TECHNICAL GUIDE ON ENVIRONMENTAL SELF-MONITORING in countries of Eastern Europe, Caucasus, and Central Asia

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FOREWORD

The region of Eastern Europe, Caucasus, and Central Asia (EECCA) faces the challenge of engaging stakeholders to make environment protection a shared responsibility. Requiring industry to monitor its environmental performance and report environmental compliance data to public authorities is one of the approaches that could help countries to achieve this goal, and to promote environmentally-sound behaviour among industrial operators. Reliable self-monitoring is essential to ensure the integrity of data for decision-making. This enables scarce government resources available for inspection to be applied only where they are most needed. Besides, this policy instrument fosters transparency and public access to environmental information; and it can help demonstrate the existence of an "environmental level playing field" for industry.

The current Guide proposes benchmarks that can be used for the long-term development of self-monitoring systems in EECCA. The Guide can be used to improve the reliability of environmental information in EECCA countries thus ensuring the robustness of decision-making. The Guide focuses on general considerations of self-monitoring, and of emissions monitoring; operations and impact monitoring are discussed only in general terms. While the Guide's recommendations are based on good international practice, it is important to remember that it is a reference document with a consultative status only. Transposing these recommendations into national law requires careful assessment in terms of feasibility and sequencing of actions.

The Guide was developed in the context of the EAP Task Force work programme. Assisting transition economies to create conditions for efficient implementation of environmental policy is the core objective of the EAP Task Force Policy Programme. In this area, the role of the Task Force focuses on facilitating access to best practices and efficient environmental management tools, as well as their implementation, including carrying out pilot projects in individual EECCA countries.

The EAP Task Force is an intergovernmental body that aims to facilitate reform of environmental management systems in the EECCA region. It brings together policy makers from EECCA, Central Europe, and donor countries, as well as international institutions and other stakeholders. The Task Force was established at the 1993 "Environment for Europe" Ministerial Conference in Lucerne, Switzerland. The secretariat is provided by the OECD Environment Directorate's Environment and Globalisation Division.

The Guide complements two other publications of the EAP Task Force: the "Integrated Environmental Permitting Guidelines" and the "Toolkit for Better Environmental Inspectorates". Also, it may be used in conjunction with the UNECE "Guidelines on Enterprise Monitoring and Reporting in EECCA". The Guide's recommendations on policy reform draw on experience gained in Kazakhstan as part of an EAP Task Force demonstration project.

In addition to the materials developed by the OECD Secretariat as part of its work on Good Laboratory Practice and Pollutant Release and Transfer Registers, several legal and guidance documents from OECD member countries were used extensively to develop this Guide:

- European Union (EU) documents: the "Directive on Integrated Pollution Prevention and Control", the "Reference document for Best Available Techniques on Monitoring", and other technical documents of the IMPEL Network;

- Experience from individual members of the EU, including Finland, Estonia, Ireland, Norway, and the UK;

- North American experience: mainly that of Environment Canada and the US Environment Protection Agency;

- Documents available through the International Network for Environmental Compliance and Enforcement.

The Guide was compiled by Angela Bularga of the OECD/EAP Task Force Secretariat with substantive support from Aare Sirendi. Several experts contributed to the development of this Guide, including (in alphabetical order): Tatiana Guseva, Russia; Andrey Korchevsky, Kazakhstan; Hans-Roland Lindgren, Sweden; and Marianne Lindstrom, Finland. Financial support for developing the Guide was provided by the Netherlands and Norway.

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ACRONYMS

BAT	Best Available Techniques
BOD	Biochemical oxygen demand
BREF	BAT Reference Document
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	Chemical oxygen demand
CEN	European Committee for Standardisation
ELV	Emission Limit Value
EMAS	Environmental Management and Audit Scheme
EPER	European Polluting Emissions Register
EU	European Union
GLP	Good Laboratory Practice
H_2S	Hydrogen sulphide
HCl	Hydrochloric acid, hydrogen chloride
IEC	International Electrotechnical Commission
IMPEL	EU's network for the implementation of environmental law
INECE	International Network for Environmental Compliance and Enforcement
IPPC	Integrated Pollution Prevention and Control
ISO	International Organisation for Standardisation
NH_3	Ammonia
NO_x	Oxides of nitrogen
OECD	Organisation for Economic Co-operation and

	Development
PM	Particulate matter
PRTR	Pollutant Release and Transfer Register.
QA	Quality assessment
QC	Quality control
scm	Standard cubic metre
SO_2	Sulphur dioxide
SO_x	Oxides of sulphur
TKN	Total Kjeldahl Nitrogen
TOC	Total organic carbon
TRI	Toxics Release Inventory
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNITAR	United Nations Institute for Training and Research
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compounds including methane (CH4)

CHAPTER 1:
A BLUEPRINT FOR SELF-MONITORING REFORMS

Environmental self-monitoring by industrial operators (also known as "enterprise monitoring and reporting") is an important element of environmental management in EECCA and worldwide. In some EECCA countries, this instrument has a long history of use by the largest industries: the oldest enterprises established self-monitoring programmes in the mid-1970s. The design of self-monitoring in EECCA has many elements that correspond to good international practice, but some of its weaknesses[1] and its poor link to the new economic and social context largely diminish its potential benefits. This chapter outlines the main directions for reform and the ways to manage the transition towards an improved system.

Main directions for reform in EECCA

Within a comprehensive reform of self-monitoring, the EECCA countries should aim, first of all, at enhancing the quality and use of self-monitoring data for decision-making. To this end, a number of obsolete characteristics of self-monitoring should be addressed.

First of all, the resource-intensity of self-monitoring for both industry and the regulator has to reflect a new economic and social reality. In this regard, the competent authorities of EECCA will need to start considering the costs of data production and reporting while defining self-monitoring requirements. Adequate scope and frequency of self-monitoring should be defined based on robust, simple, and transparent prioritisation techniques. The competent authorities should allow for a combined use of various types of monitoring and industries should not be expected to carry out all-encompassing direct monitoring. Various organisational forms of self-monitoring should be allowed to better suit the resources available to particular categories of enterprises.

[1] See "Translating Environmental Law into Practice: Progress in Modernising Environmental Regulation and Compliance Assurance in EECCA" (OECD, 2007).

Whenever possible, constructive dialogue needs to be established between the authorities and the regulatees in order to clarify and strengthen the industry's motivation to adequately perform self-monitoring. Enforceability and feasibility of permit requirements should be a mandatory pre-condition for effective and efficient self-monitoring.

An important challenge will be to tie the reform of self-monitoring with permitting reforms. Mirroring the necessity for permitting reforms, a differentiated scope of self-monitoring needs to be introduced for large industries and small and medium-sized industries (SMEs); for the latter, self-monitoring requirements could be part of general binding rules. In the same vein, competent authorities need to allow for a longer validity of self-monitoring programmes, with the possibility to amend them when necessary. The introduction of post-closure requirements is also necessary.

Data management and, especially, analysis need to be improved to ensure optimal policy and operational decisions. Currently, several factors affect the quality of self-monitoring data, including the poor development of laboratory facilities and their methodical support, data processing deficiencies, and personnel training. The way forward is to create reference laboratories and analytical centres, participating in the international inter-calibration, training, and certification of personnel. Adequate information systems employing modern technologies, including e-reporting, would be another element to put in place in a longer-term perspective. This will enable better public access to data.

The ministries of environment in EECCA will need to adjust the existing legal basis to reflect the elements that make up the foundation for the functioning of self-monitoring. Institutional changes are also required. This does not necessarily mean structural changes. Focus should be put on co-ordinating the work of relevant competent authorities through internal procedures of decision-making in order to reduce administrative burdens on industry.

Management of the transition

A transition period (seven to eight years) should be envisaged for improving self-monitoring systems, with the adoption of an intermediate model that will facilitate the step-by-step achievement of feasible objectives and bring the system closer to international

practices. This will need to be fully co-ordinated with the process of implementation of requirements under the Kiev Protocol on Pollutant Release and Transfer Registers (PRTR).

Improving the legal basis[2]

In the short term (one year), the ministries of environment could propose amendments to the existing legal basis in order to strengthen the foundations of self-monitoring. In this context, the definition of self-monitoring and other basic concepts (Box 1), as well as elements and forms of self-monitoring will need to be clarified, the differentiated approach towards large industry and small and medium-sized enterprises enacted, and the powers of the competent authorities stipulated more precisely.

Box 1. Clarifying basic concepts

Within the reform of self-monitoring, several key terms need to be legally defined:

"Installation" – a stationary technical unit where one or more activities are carried out on the same site and that could have a negative environmental impact;

"Measuring" – a set of operations to determine the value of a parameter implying that an individual quantitative result is obtained;

"Monitoring" – a systematic surveillance of the variations of a certain chemical or physical characteristic of an emission, discharge, consumption, equivalent parameter, or technical measures, etc.

"Operator" – a natural or legal person who is the owner or the manager of the regulated installation and has the authority and ability to ensure compliance with the permit.

The Administrative and Penal Codes will also need to be amended to strengthen sanctions against any falsification of data. In the long term, these Codes will have to be completed with articles that permit use of active condoning of insignificant violations that are self-reported by enterprises.

[2] See also the paper ECE/MP.PP/AC.1/2005/6 developed by the UNECE on institutional and legal implementation of the PRTR protocol, http://www.unece.org/env/documents/2005/pp/ece/ac.1/ece.mp.pp.ac.1.2005.6.e.doc

Good laboratory practice and other process-relevant requirements need to be mandated in secondary legislation. The quality of legal amendments will need to be monitored intensively, based on feedback from practice during a period of two to three years, with a view to further improving the legal basis, if necessary.

The development and approval of a thematic law may be envisaged, but only through a wide stakeholder consultation process. In this context, the ministries of environment need to understand that directly mandating self-monitoring and determining its elements in great detail may restrict future developments in the field concerned. It also can be a serious impediment for correcting the design of this system, if the primary legislation is not exact or is misleading. However, legal requirements of direct application may be more easily enforceable and have a stronger impact on compliance behaviour than requirements imposed through secondary legislation.

An important task is to link the reform of self-monitoring with the reform of permitting and introduction of differentiated requirements for large industry and other members of the regulated community.

Addressing institutional issues

As a matter of immediate priority, the competent authorities should strengthen communication and co-operation between its departments and other sub-divisions that contribute to the reform and functioning of self-monitoring. Focus should be put on developing procedures of data sharing and joint decision-making, including:

- Co-ordination of any plans to develop secondary legislation and guidance for industry to conduct self-control;
- Joint review of permit requirements;
- Immediate feedback from inspection to permit-writers;
- Establishment of a database on compliance history of facilities (including permit-related documents, reports from site visits, reports from the facility, etc.) that would be accessible to all government stakeholders and easy to use;
- Regular and *ad-hoc* co-ordination meetings.

In order to facilitate the work of regulators and inspectors, the competent authorities might develop general and sector-specific technical guidance that would describe the mandatory and desirable elements of self-monitoring within a branch. This could be based on the Annexes to the current Guide. Such guidance should be widely available and disseminated through all means.

Training will be necessary for various stakeholders to better understand the design of modern self-monitoring systems. A training course could be included in the programme delivered by specialised training centres.

Establishing a powerful information system to share data reported by operators and make them available to the general public can greatly contribute towards increasing the value added of self-monitoring. This should be done within the framework of implementation of the Kiev protocol on PRTRs. Also the competent authorities may want to adopt electronic reporting within the framework of the e-government introduction.

Improving laboratory infrastructure and practice

The competent authorities will need to promote and support the creation of reference laboratories and analytical centres, and their participation in the international inter-calibration, training, and certification of personnel. This could include the improvement of both the existing laboratories and the technical skills available within competent authorities, and at the same time, the development of independent private laboratories, this often being a more cost-effective approach. In the latter case, a legal right to sub-contract sampling and laboratory analysis should be given to both competent authorities and regulatees. In conjunction with this reform, a more rigorous verification of laboratory practices will be necessary.

It will be important to review and develop the capacity to monitor pollutants that are specified in international agreements. International experience should be used to improve laboratory practices and techniques. In this context, a very helpful tool is the OECD's Resource Centre for PRTR Release Estimation Techniques. The Resource Centre is an Internet site that has been developed by the Task Force on PRTRs of the OECD's Environment, Health, and Safety Programme. The purpose of the site is to provide a clearing house of guidance manuals/documents about release estimation techniques for

the principal pollutant release and transfer registries developed by OECD member countries. The manuals and documents include descriptive information on the sources of pollution and the pollutants that are released, as well as information on emission factors, mass balance methods, engineering calculations, and monitoring information. The Resource Centre[3] will be updated on a regular basis.

Implementing facility-specific pilot projects

Pilot projects can be a useful tool to assess, among other things, the benefits and costs of implementation of self-control, in particular as part of the transition to integrated permitting. Such pilot projects can be recommended particularly for large new investments where enterprises have sufficient capacity. Criteria for selecting installations for such pilot projects include, most importantly, the environmental impact, compliance costs, and financial performance.

[3] See http://206.191.48.253/

CHAPTER 2:
CRITICAL ELEMENTS OF SELF-MONITORING[4]

Definition of "environmental self-monitoring"

Based on international practice, "environmental self-monitoring" can be defined as the system of organisational and technical measures put in place and financed by regulatees subject to environmental permitting or general binding rules, in order to ensure their compliance with regulatory requirements, including:

- Monitoring of: (i) operations; (ii) emissions and other impacts regulated by permits or general binding rules; (iii) ambient conditions in the vicinity of the facility concerned with a scope that would optimally balance environmental effectiveness with costs of monitoring;

- Record keeping of data obtained through monitoring of any unforeseen circumstances, non-compliance episodes, corrective measures, and complaints from the general public;

- Providing reports to the competent authorities – in mandated cases – with a specified regularity, and in a duly aggregate form;

- Other internal measures, such as providing basic environmental training and conducting self-inspection.

The operator will regularly compare self-monitoring data with the compliance objectives and environmental objectives and targets set by the industry to check whether they are being met. This self-diagnostic element will be complemented by self-correction actions.

[4] See also the UNECE Guidelines on Enterprise Environmental Monitoring and Reporting.

Benefits of environmental self-monitoring

Despite a mandatory character that differentiates self-monitoring from voluntary environmental management systems[5], this instrument combines public and private interests. Its primary goal is to ensure the earliest possible response to any environmental problem occurring because of malfunctions in production processes and, at the same time, reduce public spending on governmental compliance monitoring. Self-monitoring data can provide a basis for verification of compliance with legal requirements and enforcement, and for calculation of environmental or administrative charges. They also help to optimise national, regional, and local ambient monitoring systems, and establish priorities for inspection.

For the regulated community, reliable data on emissions, and the environmental impact of their production, can be significant from an economic viewpoint. For example, such data can help to better identify and reduce environment-related costs (that can be as high as 30 per cent of operational costs in some branches), and minimise environmental liabilities. Disclosure of facility-specific data and their comparison between enterprises within the same industrial sector, or with international benchmarks, can further indicate where cost-savings are possible. Furthermore, access to other companies' facility-specific data can build trust within industries that the government is targeting to ensure a level playing field.

Disclosure of facility-specific data can help citizens to take individual decisions that affect not only their health but also economic well-being, such as where to buy property. In EECCA, the social relevance of self-monitoring is growing due to higher public access to environmental information, in particular in light of the eventual establishment of the national Pollutant Release and Transfer Register (PRTR) following the ratification of the 2003 Kiev Protocol to the Aarhus Convention (Box 2).

[5] In the future, it is likely that these instruments will converge even more than presently.

Box 2. Introduction to Pollutant Release and Transfer Registers (PRTRs)

PRTRs are inventories of pollution from industrial sites and other sources. The PRTR should be based on a reporting scheme that is mandatory, annual, multimedia (air, water, and land), facility-specific, pollutant-specific for releases, and pollutant-specific or waste-specific for transfers. The Protocol requires each party to establish a PRTR which:

- Is publicly accessible through Internet, free of charge;
- Is searchable according to separate parameters (facility, pollutant, location, medium, etc.);
- Is user-friendly in its structure and provides links to other relevant registers;
- Presents standardised, timely data on a structured, computerised database;
- Covers releases and transfers of at least 86 pollutants covered by the Protocol, such as greenhouse gases, acid rain pollutants, ozone-depleting substances, heavy metals, and certain carcinogens, such as dioxins;
- Covers releases and transfers from certain types of major point sources (*e.g.* thermal power stations, mining and metallurgical industries, chemical plants, waste and waste-water treatment plants, paper and timber industries);
- Accommodates available data on releases from diffuse sources (*e.g.* transport and agriculture);
- Has limited confidentiality provisions;
- Allows for public participation in its development and modification.

Source: www.unece.org/env/pp/prtr.ng.htm

While there are many other benefits of self-monitoring, they will be harnessed only if its results are actually used by stakeholders within decision-making processes. Data collection for the sake of data will lead, most likely, to an erosion of the system's value.

Overall obligations of the operator

The operator must **develop a draft self-monitoring programme** and already include a proposal for such a programme in the permit application. The operator will allow appropriate time for the competent authorities to consider the proposed programme. The operator will

explain and justify the proposed elements of the programme. When needed, the operator will provide additional information to enable better decisions. Based on the quality of the programme, the competent authorities may either accept it or reject and require modifications. To magnify self-monitoring benefits, the competent authorities should encourage involvement of facility managers in the development and implementation of self-monitoring programmes.

As part of **programme's implementation**, the operator will have to:

- Conduct and document self-monitoring;
- Follow all procedural requirements, and perform quality control and quality assurance;
- Follow safety precautions;
- Commission monitoring to a third accredited party, when needed;
- Evaluate the performance of the methods of programme implementation;
- Provide inspectors with access to facility and data.

The operator must secure the necessary expertise, equipment, and analytical facilities to carry out the activities specified in the self-monitoring programme. This infrastructure may be owned by the operator or be sub-contracted. Combinations of these arrangements are allowed, for example, when the operator takes samples and has the analyses carried out by an external laboratory. In the EECCA region, in most cases it seems to be preferable to contract out to a specialised laboratory or even select one well-established operator laboratory and conduct analyses of several neighbouring enterprises there, *e.g.* based on sub-contracts.

The **analysis and reporting of results** will imply the following obligations:

- Evaluate results, including through a statistical analysis;
- Assess compliance by comparison of monitoring results with regulatory requirements;
- Report and explain results to the competent authority and the public.

The operator will submit self-monitoring data to the competent authority:

- Periodically, according to a predefined schedule;
- Immediately, when violations are discovered, in the case of any incident or accident that is causing or may cause significant pollution; and/or
- Upon the request of the competent authority.

Presently, good practice requires reporting to one government authority that will be responsible for circulating this information to other stakeholders ("one window" principle). The regulatee will submit the necessary number of hard copies (where this is the requirement) to the co-ordinating authority.

Besides analysis and reporting, the operator will have to **take actions for improvement** when self-monitoring data show non-compliance with regulatory requirements.

Adequate **staff training and shared responsibility between managers and the personnel for self-monitoring** will need to be ensured. Company management will need to carefully consider and use incentives that will induce environmentally responsible behaviour among staff, regardless of their position in the hierarchy.

Role of the competent authority

Self-monitoring is not meant to replace government supervision: it only provides additional information based on which the competent authorities can judge whether an operator is complying with relevant legislation and permit conditions. The competent authorities will be responsible for assessing, endorsing, and checking the correct implementation of the self-monitoring programmes. To this end, a number of powers are required (Box 3).

Box 3. Necessary government powers

Authority to require operators to perform self-monitoring according to an endorsed programme;

Authority to require additional monitoring;

Authority to gather additional information;

Authority to sample and analyse;

Access to data (reviewing/copying any documentation; ordering the Operator to copy documentation and send to the competent authority);

Access to the site for verification;

Authority to use submitted data and records as evidence in administrative and criminal cases.

The competent authorities will aim at conducting, whenever possible, constructive dialogue with the operator in order to define optimal requirements for self-monitoring and strengthen the motivation of operators to adequately perform self-monitoring. To enable effective and efficient self-monitoring, the competent authority will seek to establish compliance objectives, including permit conditions, that are specific, and technically and economically achievable.

Through a consensus building process, the competent authorities and the operator will ensure that the self-monitoring programmes generate adequate types and amounts of data at the minimum costs for the company and society as a whole. While imposing self-monitoring requirements, the competent authorities will consider the costs of data production, analysis, and reporting that will need to be demonstrated by the operators.

The monitoring approach to be adopted in a compliance monitoring programme may be chosen, proposed, or specified for use by the competent authority, the operators (usually a proposal that still needs approval by the authority), or an expert (usually an independent consultant who may propose on behalf of the operators, but this proposal still needs approval by the authority). The competent authority will be responsible for deciding whether the method is acceptable and will take into account if the method is suited to the original reason for monitoring, as shown, for example, by the limits and performance criteria for an installation, and availability of adequate facilities and expertise for the proposed method.

Self-monitoring does not change the duty of the competent authorities to assess compliance by means of inspection, and by using its own monitoring data. Observance of self-monitoring obligations will be subject of checks alongside with verification of compliance with other environmental regulatory requirements. The accuracy and reliability of self-monitoring systems will influence the frequency of inspection. In order to be consistent with cost-effectiveness requirements, less frequent inspections will be conducted at facilities with a history of compliance.

The competent authorities will regularly compare the results reported by different facilities in order to identify differences in compliance behaviour and ensure consistency across the regulated community, thus guaranteeing a level playing field.

The competent authorities will aim to ensure that neither the amount of information reported nor the frequency of reporting exceeds their ability to process and use the information. Where more than one governmental institution is involved in the administration of self-monitoring, co-ordination mechanisms will be established to decrease the administrative burden on all parties concerned.

Development of self-monitoring programmes: key stages

A self-monitoring programme will be designed proceeding from the need to obtain the most relevant information on the compliance status. Programme developers should aim at both the quality of the results and the cost-effectiveness of data collection, management, and analysis. Before self-monitoring begins, operators and authorities will develop a clear understanding of **why** the self-monitoring programme is necessary. The objectives will be documented at the start, and kept

under systematic review. Over time, the self-monitoring data will regularly be compared with the programme objectives to check that they are being met.

In addition to the understanding of data uses, the actual and potential users of self-monitoring data will also have to be identified. The objectives of self-monitoring will need to be made clear to, and discussed with, these users and to any third party involved, including external contractors.

A well-organised process of programme development will involve the following stages, which, after their completion, need to be reflected in the self-monitoring programme:

1. Specifying the aims of self-monitoring;
2. Stating the responsibilities;
3. Identifying the scope of self-monitoring;
4. Considering the general (direct or indirect) approach to the monitoring available for relevant needs and defining monitoring methods;
5. Specifying the technical details of a particular standard (or alternative) measurement method and the units of measurement;
6. Specifying the monitoring timing requirements of sampling and measurements;
7. Stating clearly the location where samples and measurements are to be taken;
8. Stating the operational conditions;
9. Addressing appropriate quality assurance and control requirements;
10. Clarifying the recording and reporting requirements, including the assessment and reporting of exceptional emissions;
11. Clearly stating the compliance assessment procedures and non-compliance response.

The considerations addressed at each stage of programme development 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.

Content of facility-specific self-monitoring programmes

A comprehensive self-monitoring programme should describe the following:

- Monitored parameters, sampling points, and measurement locations; safe means of access to sampling points;
- Timing considerations (period, duration, and frequency) of monitoring and measurements;
- Monitoring methods, including detection limits and sensibility of available measurement methods with regard to the emission limit values set in permits;
- Methods and frequency of record keeping, data analysis, and reporting;
- Compliance assessment procedures and internal procedures of self-correction (including the internal non-compliance response tools);
- Quality assurance and quality control arrangements;
- Actions in emergency situations;
- Internal measures to ensure environmental compliance, including allocation of environmental responsibilities to the facility's personnel at all levels, the system of internal audits (self-inspection), corrective actions, and staff training;
- Organisational measures to implement the programme.

Within the framework of environmental management systems, operators may want to establish self-monitoring programmes that go beyond regulatory requirements. For instance, this would be the case when the company wants to demonstrate its high environmental performance to international customers. The competent authorities will take these initiatives into account when defining inspection strategies but will not request companies to self-report these data.

Types of self-monitoring according to the category of installation

The following types of self-monitoring will be carried out:

- Operation (process) monitoring – the surveillance of the physical and chemical parameters (*e.g.* pressure, temperature, stream flow rate) of the technological process in order to confirm that the process performance is within the range appropriate for its correct design operation;

- Emissions monitoring – the surveillance of industrial emissions at source, *i.e.* monitoring of releases from the installation to the environment;

- Impact monitoring – the monitoring of pollutants levels within the environs of the plant and its area of influence, and the effects on ecosystems and public health.

Installations should be subject to different types and regimes of self-monitoring according to their category of risk. The risk posed by an enterprise will be defined based on several criteria, including the volume and toxicity of pollution, sensitivity of the receiving environment, and the compliance history.

The competent authorities will decide on the design of emissions and impact monitoring programmes. The design of operation monitoring will be defined by the operators themselves. Exceptions may apply for the monitoring of parameters that are crucial in calculating emissions indirectly or describe the conditions of emissions and impact monitoring. The competent authority may impose special terms for operation monitoring of purification or abatement equipment.

The competent authorities should not impose impact monitoring on all facilities or in all cases. It may be required in the following cases:

- At the design phase or during substantive changes;
- In the vicinity of sensitive ecosystems or human dwellings;
- After accidental spills;
- For “calibrating” express and bio-indication methods;
- When it is more cost-effective than emission monitoring.

The impact monitoring net and parameters will be discussed and agreed with other stakeholders, including the competent environment authorities, other government authorities, local public authorities, and representatives of the general public. The competent authorities should allow joint impact monitoring by several companies if their installations share the same area of impact.

In order to ensure the quality and integrity of impact monitoring, operators should sub-contract it to independent companies or research institutes. The latter should be required to prove their competence in impact monitoring.

In the case of SMEs, the competent authority will first focus on provision of technical guidance and assistance in establishing simple and easy to implement programmes of self-monitoring, including reporting of results. The SMEs will be encouraged to find, and to take the necessary actions to correct, problems before the problems develop into major environmental or human health issues. The competent authority will also need to develop environmental self-monitoring checklists in a number of areas, such as water, air, solid waste, and hazardous waste. These checklists will be published on the official websites of environmental ministries or other competent authorities.

Optimising costs of self-monitoring

Self-monitoring obligations arise from the Polluter Pays Principle (PPP), therefore their costs must be borne by the polluter. This does not mean, however, that benefits of self-monitoring should not be commensurate with its costs since these can sometimes be high. A self-monitoring programme will not have the desired positive impact if it results in significant capital and operational costs for the operator. Excessive costs, even occurring at a limited number of facilities, may lead to non-compliance and, possibly, fraud, thus undermining the whole system of compliance monitoring and environmental management in general through a cascade of false information and faulty policy decisions.

Given the above-mentioned facts, the assessment of costs of self-monitoring should be undertaken to reach an optimal balance between the scope and accuracy of self-monitoring and the associated costs. A general rule can guide the design of self-monitoring programmes: a **streamlined monitoring system that works well is better than a more elaborated system that does not work properly**. On the other hand, optimisation of costs should be undertaken without losing sight of the overall objectives of self-monitoring.

Costs associated with self-monitoring

In general, self-monitoring costs may comprise those associated with:

- Resources to design the system, including staff time, hiring of outside contractors, etc.;
- Design and construction of dedicated lines, control loops, wells, access hatches, sampling ports, etc.
- Laboratory and analytical costs, including personnel, buildings and rooms, separate storage of gases and reactants, calibration, maintenance, spare parts, initial training of operators, etc.
- Training of managers to promote effective use of information for planning and business development;

- Continuous staff training to run the self-monitoring programme;

- Sampling, including personnel time, containers (disposable or reusable vials, bottles, etc.), sampling equipment (pumps, samplers, cooling devices, etc.), data loggers, recorders, etc.

- Transport of samples (for instance in large units, a dedicated vehicle for sample collection and transport is needed);

- Treatment of samples, including pre-treatment, dividing, labelling, storage (under refrigerated conditions), disposal of samples, etc.

- Data processing, including software and data storage (*e.g.* laboratory information management system [LIMS]), assessment, review, data handling, etc.

- Distribution of data, 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;

- Modification of the monitoring system as necessary;

- Penalties for inadequate functioning of self-monitoring.

Possible actions to optimise costs

In order to improve the cost-effectiveness of the emission monitoring the following 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 only 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;

- Standardise data collection techniques, use (adapt to the needs) existing procedures and tools of data management and analysis;

- Consider whether data collection matches the capacity to respond to and capitalise on the information generated;

- 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.

Public review of self-monitoring programmes and data

Self-monitoring programmes should be available for review by the general public, electronically or in hard copy, from the competent authorities, or local public administration, where feasible. Information obtained through mandatory self-reporting should be made available to the general public. In the short term, this can be done upon request, while, with a longer-term perspective, such data will be available as part of the national PRTR. Furthermore, the PRTR could be completed with data on the compliance status of each facility and on government actions to ensure compliance and respond to non-compliance.

CHAPTER 3:
DESIGNING SELF-MONITORING PROGRAMMES FOR LARGE INDUSTRY

Scope and groups of parameters subject to self-monitoring

The programme will need to specify clearly and unambiguously the pollutants or parameters being monitored. Given the diversity of parameters that are likely to require monitoring, the competent authorities need to carefully consider which of them can serve the needs of both environmental and plant operation monitoring. This will increase the acceptance of environmental self-monitoring programmes and will demonstrate their usefulness to the operators.

Self-monitoring requirements will cover, but will not be limited to, the following groups of parameters:

- Raw material **inputs** (such as trace contaminants);
- The **operating conditions** (such as process temperature, pressure, and flow rate);
- Use of **raw materials** and **energy**;
- Controlled **emissions** of waste gases and airborne particles to air via chimney stacks;
- Controlled direct and indirect **discharges** of waste water[6];
- Controlled disposals of **solid waste** to landfill sites, as well as controlled disposals of solid and **liquid wastes**, including organics, to incinerators;

[6] It will be important to agree on the self-monitoring programme with the utility receiving waste waters.

- **Fugitive releases** to air, water, and land;

- Nuisance level of **noise, vibration, and odour**;

- **Process/plant conditions** that are relevant to the time when measurements are taken or that may affect releases, such as down-time of plant or percentage of plant utilisation (in comparison with design capacity);

- Operation and maintenance of **monitoring and other relevant equipment**;

- In certain instances, the quality of **receiving environments** such as ambient air, water bodies, soil surface and ground waters, and ecosystems.

Moreover, the operator can be requested to monitor **progress with the implementation of environmental programmes**[7]. This will help demonstrate that meaningful improvements were accomplished, and that the specific compliance targets were achieved in a timely, effective, and efficient manner.

Since self-monitoring must provide authorities with adequate information on the emissions and their variations in time, in exceptional cases the parameters to be monitored may exceed the parameters for which emission limit values are established (*i.e.* for large polluters, major industry situated near sensitive areas, or significant violators). When this is the case, the monitoring of additional parameters will primarily play an information function.

Parameters to be monitored, frequency of monitoring, types, methods, and organisational forms of self-monitoring may vary according to the risk that different categories of industrial facilities pose for the environment and human health, individually, or due to a high cumulative effect of multiple sources. Minimum criteria for parameters to be monitored will be established for key sectors. **Annex 1** provides some sector-specific guidance on parameters to be monitored. Some

[7] Environmental programmes are developed by existing major installations when the immediate achievement of compliance objectives is not feasible. To transform them into an effective tool, it is recommended that these programmes contain specific targets and timeframes. Responsibility for their implementation needs to be integrated into the day-to-day business activities of managers and staff.

of those parameters should be considered as a long-term target for EECCA countries rather than a matter for immediate application.

As mentioned above, the compliance history of an installation will influence the decision on the comprehensiveness of self-monitoring. This will be assessed based on the following criteria:

- Past history of significant non-compliance with emission limit values and other permit requirements;
- Past history of false or questionable self-monitoring results;
- Past history of incidents or accidents that led to substantial pollution.

Self-monitoring will be mandatory for all installations subject to environmental permitting. Also, the competent authority may order the operator to measure, calculate, or estimate emissions or pollutants that must be addressed and reported under the national Pollutant Release and Transfer Register. The obligation to conduct self-monitoring will apply regardless of ownership; uniform self-monitoring requirements will be established for public and private companies.

As part of the regulatory reform, it is recommended that EECCA countries introduce integrated permitting for large facilities with high impact on the environment and make self-monitoring part of the permit conditions. A simplified permitting scheme or a simple declaration of activity could be, in parallel, introduced for facilities with lower environmental impacts. In such cases, self-monitoring would be directly mandated in the legislation in the form of general binding rules.

It is highly important that the self-monitoring responsibilities of the operator are clearly stated in permits. The permit will indicate that the ultimate responsibility for the monitoring and its quality remains with the operator although the operators can use external contractors to undertake monitoring work on their behalf. Clarity about the relationship between the emission limit values (ELVs) and the self-monitoring programme is essential.

To meet feasibility requirements, it is useful if during the process of setting ELVs the competent authority considers carefully the availability of measurement methods. The limit setting process must 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.

The different types of ELVs, or equivalent parameters that may be used, include[8]:

- 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 per unit of production);
- Percentage capture of monitoring data (*i.e.* the minimum percentage of the monitoring data needed to make averages).

Duration and validity of self-monitoring programmes

The total duration of a self-monitoring programme should be linked to the operating life of a process when the timeframe(s) for any harmful effects is short compared to the operating life. When needed, the operator should be required to carry out an assessment before a process has begun operating, *e.g.* to establish baseline ambient concentrations. Operators or owners will sometimes be required to continue monitoring certain parameters after a process has ceased to operate if its harmful effects are more durable (*e.g.* monitoring of groundwater after closure of fuel depots, landfill sites, or nuclear installations). The post-operation self-monitoring should be decided based on the likelihood of such remote effects of specific processes.

[8] See also "Guidelines for Integrated Environmental Permitting in Countries of Eastern Europe, Caucasus, and Central Asia" (OECD, 2004).

In order to lower the administrative burdens, it is recommended that self-monitoring programmes be valid for the duration of process operation without substantial changes or for the period indicated in the permit, but not less than three years. It should be possible to review the content and conditions of these programmes as needed, *e.g.* in the case of permit review, new regulations being enacted, changed environmental conditions, or as part of non-compliance response. The regulatory framework should specify that changes to the programme can be initiated by the operator, the competent authority, or by a court order in response to citizens' actions.

Direct and indirect monitoring approaches

The self-monitoring programme will first identify and describe the general type of monitoring required, before giving technical details of particular methods. There are various approaches that can be taken to monitor a parameter, including direct measurements, surrogate parameters, mass balances, emission factors, and other calculations. When choosing one of these approaches for monitoring there must be a balance between the availability of the method, its reliability, level of confidence, costs, and the environmental benefits.

The self-monitoring programmes will use both direct (based on measurements) monitoring approaches, indirect (based on estimates) monitoring approaches, or, most often, a combination of different approaches. In principle, it is more straightforward, but not necessarily more accurate, to use direct measurements. In cases when direct measurements are complex, costly, and/or impractical, indirect approaches should be assessed to find the best option (Table 1).

Table 1. Overall characteristics of indirect methods of emission measurement

Monitoring technique	Definition	Advantages	Disadvantages	Examples
Surrogate parameters	Measurable or calculable quantities that can be closely related, directly or indirectly, to values obtained through conventional direct measurements of pollutants.	– Greater cost-effectiveness; – Reduced complexity; – Larger number of data	– The need for calibration against direct measurements; – May only be valid over part of the entire emissions range; – May not be valid for legal purposes.	Furnaces: calculation of the content of SO_2 .
Calculations	Estimations based on theoretical and complex equations, or models that use physical/chemical properties of the substance (*e.g.* vapour pressure) and mathematical relationships (*e.g.* ideal gas law).	– Usually provide a reasonably accurate estimate if the model is based on valid assumptions	– Require validation; – Scope should correspond to the case studied; – Require data that are reliable and specific to the conditions of the facility; – More time consuming and complex than application of emission factors.	Prediction of SO_2 emissions, metals, and other emissions based on the application conservation laws, if the fuel mass flow rate is available.
Emission factors	Numbers that can be multiplied by an activity rate or by throughput data from a facility (*e.g.* production output, water consumption, etc.).	– Emission factors are largely available (*e.g.* EPA 42, CORINAIR, UNICE, OECD) – Can be developed for a specific process to estimate emissions when a company has several sites with identical processes.	– Require accurate "activity data" (which may not be the case when facilities try to hide their performance in order to avoid their fiscal duties); – Need reviewing and prior approval by the authorities; – Not for all pollutants; – Not for all processes.	Emission of some specific organic substances in textile, or pulp and paper industries.

Source: European IPPC Bureau (2003)

The choice of approaches will be based on the following considerations:

- Fitness for purpose, *i.e.* is the method suited to the original reason for monitoring;

- Compliance with legal requirements, *i.e.* is the method in line with international and national legislation;

- Adequacy of facilities and expertise, *i.e.* is the available technical equipment and professional expertise of the staff adequate for the proposed method.

In each situation, the competent authorities will weigh the necessity for, and added value of, direct measurements against the possibility of simpler verification using indirect methods. Whenever direct measurements are not used, the relationship between the method used and the parameter of interest should be demonstrated and well documented.

When necessary, direct monitoring may be carried out by in-house staff and/or by external accredited laboratories. Preferably, operators of large installations should be able to carry out measurements themselves. It is recommended that authorities decide on the scope and methods of monitoring based on a combination of the sector-specific and individual risks of each facility.

Direct monitoring (measurements)

Commonly, pollution charges are calculated on the basis of self-monitoring data. If the self-monitoring programme does not require direct measurements, the emission factors are used to calculate the quarterly and yearly amounts of pollutants. As the theoretical calculation methods most often give the highest estimates, the operators may be interested in performing direct measurements themselves in order to reduce the pollution charges they have to pay.

Monitoring techniques for direct measurement (specific quantitative determination of the emitted compounds at the source) can be divided into two main categories: continuous and intermittent.

Continuous monitoring

Continuous monitoring involves an ongoing series of automatic measurements that provide data with a high time resolution (*e.g.* readings from rapid-response instruments). The data are often available in real time (*e.g.* as instrumental read-outs or electronic displays) and so are useful for short-term process control purposes. Besides, continuous monitoring provides data that are statistically more reliable. Two types of continuous monitoring techniques can be considered:

- **Fixed *in-situ* 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; and

- **Fixed on-line (or extractive) continuous reading instruments.** This type of instrumentation continuously extracts samples of the emission along a sampling line, transports 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 pre-treatment of the sample.

Continuous monitoring techniques may be relatively expensive compared to intermittent monitoring and the accuracy of on-line process analysers may be lower than periodic laboratory analyses. These techniques will be less necessary for very stable processes.

It will also not be considered as an option for some pollutants/situations if: (i) appropriate instruments for continuous monitoring have not yet been developed, or (ii) detection limits are too high to allow measurements without pre-concentration of samples (*i.e.* when samples must be accumulated over a period in order to be detectable). 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.

The competent authorities will follow some other criteria to decide on the use of continuous monitoring in specific cases, including:

- Whether continuous monitoring is a legal (national or international) requirement for a certain sector or type of installation;

- Whether local issues and environmental risk associated with the emissions prompt the use of continuous monitoring, *e.g.* is the plant a large polluter and does it gravely reduce local air quality and influence human health;

- The required level of uncertainty;

- Whether continuous monitoring is the most economical option (*e.g.* in the case where continuous monitoring is needed for process control);

- Capacity to provide a response whose rapidity is commensurate with the rapidity of data production, *e.g.* is a system in place to promptly act upon monitoring data;

- Likelihood of periodic upsets;

- Required precision in the determination of total loads;

- Public pressure to use continuous monitoring for ensuring higher public confidence.

Intermittent monitoring

Intermittent monitoring can be divided into four sub-categories:

- Intermittent periodic monitoring: This involves measurements made at regular intervals in order to cover a defined part of the operating time of a process. It may involve spot measurements made at regular intervals, analysis of samples accumulated over regular periods, or instrumental data obtained at regular intervals during operation of the process. The periods of monitoring should be specified in advance (*e.g.* in a permit or legislation) and designed to be representative of the total operation;

- **Intermittent response monitoring**: This involves measurements made in response to special events that are foreseeable but cannot be precisely scheduled (*e.g.* start-up and shut-down conditions, low and high utilisation conditions). The monitoring is done at irregular intervals. It is "routine" because the events to be measured can be anticipated but not their timing;

- **Intermittent reactive monitoring**: This involves measurements made in reaction to special events such as exceeding of limits, which cannot be foreseen. The work is therefore devised on an *ad-hoc* basis rather than specified in advance, and is done at irregular intervals. Because of the nature of this monitoring, it may not be possible to specify the measurement methods in advance;

- **Intermittent campaign monitoring**: This involves measurements made in response to a need or interest in obtaining more fundamental information than routine, day-by-day monitoring normally provides. The types of events that may trigger campaigns include evidence of epidemiological effects, and permit (license) applications for new processes where baseline monitoring is needed to aid assessments. Campaign monitoring usually involves measurements that are relatively detailed, extensive, and expensive, so that they cannot be justified on a regular basis. Examples are: sampling of dioxins in soil around incinerators; detailed specification of volatile organic compounds for odour or other investigations; studies to verify more conventional measurements and estimate uncertainties; eco-toxicological surveys; and fundamental research studies.

The campaign monitoring will be carried out in the following situations:

- 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.

The following techniques of intermittent monitoring can be considered:

- **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, which provides a spot result, which is representative only of the time at which the sample was taken;

- **Laboratory analysis of samples taken by fixed, *in-situ*, on-line samplers.** These samplers withdraw samples continuously and collect them individually in containers. 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;

- **Express analysis used for periodic campaigns.** In order to conduct express analysis, portable equipment is 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;

- **Check lists** of operation and maintenance of monitoring and other relevant equipment.

Direct measurements should be carried out in accordance with the standard methods indicated for intermittent or continuous measurements in the permit or the self-monitoring programme. If standardised measurement methods do not yet exist for certain parameters, measurements can be carried out where possible in accordance with the generally accepted measurement practice.

Approaches complementing or substituting direct measurements

Although specific quantitative determination of the emitted compounds at the source is more straightforward, direct measurements may not be appropriate when it implies a very high cost. Therefore in addition to direct measurement of emissions, several other approaches to monitoring can be used: surrogate parameters, calculations, and emission factors. In each situation the necessity for direct measurements will be weighed against the possibility of simpler verification using surrogate parameters.

Surrogate parameters

Surrogate parameters are measurable or calculable quantities that 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.

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. For example, when polluting substances in waste gas are in constant relation with each other, then continuous measurement of the leading component can be used as a surrogate for the rest of the pollutant substances.

The **advantages** of the use of surrogates may include:

- Cost savings, thus greater cost-effectiveness;
- Reduced complexity;
- Wider scope: more discharge points can be monitored using the same amount of resources, or less;
- Sometimes more accurate than direct values;
- Give an early warning of possible upset conditions or abnormal emissions;
- Less disruption to the process operation than direct measurements;
- Information from several 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.

The **disadvantages** of the use of surrogates may include:

- The needed for calibration against direct measurements;
- 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;

- May not be valid for legal purposes.

The surrogates may be divided into **three categories** on the basis of the strength of the relationship between the emission and surrogate. Using them in combinations may result in a stronger relationship and a stronger surrogate.

- **Quantitative surrogates**- these give a reliable quantitative picture of the emission and can be substituted for direct measurements. Examples of a quantitative surrogate are, the assessment of the total organic compounds instead of the individual organic compounds, particulate matter measurements to indicate emissions of some heavy metals;

- **Qualitative surrogates** – these give reliable qualitative information on 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 carbon monoxide (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.

- **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.

Table 2. Examples of installations using surrogates

Type of installation	Surrogate parameters
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).
Furnaces	1. Calculation of the content of SO2 (quantitative).
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).

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

- It is closely and consistently related to a required direct value;
- 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.

Toxicity parameters – a special group of surrogate parameters

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. These biological test methods are often used to obtain additional information to the information that can be gained from sum parameter measurements.

With toxicity tests it is possible to asses the possible hazardous character of waste water in an integrated manner and to asses all synergistic effects that 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.

Mass balances

Mass balance is an approach to monitoring that consists 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. Mass balances can be used for an estimation of the emissions to the environment from a site, process, or piece of equipment. They are especially useful when the input and output streams can be readily characterised, as is often the case for small processes and operations. 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 use of mass balances has the greatest potential when:

- The emissions are the same order of magnitude as process inputs or outputs;

- The amounts of the substance (input, output, transfer, accumulation) can be readily quantified over a defined period of time.

Estimating emissions by a mass balance is based on the following equation:

Total mass into process = accumulations +total mass out of process +uncertainties

In case of a site or process it can be said that input is equal to the sum of products (products and materials [*e.g.* by-products] exported from the facility), transfers (they 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.)

Inputs = products +transfers +accumulations +emissions +uncertainties

When using mass balances it must be taken into account that 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.

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 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.

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

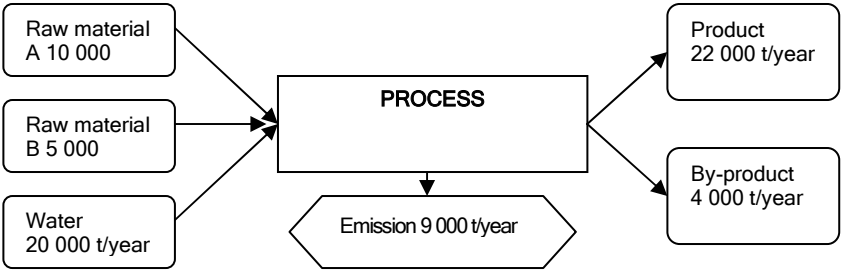
Based on the idea of mass balance, the input of substance is equal to the output, and the latter consists of the amount of substance in product, amount of substance in waste, amount of substance transformed or consumed in process, accumulation of substance, and emissions of substance. If there is a certain amount of substance that is generated in process it should be added to the input value.

The mass balance method can be applied for a whole facility or individual unit processes or pieces of equipment. This requires that information is available on the inputs (*i.e.* flow rates, concentrations, densities) and outputs of the unit process.

For example:

A process **uses**: 10 thousand tonnes (t) of raw material A;
5 thousand tonnes of raw material B;
20 thousand tonnes of water.

to produce: 22 thousand tonnes of product;
4 thousand tonnes of by-product annually.



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

Step 1. Calculate total input to process

Total inputs = mass of A + mass of B + mass of water
= 10 000 + 5 000 + 20 000 =35 000t/year

Step 2. Calculate total output from process

Total outputs = mass of product + mass of by-product
= 22 000 + 4 000 = 26 000t/year

Step 3. Calculate total amount of emissions (air, water, land) produced

Total emissions = mass of inputs – mass of outputs
= 35 000 – 26 000 = 9 000t/year

Step 4. Identify transfers and spills

The facility will need to identify all its emissions. For example, of the 9 000t/year of emissions, 2 800t of solid wastes may be collected and sent for off-site disposal, while approximately 6 000t of waste water may be sent to an on-site water treatment facility prior to discharge to a sewer. This would then indicate that 200t of emissions have been released into the environment (for example, to the atmosphere, as a direct release to a water body, etc.). It is important to note that account must be taken of any pertinent emissions controls.

Calculations

These are estimations based on theoretical and complex equations, or models that use physical/chemical properties of the substance (*e.g.* vapour pressure) and mathematical relationships (*e.g.* ideal gas law). They usually provide a reasonably accurate estimate if the model is based on valid assumptions. Examples of use are as follows: prediction of sulphur dioxide (SO_2) emissions, metals, and other emissions based on the application conservation laws, if the fuel mass flow rate is available.

For example, fuel analysis can be used to predict SO_2, metals, and other emissions based on the application of conservation laws, but the fuel mass flow rate must be available. Thus, the amount of sulphur dioxide emitted into air can be calculated by the following equation:

$$M_{SO2} = Q \times C/100 \times (64/32) \times t$$

Where:

M_{SO2} = Annual load of sulphur dioxide emitted (kg/yr)

Q = Fuel mass flow rate (kg/h)

C = Concentration of sulphur in fuel (wt%)

64 = Molecular weight of sulphur dioxide emitted (kg/kg-mole)

32 = Elemental weight of sulphur in fuel (kg/kg-mole)

τ = Operating hours (h/yr).

It should be taken into account that for most of the fuels the real emitted amount of SO_2 is smaller because the fly ash binds part of the sulphur (especially in case of solid fuels) and measurement is still necessary for determining the exact amount of the SO_2 emitted.

There are a number of disadvantages of using calculations:

- They require validation;
- Scope should correspond to the case studied;

- They require data that are reliable and specific to the conditions of the facility;

- More time consuming and complex than application of emission factors.

Emission factors

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 used 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 certain 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 energy content of the fuel fed into the boiler). In the absence of other information the literature values of emission factors 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 formula for calculation of emissions is the following:

Emission Rate = Emission Factor x Activity Data

(kg/h) (kg/kg production or fuel burned) (kg production or fuel burned/h)

Emission factors need reviewing and approving by authorities when used for emissions estimation. Emission factors can be obtained from European and American sources (USEPA method AP-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.

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.

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.

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.

Stating the units used for compliance monitoring

Besides parameters, units to be used for compliance monitoring purposes should be clearly stated, be internationally recognised, and match the relevant parameter, application and, context. The following types of units can be applied: (i) concentration units; (ii) units of load over time; (iii) specific units and emission factors; (iv) thermal effect units; (v) other emission value units; and (vi) normalised units. The definitions and examples of each category are given in Box 4.

Box 4. Definitions and examples of different categories of units

Concentration units: They are applied when ELVs aim at demonstrating the correctitude of performance of a process or an end-of-pipe abatement technology. Most frequently, they are expressed as mass per unit of volume (*e.g.*, mg/m^3, mg/l). ELVs, set in units of concentration, are often complemented with load units over time to prevent situations where operators meet ELVs thorough dilution. Concentration units are frequently associated with an averaging time, *e.g.* hourly or daily value.

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/day 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/year, 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.

Specific units and emission factors: These are 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 a unit of heat per unit of time (*e.g.* W, to assess the thermal effects in receiving waters).

Other emission value units: These can be 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.* m^3/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, with regard to 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. There is a difference between "normal" and "standard" conditions.

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 de Normalisation*); and match the relevant parameter, application, and context.

Determination of the timing requirements

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.

In general, the description of the ELV in the permit (in terms of, *e.g.*, total amount and peaks) is the basis for setting 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.

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;
- 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;

- The environmental objectives.

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.

Most commonly in permits, **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. This can be referred to as the averaging time of the monitoring equipment. For example, if one result was produced every 10 seconds the average over 24 hours is the mathematical average of 8640 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.

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 six to eight hours.

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; the emission for which the parameter has been used can then be monitored at a lower frequency.

The monitoring frequency should be matched to the time frames over which harmful effects or potentially harmful trends may occur. If harmful effects may occur due to short-term pollutant impacts, then it is best to monitor frequently. The monitoring frequency should be reviewed and if necessary revised as more information becomes available.

There are different types of approaches available for determining the frequency. Risk based approaches are commonly used for this purpose, although there are other possible procedures for determining the frequency, such as the Capability Index[9].

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.

Averaging time and the frequency depends on the type of process:

[9] **Process Capability Index:** the number of standard deviations between the process mean and the closest process specification limit divided by three, abbreviation Cpk. For example, if there are six standard deviations between the mean and the nearest specification limit the process Cpk is 2.0. Generally speaking a Cpk >1.3 is considered capable (four std deviations) and >2.0 is excellent.

- 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. The averaging time is also not so important since whatever time we choose (*e.g.* half-hour, one hour, 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.

- 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.

- 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 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.

- A **highly variable process**: Again, the 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 is likely to be necessary, since a lower frequency is likely to produce non-reliable results.

Criteria to set the regime of self-monitoring

The monitoring regimes are grouped as follows:

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

3. **Frequent** (once per week to once per day): 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 times per day): this is used when, for instance, unstable conditions are likely to lead to an exceedence 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.

Selection of the monitoring regime will be matched with the level of potential risk of environmental damage. Two major groups of criteria will be considered: (i) the likelihood of exceeding the ELVs or not being in compliance with any other requirement set in the permit(s) and legislation, and (ii) the consequences of non-compliance. The risk evaluation should take local conditions into consideration. The final assessment of likelihood or consequences should be based on the combination of all items, not on a single item.

Items to be considered when assessing the **likelihood of exceeding ELVs** include:

- Number of sources (on the site) contributing to pollution (single, several, or numerous);
- Stability of process conditions (stable or unstable);
- Buffer capacity of effluent treatment available (sufficient to cope with upsets, limited, or none);
- Treatment capacity of the source for excess emissions (able to cope with peaks, *e.g.* by dilution, oversize, spare treatment, limited or absent capabilities);
- Potential for mechanical failure caused by corrosion (no or limited corrosion, normal corrosion, covered by design, or advanced corrosion);
- Flexibility in product output (single dedicated production unit, limited number of grades, many grades of flexibility, multipurpose plant);
- 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 flow rate);
- Fluctuations in the composition of the effluent.

Criteria to be considered 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 installations (*e.g.* proximity to residential areas or specially protected areas);
- Dilution ratio in the receiving media;
- Meteorological conditions.

Dealing with uncertainties

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:

- External dispersion - this expresses how different ("reproducible") the results of different laboratories performing the considered measurement according to the applicable standard(s) are; and
- 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 a standard method of measurement.

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. Identification of the uncertainty sources can be useful to reduce the total uncertainty, this can be especially important in those cases where 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 and sample pre-treatment;
- 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 that may exist between results obtained with different applicable standard measurement methods for the same regulated parameter;

- Uncertainties due to the use of a 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 the uncertainty may have been experimentally determined by interlaboratory tests and then indicated in the standards.

Monitoring points

An unambiguous monitoring programme must clearly state the positions where samples and measurements are to be taken. These must match the positions where the limits are applied. The possibilities can be grouped into the following:

- **Source positions.** These are positions within or at the exit from a process: in a combustion chamber, before and after abatement equipment, within a flue or chimney stack for emissions to air, and at an outlet from an effluent pipe for waste water emissions;

- **Pathway positions.** These are positions in the receiving environments (*e.g.* air, water, soil) where the flow and dispersion require monitoring because they affect compliance

with ambient limits: in a river, for monitoring of river flow; in the air, for monitoring of atmospheric dispersion conditions.

- **Receptor positions.** These are the sensitive positions in receiving environments where pollutants after emission or impacts (such as noise or odour) from sources and dispersion along pathways are:

  – At a point of maximum ground-level concentration or deposition;

  – At a position occupied by the most exposed population;

  – Across a local ecosystem.

All sampling and monitoring points are to be identified and located on a scaled map, with clear indication of their National Grid References. The numbering/labelling format for sampling and monitoring points must be logical, simple, and sequential.

Use of the following system, where appropriate, is encouraged:

- Air emission points: A_1, A_2, …, A_N;
- Surface water monitoring points: SW_1, SW_2, …, SW_N;
- Sewage discharge monitoring points: SD_1, SD_2, …, SD_N;
- Noise monitoring points: N_1, N_2, …, N_N;
- Groundwater monitoring points: GW_1, GW_2, …, GW_N;
- Soil/ground monitoring points: SG_1, SG_2, …, SG_N;
- Waste monitoring points: W_1, W_2, …, W_N.

Ambient monitoring locations should be prefixed by the character I (impact monitoring). For example, ambient air monitoring locations will be labelled IA_1 to IA_N; groundwater locations will be labelled IGW_1 to IGW_N, etc.

CHAPTER 4:
DATA PRODUCTION CHAIN

General considerations

Guaranteeing the practical value of self-monitoring data requires that they acquire two essential features: reliability and comparability. Data reliability, or the degree of confidence that can be placed on the results, is a measure of the closeness of the data to their true value. It is important, among other things, to ensure the correctitude of decisions regarding process operation and update of self-monitoring, as well as non-compliance responses (including sanctions imposed by authorities). Comparability is a measure of the confidence with which one data set can be compared to another, *e.g.* as part of comparison among different installations or sectors. In order to allow a proper comparison of 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.

The production of reliable and comparable data presupposes the use of:

- Statistical concepts to design the self-monitoring programme;
- Standard sampling and analysis procedures, when available;
- Standard handling and shipping procedures for all samples;
- Thorough documentation of each and every step of the sampling and post-sampling process according to documented protocols;
- Consistent units when reporting the results;
- Skilled and continuously trained personnel;

- Data comparison with sampling results obtained by competent authorities during planned inspections;

- Participation in collaborative studies to ascertain accuracy and precision of the results and to ensure that results are comparable to those produced elsewhere;

- Regular self-inspection by a QA Officer of every aspect of the sampling programme and issuance of a QA/QC report on a periodic basis, usually quarterly or annually;

- Site-specific safety assurance protocols.

Furthermore, ensuring reliability and comparability of data requires following several consecutive steps, which form a so-called “data production chain”. At the same time, the data production chain should always be implemented as a single entirety. The chain consists of the following steps:

1. Flow measurement;

2. Sampling;

3. Storage, transport, and preservation of samples;

4. Sample treatment;

5. Sample analysis;

6. Data processing;

7. Recording and reporting of data.

The current chapter describes some general aspects of these key steps of data production.

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 the 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 case of air, waste water, and waste monitoring are presented in Section 7.

Step 1: Flow/volume measurement

Measurement of flow/volume is necessary in order to reflect complete spatial and timely coverage of the reported emissions. The accuracy of the flow/volume 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.

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

Step 2: Sampling

Sampling is the 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. 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 must be carried out according to relevant standards or agreed procedures.

Generally, sampling should comply with two major requirements:

- The sample must be **representative in time and space**. This means that when monitoring the releases from an industry, the sample should represent all that is discharged during the period of interest, for example, a working day (time representativeness). Equally, the sample should represent the whole amount being released from the emission source (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; and

- The sampling should be carried out with **no change in the composition** of the sample, or to an intended and more stable form. There are parameters 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.

For defining the sampling plan and interpreting the results, the following issues must be considered:

- 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. For new installations there is a need to design sampling points already during the construction;

- 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;

- The sampling **method** and/or **equipment**;
- The **type of sampling**, *e.g.* automatic (time or flow proportional), manual spot, etc.;
- The **type of sample**, *e.g.* a sample for a single or multiple parameters analysis;
- The **size of individual samples and bulking arrangements** to provide composite samples;
- The **personnel** in charge of taking the samples; they should have appropriate skills.

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. The sample numbering system must be designed to eliminate the possibility of a sample mix-up.

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:

- Method of sample collection;
- Date and time of sampling, and name of sampler;
- Sample preservation details (if applicable) or other sample treatment;
- Process relevant details;
- References to measurements made at the time when the sample was taken;
- Storage conditions;
- Time and condition of sample on receipt at laboratory.

Step 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 pre-treatment will generally be needed, *e.g.* fixation with chemicals or freezing. The method used should not affect the sample itself, nor the analysis of the sample. Any pre-treatment of the sample should be carried out according to the measurement programme. For waste water, this pre-treatment generally consists of keeping the sample in 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. For example, aiming at identification of heavy metals (total amount of each, regardless of forms of compounds), samples are to be acidified; for the identification of oil, to preserve samples, it is necessary to add CCl_4.

Regardless of which method is employed for sample transfer to the laboratory, several requirements need to be followed:

- Glass containers must never be packaged directly against each other, either within the same plastic bag or within the same transport container;

- The sample label should always be legible through the protective plastic bag;

- A copy of an investigative summary report or equivalent form should be included with the samples, protected in a plastic bag or sleeve;

- The laboratory director or a designee should be notified by telephone that the samples are being transported, the mode of transfer, and the expected arrival time.

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

Step 4: Sample treatment

Sample treatment includes operations in the laboratory prior to analysis such as dilution, concentration, pH adjustment, and adding of chemical reagents. Sample treatment should not affect the sample or

analysis. The treatment method is usually determined by the standard guideline. 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. If the method is not determined by the standard or a published guideline, it has to be documented in detail. 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 a 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 is 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.

All chemical reagents and preservatives must meet specifications identified in sampling methodology protocols. Where reagents must be

prepared or mixed, the detailed procedures for both the preparation and related quality control must be included in the written documentation for the procedure. Additionally, logs must be established and maintained that document the preparation of chemical reagents and preservatives, specifying:

- Supplier, grade, and batch number;
- If applicable, details as to drying, mixing, etc;
- Record of all laboratory operations performed and record of weights and volumes, plus all calculations;
- Identity of person who prepared the reagent or preservative.

A file of certificates for standard chemicals purchased from commercial suppliers must be kept.

Step 5: Sample analysis

Sample analysis includes physical, chemical, or biological determination of the parameter or pollutant. The analysis method should be documented in a traceable way. 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.).

Step 6: Data processing

Once measurement results are produced, the data generated need to be processed and evaluated. Data processing includes signal processing, statistical treatment of the data, interpretation of the measurement results and their validity, calculation of the results, and uncertainty analysis. All data handling and reporting procedures should be determined and agreed by the operators and authorities before the testing begins. The validation of emission data 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. 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 handling systems (mostly electronic devices) are available that can be configured to provide information in a variety of forms and which take a variety of inputs. 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.

A Field Sampling Record System must be designed to ensure sample and sampler traceability, including dates and sampler's initials or signatures. Dated and signed materials must include forms, instrumental records and printouts, as well as notebooks.

The record storage system should be designed for easy retrieval. A policy on the length of the storage and disposal of records must be established. A policy should also be established for the ownership of field notebooks, and their deposition when an individual sampler ceases employment on a project or with a company.

Potential deficiencies in sample history requirements should be monitored. Non-compliance must be identified and remedied.

Step 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. An emission report for compliance checking should give enough information to assess compliance with permit requirements. In addition to emission data and uncertainty assessment, adequate documentation of the data production chain and reference measurements should be presented.

Quality assurance and safety precautions

There are generally two types of activities conducted to ensure the accuracy of self-monitoring data: data quality assurance activities and data verification activities. Data quality assurance activities are conducted by the operator to ensure self-monitoring data are accurate. Data verification activities are conducted by the regulatory agency to ensure self-monitoring data are accurate and representative. To ensure the accuracy of self-monitoring data, authorities may require the operators to conduct various data quality assurance activities. There are several types of such activities and the authorities must determine which ones will result in data of the highest quality. Activities the authorities may require include:

- Sampling and analysing in accordance with established techniques;
- Conducting analysis using established laboratory practices;
- Conducting analysis at certified/accredited laboratories;
- Calibrating equipment in accordance with established techniques;
- Self-certifying monitoring data; and
- Participating in laboratory evaluations.

Any of the above activities, whether alone or combined with others, chosen by the authorities will help ensure accurate and valid data are submitted by the operator. The activities selected will depend to a large extent on the environmental policies and procedures already developed within a specific country. For example, some countries may not have established techniques for sampling or analysis, or may not have certification programmes for laboratories.

Quality assurance and quality control

Quality assurance means developing a system of activities to ensure that measurements meet defined standards of quality with a stated level of confidence. Development of a plan for quality assurance includes defining monitoring objectives, the quality control procedures

to be followed, and quality assessment. Monitoring objectives are defined and are then used to arrive at data quality objectives including accuracy, precision, completeness, representativeness, and comparability.

Quality assurance includes designing a network, selecting sampling or monitoring sites, selecting instruments, designing the sampling system, and developing a training schedule.

Quality control is the overall system of managerial and technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer. Quality control is both corrective and proactive in establishing techniques to prevent the generation of unacceptable data and so the policy for corrective action should be outlined. In the case of the self-monitoring programme, quality control activities are used to ensure that measurement uncertainty is maintained within acceptance criteria for the attainment of data quality objectives.

Quality control includes preparing protocols (including standard operating procedures and record keeping) for site operation and equipment maintenance; preparing protocols for equipment calibration; preparing site visit schedules; and preparing protocols for data inspection, review, validation, and usage. Quality assessment includes developing a schedule for audits and reports.

The operator of the plant is responsible for the monitoring data reliability. Proper organisation of the monitoring tasks, responsibilities, information flow, and the environmental files are the tools to improve the reliability of monitoring. Ensuring the competence of the personnel and application of suitable ways and methods is also important. Quality management systems (*e.g.* ISO 9000) are useful for ensuring that the equipment and methods used in the measurements, as well as the various monitoring tasks are carried out according to the requirements. Quality assurance includes maintenance and calibration procedures. The environmental management systems (*e.g.* ISO 14001, EMAS) assist in the systematic management of monitoring data, for instance in relevant documentation and in the practical organisation of the tasks. There are also standards for the competence requirements of the personnel carrying out the monitoring tasks and the laboratories participating in the tasks (*e.g.* ISO/IEC 17025, ISO 45000 series).

Requirements set for data quality are based on the following data quality objectives:

- **Accuracy.** Accurate data is reliable and precise in the sense that they do not include systematic over or underestimations and the uncertainty is as low as possible;

- **Comparability.** This includes elements such as a harmonised source nomenclature; consistent principles and methods in production of data, including reporting formats; and documentation of the data and its production in a traceable way; and use of accepted methodologies;

- **Completeness.** Completeness includes the temporal and spatial coverage of the emissions sources, *i.e.* all relevant channelled, diffuse, fugitive and exceptional releases, under both normal and exceptional circumstances, constitute the total emissions of an industrial site;

- **Consistency.** Use of consistent methods with the methods used previously or with methods used for other sources are fundamental for correct comparison. When changing the method, care has to be taken to ensure that the previous measured values and those produced by the new method are comparable, *i.e.* the time series of the monitoring results are consistent;

- **Transparency.** Transparency includes documentation of the collection and selection of data (*e.g.* activity data, emission factors, measurement results) and of the underlying assumptions and methods used to produce the emission estimate, which will enable recalculation. Documentation should also render comprehensible the meaning of the data.

It is recommendable to include quality considerations in the monitoring requirement associated with the relevant limit, so that the measurements are reliable, consistent, and auditable. The main quality considerations are:

- **Calibration, maintenance, and certification**. The monitoring system should be regularly calibrated and maintained; and

relevant instruments, personnel, and analytical laboratories certified under recognised schemes;

- **Updating of monitoring requirements**. The monitoring programme should be regularly reviewed and updated to take account of changes in limits, the latest compliance situation of the process, and new monitoring techniques;

- **Off-scale situations**. Under some temporary process situations the monitoring equipment may go off-scale, *e.g.* during abnormal conditions or during start-up or shut-down. In such cases it is important that the permit states how long the monitoring is allowed to be off-scale before emissions are judged to be noncompliant;

- **Availability and breakdown of monitoring equipment.** The permit should state if or how long a process is allowed to continue operating in the event of a breakdown of monitoring equipment. Consideration should be given to specifying requirements for data capture, off-line maintenance/calibration periods, and back-up monitoring (*e.g.* taking of occasional spot samples while continuous monitoring is unavailable).

Safety precautions

Safety should be carefully considered before monitoring begins (either at a process or in a receiving environment) and then appropriate precautions followed. Every monitoring programme should include a requirement for a risk assessment based on a safety audit to develop a safe working plan covering the following points:

- Confirmation that the equipment and facilities that will be used are safe and adequate (*e.g.* electrical and sampling equipment, gas cylinders, walkways, ladders);

- Guidance or briefing on how safely to access locations where monitoring is to be done;

- Availability of appropriate number of qualified personnel;

- Reminders concerning risks and precautions in relation to physical and toxic hazards;

- Safety training of staff, including training in emergency and evacuation procedures (*e.g.* by means of site induction and safety courses).

Certification, accreditation, and calibration issues

The quality requirements for practical monitoring must be set out in the monitoring programme in line with the permit conditions and/or other relevant legislation. It is best practice to include monitoring activities within an overall Quality Management System (*e.g.* for an installation).

The operators of an installation may set policies that commit the company to using recognised quality systems to manage its process operations and environmental impacts. Such policies and systems can include procedures to ensure the quality of monitoring and to help the company to develop a best practice monitoring scheme.

These quality policies and systems can be used to define general objectives for a best practice monitoring scheme including:

- Reliability (*e.g.* low risk of breakdown);

- Compatibility (*e.g.* with process conditions and operations);

- Uncertainty and repeatability (*e.g.* of measurements);

- Availability of relevant technical skills (*e.g.* qualified staff);

- Transparency and public accessibility.

These quality policies and systems can also be used to define specific targets for a best practice monitoring scheme. For instrumental measurements this means having equipment which is:

- "Fit for purpose" (*e.g.* has appropriate range and response);

- Appropriately sited (*e.g.* in a process stream or a receiving environment);

- Measuring at appropriate times (*e.g.* during relevant process operating conditions);

- Subject to appropriate checks (*e.g.* is calibrated and maintained);

- Meets availability requirements for data capture.

Once a best practice monitoring scheme has been defined, the quality of the scheme may be established and maintained by applying a recognised quality assurance system (*e.g.* one based on international standards). Best practice involves applying procedures to assure quality before, during, and after monitoring so that:

- Before the measurements start, all necessary steps have been taken to design and construct a robust and representative monitoring regime;

- Have quick access to spare equipment if there is a breakdown;

- There is application of proper safeguards during the measurements, *e.g.* checks are made to ensure that appropriate conditions of process operation are maintained;

- After the measurements, the methods used to analyse samples or to infer results are checked, *e.g.* checking of methods used to infer direct values from surrogate data.

It is important to have formal procedures within the quality assurance system for certification, accreditation, and calibration, as explained below.

Certification

This is used to judge if the monitoring facilities and activities at an installation conform with a specific standard. It is done by an organisation which is formally accredited as competent to do it, and which is independent of the operator and authority. Certification involves systematically comparing different aspects of monitoring, such as equipment, quality management systems, and personnel with documented criteria and procedures. National certification schemes

exist in most developed countries. For best practice, the quality management system of an installation will explain: (a) which facilities and activities are certified, (b) to what standards they are certified, and (c) what requirements this satisfies (*e.g.* legal requirements, permit conditions).

In addition, self-certification is required for all reports submitted by a facility in some countries. The report must be signed by an authorised person or their authorised designee and must include certification stating, under penalty of law, that the information submitted is true, accurate, and complete. An example of a self-certification statement used in the United States pre-treatment programme is the following:

> "I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

Accreditation

This is used formally to show that an organisation is competent to do a specific task, or that a method is fit for a particular purpose. An analytical laboratory is accredited to do one or more specific analyses. For best practice, the quality management system of an installation and/or its permit will require that accredited organisations and methods are used for monitoring work. National accreditation bodies exist in all developed countries. Authorities should define procedures for dealing with any falsification of monitoring results. These can include unannounced audits and effective legal sanctions.

To further ensure the quality of the reported self-monitoring data, authorities conduct independent data verification activities. These activities include:

- Analysing duplicate or split samples;

- Inspecting the laboratories that are analysing samples;

- Inspecting the operators including their sampling and analysis procedures;

- Random, unprogrammed check monitoring.

When analysing duplicate or split samples the regulatory authority should require the operators to submit the split or duplicate samples for analysis. The regulatory authority can then conduct its own analysis and compare the results with the results from the operator. Inspections of either laboratories or operators will ensure that the sampling and analysis is conducted in accordance with established guidelines and procedures. Any of these activities can help the authorities to determine if the data being submitted by the operator are complete and accurate.

Calibration

This is used to test the performance of monitoring equipment against standard samples (*e.g.* of gas cylinders, permeation tube systems) under controlled conditions, in order to check that the equipment is giving results that are accurate to within required limits. Calibrations may be done at an installation or in an off-site laboratory, and must be repeated at regular intervals to ensure that the required performance is maintained. Particular quality considerations include:

- Calibrations must be done by personnel who are suitably qualified;

- Calibration procedures vary between different equipment and types of monitoring;

- The intervals between calibrations vary between different equipment and situations;

- Calibration records must be kept and archived for inspection, *e.g.* by the authority.

Field quality assurance programme

General requirements

The field quality assurance programme is a systematic process that, together with the laboratory and data storage quality assurance programmes, ensures a specified degree of confidence in the data collected for an environmental survey. The field quality assurance programme involves a series of steps, procedures, and practices that are described below.

The quality of data generated in a laboratory depends, to a large degree, on the integrity of the samples that arrive at the laboratory. Consequently, the field investigator must take the necessary precautions to protect samples from contamination and deterioration.

There are many sources of contamination; the following are some basic precautions to heed:

- Field measurements should always be made using a separate sub-sample that is then discarded once the measurements have been made. They should never be made on a water sample that is returned to the analytical laboratory for further chemical analyses. For example, specific conductance should never be measured in sample water that was first used for pH measurements, because potassium chloride diffusing from the pH probe alters the conductivity of the sample. Similarly, pH should not be measured from a sample that will be analysed for phosphorus, as some pH buffers contain phosphorus;

- Sample bottles, including bottle caps, must be cleaned according to the recommended methods and certified by the issuing laboratory as “contamination free” (if pre-cleaned by the laboratory), for the intended analysis. Sample bottles that are pre-cleaned by the laboratory must not be rinsed with the sample water being collected. Bottles must be supplied with cap in place. Cleaned and reused bottles are not suitable for some trace constituents. When using a mixture of pre-cleaned, not pre-cleaned, and/or re-used bottles, each bottle type should be labelled to avoid confusion;

- Only the recommended type of sample bottle should be used for each analysis;

- Reagents and preservatives must be of analytical grade and certified by the issuing laboratory to be contamination free. Containers holding chemical reagents and preservatives should be clearly labelled both as to contents and as to expiry date. No reagent or preservative should be used after the expiry date;

- If conditions dictate that samples from multiple sites be preserved at the same time (such as when returning to shore after sampling several deep stations), the possibility of adding the wrong preservative to a sample or cross-contaminating the preservative stocks should be minimised by preserving all the samples for a particular group of variables together. Colour-coded bottles and matching preservatives prevent mix-ups;

- The inner portion of sample (and preservative) bottles and caps must not be touched by anything (*e.g.*, bare hands, gloves, thermometers, probes, etc.) other than the sample water and preservative. Caps should be removed only just before sampling and re-capped right away;

- Sample bottles should be kept in a clean environment, away from dust, dirt, fumes, and grime. Bottles must be capped at all times and stored in clean shipping containers (coolers) both before and after the collection of the sample. Vehicle cleanliness is an important factor in eliminating contamination problems. During sample collection, bottle caps should be stored in a clean, resealable plastic bag, not in pockets, etc.;

- Petroleum products (gasoline, oil, exhaust fumes) are prime sources of contamination. Spills or drippings (that are apt to occur in boats) must be removed immediately. Exhaust fumes and cigarette smoke can contaminate samples with lead and other heavy metals. Air conditioning units are also a source of trace metal contamination;

- Filter units and related apparatus must be kept clean, using routine procedures such as acid washes and soakings in de-

ionised water. Cleaned filter units should be stored in labelled, sealed plastic bags;

- Samples must never be permitted to get warm; they should be stored in a cool, dark place. Coolers packed with ice packs are recommended (most samples must be cooled to 4°C during transit to the laboratory). Conversely, samples must not be permitted to freeze unless freezing is part of the preservation protocol. Samples must be cooled as quickly as possible;

- Samples must be shipped to the laboratory without delay so that they arrive within 24 hours of sampling. Certain analyses must be conducted within 48 hours;

- Sample collectors should keep their hands clean and refrain from eating or smoking while working with water samples;

- Sample equipment and shipping coolers must be cleaned after each sampling round. Field cleaning is often not as effective as cleaning equipment at a support facility. Depending upon the analyte and concentration (*i.e.* metals or organics), it may only be possible to conduct effective cleaning procedures at a support facility, rather than in the field. Bleaches and strong detergents should be avoided;

- De-ionised water should not be used after six months (shelf-life period), and the containers should be clearly labelled with both the filling date and disposal date.

Quality Control

Quality control is an essential element of a field quality assurance programme. In addition to standardised field procedures, field quality control requires the submission of blank samples to test:

- The purity of chemical preservatives;

- To check for contamination of sample containers, filter papers, filtering equipment, or any other equipment that is used in sample collection, handling, or transportation; and

- To detect other systematic and random errors occurring from the time of the sampling to the time of analysis.

Replicate samples must also be collected to check that the sample is reproducible. Replicate samples allow the precision of the sampling and measurement process to be estimated, and are an additional check on sample contamination. The timing and the frequency of blank and replicate samples are established in the project design and will vary with each project. Another aspect of quality control is the use of certified or standard reference materials (CRM's or SRM's) and of spiked samples to assess laboratory process.

Blanks

Blanks are samples that do not contain the variable to be analysed and are used to assess and control sample contamination. They are most often used to assess contamination of the trace measurements (metals and nutrients) but should also be used on occasion to test potential contamination of the other analyses (such as general ions). Most blanks are carried through the entire sample collection and handling process so that the blank is exposed to the same potential sources of contamination as actual samples. Ideally, blanks should be prepared by the analytical laboratory in the appropriate sample bottles under clean conditions. Some of the blanks remain in the laboratory for analysis (laboratory blanks), while the remainder travel to the field for use as trip, field, equipment, and filtration blanks. Alternatively, blanks may be prepared in the field as outlined below.

- Trip blanks. Trip blanks are meant to detect any widespread contamination resulting from the container (including caps) and preservative during transport and storage. The recommended practice for organic parameters is to use carbon free de-ionised water for trip blanks;

- Field blanks. Field blanks mimic the extra sampling and preservative process but do not come in contact with ambient water. Field blanks are exposed to the sampling environment at the sample site. Consequently, they provide information on contamination resulting from the handling technique and through exposure to the atmosphere. They are processed in the same manner as the associate samples (*i.e.* they are exposed to all the same potential sources of contamination as

the sample). This includes handling and, in some cases, filtration and/or preservation;

- **Equipment blanks (prepared prior to the field trip).** A field equipment blank is a sample of de-ionised water that has been used to rinse sampling equipment. This is useful in documenting adequate decontamination of equipment. It is collected after completion of the decontamination process (washing) and prior to sampling;

- **Filtration blanks.** Filtration blanks (or rinsate blanks) are de-ionised water that is passed through the filtration apparatus in the same manner as the sample. Analysis of the filtrate provides an indication of the types of contaminants that may have been introduced through contact with the filtration apparatus. Filtration blanks are also used as a check for potential cross-contamination through inadequate field cleaning techniques (rinsing of the apparatus with de-ionised water between samples). It should be done both at the start and again at some point between samples (after the apparatus has been cleaned and immediately before the next "real" sample is filtered). Each blank is preserved in the same fashion as the associate samples.

Replicate Samples

Replicate samples are particularly recommended for QC studies. There are two types of replicate samples:

- **Co-located samples (field duplicate, triplicate, etc.)** Co-located samples are independent samples collected as close as possible to the same point in space and time and are intended to be identical. These samples are essential in documenting the precision of the entire sampling and analytical (laboratory) process;

- **Split samples***.* Split samples are aliquots taken from the same container and analysed independently by one or more laboratories. They are used to obtain the magnitude of errors owing to contamination, random and systematic errors, and any other variability, that are introduced after the time of sampling through analysis at the laboratory(ies). Split samples are commonly used to compare two or more

laboratories. Care must be taken to ensure that the samples are split in a way to ensure homogeneity (a sample splitter must be used for samples containing suspended solids or effluents).

(Field) spiked samples

Spiked samples for each variable being tested are prepared by spiking aliquots of a single water sample with known amounts of the variable of interest. The information gained from spiked samples is used to reveal any systematic errors (or bias) in the analytical method. The spike solution is prepared by an analytical laboratory (preferably) or it can be prepared by the field staff (far less desirable) prior to the sampling trip.

Reference samples

Reference samples are used to document the bias of the analytical (laboratory) process. There are two types of reference samples. The first, and simplest, is when an independent laboratory prepares a water sample with the addition of a known quantity of a variable of interest. In this case, the independent laboratory should provide calculated and measured concentrations of the variable. The second type of reference material is a certified reference sample. It is obtained from a recognised national scientific body. The sample itself is an aliquot of a very large, stabilised (may be preserved) batch sample that was collected from one place at one time. The batch sample will have been subjected to a large number of analyses performed by independent laboratories using several different analytical techniques, but some reference materials are analysed by different labs using the same methodology.

Consequently, the distributing agency can provide a mean value and confidence interval for the variable concerned. These samples are submitted blind to the analysing laboratory along with the samples collected during a field trip. There is the option of submitting them blind (labelled as a regular sample) or non-blind with labelling that it is a certified reference material. The former is a more desirable quality assurance tool.

CHAPTER 5:
REPORTING AND RECORD KEEPING

The operator is required to summarise and present self-monitoring results, related information, and compliance findings. The major purpose of self-reporting is to provide a basis for the competent authorities to assess regulatory compliance; to identify and trigger follow-up actions to the discovery of non-compliance, such as on-site visits; or to understand compliance assistance needs, *e.g.* when similar non-compliance patterns are established for a group of facilities of a specific industrial sector. Moreover, self-monitoring provides data to compile emission inventories, which are often publicly accessible, and to determine regulatory charges and environmental taxes. These, and other uses, will determine the character of reporting requirements.

Types of data that must be recorded

In the framework of self-monitoring programmes, the operator will be required to record the following information:

- All sampling, analyses, measurements, examinations, calibrations, and maintenance carried out in accordance with the environmental permit or the self-monitoring programme;
- All planned changes (alterations or additions) to the permitted installation;
- All incidents which affect the normal operation of the activity and which may create an environmental risk;
- All non-compliance cases and self-correction measures;
- All complaints of an environmental nature related to the operation of the activity. A record must also be kept of the response made in the case of each complaint.

It is not required for all data to be sent from the operator to the competent authorities, in particular results of operation monitoring. In those cases where reporting will not be necessary, the competent authority may only stipulate record keeping requirements.

Reporting types and frequency

Self-monitoring data must be reported in line with agreed schedules and criteria, or in response to requests. The aim of the Ministry of Environment is to reduce the frequency of environmental reporting but to improve its quality, clarity, and usefulness.

The self-monitoring programme must contain specific reporting conditions and 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 schedules must specify the type of reporting, the frequency of recurring reporting, and the report submission date (see Table 3). 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).

Table 3. Example of a simple schedule of recurring reports

Report	Reporting Frequency	Report Submission Date
Monitoring of emission to atmosphere	Quarterly	Ten days after end of the quarter being reported on.
Monitoring of emission to water	Quarterly	Ten days after end of the quarter being reported on.
Groundwater monitoring results	Annually	As part of the AER.
Complaints (where these arise)	Monthly	Ten days after end of the month being reported on.
Annual Corporate Environment Report (ACER)	Annually	By 31 March 2004 and each year thereafter.

Source: Irish Environment Protection Agency (2000). Integrated pollution control licensing: Guidance note for Annual Environmental Report.

The operator must submit recurrent reports, including continuous, monthly, quarterly, and annual reports. These must conform to specified reporting dates and formats.

Major industry may be asked to submit an **Annual Environmental Report** (AER) that can present the self-monitoring information in an integrated, structured, and logical manner. The AER will bring together all the individual reports required as part of self-monitoring and will allow for effective evaluation of the environmental issues at the site. The report will also set out the programme of work to be completed in the coming year. The AER for various facilities and sectors will vary depending upon the complexity of the processes and specific permit conditions.

The operator must submit a **report on any complaints of an environmental nature** during the month following such complaints, giving details of causes and remedial actions. A summary of the number and nature of complaints received must be included in the annual report.

Within 24 hours, the operator is required to orally **report any non-compliance** that may endanger health or the environment; and immediately, **any emergency situations** (incidents or accidents). A written submission must also be provided within five days of the time the operator becomes aware of circumstances. The written submission must contain:

- A description of the non-compliance and its cause;
- The period of non-compliance (including exact dates and times);
- If the non-compliance has not been corrected, the anticipated amount of time it is expected to continue;
- The steps taken or planned to reduce, eliminate, and prevent recurrence of the non-compliance; and
- The steps taken to minimise any adverse impacts on the ecosystems and human health.

The competent authority may waive the written report on a case-by-case basis if the oral report has been received within 24 hours and the non-compliance does not endanger health or the environment.

Also, the operator must send an **advance notice** to the competent authority, as soon as possible, of any planned changes to the installation. In particular, this is important when such changes may result in anticipated non-compliance with permit conditions.

If the operator becomes aware that it submitted incorrect information in any report to the competent authorities, it must promptly submit the correct information.

The operator must submit any **reporting upon request from the competent authority** that may be needed to determine whether reasons exist to modify, revoke, or terminate a permit. The operator must also furnish, upon request, copies of records required to be kept and that are not subject to recurrent reporting.

Finally, **specialised reports** may be required. These are reports on relatively complex or novel techniques that are occasionally used to supplement more routine monitoring methods. Typical examples include telemetry (the electronic transfer of monitoring data to users in real time) or neural networks (using a computer to develop correlations between process conditions and measured emissions).

Data collection

Data collection involves the acquisition of basic measurements and facts. Considerations of the following items are good practice in data collection:

- **Use of 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;

- **Compliance with 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, such as timing considerations;

- **Recording of 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);

- **Recording details on the operational context** – 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).

Reporting protocols

The operators should use standardised reporting formats. Electronic reporting forms can be made available on the web site of the competent authority. Each operator will be assigned a user name, and a password, to be able to download these forms.

The operator should fill in the reporting forms and return them to the competent authorities via regular post or e-mail by the agreed deadline. Reports should be prepared by a competent person (or team). A nominated person must be responsible for the authenticity and quality of the information in each report using a "sign-off" system, which may be manual or electronic.

The operator must put in place special contingency arrangements for rapid reporting of abnormal or upset events, including off-scale conditions and breakdowns of monitoring equipment.

Once the authorities receive the report, the responsible person should check it within the following five days, and take necessary actions, *e.g.* require additional information, require that some data are verified, or conduct an inspection to validate data. After the responsible person validates self-monitoring data, they should be uploaded to the relevant database.

The competent authorities must state which kind of data transfer protocol has to be used during the approval of self-monitoring programmes.

Record keeping and data management

The competent authorities may need historic data on self-monitoring and reporting to serve as a source of information in the event of an enforcement action, to help determine the past performance of the regulatee, and appropriateness of past and current practices. When endorsing self-monitoring programmes, the competent authorities will identify what records must be kept to meet its needs.

Furthermore, records must be kept for a sufficient amount of time. The retention period for records will depend upon the type of self-monitoring (*i.e.* operational, emissions, and impact), the parameter monitored, and category of facility. Data on persistent pollutants should be kept for a period equal to their disintegration in the environment. Data on toxic substances, especially carcinogenic ones, should be kept for a period equivalent to the duration required for the manifestation of intoxication symptoms due to chronic exposure, either directly or through biomagnification in food chains.

The operator may decide on a longer period of data retention. Shortening standard periods of record keeping is not allowed.

Data management involves the organisation of data and its conversion into information. Consideration of the following items is necessary in data management:

- **Transfers and databases** – 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** – a plan for the collation, analysis, and condensation of data will be needed. 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 that are below the detection limit - the approach for estimating these values should be explained when reporting the data;

- **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.

Regulators should define procedures for dealing with any falsification of reported monitoring results. These can include unannounced audits and effective legal sanctions. Chapter 7 gives more details about this subject.

CHAPTER 6:
MEDIUM-SPECIFIC PARTICULARITIES

Air emissions and air quality monitoring

In OECD countries, 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 over time, a number of individual measurements are made during undisturbed continuous operation at periods of representative level of emissions. In facilities whose operating conditions vary over 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.* three 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 <5-10µm, the effect of this inertia is practically negligible. Applicable standards require isokinetic particle sampling.

Continuous monitoring is a legal requirement in several countries 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 0ºC and 1atm respectively, although sometimes they may be referenced to 25ºC and 1atm.

The following conditions may be used when presenting data:

- m^3 - actual cubic metre (at actual temperature and pressure);
- Nm^3 - normal cubic metre (typically at 0ºC and 1atmosphere);
- scm - standard cubic metre (typically at 25ºC and 1atmosphere, although sometimes it may be at 20ºC). This unit is mainly used in the USA.

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

Effluent and water quality monitoring

Sampling methods for waste water

There are basically two sampling methods for waste water:

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 10m3). For time-proportional samples, a fixed amount of sample is taken for each time unit (*e.g.* every five 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 was collected. It is normal to collect composite samples over 24 hours to give a daily mean value. Shorter times are also used, for example two hours, or half an hour. Composite sampling is usually automatic; instruments automatically withdraw a portion of sample when the appropriate volume is discharged or at the appropriate 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 in the composition and lead to the storage of large amounts. For annual load calculations, composite samples are generally preferred; and

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

The annual average concentration may be determined as follows:

$C = \sum (C_{sample} \text{ or } C_{day})$ /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.*:

    1. daily load = concentration x daily flow

    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.*

1. daily load = representative daily concentration x representative daily flow

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 and metals is determined using coefficients based on production figures or on the discharged/consumed amount of water.

Waste monitoring

For the waste received at or produced by the permitted installation, the operators should record and retain the following records for an appropriate period: its composition, the best estimate of the quantity produced, its disposal routes, a best estimate of the amount sent to recovery, registration/licenses for carriers and waste disposal sites.

CHAPTER 7:
COMPLIANCE ASSESSMENT AND ENFORCEMENT

Self-monitoring provides information based on which the operator and competent authorities can judge whether compliance with relevant legislation and permit conditions has been achieved. Such judgements will be are based on specific approaches to verifying compliance with quantitative norms but also the technical state of facilities. Additionally, the competent authorities will inspect the operator's self-monitoring arrangements and results. When non-compliance is discovered, the competent authorities will provide a response proportional to the offence. The current section addresses specific aspects that need consideration as part of compliance assessment and enforcement.

Approaches to assessing compliance

Based on monitoring data, the operator will assess its own compliance with environmental regulatory requirements. Within this framework, two aspects of compliance need to be considered:

- Compliance with requirements to provide adequate monitoring evidence, *i.e.* evidential compliance; and

- Compliance with requirements for emissions not to exceed numerical limits in permits, or for ambient impacts not to exceed quality standards in receiving environments.

As concerns evidential compliance, there are two aspects to be considered:

- **The adequacy of the measurements made.** This requires information on all contributions to the uncertainty in measurements, such as contributions due to sampling, analysis, the basic method under ideal experimental conditions, field conditions, etc.; and

- **The adequacy of the available contextual information concerning the situation in which the measurements were made.** This information is needed to confirm that the measurements were made in a situation where the limit value applies (*e.g.* in normal operating conditions, or start-up or shut-down conditions).

In order to assess compliance with limit values it is necessary to have four items of information:

i. **The limit value for the relevant operating condition.** This is typically a pollutant emission value (*e.g.* mass release rate or discharge concentration) or an ambient pollutant loading (*e.g.* concentration or deposition on an environmental receptor). However, it may be a surrogate parameter value (*e.g.* opacity in place of particulate concentration), or an efficiency value (*e.g.* efficiency of effluent treatment);

ii. **The relevant measured pollutant or parameter value.** This must be based on the same operating situation and units as referred to in the limit value. It may be a single result, or based on several results (*e.g.* an average). The measured value is typically **expressed** as an absolute amount;

iii. **An estimate of the uncertainty in measurements.** This is the overall uncertainty in measurements; and

iv. **A level of statistical probability or confidence above which measurements are deemed to be non compliant.** The probability level may typically be 1 in 20, which corresponds to a 95% level of confidence.

Based on this information, a statistical comparison between the following items will be made to assess compliance:

- The measurements, or a summary statistic estimated from the measurements;
- The uncertainty of the measurements;
- The relevant ELV or equivalent parameter.

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.

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)); and

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).

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.* ± 2 mg/m3). 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, 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 there is a need 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;
- The personnel doing the interpretation are professionally competent in statistics, uncertainty analysis, and environmental law, and have a sound understanding of practical monitoring methods;
- Authorities and operators are aware of the quality of evidence needed to mount successful prosecutions/appeals using compliance monitoring data.

The results of compliance assessments should be fed back promptly to the relevant parties. The feedback should be documented and used to ensure that monitoring effort is kept in balance with the compliance situation and is directed to the most critical or sensitive parts of the process or of the receiving environment.

Self-inspecting the technical state of facilities

Self-inspection has a considerable potential for assessing the technical state of facilities and entails applying a pre-set checklist (usually tailored to different industry sectors) to determine if their premises are achieving a basic level of environmental good practice. The aim is to foster a basic level of regulatory compliance and good environmental behaviour. In order to minimise the burden involved, the

list is confined to a limited range of issues (for example, the top four pollution issues in a particular sector).

Self-inspections will be performed by facility personnel. The Facility Manager at each facility will designate the staff person(s) who is responsible for performing self-inspections. A "self-inspector" need not be an environmental professional. However, it would be beneficial if authorities encourage the development and implementation of industry-specific self-inspection training courses for personnel responsible for performing this task.

Normally, the individual conducting the self-inspection will:

- Review the previous self-inspection report;
- Review the facility's self-inspection checklist;
- Visually observe each area at the facility where environmentally sensitive activities are performed;
- Write an inspection report following the inspection checklist and a brief narrative description of any deficient items (including those corrected during the inspection);
- Inform the Facility Manager of all deficient items as soon as possible;
- Deliver a copy of the inspection report to the Facility Manager and place a copy in the appropriate file at the facility.

The person performing a self-inspection can use standard checklists or a facility-specific checklist (more appropriate) that has been reviewed by environmental authorities and approved by the Facility Manager. A self-inspection checklist will cover priority environmental themes in terms of eventual concerns and conditions on-site. Comments may be necessary to clarify the conditions on-site. Each area is to be inspected for the listed concerns and any other indications of problems, deterioration, or malfunction. Areas with problems should be marked and both the problem and the corrective action should be described. The Facility Manager is responsible for ensuring that all deficiencies identified in self-inspection reports are promptly corrected.

Inspection by the competent authorities

The competent authorities will verify operator's self-monitoring arrangements within the framework of planned inspections. Particular technical aspects requiring scrutiny (beyond the availability of a self-monitoring programme and appropriate arrangements to implement this programme) include:

- The positioning and serviceability of fixed instrumentation;
- Records confirming the maintenance and calibration of fixed and portable instrumentation and sampling equipment;
- Manual sampling procedures;
- Analytical procedures;
- Record keeping, including samples and analysis logs, data-capture arrangements, for example computers, charts, etc., for instruments;
- Data-reduction calculations;
- The professional competency, including training, of relevant staff;
- Checking that an operator has carried out appropriate actions under self-correction arrangements.

The more technical aspects of checking the correct operation of instruments, the correct application of manual stack-emission sampling, and analytical procedures may require the use of specialist staff.

The scope, frequency, and extent of the competent authorities' independent monitoring should be proportionate to that undertaken by the operator carrying out self-monitoring so as to avoid unnecessary duplication. The competent authorities' independent monitoring should be targeted by risk-based assessment of:

- The reliability of the operator's self-monitoring regime;

- The hazard to the environment of normal operations;

- The operator's compliance history.

The competent authorities should also arrange for independent monitoring to be undertaken to provide checks on the reliability of self-monitoring data. This independent monitoring may include:

- The calibration of instruments;

- Sampling and analysis;

- Analysis of split or replicate self-monitoring samples.

Inspection follow up

The competent authority's response to an assessed situation will be in proportion to the degree of compliance or non-compliance. This means that the responses of the authority will graduate from:

- Confirming and accepting a satisfactory performance;

- Seeking improvements in the monitoring arrangements where the quality of results does not provide adequate evidence;

- Precautionary advice and negotiation of voluntary improvements in borderline situations, where the general approach is to influence the operator towards reducing the risk of a non-compliance occurring;

- Revision of a permit limit where a non-compliance has an acceptable environmental impact, within the provisions of the relevant legislation and taking into account the costs and benefits and the principles of precaution and prevention;

- Enforcement actions in non-compliant situations (including both lack of quality monitoring for adequate evidence and non-compliance with limit values), where the general approach is to ensure compliance by imposing corrective actions;

- Prosecution/court action where legislation requires such action for all non-compliances or where the non-compliance is great and has a significant environmental impact and/or the process operator has a history of non-compliances and may have an impact on human health.

The main consideration for the competent authority to take into account when deciding on an appropriate response is the compliance zone to which a particular situation belongs. However, the authority may also take a precautionary approach, particularly when other considerations give further information on the risk of non-compliances occurring in future. These extra considerations are often qualitative and may include:

- The competence of the operator;,
- The reliability of the process equipment, procedures, and management control,;
- The previous compliance performance of the installation and/or operator;,
- The sensitivity of the receiving environment;,
- The possible risk of harm to the receiving environment and human health.

These qualitative considerations may lead the competent authority to adjust the thresholds at which the three forms of response (*i.e.* acceptance, negotiation, or enforcement) may be adopted for a particular situation. For example, if the previous performance and competence of the operator are poor, the authority may start negotiating for improvements when the measured results are between the compliant and borderline zones.

In compliant situations, the competent authorities could consider taking the following actions:

- Recommending continuation of the monitoring programme with the same scope or re-focusing on higher priorities;,

- Recommending reductions in the frequency and/or scope of the monitoring programme;,

- Switching from monitoring of direct values to surrogate parameters in order to save costs where the generally greater uncertainty of surrogates is acceptable in such compliant situations.

Responses are needed in borderline situations in order to reduce the probability of exceeding the limit. Best practice is for the authority to negotiate with the operator and encourage the operator to make voluntary improvements. (This approach is constrained by legal requirements in some countries.) Best practice is to consider requiring the process operator to:

- Carry out a detailed investigation of the individual process activities in order to establish why a borderline situation has arisen;

- Develop a time-tabled plan, based on the investigation, for specific actions and improvements which can be undertaken to re-establish or achieve compliance;,

- Carry- out additional monitoring and reporting while the plan is being implemented, in order to demonstrate that progress is satisfactory.

In borderline situations, it is usually possible for responses to be made with less urgency and with less disruption or cost to the process operator than in non-compliant situations. For example, improvements may be scheduled during maintenance periods or timed to coincide with refurbishment or updating of the process.

If an approach based on negotiation is not successful, then the authority will respond using enforcement. There are variations in the responses to non-compliant situations in different countries, because of the differences allowed in national legal systems.

After confirmation of a non-compliant situation the following initial responses should take place:

- The operator should take action to minimise and mitigate any adverse impact to the environment, and should inform the competent authority;

- The competent authority should take action to check that any adverse impact is minimised and mitigated, and should require the operator to investigate and report on the reasons for the non-compliance; the authority should also consider carrying out its own investigation.

Once any adverse impact to the environment has been minimised and mitigated, and the results of the investigation(s) are available, the authority should decide on further actions based on an assessment of the severity of the non-compliance on the basis of:

- Its duration, frequency, and foreseeability;

- The number of limits exceeded, *e.g.* for different substances;

- The magnitude of the exceedence(s);

- The reactions of the operator to minimising and mitigating adverse impacts to the environment.

The severity of the non-compliance should be taken into account by the competent authority when deciding on further enforcement action. These possible actions form a sequence of responses which can be escalated to match the severity of the non-compliance. In order of increasing stringency, these actions may include:

a) A **warning note** is issued whenever a non-compliance is found;

b) The authority can prohibit any operation (or part of it) which poses an unacceptable risk to the environment and/or cannot comply with a permit or other legal requirement;

c) The authority can give orders to close down an installation which has been built, operated, or modified without having an appropriate permit; and

d) Fines may be imposed through legal actions taken in the courts or under administrative powers provided for by the legislation in some countries.

The operator may be entitled to appeal against any of the actions and to seek compensation if the appeal is upheld.

Serious, including criminal response, is reserved for the most serious cases. Also, in such cases enforcement response policies elaborate what is the proportionate government response to the range of possible violations. This response will be heavy when one or more aggravating factor(s) is/are present, such as a large and sophisticated enterprise with long-established and feasible requirements which is not making best efforts (evasive behaviour, delayed efforts), experiencing large (intolerable) or avoidable spills, presence of environmental damage, and/or repeated nature of offence(s).

All legally required self-reporting data can be brought, by the authorities as evidence, into court. Except for incidents and accidents, self-monitoring information will be used as a basis for non-compliance actions and prosecution against the facility.

When non-compliance is not reported as it should be, government will be strict. This is because honest self-reporting is essential to assure: fair economic competition among all competitors in the sector facing the same pollution control challenges, the integrity of government data, and the application of scarce public resources only where needed. For these reasons, false reporting, inexcusable failure to report, tampering with a monitoring device, falsifying or failing to keep records will be treated as criminal offence.

To avoid strategic misreporting in the absence of frequent inspection, the Penal Code will provide for potentially large criminal penalties for fraud, negligence, falsification of data, and any other intentional misreporting. The infringement of self-monitoring conditions will also be illegal and sanctions can be used against the violators in these cases.

When there is non-compliance to be reported by the operator, the competent authorities will act with proportionality and fairness, and a publicly-available **non-compliance response policy** will elaborate what is the proportionate sanction for the range of possible violations. For example, self-reporting of a small deviation from ELVs may be handled administratively and will not necessarily mean a penalty: compliance assistance only may be necessary when one or more mitigating factor(s) is/are present.

The above policy approaches apply only to legally-required self-monitoring. Different government approaches, policy considerations, and incentives apply to voluntary self-auditing and environmental management systems that sometimes include self-monitoring that exceeds (is beyond, broader, or deeper) than what is legally required. These self-monitoring results will not cause any penalty; instead, they are more likely to mitigate (reduce) penalties for violations of related legal requirements.

ANNEX 1:
INDICATIVE LIST OF PARAMETERS FOR MONITORING AIR EMISSIONS AND WASTEWATER DISCHARGES FROM DIFFERENT SOURCE CATEGORIES

Source category	Parameters to be monitored in air emissions	Parameters to be monitored in wastewater
Combustion plants >50MW	CO, CO_2, NO_x, SO_2, heavy metals, dioxins and furans, polycyclic aromatic hydrocarbons, PM_{10}, inorganic compounds of fluorine and chlorine	Total nitrogen, total phosphorus, heavy metals, aromatic hydrocarbons, polycyclic aromatic hydrocarbons, total organic carbon, chlorides, fluorides
Refineries	CO, CO_2, NO_x, SO_2, heavy metals, benzene, volatile organic compounds, polycyclic aromatic hydrocarbons, PM_{10}, inorganic compounds of fluorine and chlorine	Total nitrogen, heavy metals, halogenated organic compounds, aromatic hydrocarbons, polycyclic aromatic hydrocarbons, total organic carbon, chlorides, fluorides, phenols, cyanides
Coke ovens	CO, CO_2, NH_3, NO_x, SO_2, heavy metals, benzene, volatile organic compounds, polycyclic aromatic hydrocarbons, PM_{10}, HCN	Total nitrogen, total phosphorus, aromatic hydrocarbons, polycyclic aromatic hydrocarbons, total organic carbon, phenols, cyanides
Cement plants,; installations for the production of lime, glass, mineral substances, or ceramic products	CO, CO_2, HFCs, NH3, NO_x, SO_2, heavy metals, dioxins and furans, benzene, volatile organic compounds, polycyclic aromatic hydrocarbons, PM_{10}, inorganic compounds of fluorine and chlorine	Total nitrogen, total phosphorus, heavy metals, aromatic hydrocarbons, total organic carbon, fluorides
Metal industry	CO, CO_2, PFCs, SF_6, NH_3, NO_x, SO_2, heavy metals, dioxins and furans, benzene, volatile organic compounds, polycyclic aromatic hydrocarbons, PM_{10}, inorganic compounds of fluorine and chlorine, HCN	Total nitrogen, total phosphorus, heavy metals, halogenated organic compounds, aromatic hydrocarbons, polycyclic aromatic hydrocarbons, total organic carbon, chlorides, fluorides, phenols, cyanides

Source category	Parameters to be monitored in air emissions	Parameters to be monitored in wastewater
Chemical industry	CO, CO_2, HFCs, PFCs, SF_6, NH_3, NO_x, SO_2, heavy metals, dioxins and furans, benzene, volatile organic compounds, polycyclic aromatic hydrocarbons, PM_{10}, inorganic compounds of chlorine	Total nitrogen, total phosphorus, heavy metals, halogenated organic compounds, aromatic hydrocarbons, polycyclic aromatic hydrocarbons, total organic carbon, chlorides, fluorides, phenols, cyanides
Textile industry	CO_2, NH_3, volatile organic compounds, NO_x, SO_2, PM_{10}	Total nitrogen, total phosphorus, heavy metals, halogenated organic compounds, aromatic hydrocarbons, polycyclic aromatic hydrocarbons, total organic carbon, chlorides, phenols
Food industry	CO_2, HFCs, NH_3, volatile organic compounds, NO_x, CO, SO_2, PM_{10}	Total nitrogen, total phosphorus, total organic compounds, chlorides

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