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QUALITY ASSURANCE AND QUALITY CONTROL

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ABSTRACT

Quality Assurance (QA) and Quality Control (QC) are critical aspects of any industry, ensuring product quality, customer satisfaction, and regulatory compliance. This paper provides a comprehensive overview of QA & QC principles, methodologies, and applications. It examines the distinct roles of QA, which focuses on preventing defects through proactive measures and system-level improvements, and QC, which emphasizes defect detection through reactive inspections and product testing. The paper explores various QA & QC tools and techniques, including statistical process control, risk management, and root cause analysis. Furthermore, it discusses the evolving landscape of QA & QC in the context of globalization, technological advancements, and increasing regulatory requirements, emphasizing the importance of continuous improvement and adaptation to maintain a competitive edge. Case studies from diverse industries illustrate the practical implementation and benefits of effective QA & QC systems.

I. INTRODUCTION

An important goal of IPCC good practice guidance is to support the development of national greenhouse gas inventories that can be readily assessed in terms of quality and completeness. It is good practice to implement quality assurance and quality control (QA/QC) procedures in the development of national greenhouse gas inventories to accomplish this goal.

This guidance establishes good practice consistent with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines). The QA/QC good practice guidance outlined here reflects practicality, acceptability, cost-effectiveness, existing experience, and the potential for application on a worldwide basis.

A QA/QC program me contributes to the objectives of good practice guidance, namely to improve transparency, consistency, comparability, completeness, and confidence in national inventories of emissions estimates.

The outcomes of the QA/QC process may result in a reassessment of inventory or source category uncertainty estimates. For example, if data quality is found to be lower than previously thought and this situation cannot be rectified in the timeframe of the current inventory, the uncertainty estimates ought to be re-evaluated.

The terms ‘quality control’ and ‘quality assurance’ are often used incorrectly. The definitions of QC and QA in will be used for the purposes of good practice guidance.

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DEFINITION OF QA/QC

Quality Control (QC) is a system of routine technical activities, to measure and control the quality of the inventory as it is being developed. The QC system is designed to: Provide routine and consistent checks to ensure data integrity, correctness, and completeness;

- Identify and address errors and omissions;
- Document and archive inventory material and record all QC activities.
- Higher tier QC activities include technical reviews of source categories, activity and emission factor data, and methods.
- Quality Assurance (QA) activities include a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process.
- Reviews, preferably by independent third parties, should be performed upon a finalized inventory following the implementation of QC procedures.
- Reviews verify that data quality objectives were met, ensure that the inventory represents the best possible estimates of emissions and sinks given the current state of scientific knowledge and data available, and support the effectiveness of the QC programme.
- Before implementing QA/QC activities, it is necessary to determine which techniques should be used, and where and when they will be applied. There are technical and practical considerations in making these decisions.
- The technical considerations related to the various QA/QC techniques are discussed in general in this chapter, and specific applications to source categories are described in the source category-specific good practice guidance in the practical considerations involve assessing national circumstances such as available resources and expertise and the particular characteristics of the inventory.
- The level of QA/QC activities should be compatible with the methods or tiers used to estimate emissions for particular source categories. In addition, resources should be focused on priority areas, such as the key source categories.

PRACTICAL CONSIDERATIONS IN DEVELOPING QA/QC SYSTEMS

Implementing QA/QC procedures requires resources, expertise and time. In developing any QA/QC system, it is expected that judgments will need to be made on the following:

- Resources allocated to QC for different source categories and the compilation process;
- Time allocated to conduct the checks and reviews of emissions estimates;
- Availability and access to information on activity data and emission factors, including data quality;
- Procedures to ensure confidentiality of inventory and source category information, when required;

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- Requirements for archiving information;
- Frequency of QA/QC checks on different parts of the inventory;
- The level of QC appropriate for each source category;
- Whether increased effort on QC will result in improved emissions estimates and reduced uncle.

ELEMENTS OF A QA/QC SYSTEM

The following are the major elements to be considered in the development of a QA/QC system to be implemented in tracking inventory compilation:

- An inventory agency responsible for coordinating QA/QC activities;
- QA/QC plan;
- General QC procedures
- Source category-specific QC procedures
- QA review procedures;
- Reporting, documentation, and archiving procedures.
- For purposes of the QA/QC system, the Tier 2 QC approach includes all procedures in Tier 1 plus additional

INVENTORY AGENCY

The inventory agency is responsible for coordinating QA/QC activities for the national inventory. The inventory agency may designate responsibilities for implementing and documenting these QA/QC procedures to other agencies or organizations.

The inventory agency should ensure that other organizations involved in the preparations of the inventory are following applicable QA/QC procedures.

The inventory agency is also responsible for ensuring that the QA/QC plan is developed and implemented. It is good practice for the inventory agency to designate a QA/QC coordinator,

Who would be responsible for ensuring that the objectives of the QA/QC programme are implemented?

QA/QC PLAN

A QA/QC plan is a fundamental element of a QA/QC system, and it is good practice to develop one. The plan should, in general, outline QA/QC activities that will be implemented, and include a scheduled time frame that follows inventory preparation from its initial development through to final reporting in any year.

The QA/QC plan is an internal document to organize, plan, and implement QA/QC activities can be referenced and used in subsequent inventory preparation, or modified as appropriate (i.e. when changes in processes occur or on advice of independent reviewers). This plan should be available for external review.

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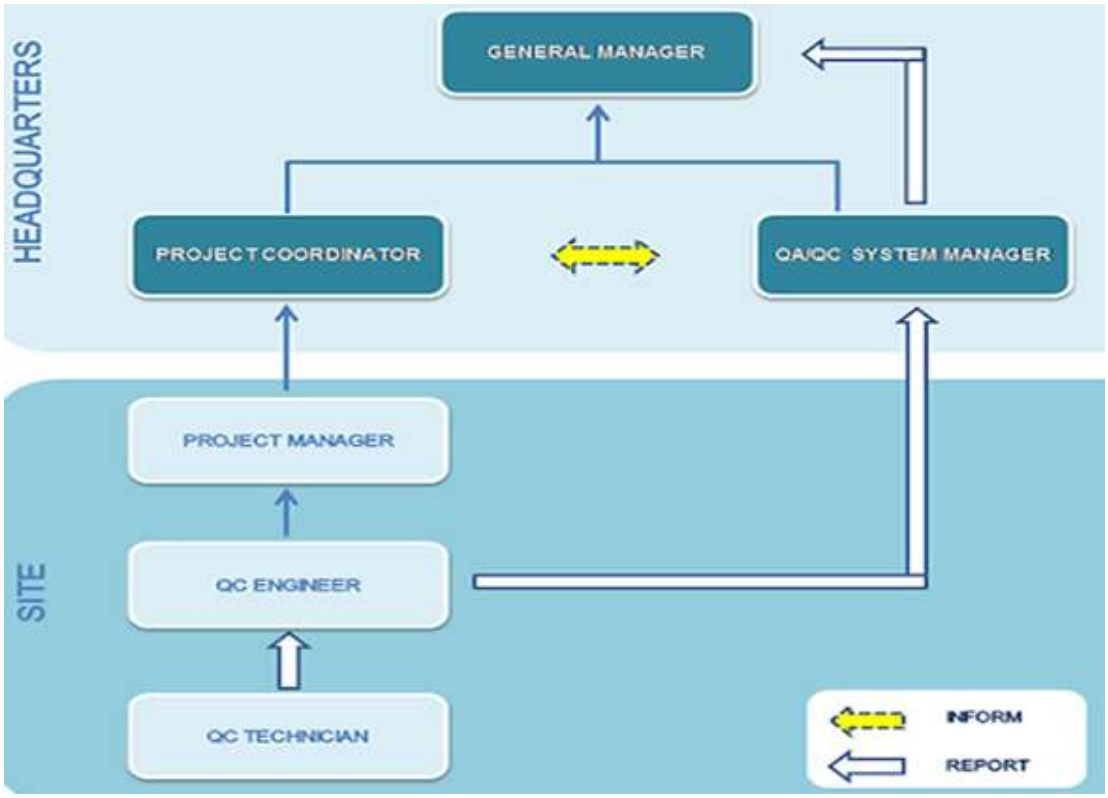

In developing and implementing the QA/QC plan, it may be useful to refer to the standards and guidelines published by the International Organization for Standardization (ISO), including the ISO 9000 series. Although ISO 9000 standards are not specifically designed for emissions inventories, they have been applied by some countries to help organize QA/QC activities.

ISO AS A DATA QUALITY MANAGEMENT SYSTEM

The International Organization for Standardization (ISO) series programme provides standards for data documentation and audits as part of a quality management system. Though the ISO series is not designed explicitly for emissions data development, many of the principles may be applied to ensure the production of a quality inventory. Inventory agencies may find these documents useful source material for developing QA/QC plans for greenhouse gas inventories.

Some countries (e.g. the United Kingdom and the Netherlands) have already applied some elements of the ISO standards for their inventory development process and data management.

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The following standards and guidelines published under the ISO series may supplement source

Category-specific QA/QC procedures for inventory development and provide practical guidance

For ensuring data quality and a transparent reporting system.

ISO 9004-1: General quality guidelines to implement a quality system.

ISO 9004-4: Guidelines for implementing continuous quality improvement with Organization, using tools and techniques based on data collection and analysis.

ISO 10005: Guidance on how to prepare quality plans for the control of specific projects.

ISO 10011-1: Guidelines for auditing a quality system.

ISO 10011-2: Guidance on the qualification criteria for quality systems auditors.

ISO 10011-3: Guidelines for managing quality system audit programmes.

ISO 10012: Guidelines on calibration systems and statistical controls to ensure the Measurements are made with the intended accuracy.

ISO 10013: Guidelines for developing quality manuals to meet specific need.

II. GENERAL QC PROCEDURES

The focus of general QC techniques is on the processing, handling, documenting, archiving and reporting procedures that are common to all the inventory source categories.

Procedures, lists the general QC checks that the inventory agency should use routinely throughout the preparation of the annual inventory. Most of the checks shown in could be performed by cross-checks, recalculation, or through visual inspections.

The results of these QC activities and procedures should be documented as set out in Section Internal Documentation and Archiving, below. If checks are performed electronically, these systems should be periodically reviewed to ensure the integrity of the checking function.

It will not be possible to check all aspects of inventory input data, parameters and calculations every year.

Checks may be performed on selected sets of data and processes, such that identified key source categories are considered every year. Checks on other source categories may be conducted less frequently. However, a sample of data and calculations from every sector should be included in the QC process each year to ensure that all sectors are addressed on an ongoing basis.

In establishing criteria and processes for selecting the sample data sets and processes, it is good practice for the inventory agency to plan to undertake QC checks on all parts of the inventory over an appropriate period of time.

SOURCE CATERGORY-SPECIFIC QC PROCEDURES

In contrast to general inventory QC techniques, source category-specific QC procedures are directed at specific types of data used in the methods for individual source categories and require knowledge of the emission source category, the types of data available and the parameters associated with emissions.

It is important to note that source category-specific QC activities are in addition to the general QC conducted as part .The source category-specific measures are applied on a case-by-case basis focusing on key source categories (see, Methodological Choice and Recalculation) and on source categories where significant methodological and data revisions have taken place. It is good practice that inventory agencies applying higher tier methods in compiling national inventories utilise QC procedures.

Source category-specific QC activities include the following:

- Emission data QC
- Activity data QC
- QC of uncertainty estimates.

The first two activities relate to the types of data used to prepare the emissions estimates for a given source category. QC of uncertainty estimates covers activities associated with determining uncertainties in emissions estimates (for more information on the determination of these uncertainties, see, Quantifying Uncertainties in Practice).

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The actual QC procedures that need to be implemented by the inventory agency will depend on the method used to estimate the emissions for a given source category. If estimates are developed by outside agencies, the inventory agency may, upon review, reference the QC activities of the outside agency as part of the QA/QC plan.

There is no need to duplicate QC activities if the inventory agency is satisfied that the QC activities performed by the outside agency meet the minimum requirements of the QA/QC plan.

Emissions data QC

The following sections describe QC checks on IPCC default factors, country-specific emission factors, and direct emission measurements from individual sites (used either as the basis for a site-specific emission factor or directly for an emissions estimate). Emission comparison procedures are described in Emission Comparisons.

Inventory agencies should take into account the practical considerations discussed in Section Practical Considerations in Developing QA/QC Systems, when determining what level of QC activities to undertake

IPCC DEFAULT EMISSION FACTORS

Where IPCC default emission factors are used, it is good practice for the inventory agency to assess the applicability of these factors to national circumstances. This assessment may include an evaluation of national conditions compared to the context of the studies upon which the IPCC default factors were based.

If there is insufficient information on the context of the IPCC default factors, the inventory agency should take account of this in assessing the uncertainty of the national emissions estimates based on the IPCC default emission factors.

For key source categories, inventory agencies should consider options for obtaining emission factors that are known to be representative of national circumstances. The results of this assessment should be documented.

If possible, IPCC default emission factor checks could be supplemented by comparisons with national site or plant-level factors to determine their representativeness relative to actual sources in the country. This supplementary check is good practice even if data are only available for a small percentage of sites or plants.

COUNTRY-SPECIFIC EMISSION FACTORS

Country-specific emission factors may be developed at a national or other aggregated level within the country based on prevailing technology, science, local characteristics and other criteria. These factors are not necessarily site-specific, but are used to represent a source category or sub-source category. Two steps are necessary to ensure good practice emission factor QC for country-specific factors.

The first is to perform QC checks on the data used to develop the emission factors. The adequacy of the emission factors and the QA/QC performed during their development should be assessed.

If emission factors were developed based on site-specific or source-level testing, then the inventory agency should check if the measurement programme included appropriate QC procedures.

Frequently, country-specific emission factors will be based on secondary data sources, such as published studies or other literature. In these cases, the inventory agency could attempt to determine whether the QC activities conducted during the original preparation of the data are consistent with the applicable QC procedures outlined in and whether any limitations of the secondary data have been identified and documented. The inventory agency could also attempt to establish whether the secondary data have undergone peer review and record the scope of such a review.

If it is determined that the QA/QC associated with the secondary data is adequate, then the inventory agency can simply reference the data source for documentation and document the applicability of the data for use in emissions estimates.

If it is determined that the QA/QC associated with the secondary data is inadequate, then the inventory agency should attempt to have QA/QC checks on the secondary data established. It should also reassess the uncertainty of any emissions estimates derived from the secondary data. The inventory agency may also reconsider how the data are used and whether any alternative data, (including IPCC default values) may provide a better estimate of emissions from this source category.

Second, country-specific factors and circumstances should be compared with relevant IPCC default factors and the characteristics of the studies on which the default factors are based. The intent of this comparison is to

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determine whether country-specific factors are reasonable, given similarities or differences between the national source category and the 'average' source category represented by the defaults. Large differences between country-specific factors and default factors should be explained and documented.

A supplementary step is to compare the country-specific factors with site-specific or plant-level factors if these are available. For example, if there are emission factors available for a few plants (but not enough to support a bottom-up approach) these plant-specific factors could be compared with the aggregated factor used in the inventory. This type of comparison provides an indication of both the reasonableness of the country-specific factor and its representativeness.

DIRECT EMISSION MEASUREMENTS

Emissions from a source category may be estimated using direct measurements in the following ways:

- Sample emissions measurements from a facility may be used to develop a representative emission factor for that individual site, or for the entire category (i.e. for development of a national level emission factor)
- Continuous emissions monitoring (CEM) data may be used to compile an annual estimate of emissions for a particular process. In theory, CEM can provide a complete set of quantified emissions data across the inventory period for an individual facility process, and does not have to be correlated back to a process parameter or input variable like an emission factor.

Regardless of how direct measurement data are being used, the inventory agency should review the processes and check the measurements as part of the QC activities.

Use of standard measurement methods improves the consistency of resulting data and knowledge of the statistical properties of the data.

If standard reference methods for measuring specific greenhouse gas emissions (and removals) are available, inventory agencies should encourage plants to use these.

If specific standard methods are not available, the inventory agency should confirm whether nationally or internationally recognized standard methods such as ISO 10012 are used for measurements and whether the measurement equipment is calibrated and maintained properly.

For example, ISO has published standards that specify procedures to quantify some of the performance characteristics of all air quality measurement methods such as bias, calibration, instability, lower detection limits, sensitivity, and upper limits of measurement (ISO, 1994).

Where direct measurement data from individual sites are in question, discussions with site managers can be useful to encourage improvement of the QA/QC practices at the sites. Also, supplementary QC activities are encouraged for bottom-up methods based on site-specific emission factors where significant uncertainty remains in the estimates. Site-specific factors can be compared between sites and also to IPCC or national level defaults.

Significant differences between sites or between a particular site and the IPCC defaults should elicit further review and checks on calculations. Large differences should be explained and documented.

EMISSION COMPARISONS

It is standard QC practice to compare emissions from each source category with emissions previously provided from the same source category or against historical trends and reference calculations as described below. The objective of these comparisons (often referred to as 'reality checks') is to ensure that the emission values are not wildly improbable or that they fall within a range that is considered reasonable. If the estimates seem unreasonable, emission checks can lead to a re-evaluation of emission factors and activity data before the inventory process has advanced to its final stages.

The first step of an emissions comparison is a consistency and completeness check using available historical inventory data for multiple years. The emission levels of most source categories do not abruptly change from year to year, as changes in both activity data and emission factors are generally gradual. In most circumstances, the change in emissions will be less than 10% per year. Thus, significant changes in emissions from previous years may indicate possible input or calculation errors. After calculating differences, the larger percentage differences (in any direction) should be flagged, by visual inspection of the list, by visual inspection of the

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graphical presentation of differences (e.g. in a spreadsheet) or by using a dedicated software programme that puts flags and rankings in the list of differences.

It is good practice to also check the annual increase or decrease of changes in emissions levels in significant sub source categories of some source categories. Sub-source categories may show greater percentage changes than the aggregated source categories. For example, total emissions from petrol cars are not likely to change substantially on an annual basis, but emissions from sub-source categories, such as catalyst-equipped petrol cars, may show substantial changes if the market share is not in equilibrium or if the technology is changing and rapidly being adopted in the marketplace.

It is good practice to check the emissions estimates for all source categories or sub- source categories that show greater than 10% change in a year compared to the previous year's inventory. Source categories and sub-source categories should be ranked according to the percentage difference in emissions from the previous year.

ORDER OF MAGNITUDE CHECKS

Order of magnitude checks look for major calculation errors and exclusion of major source categories or sub source categories. Method-based comparisons may be made depending on whether the emissions for the source category were determined using a top-down or bottom-up approach. For example, if N2O estimates for nitric acid production were determined using a bottom-up approach (i.e. emissions estimates were determined for each individual production plant based on plant-specific data), the emissions check would consist of comparing the Sum of the individual plant-level emissions to a top-down emission estimate based on national nitric acid production figures and IPCC default factors. If significant differences are found in the comparison, further investigation using the source category-specific QC techniques described in, Source Category- Specific QC Procedures would be necessary to answer the following questions:

- Are there inaccuracies associated with any of the individual plant estimates (e.g. an extreme outlier may be accounting for an unreasonable quantity of emissions)?
- Are the plant-specific emission factors significantly different from each other?
- Are the plant-specific production rates consistent with published national level production rates?
- Is there any other explanation for a significant difference, such as the effect of controls, the manner in which production is reported or possibly undocumented assumptions?

This is an example of how the result of a relatively simple emission check can lead to a more intensive investigation of the representativeness of the emissions data. Knowledge of the source category is required to isolate the parameter that is causing the difference in emissions estimates and to understand the reasons for the difference.

REFERENCE CALCULATIONS

Another emission comparison may be used for source categories that rely on empirical formulas for the calculation of emissions. Where such formulas are used, final calculated emission levels should follow stochiometric ratios and conserve energy and mass. In a number of cases where emissions are calculated as the sum of sectoral activities based on the consumption of a specific commodity (e.g. fuels or products like HFCs, PFCs or SF6), the emissions could alternatively be estimated using apparent consumption figures: national total production + import – export ± stock changes. For CO2 from fossil fuel combustion, a reference calculation based on apparent fuel consumption per fuel type is mandatory according to the IPCC Guidelines. Another example is estimating emissions from manure management. The total quantity of methane produced should not exceed the quantity that could be expected based on the carbon content of the volatile solids in the manure.

Discrepancies between inventory data and reference calculations do not necessarily imply that the inventory data are in error. It is important to consider that there may be large uncertainties associated with the reference calculations themselves when analyzing discrepancies.

Activity data QC

The estimation methods for many source categories rely on the use of activity data and associated input variables that are not directly prepared by the inventory agency. Activity data is normally collated at a national level using secondary data sources or from site-specific data prepared by site or plant personnel from their own

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measurements. Inventory agencies should take into account the practical considerations discussed above when determining the level of QC activities to undertake.

NATIONAL LEVEL ACTIVITY DATA

Where national activity data from secondary data sources are used in the inventory, it is good practice for the inventory agency or its designees to evaluate and document the associated QA/QC activities.

This is particularly important with regard to activity data, since most activity data are originally prepared for purposes other than as input to estimates of greenhouse gas emissions. Though not always readily available, many statistical organizations, for example, have their own procedures for assessing the quality of the data independently of what the end use of the data may be. If it is determined that these procedures satisfy minimum activities listed in the QA/QC plan, the inventory agency can simply reference the QA/QC activities conducted by the statistical organization.

It is good practice for the inventory agency to determine if the level of QC associated with secondary activity data includes those QC procedures listed in Table 8.1. In addition, the inventory agency may establish whether the secondary data have been peer reviewed and record the scope of this review. If it is determined that the QA/QC associated with the secondary data is adequate, then the inventory agency can simply reference the data source and document the applicability of the data for use in its emissions estimates.

If it is determined that the QC associated with the secondary data is inadequate, then the inventory agency should attempt to have QA/QC checks on the secondary data established. It should also reassess the uncertainty of emissions estimates in light of the findings from its assessment of the QA/QC associated with secondary data.

The inventory agency should also reconsider how the data are used and whether any alternative data, including IPCC default values and international data sets, may provide for a better estimate of emissions. If no alternative data sources are available, the inventory agency should document the inadequacies associated with the secondary data QC as part of its summary report on QA/QC (see Section Reporting, for reporting guidance).

For example, in the transportation category, countries typically use either fuel usage or kilometer (km) statistics to develop emissions estimates. The national statistics on fuel usage and kms travelled by vehicles are usually prepared by a different agency from the inventory agency. However, it is the responsibility of the inventory agency to determine what QA/QC activities were implemented by the agency that prepared the original fuel usage and km statistics for vehicles. Questions that may be asked in this context are:

- Does the statistical agency have a QA/QC plan that covers the preparation of the data?
- What sampling protocol was used to estimate fuel usage or kms travelled?
- How recently was the sampling protocol reviewed?
- Has any potential bias in the data been identified by the statistical agency?
- Has the statistical agency identified and documented uncertainties in the data?
- Has the statistical agency identified and documented errors in the data?

National level activity data should be compared with previous year's data for the source category being evaluated. Activity data for most source categories tend to exhibit relatively consistent changes from year to year without sharp increases or decreases. If the national activity data for any year diverge greatly from the historical trend, the activity data should be checked for errors. If the general mathematical checks do not reveal errors, the characteristics of the source category could be investigated and any change identified and documented.

Where possible, a comparison check of activity data from multiple reference sources should be undertaken. This is important for source categories that have a high level of uncertainty associated with their estimates. For example, many of the agricultural source-categories rely on government statistics for activity data such as livestock populations, areas under cultivation, and the extent of prescribed burning. Similar statistics may be prepared by industry, universities, or other organizations and can be used to compare with standard reference sources. As part of the QC check, the inventory agency should ascertain whether independent data have been used to derive alternative activity data sets. In some cases, the same data are treated differently by different agencies to meet varying needs. Comparisons may need to be made at a regional level or with a subset of the

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national data since many alternative references for such activity data have limited scope and do not cover the entire nation.

SITE-SPECIFIC ACTIVITY DATA

Some methods rely on the use of site-specific activity data used in conjunction with IPCC default or country specific emission factors. Site or plant personnel typically prepare these estimates of activity, often for purposes other than as inputs to emissions inventories. QC checks should focus on inconsistencies between sites to establish whether these reflect errors, different measurement techniques, or real differences in emissions, operating conditions or technology.

A variety of QC checks can be used to identify errors in site-level activity data. The inventory agency should establish whether recognized national or international standards were used in measuring activity data at the individual sites.

If measurements were made according to recognised national or international standards and a QA/QC process is in place, the inventory agency should satisfy itself that the QA/QC process at the site is acceptable under the inventory QA/QC plan and at least includes Tier 1 activities. Acceptable QC procedures in use at the site may be directly referenced. If the measurements were not made using standard methods and QA/QC is not of an acceptable standard, then the use of these activity data should be carefully evaluated, uncertainty estimates reconsidered, and qualifications documented.

Comparisons of activity data from different reference sources may also be used to expand the activity data QC. For example, in estimating PFC emissions from primary aluminium smelting, many inventory agencies use smelter-specific activity data to prepare the inventory estimates.

A QC check of the aggregated activity data from all aluminium smelters can be made against national production statistics for the industry. Also, production data can be compared across different sites, possibly with adjustments made for plant capacities, to evaluate the reasonableness of the production data. Similar comparisons of activity data can be made for other manufacturing-based source categories where there are published data on national production. If outliers are identified, they should be investigated to determine if the difference can be explained by the unique characteristics of the site or there is an error in the reported activity.

Site-specific activity data checks may also be applied to methods based on product usage. For example, one method for estimating SF6 emissions from use in electrical equipment relies on an account balance of gas purchases, gas sales for recycling, the amount of gas stored on site (outside of equipment), handling losses, refills for maintenance, and the total holding capacity of the equipment system. This account balance system should be used at each facility where the equipment is in place. A QC check of overall national activity could be made by performing the same kind of account balancing procedure on a national basis. This national account balancing would consider national sales of SF6 for use in electrical equipment, the nation-wide increase in the total handling capacity of the equipment (that may be obtained from equipment manufacturers), and the quantity of SF6 destroyed in the country. The results of the bottom-up and top-down account balancing analyses should agree or large differences should be explained. Similar accounting techniques can be used as QC checks on other based on gas usage (e.g. substitutes for ozone-depleting substances) to check consumption and emissions.

QC of uncertainty estimates

QC should also be undertaken on calculations or estimates of uncertainty associated with emissions estimates .Good practice for estimating inventory uncertainties is described in Chapter 6, Quantifying Uncertainties in Practice, and relies on calculations of uncertainty at the source category level that are then combined to summary levels for the entire inventory.

Some of the methods rely on the use of measured data associated with the emission factors or activity data to develop probability density functions from which uncertainty estimates can be made. In the absence of measured data, many uncertainty estimates will rely on expert judgement.

It is good practice for QC procedures to be applied to the uncertainty estimations to confirm that calculations are correct and that there is sufficient documentation to duplicate them. The assumptions on which uncertainty

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estimations have been based should be documented for each source category. Calculations of source category specific and aggregated uncertainty estimates should be checked and any errors addressed.

QA PROCEDURES

Good practice for QA procedures requires an objective review to assess the quality of the inventory, and also to identify areas where improvements could be made. The inventory may be reviewed as a whole or in parts. QA procedures are utilized in addition to the Tier 1 and Tier 2 QC. The objective in QA implementation is to involve reviewers that can conduct an unbiased review of the inventory. It is good practice to use QA reviewers that have not been involved in preparing the inventory. Preferably these reviewers would be independent experts from other agencies or a national or international expert or group not closely connected with national inventory compilation. Where third party reviewers outside the inventory agency are not available, staff from another part of the inventory agency not involved in the portion of the inventory being reviewed can also fulfil QA roles.

It is good practice for inventory agencies to conduct a basic expert peer review (Tier 1 QA) prior to inventory submission in order to identify potential problems and make corrections where possible. It is also good practice to apply this review to all source categories in the inventory. However, this will not always be practical due to timing and resource constraints. Key source categories should be given priority as well as source categories where significant changes in methods or data have been made. Inventory agencies may also choose to perform more extensive peer reviews or audits or both as additional QA procedures within the available resources.

III. DOCUMENTATION, ARCHIVING AND REPORTING

Internal documentation and archiving

As part of general QC procedures, it is good practice to document and archive all information required to produce the national emissions inventory estimates. This includes:

- Assumptions and criteria for selection of activity data and emission factors;
- Emission factors used, including references to the IPCC document for default factors or to published references or other documentation for emission factors used in higher tier methods;
- Activity data or sufficient information to enable activity data to be traced to the referenced source;
- Information on the uncertainty associated with activity data and emission factors;
- Rationale for choice of methods;
- Methods used, including those used to estimate uncertainty;
- Changes in data inputs or methods from previous years.
- Identification of individuals providing expert judgement for uncertainty estimates and their qualifications to do so;
- Details of electronic databases or software used in production of the inventory, including versions, operating manuals, hardware requirements and any other information required to enable their later use;
- Worksheets and interim calculations for source category estimates and aggregated estimates and any recalculations of previous estimates;
- Final inventory report and any analysis of trends from previous years;
- QA/QC plans and outcomes of QA/QC procedures.

It is good practice for inventory agencies to maintain this documentation for every annual inventory produced and to provide it for review. It is good practice to maintain and archive this documentation in such a way that every inventory estimate can be fully documented and reproduced if necessary. Inventory agencies should ensure that records are unambiguous; for example, a reference to 'IPCC default factor' is not sufficient.

Records of QA/QC procedures are important information to enable continuous improvement to inventory estimates. It is good practice for records of QA/QC activities to include the checks/audits/reviews that were performed, when they were performed, who performed them, and corrections and modifications to the inventory resulting from the QA/QC activity.

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Reporting

It is good practice to report a summary of implemented QA/QC activities and key findings as a supplement to each country's national inventory. However, it is not practical or necessary to report all the internal documentation that is retained by the inventory agency. The summary should describe which activities were performed internally and what external reviews were conducted for each source category and on the entire inventory in accordance with the QA/QC plan. The key findings should describe major issues regarding quality of input data, methods, processing archiving and show how they were addressed or plan to be addressed in the future.

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