. For example, the basic equation used in fuel analysis emission calculations is the following:

$$E = Q \times C / 100 \times (MW/EW) \times T$$

Where:

- E = Annual load of the chemical species emitted (kg/yr)
- Q = Fuel mass flow rate (kg/h)
- C = Concentration of the elemental pollutant in fuel (wt%)
- MW = Molecular weight of the chemical species emitted (kg/kg-mole)
- EW = Elemental weight of the pollutant in fuel (kg/kg-mole)
- T = Operating hours (h/yr)

An example of the application of this estimation method can be found in Annex 6, where SO₂ emissions from fuel oil combustion are calculated based on the concentration of sulphur in the fuel oil.

5.5 Emission factors

[Mon/tm/53]

Emission factors are numbers that can be multiplied by an activity rate or by throughput data from a facility (such as the production output, water consumption, etc.) in order to estimate the emissions from the facility. They are applied under the assumption that all industrial units of the same product line have similar emission patterns. These factors are widely used for determination of charges at small installations.

Emission factors are generally derived through the testing of a general source population of items of process equipment (e.g. boilers using a particular fuel type). This information can be used to relate the quantity of material emitted to some general measure of the scale of activity (e.g. for boilers, emission factors are generally based on the quantity of fuel consumed or the heat output of the boiler). In the absence of other information, default emission factors (for example literature values) can be used to provide an estimate of the emissions.

Emission factors require 'activity data', which are combined with the emission factor to generate the emission estimates. The generic formula is:

$$\text{Emission Rate (mass per time)} = \text{Emission Factor (mass per unit of throughput)} \times \text{Activity Data (throughput per time)}$$

Appropriate conversion factors for units may need to be applied. For example, if the emission factor has units of '*kg pollutant/m³ of fuel burned*', then the activity data required would be in terms of '*m³ fuel burned/h*', thereby generating an emission estimate of '*kg pollutant/h*'.

Emission factors need reviewing and approving by authorities when used for emissions estimation.

Emission factors are obtained from European and American sources (e.g. EPA 42, CORINAIR, UNICE, OECD) and are usually expressed as the weight of a substance emitted divided by the unit weight, volume, distance, or duration of the activity emitting the substance (e.g. kilograms of sulphur dioxide emitted per tonne of fuel burned).

The main criterion affecting the selection of an emission factor is the degree of similarity between the equipment or process selected in applying the factor, and the equipment or process from which the factor was derived.

Some published emission factors have an associated emission factor rating (EFR) code, ranging from "A" to "E". An "A" or "B" rating indicates a greater degree of certainty than a "D" or "E" rating. The less certainty the more likely that a given emission factor is not representative of the source type.

Emission factors developed from measurements for a specific process may sometimes be used to estimate emissions at other sites. If a company has several processes of similar operation and size, and emissions are measured from one process source, an emission factor can be developed and applied to similar sources in this situation.

Some examples of their use as applied to waste water are found in the textiles and pulp and paper industries. In these industries measurements of some specific organic substances (e.g. complexing agents like EDTA, DPTA in bleaching processes, optical brighteners like stilbenos-derivatives used in fitting processes) are expensive and need special analytical equipment.

In these examples good estimates of the emission loads can be calculated from emission factors given in literature or from specific measurement programmes. Naturally the selection and use of these emission factors depends on the applied treatment technology.

6 COMPLIANCE ASSESSMENT

[Mon/tm/64]

Compliance assessment generally involves a statistical comparison between the following items, which are described further below:

- (a) the measurements, or a summary statistic estimated from the measurements
- (b) the uncertainty of the measurements
- (c) the relevant ELV or equivalent parameter.

Some assessments may not involve a statistical comparison, for example they may just involve a check on whether a condition is complied with.

The validity of regulatory decisions based on the interpretation of compliance results depends on the reliability of the information from all preceding stages in the quality chain. Before starting the interpretation, it is therefore good practice for the competent authority to review the earlier stages, and in particular to check that the organisation doing the monitoring has provided all relevant information and that it is of sufficient quality.

- (a) the measurements, or a summary statistic (e.g. a percentile, such as the 95-percentile of the measurements) estimated from the measurements - this must be based on the same conditions and units as the ELV, and is typically an absolute amount (e.g. mg/m³) or a summary statistic, such as the annual average
- (b) the uncertainty of the measurements - this is typically a statistical estimate (e.g. standard error) and may be expressed as a percentage of the measured value or as an absolute value. Section 2.6 briefly explains the uncertainties occurring in monitoring and their nature
- (c) the relevant ELV or equivalent parameter - this is typically a pollutant emission value (e.g. mass release rate or discharge concentration). It may also be a surrogate parameter value (e.g. opacity in place of particulate concentration), or an efficiency value (e.g. efficiency of the effluent treatment), other equivalent parameters, general binding rules, etc. Examples of different types of limit values or equivalent parameters can be found in Section 2.7.

Before assessing compliance, all three items may need conversion. For example, if the uncertainty in a measured value of 10 mg/m³ is given as 20 %, then this uncertainty is re-expressed as ± 2 mg/m³.

The measured value can now be compared with the ELV, taking into account the associated uncertainty. The result of this comparison can be assigned to one of three categories:

1. compliant
2. borderline or
3. non-compliant.

By way of example, consider the following scenario: An ELV of 10 mg/m³ has been set and measurements are made with an uncertainty of ± 2 mg/m³. In comparing the results there are three possible outcomes and these illustrate the three compliance zones:

1. **Compliant:** the measured value is less than the ELV, even when the value is increased by the uncertainty (e.g. if the measured value is 7, then even adding the uncertainty still results in a figure less than the ELV, i.e. $7+2=9$, which is still less than 10, the ELV).
2. **Borderline:** the measured value is between (ELV-uncertainty) and (ELV+uncertainty) (e.g. in this case when the measured value is between 8 (ELV-2) and 12 (ELV+2)).

3. **Non-compliant:** the measured value is more than the limit, even when the value is decreased by the uncertainty (e.g. if the measured value is 13, then even subtracting the uncertainty still results in a figure higher than the ELV, i.e. $13-2=11$, which is still more than 10, the ELV).

These zones are shown schematically in Figure 6.1. Measured values may lie below (i.e. compliant), near (i.e. borderline) or above the limit (i.e. non-compliant). The uncertainty range of the measurements defines the size of the borderline zone.

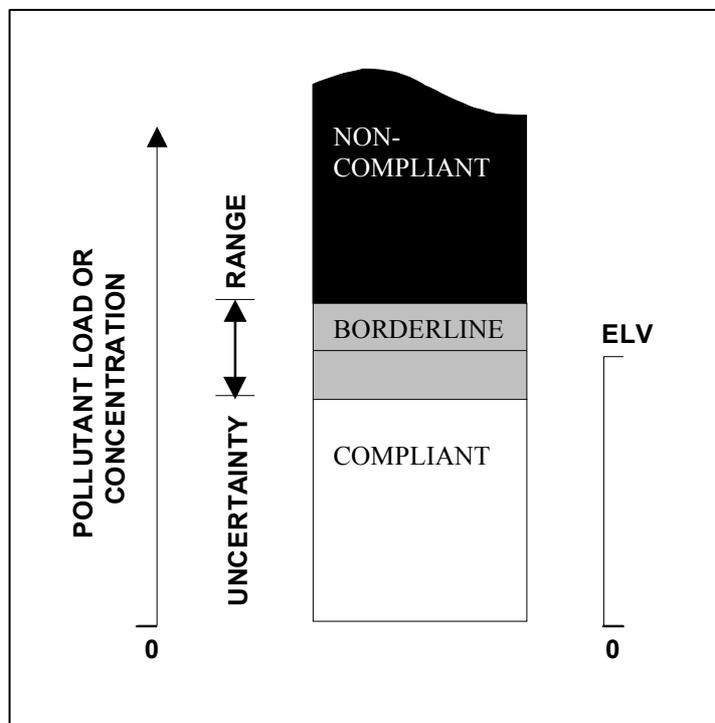


Figure 6.1: Schematic diagram of the three possible compliance assessment scenarios

An alternative approach is to take the uncertainty of the measurement into consideration when setting the ELV, i.e. by increasing the ELV with a certain "normal" uncertainty for the intended method. In this case, compliance with the ELV is achieved when the control value is lower or equal to the limit value.

The uncertainty in a measurement is summarised above using a range value (e.g. $\pm 2 \text{ mg/m}^3$). However, this value is actually a summary of a statistical distribution according to which there is a defined probability of the true measurement being within the range (e.g. 95 % if the range is two standard deviations). The way in which the range value is defined (e.g. number of standard deviations) can be varied to increase or decrease the stringency of the assessment procedure. Statistical approaches such as the Standard ISO 4259 can be used for this purpose.

The authorities may specify with the ELV, or the equivalent parameter, a performance criteria for the uncertainty, for example they may specify that the uncertainty cannot be more than 10 % of the ELV. Such a specification would prevent methods with large uncertainties gaining any benefit from the approach described above. Otherwise, theoretically if a laboratory/method had an uncertainty of 50 % of the ELV, it would be easier for the plant to comply with the ELV, compared to a method with a lower uncertainty. This could encourage a preference for poor performing laboratories/methods over good performing laboratories/methods.

For quality purposes, it is good practice to check that:

- information is interpreted within the context of the prevailing process conditions and is not extrapolated to dissimilar conditions
- where interpretations are based on similar compliance results and have been obtained under similar process conditions, they are broadly consistent
- authorities and operators are aware of the quality of evidence needed to mount successful prosecutions/appeals using compliance monitoring data
- the personnel doing the interpretation are professionally competent in statistics, uncertainty analysis and environmental law, and have a sound understanding of practical monitoring methods.

7 REPORTING OF MONITORING RESULTS

[Mon/tm/64]

Reporting of monitoring results involves summarising and presenting monitoring results, related information and compliance findings in an effective way. Good practice is based on consideration of the following items:

- requirements and audiences for the report
- responsibilities for producing the report
- scope of the report
- type of report
- good reporting practices
- quality considerations.

7.1 Requirements and audiences for the report

[Mon/tm/64]

Monitoring reports may be required for a range of applications, including:

- Legislation - to comply with national and EU law; also with legally enforceable permit conditions and relevant legislation.
- Environmental performance - to show that processes are applying the required techniques for minimising environmental impact, such as Best Available Techniques, using resources efficiently and contributing to sustainable development.
- Evidence - to provide data that operators and authorities can use as evidence of compliance or non-compliance in judicial situations (e.g. prosecutions; appeals).
- Inventories - to provide basic information for use in emission inventories.
- Emissions trading - to provide data on pollutant emissions for negotiation and trading of permitted emission quotas (e.g. between installations, industry sectors, Member States).
- Charging - to provide data for allocating regulatory charges and environmental taxes.
- Public interest - to inform residents and public groups (e.g. under the Aarhus “Freedom of Information” convention).

The above list shows that there is a range of potential users or “audiences” for monitoring reports, e.g.:

- legislators
- prosecutors
- regulators
- operators
- inventory specialists
- certification and accreditation bodies
- charging and taxation authorities
- permit traders
- the general public.

It is good practice for organisations with responsibility for preparing reports to know how and by whom the information will be used, so that they can design their reports to be useable for these applications and users.

7.2 Responsibilities for producing the report

The responsibility for reporting monitoring results is assigned to different organisations, depending on whether the results are being applied to an individual process, a group of processes or a wider strategic review. It is good practice to assign reporting responsibilities to the appropriate level and organisation. There is a general trend in EU Member States towards putting more responsibility onto the operator.

In general, there are three main levels of information and, therefore, responsibility:

- (a) **Reports for individual installations** - this is the most basic level of reporting. The operator is generally responsible for reporting compliance monitoring results for his installation to the competent authority. The authority is occasionally required to produce a report on individual installations (e.g. to report the results of independent check monitoring). These may be of interest to the operator, the competent authority itself, government departments, pressure groups and the general public. The IPPC Directive requires that the operator's duty to report results from their own processes is stated unambiguously in the relevant permit or legislation, including specifying the scope and timing of the reports.
- (b) **Reports for groups of installations** - this is an intermediate level of reporting covering various collections of results (e.g. for processes in a particular area or industry sector). In certain cases, the operator of the installation can be responsible for collecting and reporting the information (e.g. through local industry committees). However, more often the competent authority is responsible for collating and reporting operators' results and any authority results where the requirements transcend industrial sectors or geographical areas. Good practice means ensuring that the relative responsibilities and requirements in terms of timing, scope and format are understood and, where appropriate, defined in permits or legislation.
- (c) **Regional or national reporting** - this is the highest level of information and covers data relevant to wider environmental policies (e.g. national policies). The information is usually collated and reported by the competent authority or a relevant government department. Operators have a duty to supply results in a form that can be used for strategic reports, and it is good practice to make reference to this duty, where appropriate, in the relevant permits or legislation.

7.3 Scope of the report

There are three main aspects to consider when planning the scope of a monitoring report:

- (a) **Type of situation** - good practice involves defining and addressing the situation(s) which led to the requirement for monitoring. Examples include:
- commissioning trials for a new process
 - changes to an existing process, e.g. to fuel, feedstock or abatement equipment
 - exceedences of ELVs or ambient impacts
 - complaints or evidence of harmful or nuisance effects
 - a permit condition which requires regular reporting of releases
 - international reporting requirements (e.g. for EU Directives, climate protocol)
 - a qualification condition for an environmental certification scheme
 - an audit to check on the accuracy of routine monitoring
 - part of a general analysis of plant performance (e.g. life-cycle or cost-benefit analysis).
- (b) **Timing requirements** - good practice involves defining and addressing the timing requirements specified in the permit or relevant legislation and those needed to assess compliance and/or environmental impacts. This includes aspects such as:
- the total period covered and advice on how representative it is
 - the frequency of samples or readings taken during the period
 - the response times of the instruments used
 - the averaging time
 - the type of percentile and the method of computation.
- (c) **Location** - reports should cover all locations of interest for the monitoring objective. These can vary widely (e.g. from one sampling point at a single process to the whole site). In several cases it is important to report the total emission from an installation, for example when comparing environmental performance with a BAT Reference document.

Good practice includes reporting details of:

- monitoring locations, i.e. description and explanation of why/how they were chosen
- point and area sources, i.e. type, height and/or area of the emission
- grid reference, i.e. definition of the position of each emission
- receiving environments, i.e. details of local receiving environments
- groups, i.e. say how groups of locations are defined.

7.4 Type of report

Monitoring reports can be classified as follows:

- (a) **Local or basic reports.** - these are usually prepared by operators (e.g. as part of their self-monitoring) and should be of standard suitable for input into national and strategic reports. Where appropriate, they should meet any permit requirements. Local or basic reports are relatively simple, concise and can be prepared in a short response time following a request or need. They typically concern, for example:
- an individual site, installation or discrete source, or a particular location in the environment
 - a recent campaign or an occurrence which covers a short period and needs to be reported promptly (e.g. an exceedence report or a monthly emissions report)
 - basic or partial results which are not yet fully collated or analysed (e.g. for a sub-period)
 - compliance with a specific quantitative limit, rather than with a strategic aim or policy
 - information for use in relatively short-term responses or process management
 - local audiences (e.g. the site regulator or local residents).
- (b) **National or strategic reports** - these reports will generally be prepared by the competent authorities or government departments, although operators may also prepare this type of report, for example for an industry sector. These are usually summary reports and are less frequently prepared. They typically concern, for example:
- several sites or installations, or a broad sector of activity (e.g. the energy supply sector)
 - longer periods in order to show trends (e.g. several years)
 - more complete and sophisticated analyses (e.g. full statistical analyses of annual data)
 - a range of environmental receptors covering a wide geographical area
 - a particular category or group of pollutants (e.g. volatile organic compounds)
 - compliance with a range of limits or with a strategic aim e.g. energy efficiency
 - information for longer-term process management (e.g. for planning capital investment)
 - national or international audiences (e.g. policy departments, national and international decision making bodies).
- (c) **Specialised reports** - these are reports on relatively complex or novel techniques that are occasionally used to supplement more routine monitoring methods. Typical examples include:
- Telemetry - this involves the electronic transfer of monitoring data to users in real time (e.g. to a regulator's computer, to residents via an electronic display at a works entrance)
 - Neural networks - these involve using a computer to develop correlations between process conditions and measured emissions, which can then be used for emission control
 - Deposition surveys - these involve sampling pollutant deposits in and around an installation (e.g. dioxins in soil around an incinerator, metals in river sediment near a sewage works).

7.5 Good reporting practices

There are three stages in the reporting of information on monitoring:

- (a) Data collection
- (b) Data management
- (c) Presentation of results

(a) **Data collection** - this involves the acquisition of basic measurements and facts. Considerations of the following items are good practice in data collection:

- schedules – permits can contain schedules which state how, when, by whom and to whom the data are to be reported, and what types of data are acceptable (e.g. calculated, measured, estimated).

The schedule may cover the time-scales and locations of interest, and the format of the data. It can also give details of relevant limits, the units to be used and any normalisation required (e.g. to standard conditions of temperature and pressure).

- forms - standard forms can be used for collecting data so that it is easy to compare values and to identify gaps and anomalies. These forms may be paper based or electronic files
- data qualification details – standard forms can be used to record whether data values are based on measurements, calculations or estimations, and may also identify the methods used for monitoring, sampling and analysis. The forms may also include other relevant information concerning the data production chain, as described in Chapter 4, such as timing considerations
- uncertainties and limitations data - these details can be collected and reported alongside the monitoring data (e.g. details of detection limits, numbers of samples available)
- operational context details - collected data can include details of the prevailing process operations and/or environmental conditions (e.g. fuel type, feedstock, utilisation, process temperature, production load, abatement equipment, weather conditions, river level).

(b) **Data management** - this involves the organisation of data and its conversion into information. Considerations of the following items are good practice in data management:

- transfers and databases – permits can specify how and when data are to be transferred. It is not necessarily desirable for all data to be sent from the operators to the authority, or for all necessary data to be sent immediately, as this could create handling and storage problems for the authority. Instead, data may be sent in line with agreed criteria and schedules, or in response to requests
- data processing - the permit can specify a plan for the collation, analysis and condensation of data. Processing would normally be carried out in stages, so that recent data are available in a detailed form and earlier data in a more summarised form. Each operator is principally responsible for condensing the data for his installation
- results below the detection limit - the approach for estimating these values should be explained when reporting the data. Further information on this issue can be found in Section 3.3

- software and statistics - details of any software packages and statistical methods used to analyse or summarise the data can be provided in the report
 - archiving - data can be systematically archived in a secure store, so that records of past performance are readily available. It is usually more practical for the operator to maintain this archive than the authority.
- (c) **Presentation of results** - this involves the delivery of information to users in a clear and usable form. Considerations of the following items are good practice in the presentation of monitoring results, depending on the type of report:
- scope of the report - a clear reminder on the objectives of the monitoring covered by the report is useful to appreciate the impact of the results
 - programme - permits can identify the users of reports and define a programme of presentations using different events and media as appropriate (e.g. public registers, publications, meetings, Internet). Each presentation usually includes opportunities for feedback
 - trends and comparisons - presentations can set results in context by showing trends over time and comparisons with other sites and standards. Graphs and other forms of pictorial representation can be useful tools for supporting the presentation of the results
 - statistical significance - reports can indicate if exceedences or changes are significant when compared with the uncertainties in measurements and process parameters
 - interim performance - interim reports can give performance statistics for the year to date
 - strategic results - national and strategic reports can detail levels of compliance for different policies, activities, technologies, environmental receptors and geographical areas
 - non-technical summaries - reports can be prepared for the public using non-technical language which can be readily understood by non-specialists
 - distribution - permits or other relevant documents can state who is responsible for distributing reports, who should receive them and when, and the number of copies required.

EU legislation in general, and the Aarhus convention in particular, promote public access to environmental information. The IPPC Directive requires information for compliance assessment procedures. In cases where confidentiality is allowed, it is good practice for the compliance assessment and the operator to make it clear why the information is not made available to the public.

7.6 Quality considerations

In order for reports to be used in decision making processes they need to be readily available and accurate (to within stated uncertainties).

Data providers and report authors can achieve good practice in accessibility and quality of their reports by considering the following items:

- quality objectives and checks - quality objectives for the technical standard and availability of reports should be set. Checks should be carried out to test how well these are being met. These may involve checks by both internal and external experts, and even certification under a formal quality management system
- competence - reports should be prepared by competent and experienced teams who may maintain their skills by participating in relevant technical groups and quality initiatives, e.g. in workshops and certification schemes
- contingency arrangements - special contingency arrangements should be in place for rapid reporting of abnormal and upset events, including off-scale conditions and breakdowns of monitoring equipment
- sign-off systems - it is desirable that a nominated person is responsible for the authenticity and quality of the information in each report using a “sign-off” system, which may be manual or electronic
- retention of data - the operator should retain basic monitoring data and reports for periods to be agreed with the authority and make them available to the authority on request
- falsification of data - regulators should define procedures for dealing with any falsification of reported monitoring results. These can include unannounced audits and effective legal sanctions.

8 COST OF EMISSION MONITORING

Optimisation of emission monitoring costs should be undertaken whenever possible, but always without losing sight of the overall emission monitoring objective. In order to improve the cost-effectiveness of the emission monitoring the following actions can be applied:

- select the appropriate quality performance requirements
- optimise the monitoring frequency and match it with the desired accuracy of the results
- optimise the number of parameters to be monitored by only considering those that are strictly necessary
- consider the use of continuous monitoring when it provides the requested information at a lower overall monitoring cost than discontinuous monitoring
- consider, where possible, replacing expensive parameters with surrogates that are more economical and simpler to monitor
- consider complementing routine monitoring by special studies (such as campaign monitoring). This can provide a better understanding of the effluent and may reduce the monitoring regime, and therefore the cost as a result
- limit the measurement of sub-flows, as well as the number of parameters and determine the total discharge scenario on the basis of the end flow.

The cost of emission monitoring can be broken down into several elements. Some of these cost elements relate only to individual emission monitoring requirements, whereas others might serve additional purposes to the operator, for example some process control monitoring can also be useful to the operator for emission monitoring purposes. The cost elements for these multi-purpose monitoring items can then be somehow shared between the different purposes. For this reason it is important to be clear about what items are included in the cost assessment of emission monitoring.

The following capital cost elements form part of the overall operator monitoring costs, and a proportion may need to be taken into account when assessing the cost of emission monitoring:

- control rooms hardware and software - these mainly relate to process control, but can also be used for direct or indirect emission monitoring
- analytical rooms – these are usually located on site, close to process equipment and process lines, or in dedicated isolated boxes (e.g. to avoid the problems of flammable atmospheres and other risks). They include sampling lines and utilities delivery which can be used for emission monitoring purposes
- existing process equipment – some pieces of equipment operate with parameters that can also provide information for emission monitoring purposes.

Similarly, when monitoring data is used for more than one purpose or programme, the running costs attributable to each may be difficult to break down. Consideration of the following overlaps may be needed when assessing emission monitoring costs:

- safety inspections of materials, process conditions, incidents – this could involve information about accidental releases or leaks (usually estimated or calculated by indirect parameters) that could also be useful for emission monitoring purposes
- health monitoring - this could involve information about, e.g. concentration levels within the workplace (typically inside buildings) or flowrates for ventilation. In many cases, the same or similar equipment, methods and parameters used in health monitoring could also be used for emission monitoring purposes
- other inspection and monitoring programmes - other work programmes, such as those intended for preventive maintenance or operational checks (visual and checking rounds, mechanical examination, etc.) can also be used for emission monitoring purposes.

Some cost elements related to emission monitoring may occur only once, e.g. at the engineering design stage of a new unit, for the renewal of a permit, or during a modification of a unit (process change or extension of capacity). Typical examples and values of these costs are given in Annex 7. At these times some special emission monitoring activities may be necessary, for example to assess the environmental load or emission characteristics.

When assessing the total cost of emission monitoring the following additional elements need to be taken into account:

- the design and construction of dedicated lines, control loops, wells, access hatches, sampling ports, etc.
- sampling, including personnel, containers (disposable or reusable vials, bottles, etc.), sampling equipment (pumps, samplers, cooling devices, etc.), data loggers, recorders, etc.
- the transport of samples (for instance in large units, a dedicated vehicle for sample collection and transport is needed)
- the treatment of samples, including pretreatment, dividing, labelling, storage (under refrigerated conditions), disposal of samples, etc.
- laboratory and analytical costs, including: personnel, buildings and rooms, separate storage of gases and reactants, calibration, maintenance, spare parts, training operators, etc.
- data processing, including software and data storage (e.g. LIMS: laboratory information management system), assessment, review, data handling, etc.
- data distribution, including regular reports to authorities, to national or corporate services, to external groups, the publication of environmental reports, replies to inquiries, etc.
- hiring of third party contractors to perform parts of the monitoring, as often requested by the permit.

Examples of individual monitoring costs and aggregated costs are given in Annex 7.

9 CONCLUDING REMARKS

9.1 Timing of the work

The work on this Reference Document on “The General Principles of Monitoring” kicked-off on the 25th-26th of June 1998 with the first meeting of the Technical Working Group (TWG). In this meeting it was agreed to produce a document on the general principles of monitoring, as well as to explore current monitoring practices to raise awareness of selected monitoring issues, such as the handling of values under the limit of detection, the use of surrogate parameters, etc.

The first draft of the general principles document was sent out for consultation in January 1999. The second draft, completely different from the first draft, was issued in October 2000, prior to a second TWG meeting that took place in November 2000.

The third draft was sent to the TWG in April 2002, prior to a final TWG meeting in May 2002, where many specific issues were discussed. The fourth draft was sent out for final check to the TWG in July 2002, and the final drafting took place in September 2002.

9.2 Questionnaire of current practices

As part of the information exchange it was decided during the kick-off meeting of the TWG to carry out a survey by questionnaire to explore current practices in EU MSs on selected monitoring topics. The following topics were identified as potentially important:

- deciding monitoring frequency
- data generation
- data handling and processing
- quality assurance/quality control
- surrogate parameters
- fugitive emissions
- efficiency of raw material, energy and water consumption
- noise monitoring
- odour monitoring
- emergency monitoring.

A questionnaire was thus developed, in parallel with the general principles document and, after several rounds of consultation to reach agreement on the questions and the format of the questionnaire, was sent to the TWG members to complete the survey. There were two versions of the questionnaire prepared, one for authorities and a slightly different version for industry.

The response from the questionnaires provided valuable inputs for the general principles document and served the purpose of raising awareness on the selected monitoring topics. The results of the survey emphasised the spread approach of many of the monitoring issues throughout the TWG members and hence throughout MSs. It was decided not to produce a separate document on the results of the questionnaire, but rather to use them as inputs to the general principles document.

9.3 Sources of information

Only limited information is available on general monitoring principles. Most of the available literature on monitoring is too specific for a general approach across different industrial sectors and MSs as covered in this general principles document.

Several sources of information, all included in the list of references, have been used when preparing this document. Some of these references form the building blocks of the document, including:

- Operator Self-Monitoring [Mon/tm/15].
- Data production chain in monitoring of emissions [Mon/tm/39].
- Dutch Notes on Monitoring of Emissions into Water [Mon/tm/56].
- Best Practice in Compliance Monitoring [Mon/tm/64].
- Monitoring of Total Emissions Including Exceptional Emissions [Mon/tm/67].

9.4 Level of consensus

There was a high degree of consensus on the issues discussed at the final meeting and on the content and structure of this final draft. To reach this point many issues and opposing views had to be resolved during the information exchange process. Compromise solutions and agreements were reached over all the major issues, albeit after very lengthy periods of times.

However, the TWG could not agree conclusions over several issues, especially regarding harmonisation of monitoring procedures. This point is reviewed in Chapter 9.5.

9.5 Recommendations for future work

It is suggested for the future revision of this document that the scope is clearly set out from the beginning, and that the TWG commits itself to provide the necessary information to cover the scope. Within the context of this document, many suggestions for the scope were originally made, but the information exchanged by the TWG led to a narrowing of the scope.

Some of the issues pointed out by the TWG members during the information exchange have not been covered, generally due to the lack of information or supporting contributions. For the future revision of this document it is important to consider the following elements:

- encouraging **harmonisation** of monitoring procedures throughout Europe – this has been identified by the TWG as desirable as it would be useful for comparability of monitoring data throughout the EU and throughout different industrial sectors. However, little information has been exchanged and few proposals made that could lead the Member States in this direction; there was simply not enough support from the TWG. In order to further improve harmonisation the following items need to be considered:
 - how to decide monitoring frequency – a risk-based approach has been presented in this document, however the considerations for choosing the frequency remains very different from one country to another and from one industrial sector to another
 - data handling methodologies – how data reduction and the calculation of averages are treated in data handling methodologies also merits further consideration for future revisions. It is important for harmonisation that averages are calculated in the similar way
 - compliance assessment procedures – at present these vary greatly between different member states
 - values under the limit of detection – different approaches have been presented in Section 3.3, however it has not been possible to make any definitive recommendation
 - comparability of data – comparability of emission monitoring data is an essential element when assessing compliance with environmental permit conditions, when evaluating environmental performances in emission inventories and registers (such as the EPER inventory) and in emission trading

- data production chain for **different media/aspects** – this document has considered only limited information relating to the data production chain in air, waste water and wastes (see Section 4.3). Very little information has been received on other media/aspects. A more comprehensive analysis is recommended for the future revision of this document, including widening the number of media/aspects covered, including soil, energy, noise, odour, etc.
- **costs** of emission monitoring – information on costs is provided in Chapter 8 and Annex 7 but for a more comprehensive analysis more data on **costs** are needed. This is essential to allow a true comparison of costs throughout MSs and throughout different industrial sectors
- **working examples** - further working examples of practical real life case studies should be developed to illustrate the results of different approaches in sampling, data treatment and reduction, influence of uncertainties, compliance assessment, mass balances, and other items mentioned in this document.

The EC is launching and supporting, through its RTD programmes, a series of projects dealing with clean technologies, emerging effluent treatment and recycling technologies and management strategies. Potentially these projects could provide a useful contribution to future BREF reviews. Readers are therefore invited to inform the EIPPCB of any research results which are relevant to the scope of this document (see also the preface of this document).

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ANNEX 1. GLOSSARY OF TERMS

[Mon/tm/72], [Mon/tm/50],[Mon/tm/78]

Accreditation (of a testing laboratory): formal recognition that a testing laboratory is competent to carry out specific tests or specific types of tests.

Accuracy: is associated with measured values. It is an assessment of how close a measurement is to the accepted or true value. Chemical preparations of known purity and/or concentration are used to assess accuracy; these preparations, known as “standards”, are analysed using the same method by which the samples are measured. Accuracy should never be confused with precision: precision measures how closely the analytical results can be duplicated.

Adjustment / Set-up (of a measuring system): operation of bringing a measuring system into a state of performance suitable for its use.

Analysis: characterisation of the nature of a sample. Analysis versus assessment: a formal, usually quantitative determination of the effects of an action (as in risk analysis and impact analysis).

Approval (of a testing laboratory): authorisation given by the competent authority to a testing laboratory to perform regulatory measurements, controls or inspection in a specified field.

Approval (of a product, process or service): permission for a product, process or service to be marketed or used for stated purposes or under stated conditions.

Assessment: examination of the level of adequacy between a set of observations and a commensurate set of criteria sufficient for fixed objectives in order to take a decision. Also the combination of analysis with policy related activities such as identification of issues and comparison of risk and benefits (as in risk assessment and impact assessment).

Assessment method of emissions: set of relations between measured data, physical properties, meteorological data, and design data related to equipment or process parameters, and intended to calculate or to assess an emission or an emission factor.

Automatic measuring system: system for measuring the material under investigation, returning an output signal proportional to the physical unit of the parameter to be measured and capable of producing measurement results without human intervention.

Availability (of an automatic measuring system): percentage of time that the automatic measuring system is operational and for which valid data are available.

Basic state: a specific state of a measuring system used as a fixed point of reference for evaluating actual states of the measuring system. Note A state of equilibrium may also be considered a basic state. In air quality measurements of gaseous compounds, the use of a “zero reference gas” often establishes the basic state.

Best Available Techniques (BAT)[IPPC Directive]: the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole:

- 'techniques' shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned,
- 'available' techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator,
- 'best' shall mean most effective in achieving a high general level of protection of the environment as a whole.

In determining the best available techniques, special consideration should be given to the items listed in Annex IV of the IPPC Directive.

Calculated value: the result of an assessment of an emission based on calculations only.

Calibration: set of operations that establishes, under specified conditions, the systematic difference that may exist between the values of a parameter to be measured and those indicated by a measuring system (with the corresponding values given in reference to a specific "reference" system, including reference materials and their accepted values). **Note:** The result of a calibration allows either the assignment of values of the parameters to be measured to the indications or the determination of corrections with respect to indications.

Campaign monitoring: Measurements made in response to a need or an interest to obtain further fundamental information than that which routine/conventional monitoring provides. Examples are campaign monitoring during a special time period for estimating uncertainties, estimating variations in emission patterns or for evaluating the chemical content or the ecotoxicological effects of the emission/s by more advanced analyses.

Certification: procedure by which a third party gives written assurance that a product, process or service conforms to specified requirements. Certification can apply to instruments, equipment and/or personnel.

Checking: method of assessing/verifying a value or a parameter or a physical state in order to compare it with an agreed reference situation or to detect anomalies (checking does not include the follow-up of a procedure nor the whole traceability of the comparison).

Comparability: process for identifying and/or assessing differences and/or common characteristics between two (or more) samples, measurements, monitoring results, etc. Comparability is related to uncertainty, traceability to the specified reference, averaging time and frequency.

Competent authority [IPPC Directive]: the authority or authorities or bodies responsible under the legal provisions of the Member States for carrying out the obligations arising from the Directive.

Compliance assessment: process to compare actual emissions of pollutants from an installation [manufacturing unit] with the permitted emission limit values, within a defined degree of confidence.

Composite sample: sample prepared by an operator or by an automatic device and that has been obtained by mixing several spot samples.

Continuous monitoring: Two types of continuous monitoring techniques are considered:

- **fixed in-situ (or in-line)** continuous reading instruments. The measuring cell is placed in the duct, pipe or stream itself. These instruments do not need to withdraw any sample to analyse it and are usually based on optical properties. Regular maintenance and calibration of these instruments are essential
- **fixed on-line (or extractive)** continuous reading instruments. This type of instrumentation extracts a sample of the emission along a sampling line, which is driven to a measurement station, where the sample is then analysed continuously. The measurement station may be remote from the duct, and therefore care must be taken so that the sample integrity is maintained. This type of equipment may allow certain conditioning of the sample.

Continuous automatic measuring system: automatic measuring system returning a continuous output from the continuous measurement of the material under investigation.

Continuous sampling: sampling on a continuous basis, and without interruption, of a portion of an effluent, which itself can be continuous or discontinuous. An aliquot of the flow is taken at any time when there is discharge. Two formats can be identified:

- **continuous flow-proportional sampling** where a continuous sample is taken from a partial flow at a fixed ratio of the sample volume to the effluent flow rate
- **continuous sampling at fixed time intervals** where equal volumes are taken at fixed time intervals.

Control of emission: techniques used to limit, reduce, minimise, or prevent emissions.

Determinand: value or parameter that needs to be determined by measurement or analysis.

Diffuse emission: an emission arising from direct contact of volatile or light dusty substances with the environment under normal operating circumstances. These can result from:

- the inherent design of the equipment (e.g. filters, dryers ...)
- the operating conditions (e.g. during transfer of material between containers)
- the type of operation (e.g. maintenance activities)
- a gradual release to other media (e.g. to cooling water or waste water).

Diffuse emission sources can be point, linear, surface or volume sources. Multiple emissions inside a building are normally considered as diffuse emissions, whereas the general ventilation system exhaust is a channelled emission.

Examples of diffuse emissions include the opening of a filter or a vessel, diffusion through an open surface, volatile compounds emissions from sewers, loading/unloading operations without capture of vented vapours, dust from bulk storage ...

Fugitive emissions are a subset of diffuse emissions.

Diffuse sources: multiple sources of similar emissions distributed inside a defined area.

Direct measurements: specific quantitative determination of the emitted compounds at the source.

Discharge: physical release of a pollutant through a defined outlet (i.e. channelled) system (sewer, stack, vent, curbing area, outfall ...).

Discrete: not continuous, i.e. having gaps between all possible values.

Effluent: physical fluid (air or water together with contaminants) forming an emission.

Emission factor: numbers that can be multiplied by an activity rate or by throughput data from a facility (such as the production output, water consumption, etc.) in order to estimate the emissions from the facility. They are applied under the assumption that all industrial units of the same product line have similar emission patterns.

Emission Limit Value (ELV)[IPPC Directive]: the mass, expressed in terms of certain specific parameters, concentration and/or level of an emission, which may not be exceeded during one or more periods of time. ELVs may also be laid down for certain groups, families or categories of substances, in particular those listed in annex III of the IPPC directive.

Emission pattern: type of variation of emission over time, for example, emissions can be stable, cyclic, random peaking, random variable, erratic, ...

Emission [IPPC Directive]: the direct or indirect release of substances, vibrations, heat or noise from individual or diffuse sources in the installation into the air, water or land.

Environmental quality standard [IPPC Directive]: set of requirements which must be fulfilled at a given time by a given environment or particular part thereof, as set out in Community legislation.

Equivalent parameter: parameter related to an emission, which provides the same [similar] level of information with the same [similar] level of confidence.

Error (measurement error): the amount by which an observed or approximate result differs from the true or exact one. These typically result from an inaccuracy or imprecision in the measurement of parameter values.

Estimated value: result of an assessment of an emission, using emission factors, surrogates, calculations or similar methods using indirect parameters.

Examination of a sample: preliminary characterisation intended to record visual characteristics which indicate the nature and origin of the sample and that can be used for defining the further treatment of the sample.

Fugitive emission: emissions into the environment resulting from a gradual loss of tightness of a piece of equipment designed to contain an enclosed fluid (gaseous or liquid), typically this could be caused by a pressure difference and a resulting leak. Examples of fugitive emissions include leakages from a flange, a pump, or a piece of equipment and losses from the storage facilities of gaseous or liquid products.

Good practice: approach which provides a good framework to the given activity. It does not preclude other approaches which may be more appropriate for a given requirement.

Incident: an occurrence or an event involving a loss of containment of material or energy.

Independent measurement: measurement achieved by another control body, using other dedicated equipment (sampling, measuring, standard material, software, etc.).

Inspection: process consisting of surveys, checks, controls and validations in an industrial unit, carried out by authorities or by internal or external experts, in order to analyse and assess procedures, operating modes, operating conditions of the process and the related equipment, mechanical integrity, level of performance, and the records and results obtained by the industrial operator. Inspection therefore covers a domain larger than 'emission monitoring'. Some of the inspection activities can be delegated to the industrial operator.

Installation [IPPC Directive]: stationary technical unit where one or more activities listed in Annex I of the Directive are carried out, and any other directly associated activities which have a technical connection with the activities carried out on that site and which could have an effect on emissions and pollution.

Interferent substance: substance present in the material under investigation, other than the measurand, which, because of its presence, induces variations in the response of the measuring system.

Isokinetic sampling: sampling technique where the velocity at which the sample enters the sampling nozzle is the same as the flow velocity in the duct.

Limit of detection (LOD): the lowest detectable amount of a compound

Limit of quantification (LOQ): the lowest quantifiable amount of a compound.

Mass balance: approach to monitoring, consisting of accounting for inputs, accumulations, outputs and the generation or destruction of the substance of interest, and accounting for the difference by classifying it as a release to the environment. The result of a mass balance is usually a small difference between a large input and a large output, also taking into account the uncertainties involved. Therefore, mass balances are only applicable in practice when accurate input, output and uncertainties quantities can be determined.

Measurand: the particular quantity of material subjected to measurement.

Measured value: the result of a measurement.

Measurement: set of operations for determining the value of a quantity.

Measuring system: complete set of measuring instruments and other equipment, including all operating procedures used for carrying out specified measurements.

Method of measurement: logical sequence of operations, described generically, used to carry out measurements.

Monitoring: systematic surveillance of the variations of a certain chemical or physical characteristic of an emission, discharge, consumption, equivalent parameter or technical measure etc. This is based on repeated measurements or observations, at an appropriate frequency in accordance with documented and agreed procedures, and is done to provide useful information.

Nameplate (or nominal) capacity: quantity of production that a unit is able to produce by design at normal operating conditions.

Non-continuous automatic measuring system: automatic measuring system returning a series of discrete output signals.

Outliers: results deviating significantly from the others in a measurement series (typically a series of monitoring data) and which cannot be assigned to the operation of a facility or process. They are identified by expert judgement on the basis of a statistical test (e.g. Dixon test) together with other considerations, such as an abnormal emission pattern in the particular facility.

Operator [IPPC Directive]: Any natural or legal person who operates or controls the installation or, where this is provided for in national legislation, to whom decisive economic power over the technical functioning of the installation has been delegated.

Parameter: measurable magnitude representing the main features of a statistical group.

Percentage capture of data: percentage of the expected number of data that have been actually provided.

Periodic sampling (discrete/individual/separate/discontinuous/grab/spot sampling): individual samples taken in batches, time or effluent-volume dependent. Three formats can be identified:

1. **periodic time dependent sampling:** discrete samples of equal volume are taken at equal time intervals
2. **periodic flow proportional sampling:** discrete samples are taken of variable flow-proportional volumes at equal time intervals
3. **periodic samples taken at fixed flow intervals:** discrete samples of equal volume are taken after the passage of a constant volume.

Permit [IPPC permit]: part or the whole of a written decision (or several such decisions) granting authorisation to operate all or part of an installation, subject to certain conditions which guarantee that the installation complies with the requirements of this Directive. A permit may cover one or more installations or parts of installations on the same site operated by the same operator.

Pollutant: individual substance or a group of substances which can harm or affect the environment.

Pollution [IPPC Directive]: the direct or indirect introduction as a result of human activity, of substances, vibrations, heat or noise into the air, water or land which may be harmful to human health or the quality of the environment, result in damage to material property, or impair or interfere with amenities and other legitimate uses of the environment.

Precision: measurement of how closely the analytical results can be duplicated. Precision is associated with measured values. Replicate samples (prepared identically from the same sample) are analysed in order to establish the precision of a measurement. The precision is usually reported as a standard deviation or average replicate error. Note, precision should never be confused with accuracy: accuracy measures how close a measurement is to the accepted or true value.

Qualitative monitoring: specific type of monitoring carried out using techniques, procedures or methods that may rely on observation or human sense (e.g. odour monitoring, visual checks, comparison scales). The results of qualitative monitoring may be expressed as quantitative measurements.

Release: actual discharge (routine, usual, or accidental) of an emission into the environment.

Repeatability (of a measuring system): the ability of a measuring system to provide closely similar values for repeated measurements of the same parameter, being measured and under the same conditions of measurement.

Reporting: process of periodic transmission of information about environmental performance, including emissions and emission compliance, to authorities or to the internal management of the installation and other agencies, such as the general public.

Result: value attributed to a measurand, obtained by measurement. Note, a complete statement of the result of a measurement includes information about the uncertainty of measurement, as well as all the relevant information necessary to understand and compare results.

Sample:

- **laboratory sample** - sample or sub-sample(s) sent to or received by the laboratory
- **test sample** - sample, prepared from the laboratory sample, from which test portions are removed for testing or for analysis
- **test portion** - amount or volume of the test sample taken for analysis, usually of known weight or volume
- **primary sample** or **field sample** - obtained according to the spatial sampling plan by aggregating sample units taken at specified locations and/or according to the temporal sampling plan by aggregating sample units taken at given location(s) and at specified points in time. In the analytical process the field sample ultimately becomes the laboratory sample(s)
- **integrated sample** - sample accumulated/averaged over a defined period of time.

Sampling: process by which a portion of substance, material or product is removed to form a representative sample of the whole, for the purpose of examination of the substance, material or product under consideration. The sampling plan, the sampling and the analytical considerations should always be taken into account simultaneously.

Self-monitoring: monitoring of industrial emissions by the operator of an industrial installation, according to an appropriate, defined and agreed sampling programme and according to recognised measurement protocols (norms or demonstrated analytical methods or calculation/estimation methods). Operators may also contract an appropriate external body to perform the self-monitoring on their behalf.

Source: any physical element that can be the origin of an emission. This can be an installation, equipment, component, etc. and can be fixed or mobile, unique or numerous, diffuse or fugitive, etc.

Specific emission: emission related to a defined reference basis, such as production capacity, actual production (e.g. grams per tonne or per unit produced, number of pieces of equipment, m² of material produced, etc.), etc.

Standardisation: set of all operations that establish, under specified conditions, the relationship between values sizes reported by a measuring device or a measuring system, or the values represented by a measure or by a reference material, and the corresponding values achieved by standards.

Substance [IPPC Directive]: any chemical element and its compounds, with the exception of radioactive substances within the meaning of Directive 80/836/Euratom(1) and genetically modified organisms within the meaning of Directive 90/219/EEC(2) and Directive 90/220/EEC(3).

Surrogate parameter: measurable or calculable quantities which can be closely related, directly or indirectly, to conventional direct measurements of pollutants, and which may therefore be monitored and used instead of the direct pollutant values for some practical purposes. The use of surrogates, used either individually or in combination with other surrogates, may provide a sufficiently reliable picture of the nature and proportions of the emission.

Systematic sampling: a sampling technique used to obtain samples by selecting every kth item in a list, a sequence, an area, a lot, etc. A systematic sample is chosen by a cyclic sampling scheme, e.g. choosing every 20th item to get a 5 % sample.

Traceability: a property of the result of a measurement or the value of a standard whereby it can be related to stated references through an unbroken chain of comparisons, all having stated uncertainties.

True value: value that could be obtained in theory with a perfect measuring chain.

Uncertainty: a measure, often qualitative, of the degree of doubt or lack of certainty associated with an estimate of the true value of a parameter. The uncertainty includes several components, some of which can be assessed from the statistical distribution of the results from the measuring series.

Uncertainty of measurement: parameter associated with the result of a measurement that characterises the dispersion of the values that can be reasonably attributed to the measurand (i.e. the particular quantity of material subjected to measurement).

Upset conditions: the process operating conditions during a disturbing event (failure, rupture, temporary loss of control, etc.) that can lead to an abnormal emission.

Validation: confirmation of the final result of a monitoring process. This typically involves reviewing all the steps of the data production chain (such as flow determination, sampling, measurement, data processing, etc.) by comparing them with relevant methods, norms, good practices, state of the art, etc.

Value: (see emission limit value, measured value, estimated value, calculated value): a quantitative expression of a particular magnitude, usually expressed as a number followed by a measurement unit.

ANNEX 2. LIST OF CEN STANDARDS AND PRE-STANDARDS

[Mon/tm/78]

The tables of CEN standards are provided for the following groups of measurements, in accordance with the requirements of the TWG Monitoring:

- Air emissions
- Water emissions
- Residues
- Sludges

General information on standards can be found on the CEN website (<http://www.cenorm.be>). It provides a direct link with the website of each national standardisation institute from which European standards may be obtained.

These tables are limited to the number and title of the CEN standards and are structured to provide a first approach of their scope of application. A more comprehensive document extended to scopes will be available at CEN.

These tables also have been structured so as to provide to list all the standards covering a given measurement. A measurement is defined as "the set of operations having the object of determining a value of a quantity" (VIM International Vocabulary of Metrology), for instance the measurement of the concentration in mercury in stack gases. The main steps of such measurements are the headings of several columns: sampling plan, taking of sample, transport and storage, pretreatment, extraction, analysis/quantification, overall measurement report. For air emissions, in most cases, a single standard address all the steps of a given measurement and an extraction is generally performed in the field. For other media, several standards are to be combined for addressing all the steps of a given measurement: they appear on the line dedicated to this measurement..

At the date of this document,

- published standards are given as ENxxxxx and ENVxxxxx with the publication year in brackets to avoid confusion with the digits of the standard number
- draft standards are given as prENxxxxx when they are publicly available (but subject to significant or editorial changes in the course of adoption by CEN (CEN inquiry and formal vote)
- draft standards are given as WI xxx-yyy (xxx = CEN/TC number) when they are not publicly available and are under preparation subject to adoption-publication later on. They are mentioned when they are likely to mature in a CEN standard before this document is revised as scheduled each five years. Later on the WI number could be used to check with CEN and/or the national standardisation institutes whether a standard has been issued further to this WI.

Regarding the issue of uncertainty, information is provided in the right column, "U-data": "whole measur." indicates availability in the CEN standard of uncertainty data covering all steps of the measurement method while "analysis" indicates availability in the CEN standard of uncertainty data covering only the analytical step of the measurement.

For several media and some steps of measurement, general recommendation are available in the form of "guidance for.....". They are quoted in the tables as " GRx, indicating that the quoted document provides General Recommendations as opposed to unambiguous requirements. The document title is given in the notes of the corresponding table. It may be associated to a specific standard providing mainly requirements e.g. for analysis, but also for the main step concerned by this GR, e.g. sampling.

Annex 2.1. Table of CEN standards for air emissions

	<u>Air Emission Measurement</u>	Sampling plan	Taking of sample	Extraction	Transport Storage	Pre-treatment + extraction	Analysis Quantification	Overall measurement report	U - data
1	Gaseous HCl	EN 1911-1 + EN 1911-2 + EN 1911-3 (1998)							whole measur.
2	Dioxins and furans	EN 1948-1 + EN 1948-2 + EN 1948-3 (1996)							whole measur.
3	Total gaseous carbon	Low concentration = EN 12619 (1999) and high concentration = EN 13526 (2001)							whole measur.
4	Total mercury (reference)	EN 13211-1 (2001)							whole measur.
5	Total mercury (AMS validation)	prEN 13211-2							
6	Dust – low mass concentration (reference)	EN 13284-1 (2001)							whole measur.
7	Dust – low mass concentration (AMS validation)	prEN 13284-2							
8	Individual gaseous organic compounds	EN 13649 (2001)							whole measur.
9	Total specific elements As-Cd-Co-Cr-Cu-Mn-Ni-Pb-Sb-Ti-V	prEN 14385							whole measur.
10	Nitrogen oxides NO _x (NO+NO ₂)	WI 264-043							whole measur.
11	Sulphur dioxide SO ₂	WI 264-042							whole measur.
12	Oxygen O ₂	WI 264-040							whole measur.
13	Water vapour	WI 264-041							whole measur.
14	Carbon monoxide CO	WI 264-039							whole measur.
15	Velocity and volumetric flow in ducts	WI 264-xxx							
16	Fugitive and diffuse emissions	WI 264-044							whole measur.
17	Odour by dynamic olfactometry		prEN 13725						whole measur.
18	Deposition of heavy metals and metalloids		WI 264-046						
19	Evaluation of the suitability of an Air Quality AMS for a stated uncertainty		EN ISO 14956 (2002)						
20	Quality assurance of an Air Emission Automatic Measuring System (AMS)	prEN 14181							
21	Minimum requirements for an Air Quality Automatic Measurement System (AMS) certification scheme		WI 264-xxx						
22	Planning, sampling strategy and reporting of emission measurements	WI 264-xxx							
23	Guidelines for the elaboration of standardised methods for emission measurements	WI 264-xxx							
24	Application of EN ISO/IEC 17025 (2000) to stack emission measurements	WI 264-xxx							
25	General requirements for competence of testing and calibration laboratories	EN ISO/IEC 17025 (2000)							

	<u>Air Emission Measurement</u>	Sampling plan	Taking of sample	Extraction	Transport Storage	Pre-treatment + extraction	Analysis Quantification	Overall measurement report	U - data
26	Definition and determination of performance characteristics of AMS under specified test conditions		ISO 6879 (1996) and ISO 9169 (1994) under revision under the Vienna agreement as an EN ISO standard (presently ISO/WD 9169 = CEN/WI 264-xxx)						
27	Guide to estimating uncertainty in Air Quality measurements	WI 264-xxx prepared under the Vienna agreement as an EN-ISO standard (presently ISO/AWI 20988)							
28	GUM = Guide to the expression of uncertainty (1995) published by BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML	ENV 13005 (2000)							
Notes									
<ul style="list-style-type: none"> • Unless otherwise specified in the title, all standards apply only to air emission measurement • At the date of this document EN and ENV are published, • prEN are draft standards publicly available but subject to significant or editorial changes in the course of adoption by CEN • WI denotes a standard under preparation subject to adoption-publication later on • U- data column is dedicated to Uncertainty data available in the standard(s): “whole measur.” indicates availability in the CEN standard of uncertainty data covering all steps of the measurement method while “analys.” indicates availability in the CEN standard of uncertainty data covering only the analytical step of the measurement method • AMS = Automatic Measuring System 									

Annex 2.2. Table of CEN standards for water emissions

	Water emission measurement	Sampling plan	Taking of sample	Transport Storage	Pre-treatment	Extraction	Analysis Quantification	Overall measurement report	U - data
1	Determination of chromium – Atomic absorption spectrometric method	GR1	GR2	GR3			EN 1233 (1996)		analysis
2	Determination of Mercury	GR1	GR2	GR3			EN 1483: (1997)		analysis
3	Determination of adsorbable organically bound halogens (AOX)	GR1	GR2	GR3			EN 1485 (1996)		analysis
4	Determination of cadmium by atomic absorption spectrometry	GR1	GR2	GR3			EN 5961 (1995)		analysis
5	Determination of certain organochlorine insecticides, polychlorinated biphenils and chlorobenzenes. Gas chromatographic method after liquid-liquid extraction	GR1	GR2	GR3			EN ISO 6468 (1996)		For some elements on analysis
6	Determination of highly volatile halogenated hydrocarbons by GC	GR1	GR2	GR3			EN 10301 (1997)		analysis
7	Gas chromatographic determination of some selected chlorophenols	GR1	GR2	GR3			EN 12673 (1997)		analysis
8	Determination of selected plant treatment agents – HPLC method with UV detection after solid extraction	GR1	GR2	GR3			EN 11369 (1997)		analysis
9	Detection of selected organic nitrogen and phosphorus compounds by GC	GR1	GR2	GR3			EN ISO 10695 (2000)		
10	Determination of parathion, parathion-methyl and some other organophosphorus compounds in water by dichloromethane extraction and gas chromatography	GR1	GR2	GR3			EN 12918 (1999)		
11	Determination of arsenic – Atomic absorption spectrometric method (hybrid technique)	GR1	GR2	GR3			EN 11969 (1996)		analysis
12	Determination of mercury - Enrichment methods by amalgamation	GR1	GR2	GR3			EN 12338 (1998)		analysis
13	Determination of total arsenic – Silver diethylthiocarbamate spectrophotometry	GR1	GR2	GR3			EN 26595 (1992)		
14	Determination of the inhibition of the mobility of Daphnia magna Straus – acute toxicity test	GR1	GR2	GR3			EN 6341 (1999)		
15	Determination of nitrite – Molecular absorption spectrophotometry	GR1	GR2	GR3			EN 26777 (1993)		analysis
16	Determination of phosphorus – Ammonium molybdate spectrometric method	GR1	GR2	GR3			EN 1189 (1996)		analysis
17	anionic surfactants	GR1	GR2	GR3			EN 903 (1993)		
18	Determination of dissolved oxygen – iodometric method	GR1	GR2	GR3			EN 25813 (1992)		
19	Determination of dissolved oxygen – Electrochemical probe method	GR1	GR2	GR3			EN 25814 (1992)		
20	Guideline for the determination of Total Organic Carbon (TOC) and Dissolved Organic Carbon (DOC)	GR1	GR2	GR3			EN 1484 (1997)		analysis
21	Evaluation in an aqueous medium of the "ultimate" aerobic biodegradability of organic compounds – Carbon dioxide evolution test	GR1	GR2	GR3			EN ISO 9439 (2000)		
22	Evaluation in an aqueous medium of the "ultimate" aerobic biodegradability of organic compounds – Static test (Zahn Wellens method)	GR1	GR2	GR3			EN ISO 9888 (1993)		

	<u>Water emission measurement</u>	Sampling plan	Taking of sample	Transport Storage	Pre-treatment	Extraction	Analysis Quantification	Overall measurement report	U - data
23	Evaluation in an aqueous medium of the "ultimate" aerobic biodegradability of organic compounds – Oxygen demand in closed respirometer	GR1	GR2	GR3			EN ISO 9408 (1993)		
24	Detection and enumeration of the spores of sulphite reducing anaerobes (clostridia) Part 1 by enrichment in a liquid medium, Part 2 by membrane filtration	GR1	GR2	GR3			EN 26461-1 EN 26461-2 (1993)		
25	Fresh water algal growth inhibition test <i>Scenedesmus subspicatus</i> and <i>Selenastrum capricornutum</i>	GR1	GR2	GR3			EN 28692 (1993)		
26	Evaluation of the aerobic biodegradability of organics compounds in aqueous medium – Semi-continuous activated sludge method SCAS	GR1	GR2	GR3			EN ISO 9887 (1994)		
27	Examination and determination of colour	GR1	GR2	GR3			EN ISO 7887 (1994)		
28	Determination of electrical conductivity	GR1	GR2	GR3			EN 27888 (1993)		
29	Determination of turbidity	GR1	GR2	GR3			EN ISO 27027 (1999)		
30	Evaluation in an aqueous medium of the "ultimate" aerobic biodegradability of organic compounds – DOC method	GR1	GR2	GR3			EN ISO 7827 (1995)		
31	Marine algal growth inhibition test with <i>Skeletonema costatum</i> and <i>Pheodactylum tricornutum</i>	GR1	GR2	GR3			EN ISO 10253 (1998)		analysis
32	Guidance for the preparation and treatment of poorly water-soluble organic compounds for the subsequent evaluation of their biodegradability in an aqueous medium	GR1	GR2	GR3	EN ISO 10634 (1995)				
33	Determination of dissolved fluoride, chloride, nitrite, orthophosphate, bromide, nitrate and sulphate ions, using liquid IC – Part 1 for low water contamination	GR1	GR2	GR3			EN ISO 10304-1 (1995)		analysis
34	bacteria toxicity (<i>Pseudomonas</i>)	GR1	GR2	GR3			EN ISO 10712 (1995)		
35	Determination of permanganate index	GR1	GR2	GR3			EN ISO 8467 (1995)		analysis
36	Determination of alkalinity – Part 1 Total and composite alkalinity – Part 2 carbonate alkalinity	GR1	GR2	GR3			EN ISO 9963-1 EN ISO 9963-2 (1995)		
37	Determination of biochemical oxygen demand after n days (BOD _n) – Part 1 Dilution and seeding method with allylthiourea addition – Part 2 method for undiluted samples	GR1	GR2	GR3			EN 1899 (1998)		analysis
38	Determination of nitrogen - Determination of bound nitrogen, after combustion and oxidation to nitrogen dioxide, using chemiluminescence	GR1	GR2	GR3			ENV 12260 (1996)		analysis
39	intestinal enterococci	GR1	GR2	GR3			EN ISO 7899-1 (1998)		
40	odour, flavour	GR1	GR2	GR3			EN 1622 (1997)		
41	Determination of the inhibitory effect of water samples on the light emission of luminescent bacteria – Part 1 using freshly prepared bacteria, Part 2 using liquid-dried bacteria, Part 3 using freeze-dried bacteria	GR1	GR2	GR3			EN ISO 11348-1 11348-2 11348-3 (1998)		
42	Determination of Kjeldahl nitrogen – Method after mineralisation with selenium	GR1	GR2	GR3			EN 25663 (1993)		

	Water emission measurement	Sampling plan	Taking of sample	Transport Storage	Pre-treatment	Extraction	Analysis Quantification	Overall measurement report	U - data
43	Test for the inhibition of oxygen consumption by activated sludge	GR1	GR2	GR3			EN ISO 8192 (1995)		
44	Assessment of inhibition of nitrification of activated sludge micro-organisms by chemicals and waste water	GR1	GR2	GR3			EN ISO 9509 (1995)		
45	Determination of suspended solids – Method by filtration through glass fibre filters	GR1	GR2	GR3			EN 872 (1996)		analysis
46	Determination of the acute lethal toxicity of substances to a freshwater fish - Part 1 Static method, Part 2 Semi-static method, Part 3 Flow-through method	GR1	GR2	GR3			EN ISO 7346: (1998)		
47	Determination of dissolved anions by liquid IC – Part 2 bromide, chloride, nitrate nitrite, orthophosphate and sulphate in waste water	GR1	GR2	GR3			EN ISO 10304-2 (1996)		analysis
48	Determination of dissolved anions by liquid IC – Part 3 chromate, iodide, sulphite, thiocyanate and thiosulphate	GR1	GR2	GR3			EN ISO 10304-3 (1997)		analysis
49	Determination of ammonium nitrogen by flow analysis (CFA and FIA) and spectrometric detection	GR1	GR2	GR3			EN ISO 11732 (1997)		analysis
50	Determination of nitrite nitrogen and nitrate nitrogen by flow analysis (CFA and FIA) and spectrometry	GR1	GR2	GR3			EN ISO 13395 (1996)		analysis
51	Escherichia.coli	GR1	GR2	GR3			EN ISO 9308-3 (1998)		
52	Evaluation in an aqueous medium of the "ultimate" aerobic biodegradability of organic compounds – Method by measurement of the biogas	GR1	GR2	GR3			EN ISO 11734 (1998)		
53	Evaluation of the elimination and biodegradability of organic compounds in an aqueous medium - Activated sludge simulation test	GR1	GR2	GR3			EN ISO 11733 (1998)		
54	Evaluation in an aqueous medium of the "ultimate" aerobic biodegradability of organic compounds – Analysis of BOD (closed bottle test)	GR1	GR2	GR3			EN ISO 10707 (1997)		
55	Determination of 33 elements by Inductively Coupled Plasma atomic emission spectroscopy ICP-OES	GR1	GR2	GR3			EN ISO 11885 (1997)		analysis
56	Enumeration of culturable micro-organisms – Colony count by inoculation in a nutrient agar culture medium	GR1	GR2	GR3			EN ISO 6222 (1999)		
57	Detection and enumeration of Escherichia Coli and coliform bacteria – Part 1 Membrane filtration method	GR1	GR2	GR3			EN ISO 9308-1 (2000)		
58	Detection of Salmonella species	GR1	GR2	GR3			prEN ISO 6340		
59	Faecal streptococci	GR1	GR2	GR3			prEN ISO 7899-2		
60	Biol. Classification (2 parts)	GR1	GR2	GR3			prEN ISO 8689		
61	Guidance for the surveying of aquatic macrophytes in running waters	GR1	GR2	GR3			prEN 14184		
62	Determination of mercury by atomic fluorescence	GR1	GR2	GR3			EN 13506 (2001)		
63	Digestion for the determination of selected elements in water Part 1 Aqua regia digestion Part 2 Nitric acid digestion	GR1	GR2	GR3			EN ISO 15587-1 15587-2 (2002)		
64	Determination of selenium – Part 1 AFS hybride method, Part 2 AAS hybride method	GR1	GR2	GR3			WI 230-161 WI 230-162		

	<u>Water emission measurement</u>	Sampling plan	Taking of sample	Transport Storage	Pre-treatment	Extraction	Analysis Quantification	Overall measurement report	U - data
65	Determination of dissolved anions by liquid IC – Part 4 chlorate, chloride, chlorite in water with low contamination	GR1	GR2	GR3			EN ISO 10304-4 (1999)		analysis
66	Determination of phenol index by flow analysis (FIA and CFA)	GR1	GR2	GR3			EN ISO14402 (1999)		analysis
67	Determination of total cyanide and free cyanide by continuous flow analysis (CFA)	GR1	GR2	GR3			EN ISO 14403 (2002)		
68	Determination of dissolved bromate by liquid IC	GR1	GR2	GR3			EN ISO 15061 (2001)		analysis
69	Detection of human enteroviruses by monolayer plaque assay	GR1	GR2	GR3			prEN 14486		
70	Determination of hydrocarbon oil index – Part 2 Method using solvent extraction and gas chromatography	GR1	GR2	GR3			EN ISO 9377-2 (2000)		analysis
71	Determination of antimony – Part 1 AFS hybride method, Part 2 AAS hybride method	GR1	GR2	GR3			WI 230-143 WI 230-144		
72	Determination of chloride by flow analysis (CFA et FIA) and photometric or potentiometric detection	GR1	GR2	GR3			EN ISO 15682 (2001)		analysis
73	Determination of 15 polynuclear aromatic hydrocarbons (PAH) in water by HPLC with fluorescence detection	GR1	GR2	GR3			prEN ISO 17993		
74	Determination of trace elements by AAS with graphite furnace	GR1	GR2	GR3			prEN ISO 15586		
75	Determination of methylene blue index by flow analysis (FIA and CFA)	GR1	GR2	GR3			WI 230-157		
76	Determination of selected organotin compounds	GR1	GR2	GR3			WI 230-158		
77	Determination of six complexing agents by gas chromatography	GR1	GR2	GR3			WI 230-159		
78	Determination of epichlorohydrin	GR1	GR2	GR3			prEN 1407		
79	Determination of selenium – Part 1 AFS hybride method, Part 2 AAS hybride method	GR1	GR2	GR3			WI 230-141 WI 230-142		
80	Determination of thallium	GR1	GR2	GR3			WI 230-133		
81	Determination of free chlorine and total chlorine – Part 1 Titrimetric method using N, N-diethyl-1,4-phenylenediamine	GR1	GR2	GR3			EN ISO 7393-1 (2000)		
82	Determination of free chlorine and total chlorine – Part 2 Colorimetric method using N, N-diethyl-1,4-phenylenediamine, for routine control	GR1	GR2	GR3			EN ISO 7393-2 (2000)		
83	Determination of free chlorine and total chlorine – Part 3 Iodometric titration method for the determination of total chlorine	GR1	GR2	GR3			EN ISO 7393-3 (2000)		
84	Determination of aluminium - Atomic absorption spectrometric methods	GR1	GR2	GR3			EN ISO 12020 (2000)		
85	Determination of orthophosphate and total phosphorus contents by flow analysis – Part 1 by FIA and Part 2 by CFA	GR1	GR2	GR3			prEN ISO 15681-1 15681-2		
86	Application of Inductively Coupled Plasma Mass Spectrometry – Part 1 General guidelines – Part 2 Determination of 61 elements	GR1	GR2	GR3			prEN ISO 17294-1 17294-2		
87	Determination of Chromium (VI)	GR1	GR2	GR3			WI 230-179		

	Water emission measurement	Sampling plan	Taking of sample	Transport Storage	Pre-treatment	Extraction	Analysis Quantification	Overall measurement report	U - data	
88	Dalapon and selected halogenated acetic acids	GR1	GR2	GR3			WI 230-180			
89	Determination of selected nitrophenols – Method by solid phase extraction and gas chromatography with mass spectrometric detection	GR1	GR2	GR3			EN ISO 17495 (2001)			
90	Determination of selected phthalates by gas chromatography/mass spectrometry	GR1	GR2	GR3			WI 230-187			
91	Criteria for the equivalence of microbiological methods	WI 230-168								
92	General requirements for competence of testing and calibration laboratories	EN ISO/IEC 17025 (2000)								
93	Guide to analytical quality control for water analysis	ENV ISO / TR 13530 (1998)								
94	GUM = Guide to the expression of uncertainty (1995) published by BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML	ENV 13005 (2000)								
Notes										
<ol style="list-style-type: none"> 1. Unless otherwise specified in the title, all standards apply only to water emission measurement 2. At the date of this document EN and ENV are published (the year of publication is indicated in brackets) 3. prEN are draft standards publicly available but subject to significant or editorial changes in the course of adoption by CEN 4. WI denotes a standard under preparation subject to adoption-publication later on 5. U- data column is dedicated to Uncertainty data available in the standard(s): “whole measur.” indicates availability in the CEN standard of uncertainty data covering all steps of the measurement method while “analysis.” indicates availability in the CEN standard of uncertainty data covering only the analytical step of the measurement method 6. (GR) indicates that the quoted documents provides General Recommendations as opposed to unambiguous requirements: <ul style="list-style-type: none"> • GR1 = EN ISO 5667-1 (1980/1996) Water sampling – Part1 Guidance on the design of sampling programmes • GR2 = EN ISO 5667-10 (1992) Water sampling – Part 10 Guidance on sampling waste water • GR3 = EN ISO 5667-3 (1994) Water sampling – Part 3 Guidance on the preservation and handling of samples 										
Symbols										
AAS = atomic adsorption spectroscopy AFS = atomic fluorescence spectroscopy AOX = adsorbable organically bound organics BOD = biochemical oxygen demand CFA = continuous flow analysis DOC = dissolved organic carbon FIA = flow injection analysis GC = gas chromatography HPLC = high performance liquid chromatography IC = ion chromatography ICP = inductively coupled plasma MS = mass spectrometry TOC = total organic carbon										

Annex 2.3. Table of CEN standards for solid residues

	Solid residues measurements	Sampling plan	Taking of sample	Transport Storage	Pre-treatment	Extraction	Analysis Quantification	Overall measurement report	U - data
1	Elements leached from granular waste material and sludge in a one stage batch compliance leaching test at 1/s of 2 l/kg with particle size below 4 mm (without or with size reduction)	GR4				prEN 12457-1	prEN 12506(*) prEN 13370(**)	prEN 12457-1	Whole measur. Except sampling
2	Elements leached from granular waste material and sludge in a one stage batch compliance leaching test at a 1/s of 10 l/kg with particle size below 4 mm (without or with size reduction)	GR4				prEN 12457-2	prEN 12506(*) prEN 13370(**)	prEN 12457-2	Whole measur. Except sampling
3	Elements leached from granular waste material and sludge in a two stage batch compliance leaching test at a 1/s of 2 l/kg and 8 l/kg with particle size below 4 mm (without or with size reduction)	GR4				prEN 12457-3	prEN 12506(*) prEN 13370(**)	prEN 12457-3	Whole measur. Except sampling
4	Elements leached from granular waste material and sludge in a one stage batch compliance leaching test at a 1/s of 10 l/kg with particle size below 10 mm (without or with limited size reduction)	GR4				prEN 12457-4	prEN 12506(*) prEN 13370(**)	prEN 12457-4	Whole measur. Except sampling
5	Elements leached from monolithic waste material in a three stages batch compliance leaching test	GR4				WI 292-010 and WI 292-031 for monolithic character	prEN 12506(*) prEN 13370(**)		
6	Methodology guideline for the determination of the leaching behaviour of waste under specified conditions	ENV 12920 (1998)							
7	Elements leached from granular waste material in a batch leaching test depending on pH with initial acid/base addition	GR4				prEN 14429	prEN 12506(*) prEN 13370(**)		
8	Elements leached from granular waste material in a batch leaching test depending on pH continuously adjusted	GR4				WI 292-033	prEN 12506(*) prEN 13370(**)		
9	Waste composition: Elements content in waste by microwave assisted digestion with hydrofluoric (HF), nitric (HNO ₃) and hydrochloric (HCl) acid mixture	GR4				prEN 13656			
10	Waste composition: Elements content in waste by digestion for subsequent determination of aqua regia soluble portion	GR4				prEN 13657			
11	Waste composition: Determination of total organic carbon	GR4				PrEN 13137			
12	Waste composition: Determination of hydrocarbons (C ₁₀ to C ₃₉) by gas chromatography	GR4				prEN 14039			
13	Waste composition: Determination of hydrocarbons by gravimetry	GR4				prEN 14345			
14	Waste composition: Determination of halogen and sulphur content by oxygen combustion in closed system	GR4				WI 292-007			

	Solid residues measurements	Sampling plan	Taking of sample	Transport Storage	Pre-treatment	Extraction	Analysis Quantification	Overall measurement report	U - data
15	Waste composition: Determination of dry residue and water content	GR4				prEN 14346			
16	Waste composition: Technical report on the determination of Cr (VI)	GR4					WI 292-036		
17	Waste composition: Determination of chromium (VI)	GR4					WI 292-037		
18	Determination of elemental waste composition by X-ray fluorescence	GR4					WI 292-038		
19	Determination of loss on ignition in waste, sludge and sediment	GR4					WI 292-039		
20	Preparation of waste samples using alkali-fusion techniques	GR4			WI 292-042				
21	Waste composition: Determination of Polychlorinated Biphenyls (PCB)	GR4				WI 292-021			
22	Elements leached from monolithic waste material in a dynamic leaching test under scenario related conditions	GR4			WI 292-040		prEN 12506 ^(*) prEN 13370 ^(**)		
23	Elements leached from granular waste material in a leaching test with up-flow percolation under conventional conditions	GR4			prEN14405		prEN 12506 ^(*) prEN 13370 ^(**)		
24	Elements leached from granular waste material in a leaching test with percolation under scenario related conditions	GR4			WI 292-035		prEN 12506 ^(*) prEN 13370 ^(**)		
25	Acid and base neutralisation capacity	GR4			WI 292-xxx				
26	Ecotoxicity of waste	GR4			WI 292-027				
27	General requirements for competence of testing and calibration laboratories	EN ISO/IEC 17025 (2000)							
28	Guide to analytical quality control for water analysis	ENV ISO / TR 13530 (1998)							
29	GUM = Guide to the expression of uncertainty (1995) published by BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML	ENV 13005 (2000)							
Notes									
<ol style="list-style-type: none"> Unless otherwise specified in the title, all standards apply only to solid residues measurements At the date of this document EN and ENV are published (the year of publication is indicated in brackets) prEN are draft standards publicly available but subject to significant or editorial changes in the course of adoption by CEN WI denotes a standard under preparation subject to adoption-publication later on U- data column is dedicated to Uncertainty data available in the standard(s): "whole measur." indicates availability in the CEN standard of uncertainty data covering all steps of the measurement method while "analys." indicates availability in the CEN standard of uncertainty data covering only the analytical step of the measurement method (GR) indicates that the quoted documents provides General Recommendations as opposed to unambiguous requirements: <ul style="list-style-type: none"> GR4 = WI 292-001 Waste sampling - Framework for preparation of a sampling plan. 									
(*) = Determination of pH, As, Cd, Cr Cr ^(VI) , Cu, Ni, Pb, Zn, Cl, NO ₂ , SO ₄									
(**) = Determination of ammonium-(NH ₄), AOX, conductivity, Hg, phenol index, TOC, CN _{easy liberable} , F									

Annex 2.4. Table of CEN standards for sludge

	Sludge measurements	Sampling plan	Taking of sample	Transport Storage	Pre-treatment	Extraction	Analysis Quantification	Overall measurement report	U - data	
1	Determination of pH-value of sludge	GR1	GR5	GR6			EN 12176 (1998)			
2	Determination of calorific value	GR1	GR5	GR6	WI 308-38					
3	Determination of AOX	GR1	GR5	GR6	WI 308-047					
4	Determination of the loss on ignition of dry mass	GR1	GR5	GR6	EN 12879 (2000)					
5	Determination of dry residue and water content	GR1	GR5	GR6	EN 12880 (2000)					
6	Determination of Kjeldhal Nitrogen	GR1	GR5	GR6			EN 13342 (2000)			
7	Determination of trace elements and phosphorus – Aqua regia extraction methods	GR1	GR5	GR6	EN 13346 (2000)					
8	Determination of total phosphorus	GR1	GR5	GR6			WI 308-034			
9	Determination of ammoniac nitrogen	GR1	GR5	GR6			WI 308-012			
10	Determination of PCB	GR1	GR5	GR6			WI 308-046			
11	Determination of total organic carbon (TOC) in waste, sludge and sediment	GR1	GR5	GR6			EN 13137 (2001)			
12	Good practice for sludge utilisation in agriculture	CR 13097 (2001)								
13	Good practice for sludge incineration with or without grease and screenings	CR 13767 (2001)								
14	Good practice for combined incineration of sludge and household wastes	CR 13768 (2001)								
15	Recommendations to preserve and extend sludge utilisation and disposal route	CR 13846 (2000)								
16	Good practice for sludge utilisation in land reclamation	prTR 13983								
17	Good practice for sludge drying	WI 308-045								
18	Good practice for the landfill of sludge and sludge treatment residue	WI 308-044								
19	Technical report on physical consistency and centrifugability of sludge	GR1	GR5	GR6	WI 308-035					
20	Determination of compressibility	GR1	GR5	GR6	WI 308-041					
21	Determination of physical consistency	GR1	GR5	GR6	WI 308-042					
22	Determination of centrifugability	GR1	GR5	GR6	WI 308-043					
23	Determination of capillary suction time (CST)	GR1	GR5	GR6	WI 308-037					
24	Determination of settlability / thickenability	GR1	GR5	GR6	WI 308-039					
25	Determination of specific resistance to filtration	GR1	GR5	GR6	WI 308-040					

	Sludge measurements	Sampling plan	Taking of sample	Transport Storage	Pre-treatment	Extraction	Analysis Quantification	Overall measurement report	U - data
26	Determination of laboratory chemical conditioning procedure	GR1	GR5	GR6	WI 308-036				
27	Detection and enumeration of Escherichia coli I sludge	GR1	GR5	GR6			WI 308-048		
28	Detection and enumeration of Salmonella in sludge	GR1	GR5	GR6			WI 308-049		
29	Utilisation and disposal of sludge - Vocabulary	GR1	GR5	GR6			EN 12832 (1999)		
30	General requirements for competence of testing and calibration laboratories	EN ISO/IEC 17025 (2000)							
31	Guide to analytical quality control for water analysis	ENV ISO / TR 13530 (1998)							
32	GUM = Guide to the expression of uncertainty (1995) published by BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML	ENV 13005 (2000)							
Notes									
<p>1. Unless otherwise specified in the title, all standards apply only to measurements on sludges</p> <p>2. At the date of this document EN and ENV are published (the year of publication is indicated in brackets)</p> <p>3. prEN are draft standards publicly available but subject to significant or editorial changes in the course of adoption by CEN</p> <p>4. WI denotes a standard under preparation subject to adoption-publication later on</p> <p>5. U- data column is dedicated to Uncertainty data available in the standard(s): "whole measur." indicates availability in the CEN standard of uncertainty data covering all steps of the measurement method while "analys." indicates availability in the CEN standard of uncertainty data covering only the analytical step of the measurement method</p> <p>6. (GR) indicates that the quoted documents provides General Recommendations as opposed to unambiguous requirements:</p> <ul style="list-style-type: none"> • GR1 = EN ISO 5667-1 (1980/1996) Water sampling – Part1 Guidance on the design of sampling programmes • GR5 = EN ISO 5667-13 (1998) Water sampling – Part 13 Guidance on sampling of sewage, waterworks and related sludge • GR6 = EN ISO 5667-15 (1999) Water sampling – Part 15 Guidance on sampling of sludges from sewage and water-treatment works 									

ANNEX 3. COMMON UNITS, MEASUREMENT AND SYMBOLS

TERM	MEANING
ACkWh	Kilowatt-hours (alternating current)
atm	Normal atmosphere (1 atm = 101325 N/m ²)
bar	Bar (1.013 bar = 1 atm)
barg	Bar gauge (bar + 1 atm)
billion	Thousand million (10 ⁹)
°C	Degree Celsius
cgs	Centimetre, gram, second. A system of measurements now largely replaced by SI.
cm	Centimetre
cSt	Centistokes = 10 ⁻² stokes (See St, below)
d	Day
g	Gram
GJ	Gigajoule
h	Hour
ha	Hectare (10 ⁴ m ²) (=2.47105 acres)
J	Joule
K	Kelvin (0 °C = 273.15 K)
kA	Kiloamp(ere)
kcal	Kilocalorie (1 kcal = 4.19 kJ)
kg	Kilogram (1 kg = 1000 g)
kJ	Kilojoule (1 kJ = 0.24 kcal)
kPa	Kilopascal
kt	Kilotonne
kWh	Kilowatt-hour (1 kWh = 3600 kJ = 3.6 MJ)
l	Litre
m	Metre
m ²	Square metre
m ³	Cubic metre
mg	Milligram (1 mg = 10 ⁻³ gram)
MJ	Megajoule (1 MJ = 1000 kJ = 10 ⁶ joule)
mm	Millimetre (1 mm = 10 ⁻³ m)
m/min	Metres per minute
mmWG	Millimetre water gauge
Mt	Megatonne (1 Mt = 10 ⁶ tonne)
Mt/yr	Megatonnes per year
mV	Millivolts
MW _e	Megawatts electric (energy)
MW _{th}	Megawatts thermal (energy)
ng	Nanogram (1 ng = 10 ⁻⁹ gram)
Nm ³	Normal cubic metre (101.3 kPa, 273 K)
ppb	Parts per billion
ppm	Parts per million (by weight)
ppmv	Parts per million (by volume)
s	Second
sq ft	Square foot (= 0.092 m ²)
St	Stokes. An old, cgs unit of kinematic viscosity. 1 St = 10 ⁻⁶ m ² /s

TERM	MEANING
t	Tonne, metric (1000 kg or 10 ⁶ gram)
t/d	Tonnes per day
trillion	Million million (10 ¹²)
t/yr	Tonne(s) per year
V	Volt
vol-%	Percentage by volume. (Also % v/v)
W	Watt (1 W = 1 J/s)
wt-%	Percentage by weight. (Also % w/w)
yr	Year
~	Around, more or less
ΔT	Increase of temperature
μm	Micrometre (1 μm = 10 ⁻⁶ m)
Ω	Ohm, unit of electrical resistance
Ω cm	Ohm centimetre, unit of specific resistance
% v/v	Percentage by volume. (Also vol-%)
% w/w	Percentage by weight. (Also wt-%)

SI UNIT PREFIXES

Symbol	Prefix	Term	Number
Y	yotta	10 ²⁴	1 000 000 000 000 000 000 000 000
Z	zeta	10 ²¹	1 000 000 000 000 000 000 000
E	exa	10 ¹⁸	1 000 000 000 000 000 000
P	peta	10 ¹⁵	1 000 000 000 000 000
T	tera	10 ¹²	1 000 000 000 000
G	giga	10 ⁹	1 000 000 000
M	mega	10 ⁶	1 000 000
k	kilo	10 ³	1000
h	hecto	10 ²	100
da	deca	10 ¹	10
-----	-----	1 unit	1
d	deci	10 ⁻¹	0.1
c	centi	10 ⁻²	0.01
m	milli	10 ⁻³	0.001
μ	micro	10 ⁻⁶	0.000 001
n	nano	10 ⁻⁹	0.000 000 001
p	pico	10 ⁻¹²	0.000 000 000 001
f	femto	10 ⁻¹⁵	0.000 000 000 000 001
a	atto	10 ⁻¹⁸	0.000 000 000 000 000 001
z	zepto	10 ⁻²¹	0.000 000 000 000 000 000 001
y	yocto	10 ⁻²⁴	0.000 000 000 000 000 000 000 001

ANNEX 4. EXAMPLES OF DIFFERENT APPROACHES TO VALUES UNDER THE LIMIT OF DETECTION (LOD)

The following two examples show the differences in results when using the different approaches listed in Section 3.3.

To recap, these approaches are:

1. the absolute measurement value is used in the calculations
2. the limit of detection is used in the calculations
3. half of the limit of detection is used in the calculations (or, possibly, another predefined fraction)
4. the percentage method, i.e. the following estimation is used in the calculations:
Estimation = (100 %-A)*LOD,
where A = the percentage of samples below the LOD
5. zero is used in the calculations.

In 'Example 1' there are 2 groups of figures, and in 'Example 2' there are 4 groups of figures, each group has a different number of samples below the LOD.

In each group of figures:

- column 1 is the flow (Q)
- column 2 is the concentration (c)
- column 3 is the load when using choice 3 (i.e. half of the LOD)
- column 4 is the load when using choice 5 (i.e. zero)
- column 5 is the load when using choice 4 (i.e. the percentage method).

In Example 1, the LOD is 20.

Example 1									
Q	C	1/2 det.lim. load	<det.lim=0 load	% meth. load	Q	c	1/2 det.lim. load	<det.lim=0 load	% meth. load
2035	<20	20350	0	16280	2035	26	52910	52910	52910
2304	<20	23040	0	18432	2304	<20	23040	0	32256
1809	21	37989	37989	37989	1809	21	37989	37989	37989
1910	26	49660	49660	49660	1910	26	49960	49960	49960
2102	<20	21020	0	16816	2102	25	52550	52550	52550
1981	22	43582	43582	43582	1981	22	43582	43582	43582
2025	<20	20250	0	16200	2025	22	44550	44550	44550
1958	<20	19580	0	15664	1958	<20	19580	0	27412
1895	21	39795	39795	39795	1895	21	39795	39795	39975
2134	<20	21340	0	17072	2134	<20	21340	0	29876
SUM		296606	171026	271490	SUM		384996	321036	410580
4 of 10 above det.limit <20 = 8					7 of 10 above det.limit <20 = 14				

In Example 2, the LOD is 30.

Example 2									
Q	c	1/2 det.lim. load	<det.lim=0 load	% meth. load	Q	c	1/2 det.lim. load	<det.lim=0 load	% meth. load
10934	<30	164010	0	0	10934	<30	164010	0	218680
12374	<30	185610	0	0	12374	35	433090	433090	433090
10298	<30	154470	0	0	10298	31	319238	319238	319238
SUM		504090	0	0	SUM		916338	752328	971008
All below det.limit <30 = 0					2 of 3 above det.limit <30 =20				
Q	C	1/2 det.lim. load	<det.lim=0 load	% meth. load	Q	c	1/2 det.lim. load	<det.lim=0 load	% meth. load
10934	<30	164010	0	109340	10934	32	349888	349888	349888
12374	<30	185610	0	123740	12374	35	433090	433090	433090
10298	31	319238	319238	319238	10298	31	319238	319238	319238
SUM		668858	319238	552318	SUM		1102216	1102216	1102216
1 of 3 above det.limit <30 =10					all above det.limit				

ANNEX 5. EXAMPLES OF CONVERSION OF DATA TO STANDARD CONDITIONS

Two examples of the use of sampling data to characterise annual air emissions are presented below. In Example 1, the concentration of the compound is presented under the same conditions as the measured flow rate while, in Example 2 the concentration and flue gas flows are measured under different conditions.

1. *Example 1 - Concentration and Flow Rate Measured under the Same Conditions*

In this example the concentration of the compound is presented under the same conditions as the measured flow rate. The following data are known:

- the flue gas flow from a stack is calculated at 30 Nm³/s
- the measured concentration of cadmium in the flue gas is 0.01 mg/Nm³; and
- the stack operates 24 hours per day for 300 days per year.

First of all, the number of seconds per year the stack is emitting is determined:

$$\begin{aligned} \text{No seconds/year} &= (3600 \text{ s/h} \times 24 \text{ h/d}) \times (300 \text{ d/yr}) \\ &= 2.6 \times 10^7 \text{ seconds/year} \end{aligned}$$

Using these data the emission is derived from the following formula:

$$\begin{aligned} \text{Emission} &= ((0.01 \text{ mg/Nm}^3) \times (30 \text{ Nm}^3/\text{s}) \times (2.6 \times 10^7 \text{ s/yr})) / 10^6 \text{ mg/kg} \\ &= 7.8 \text{ kg of cadmium per year} \end{aligned}$$

2. *Example 2 - Concentration and Flow Rate Measured at Different Conditions*

Additional calculations are required in this example. The following data are known:

- the flue gas flow from a stack is measured at 100 m³/s
- the measured concentration of cadmium in the flue is 0.01 mg/Nm³
- the stack operates 24 hours per day for 300 days per year; and
- the conditions at the stack tip are approximately 150 °C and 1 atm.

Using the actual stack data, the 'actual' flue gas flow can be converted to a normalised flow using a ratio of temperatures. Note however that the temperatures must be presented using the absolute temperature scale of Kelvin (i.e. 0 °C = 273 K).

The conversion is then performed as follows (noting that the actual stack conditions are 150 + 273 = 423 K):

$$\text{Flue gas (Nm}^3/\text{sec)} = 100 \text{ m}^3/\text{s} \times (273/423) = 64.5 \text{ Nm}^3/\text{s}$$

The emission rate is then derived using the same methodology as outlined in Example 1 as follows:

$$\begin{aligned} \text{Emission} &= ((0.01 \text{ mg/Nm}^3) \times (64.5 \text{ Nm}^3/\text{sc}) \times (2.6 \times 10^7 \text{ s/yr})) / 10^6 \text{ mg/kg} \\ &= 16.8 \text{ kg of cadmium per year} \end{aligned}$$

ANNEX 6. EXAMPLES OF ESTIMATING EMISSIONS TO THE ENVIRONMENT

Below are given two examples of applying methods detailed in Chapter 5 for estimating pollutant emissions to the environment. Example 1 shows the application of the Mass Balance method (see Section 5.3), and Example 2 shows the use of the calculation method (see Section 5.4).

Example 1 – Mass balance method

A process uses:

- 10000 tonnes of raw material A
- 5000 tonnes of raw material B
- 20000 tonnes of water.

to produce:

- 22000 tonnes of product
- 4000 tonnes of by-product annually.

This process is shown schematically in Figure A6.1.

What is the total amount of waste emitted from the process?

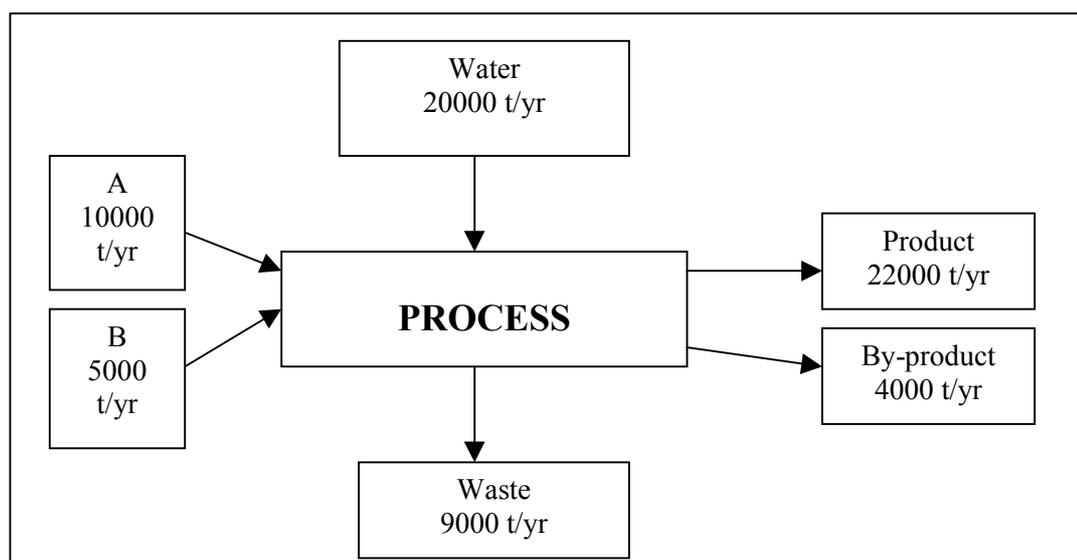


Figure A6.1: Mass balance process

The total amount of waste emitted from the process is calculated as a series of steps:

Step 1. Calculate total inputs to process

$$\begin{aligned}
 \text{Total inputs} &= \text{mass of A} + \text{mass of B} + \text{mass of water} \\
 &= 10000 + 5000 + 20000 \\
 &= 35000 \text{ tonnes}
 \end{aligned}$$

Step 2. Calculate total outputs from process

$$\begin{aligned}
 \text{Total outputs} &= \text{mass of product} + \text{mass of by-product} \\
 &= 22000 + 4000 \\
 &= 26000 \text{ tonnes}
 \end{aligned}$$

Step 3. Calculate total amount of waste produced

$$\begin{aligned}
 \text{Total quantity of waste produced} &= \text{mass of inputs} - \text{mass of outputs} \\
 &= 35000 - 26000 \\
 &= 9000 \text{ tonnes per year.}
 \end{aligned}$$

Step 4. Identify transfers and spills

The facility will need to identify these wastes. For example, of the 9000 tonnes per year of waste produced, 2800 tonnes may be collected and sent for off-site disposal, while approximately 6000 tonnes may be sent to an on-site water treatment facility prior to discharge to sewer. This would then indicate that 200 tonnes of waste have been released into the environment (in the present example, the release is to atmosphere but could also be, for example, a direct release to a water body). If the approximate proportions of substances A and B in the waste stream are known, the quantity of A and B released to the atmosphere may be determined.

It is important to note that account must be taken of any pertinent emission controls (e.g. the waste may be routed through an incinerator which destroys most or all of substances A and B before they are released to the atmosphere).

The general mass balance approach described above can also be applied to individual unit processes or pieces of equipment. This requires that information be available on the inputs (i.e. flow rates, concentrations, densities) and outputs of the unit process.

Example 2 – Calculation method

The application of this calculation method is shown in the following example, where SO₂ emissions can be calculated from the fuel combustion, based on fuel analysis results, and the known fuel flow of the engine.

This approach assumes complete conversion of sulphur to SO₂ and shows that for every kilogram of sulphur (EW = 32) burned, two kilograms of SO₂ (MW = 64) are emitted. To calculate the annual emissions of sulphur (E) some process data is needed:

$$\begin{aligned}
 \text{Fuel mass flow rate (Q)} &= 20900 \text{ kg/h} \\
 \text{Weight percent sulphur in fuel (C)} &= 1.17 \% \\
 \text{Molecular weight of sulphur dioxide (MW)} &= 64 \\
 \text{Elemental weight of sulphur (EW)} &= 32 \\
 \text{Operating hours(T)} &= 1500 \text{ h/yr}
 \end{aligned}$$

$$\begin{aligned}
 E &= Q \times C/100 \times (MW/EW) \times T \\
 &= (20900) \times (1.17/100) \times (64/32) \times 1500 \\
 &= 733590 \text{ kg/yr}
 \end{aligned}$$

ANNEX 7. COST EXAMPLES

This Annex presents examples of cost data. These data are given for information only and cannot be considered as fixed values for estimating total costs in other situations. They have not been checked extensively and as such they represent examples only, and their validity may be doubtful for practical purposes.

Costs are given in euros (€), or euros per year (€/yr).

A7.1. Examples from the chemical industry

The following examples were given by the Technical Working Group representative of the chemical industry (CEFIC) in November 2000. They are related to a typical commodity organic or inorganic production unit. Costs of the same order of magnitude could be obtained in oil, chemical and pharmaceutical facilities.

1. General costs of emission monitoring:

On a very general basis for petro-chemical commodities manufacturing activities, a very rough preliminary assessment can be made about the work load involved in monitoring:

- 100 samples per year for each 20 kt capacity of production
- 1 full time laboratory operator is needed for each 200 kt capacity of production, dedicated to the environmental monitoring program
- the yearly operational cost of an environmental laboratory is between 400 to 1000 k€/yr for a typical factory of 1000 personnel, depending on the type of activities and location of the factory
- each flux to be monitored requires a dedicated sampling line
- for routine measurements, each emitted substance (group of substances) requires dedicated sampling equipment and dedicated analytical equipment
- for non-automated analytical measurements, a laboratory operator could run 10 measurements/day
- all portable monitoring equipment require dedicated, trained and available operators
- any surrogate parameters require initial monitoring programmes to ensure the validity of the concept and periodic verification monitoring
- many analytical methods require accurate laboratory equipment and accessories (e.g. balances, detectors, fittings, bottles, etc.).

2. Typical cost examples of emission and environmental monitoring:

(a) Continuous monitoring equipment

Example of costs for an on-line analyser (e.g. GC-FID monitor for fixed area monitoring with 20 sampling lines):

investment cost	140 k€
operational cost:	2000 €/yr
spare parts	500 €/yr
example - GC-MS monitor	200 k€
example - SO _x /NO _x /HCl monitor	200 k€

(b) Conventional Environmental Parameters

Cost in € per sample analysed in laboratory

Waste water

Pretreatment	10 €
pH, alkalinity	15 €
COD, TOC	25 €
BOD5 according to ISO protocols	100 €
AOX	150 €
N Kjeldahl	150 €
NO ₂ , NO ₃	25 €
minerals (SO ₄ , PO ₄ ,...)	25 €
organic chromatograph routine FID	500 - 1500 €
heavy metals in large series	20 €
heavy metal individually with special methods	50 - 80 €

(c) Fugitive VOC Emission Monitoring

Example for 10000 components monitored, based on a 3 year frequency programme

database preparation	70 k€
portable organic analyser	10 k€
screening measurements on average:	10 €/point for the first inventory, 3 - 4 €/point for routine measurement

(d) Soil And Groudwater Monitoring

sampling piezometer for groundwater monitoring	2000 - 3000 €/well
sampling of groundwater in existing piezometer	150 €/sample
sub-soil sampling:	
▪ dedicated sample	1000 €/sample
▪ during the boring of a monitoring well	150 €/sample

(e) Monitoring Personnel Cost

day operator	30 k€/yr
shift operator	37 k€/yr
laboratory or maintenance skilled operator	35 €/h
external consultant	100 €/h

A7.2. Examples from the German delegation

The following examples were provided by the German delegation of the Monitoring Technical Working Group in April 2001. Indicative examples of cost figures are given here for monitoring air and water.

1. Examples of monitoring costs for air

The range of prices for monitors is between 10000 euros and 20000 euros per component. Examples of costs for calibration, surveillance tests and discontinuous measurements are listed in Table A7.1.

Measurement task	Costs in euros per operation	
	Calibration	Surveillance test
Calibration and surveillance tests		
- dust monitor	2500	700
- gaseous compounds	2100	600
- total Carbon (FID)	1600	800
- volume flow.	1600	650
Check of electronic evaluation system	1300	1000
Emission measurements: (3 half-hour values including measurement + report)		
- dust	1200	
- dust + 2 gaseous compounds.	1500	

Table A7.1: Costs for calibration, surveillance tests and discontinuous measurements

2. Examples of monitoring costs for water

In the following tables some examples of aggregated costs are given, to provide an idea of ranges of monitoring/inspection costs for water.

Table A7.2 shows the annual self-monitoring costs for 5 different sites.

Table A7.3. shows the annual cost of authority inspections for the same 5 sites.

Site	Parameters/frequencies***	Total costs per year (EUR)
1. Paper plant (production capacity 250000 t/year, 13000 m ³ /day waste water);	c: Temperature, volume flow d: COD, BOD, suspended solids, w: N (NH ₄ , NO ₂ , NO ₃ , P, Sulphate (Measurements at different points of different parts of the waste water treatment plant)	100000
2. Paper plant (production capacity 150000 t/year, 5000 m ³ /day waste water)	c: Temperature, volume flow d: COD, BOD, N, P, suspended solids m: AOX	55000
3. Chemical installation (production capacity (organic compounds) 65000 t/year, 12000 m ³ /day waste water, 22000m ³ /day cooling water);	c: pH, Temperature, volume flow, conductivity d: COD, TOC, N, P, Chloride, Bromide, Sulphate, Cr, Cu, Co w: BOD, Dioxins, org. solvents, toxicity (fish, algae), lumines- cent bacteria test, aerobic bio- degradability, AOX	200000
4. Chemical installation (production capacity (organic compounds) 65000 t/year, 12000 m ³ /day waste water, 22000m ³ /day cooling water)	c: pH, Temperature, volume flow, conductivity d: COD, TOC, N, P, Chloride, Ni, Zn w: Dioxins, org. solvents, AOX	170000
5. Production plant for semiconductors (1000 m ³ /day waste water from different surface treatment processes)	c: pH, Temperature, volume flow, conductivity b: suspended solids, cyanide, sulphate, sulphide, Cu, Ni, Zn, Pb, Sn, Fe, BTX, fugitive halogenated hydro- carbons	120000
***b: per batch; c: continuously; d: daily; w: weekly; m: monthly		

Table A7.2: Annual costs of self-monitoring

Site	Parameters	Total costs per year (Euro)
1. Paper plant (production capacity 250000 t/year, 13000 m ³ /day waste water).	Suspended solids, COD, BOD, AOX, DTPA Sulphate, Nitrogen (NH ₄ , NO ₂ , NO ₃), Phosphate, Cr, Cu, Ni, Zn, Hg	4000
2. Paper plant (production capacity 150000 t/year, 5000 m ³ /day waste water).	Suspended solids, COD, BOD, AOX, N, P, Cr, Cu, Ni, Zn, Pb	2000
3. Chemical installation (production capacity (organic compounds) 65000 t/year, 12000 m ³ /day waste water, 22000m ³ /day cooling water).	pH, Temperature, volume flow, conductivity, suspended solids, COD, TOC, BOD, N, P, Chloride, Bromide, Sulphate, Cr, Cu, Co, Ni, Zn, Dioxins, org. solvents, toxicity (fish, algae), luminescent bacteria test, aerobic biodegradability, AOX	7000
4. Chemical installation (production capacity (organic compounds) 65000 t/year, 12000 m ³ /day waste water, 22000m ³ /day cooling water).	pH, Temperature, volume flow, conductivity, suspended solids, COD, TOC, N, P, Chloride, Ni, Zn, Dioxins, org. solvents, AOX, toxicity (fish)	6000
5. Production plant for semiconductors (1000 m ³ /day waste water from different surface treatment processes)	pH, Temperature, volume flow, conductivity, suspended solids, cyanide, sulphate, sulphide, Cu, Ni, Zn, Pb, Sn, Fe, BTX, fugitive halogenated hydrocarbons	7000

Table A7.3: Costs of monitoring/inspection programme carried out by the authority (4 – 6 times per year)