Quality Assurance and Quality Control Approach for Local and Regional Air Pollutants Emission Inventories in Italy

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ABSTRACT

In the paper the approach followed in Italy for quality assurance (QA) and quality control (QC) in some local and regional emission inventories is presented. Particular attention is devoted to the completeness of data, the quality control of data and the validation of results. The methodology used for emission inventory preparation at local level is at first resumed. Next is introduced the QA/QC procedures followed in Italy at local and regional level to guarantee the quality of the inventories. The following main topics are discussed: definition of data collection plan, procedures for documentation of data collection ("contacts file"), validation procedure for point sources data. In this field a complete tests program has been elaborated in the frame of ISO 9001:2000 quality normative through a check list procedure. Finally the paper reports the use of the new Air Pollutants Computer System software (APEX.com) to support the QA/QC procedures.

INTRODUCTION

The emissions inventory activity in Italy started in 1980 at a national level[1] and has been applied at the local level since 1990[2]. The realization of air pollutant emissions inventory allows characterization of the different role played by the various emission sources and consequently represents a basic tool to define criteria for air quality management plans[3]. A recent paper reports a balance of air quality management activities in Italy[4].

The nomenclature used at the local level follows the guidelines of the European Commission CORINAIR working group[5]. CORINAIR nomenclature includes about 200 source categories grouped in 11 sectors:

- Combustion in energy and transformation industries (stationary source),
- Non-industrial combustion plants (stationary sources),
- Combustion in manufacturing industry (stationary sources),
- Production processes (stationary sources),
- Extraction and distribution of fossil fuels and geothermal energy,
- Solvent and other product use,
- Road transport,
- Other mobile sources and machinery,
- Waste treatment and disposal,
- Agriculture,
- Other sources and sinks.

The sources are generally split in four categories: point sources (divided in main and minor point sources), area sources and linear/nodal sources. Point sources include the fixed sources with total annual emission of one pollutant larger than a fixed threshold value. Linear/nodal sources correspond to the main communication ways (roads, rivers, railways, and seaways) and nodes (ports, airports) and generally all the highways, all the main extra-urban roads and all the main ports and airports are included. All the other sources are defined as area sources.

For main point sources, information is gathered through a questionnaire that allows collection of general data (identification, location, etc.), structural data (stacks and units characteristics) and quantitative data (pollutant concentrations at the stacks, pollutant emissions, actual production, fuel consumptions). For minor point sources information is gathered through a simplified questionnaire with general data, pollutant emissions, actual production and fuel consumptions.

Area sources (for instance, domestic solvent use and natural sources) are evaluated on a geographical basis, inside each municipal administrative unit, using statistical or survey data on suitable source categories indicators (for example: paint consumptions, fuel consumptions) and emission factors.

AIRSUITE.COM SOFTWARE

The APEX.COM emission inventory software is integrated in the computer models system AIR SUITE.COM developed by Techne Consulting. In the following a brief description of the system is reported as an introduction to QA/QC discussion. The Air Suite system scheme is reported in Figure 1.

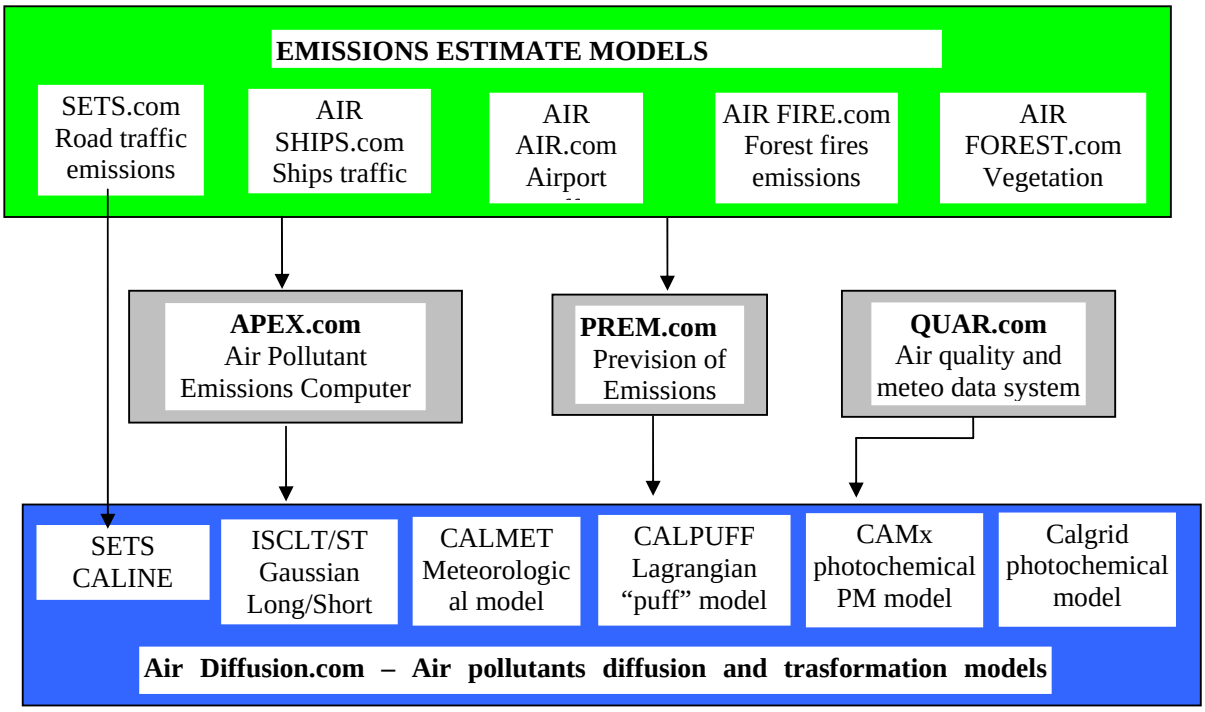

Figure 1: Structure of information system for air quality management planning (AirSuite.com)

APEX.COM

APEX is an air pollutant emissions computer system originally developed in the Windows environment with object-oriented ORACLE CARD tool[6,7,8] and with Visual Basic language, and available with an ORACLE or SQL Server database[9,10]; the system contains an emission factors database, tools and data to estimate grid and municipal emissions from more aggregated data[11]. The system uses Arc View or MapInfo for thematic maps. Recently an integrated emission inventory computer system was developed allowing the realization of emission inventories in different media (air, water, wastes, etc.)[12]. New release of the software (APEX. Com), in intranet/internet environment, was released this year.

EMISSIONS INVENTORY QUALITY

The level of accuracy of the emissions inventory is important as regarding the goodness of the estimates, but also as it represents a critical element for the management of air quality. In fact, being the inventory the base instrument for the definition of the air quality management plans, the uncertainty of the inventory has direct consequences on reliability of evaluation (models simulations, projections of the future emissions).

QA/QC ("Quality Assurance "and" Quality Control") procedures, analogous to the methodologies applied with reference to the norms UNI EN ISO 9001:2000, can be used to test the quality of the inventories. The finality of the QA/QC procedures consists in the identification and the reduction of

errors and omissions, in the optimization of the relative coherence of the procedures for the preparation and documentation of the inventory, in the facilitation of the review procedures[13, 14, 15, 16].

In order to improve the quality, once the inventory has been compiled different procedures to guarantee the quality can be activated, such as verification and revision. One of the main problems during the collection phase of the necessary information for the creation of an emissions inventory (to every scale) is data integrity. Satisfactory or unsatisfactory data integrity can be influenced by various factors, for example the non-existence of some necessary data, the impossibility of retrieve it or the lack of data supply from the owner.

If data are incomplete and the request for lacking data needs too much time, default data can be used or data can be evaluate through roughly estimates, specific for the typology of emission that is being considered.

Regarding the emissions from industrial sources, the "significance" of a single plant related to the totals amounts of pollutants emitted in the temporal domain for the inventory must be considered.

In fact, in the inventory of point sources with a considerable amount of information (geographic localization of the plant, physical characteristics of the emission stacks, data on fuel and raw materials used, etc), the insertion of a large number of plants must be carefully evaluated.

For optimal management of inventory, therefore, it is necessary to limit the number of plants defined as point sources, selecting only those that exceed a determined amount of emission (depending by the extension of the territory in examination and by the presence of particular industrial areas), and contemplating the rest of the industrial emissions from a statistical point of view as area emissions.

Usually the first selection of the point sources is carried out through analysis of the available documentation, and then emissions data and other information useful to evaluate emissions and to use mathematical models are requested through a questionnaire.

The average contribution of point sources to the total emissions in industrial sectors in a selection of regional emissions inventories in Italy is shown in Figure 1. Emissions in Figure 1 include only the macro-sectors interested by point sources (Combustion in energy and transformation industries, Combustion in manufacturing industry, Production processes, Extraction and distribution of fossil fuels and geothermal energy, Solvent and other product use, Waste treatment and disposal). The amounts of pollutants emitted from the point sources represent the preponderant percentage of the total.

Obviously the integrity of data in the case of point sources depends on the answers to the questionnaires provided by the companies. Their eventual lack, however, can be compensated with the technical information contained in the permits documentation (usually sufficient to fairly estimate the emissions in atmosphere), and/or with data of production and consumptions, used with opportune emission factors for the estimate of the emissions.

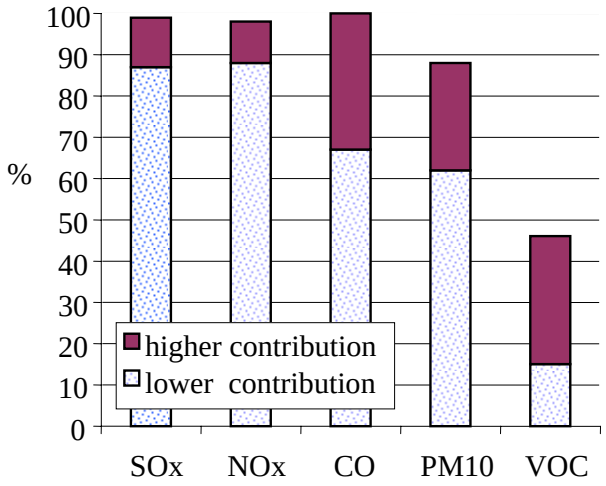

Figure 1 - Contribution of point sources to the industrial emissions in selected Italian regional inventories

Integrity of data can be not satisfactory also in case of questionnaire not exhaustive of the complete emissions framework of the plant in consequence of the lack of analysis for the period in consideration or for diffuse emissions and/or pollutants not considered by the permit.

QUALITY ASSURANCE AND QUALITY CONTROL PROCEDURES IN EMISSIONS INVENTORY

Methodology

The QA/QC procedures developed in Italy at local and regional level to guarantee the quality of the inventories follow the steps:

- Definition of data collection plan
- Procedures for documentation of data collection ("contacts file")
- Validation procedure for point sources data
  Usually point sources data are collected through a direct census and in this case the following activities are activated:
  - comparison of emission data with emission factors estimates,
  - comparison of emission data with data of similar plants,
  - integration of emission data, when not declared, with estimates through emission factors;
- Validation procedure for area and line sources:
  - check on source categories data collection and storage (check on data entry errors, check on double counting of source categories data level, etc.)
  - validation procedure for appropriate use of emission factors
- Internal validation on final emission inventory results
  In this field a complete tests program has been elaborated in the frame of ISO 9001:2000 quality normative through a check list containing procedure for:
  - Computerized check to compare estimates with other similar territorial units,
  - Computerized check to compare estimates between source categories,
  - Independent review of calculations, assumptions, and/or documentation by other experts
- External validation on emission inventory results
  As we operate as consultants of local or regional boards an external independent audit from administration functionaries often follows
- Air quality models application
  Finally emission inventories are often used as input on air quality models (diffusion and statistical models) and comparison of models results with monitoring data is useful to individuate possible errors in inventory data.

In the following some of these topics are analyzed in detail.

Definition of data collection plan

A quality plan is first defined applying the norms of quality ISO 9001:2000 to the realization of the emissions inventories, All the information useful to the data collection and to the emissions estimates (source categories data, emission factors, emission thresholds, etc), are evidenced in the plan and they are available to the staff involved in the inventory realization and to the authorities, together with the problems that can be stood out during the information retrieval.

In particular, in the plan are defined:

- all data useful to define source categories levels, characterizing the data sources;
- other useful data (emission factors, etc), characterizing the data sources.

Procedures for documentation of data collection

Once the phase of information retrieval is carried out, the correspondence of retrieved with requested information must be verified. This is an essential condition so that final results are compatible

with goals foreseen in the planning of the inventory. In this activity it can be useful to ask new information to the data owner.

All the data retrieval activities are documented through the "directory of the contacts", in which the typology of demands, the answers, the contacts, etc. are recorded in correspondence of every data owner. The data collected are inserted in the system Air Suite.com (system for the study of the atmospheric pollution), and in particular in the emission inventory management system (APEX.COM) and in the models for estimate emissions in specific sectors (SETS for road transport, AIR AIR for airports, AIR SHIPS for naval transport, AIR FIRE for forest fires, AIR FOREST for vegetation).

Validation procedure for area and line sources data

Controls are carried out through report for single source category to verify that errors have not been stored in data loading. Such controls carried out during realization of the inventory guarantee the completeness of the source categories in the inventory and a better quality control on data obtained at the end of the estimate process, after applied the emission factors.

Validation procedure for point sources data

Data collected for point sources through questionnaire to the companies are analyzed and evaluated in order to evidence eventual errors in the compilation or missing information for the corrected evaluation of the emissions. In all the cases in which a situation of uncertainty is given in the information, the technical responsible of the plant are contacted in order to obtain the necessary confirmations and to supply the due corrections and integrations.

First the subdivision of the plant in productive units is considered, based on the classification of the source categories of the inventory (extension of the most recent classification adopted in Europe within CORINAIR). Units not declared or erroneously declared are added or modified if the analysis of the productive cycle evidences them.

Next the source category indicators of every productive unit are evaluated (unit of measure, consistency of capacity with production, comparison of production with raw materials or fuel used, etc.).

The declared pollutants emissions are validated by the following steps:

- comparison of emissions data with estimates obtained with use of standard emission factors; the comparison is quite difficult for the high number of factors able to influence the emission factors (technological characteristics, abatement systems, types of fuel and raw materials used, etc.) and for uncertainty associated to its; an approximate limit in order to proceed to eventual ulterior verifications is a difference of approximately ±50% regarding the estimated value;
- verification of the declared emissions compared to those obtained for single point of emission, through:

$$E_i = 10^{-6} P\ g\ h\ C_i$$

where: P, hourly gas flow; i, pollutant; g, working days for year; h, working hours for day; C_i, average concentration of pollutant i; then the emissions are calculated for the whole plant as the sum of emissions of all stacks;

- evaluation of emissions not emitted in stacks (such as Organic Compound emissions from industrial paint); the calculation of the emissions is carried out from declared amounts of raw materials used (for example varnishing and solvents), the content of organic compound in the materials and the specific control systems adopted;
- insertion of emissions of pollutants not declared from the companies but of which the presence in relation to the activities carried out in the plant is known (calculated through emission factors).

In Table 1 is reported an example of validation of emissions from one power plant composed of two groups of 300 MWth.

In Table 2 is reported an example of validation of the declared volatile organic compound emissions from a shipyard relatively to the unit of painting for three consecutive years. In this example the comparison has been carried out with the emissions deriving from emission factors applied to the raw materials used (varnishes containing approximately 65% of solvents).

The declared emissions are less than real value, as the measurements are carried out on the points of emission of the plant (stacks and/or vents) and therefore they do not taken in consideration the diffuse emissions. In this case the values inserted in the inventory are the calculate ones.

Table 1 – Power plant emissions quality control

Pollutant (*)	Declared emissions (Mg)	Emission Factors computed emissions (Mg)	Δ %
NO_x	1,253	1,621	29,4
SO_x	2,988	3,399	13,8
CO_2	587,000	581,848	0,9
PM_{10}	122	123	1,2
VOC	-	75	-
CO	-	120	-

Fuel	Consumption	Units
Oil	174731	Mg
Natural Gas	22183000	m3

(*) cyclone control system on main group

Table 2 - Volatile Organic Compounds emissions validation from a shipyard (painting)

Year	Declared Emissions (Mg)	Varnishes used (Mg)	Estimated emissions (Mg)	Difference %
2000	3,2	13,2	8,580	168,1
2001	0,82	4,2	2,730	232,9
2002	3,3	19,8	12,870	290,0

Internal validation on final emission inventory results

In the following is reported a methodology applicable to the control and validation of final emission inventory results.

All the data used in the inventory must be submitted to validation procedures. In particular, tests and controls are specified in the Quality Plan, in agreement to the quality management systems. The description of the tests and the results are summarized in an appropriate quality control report. No data are delivered to the customer officially, until all the activities specified in the Quality Plan will not have been positively finished, and the relative documentation will not be available and approved.

The procedure of tests elaborated is defined in the "DATA CHECKLIST", document that defines the plan of the tests used in the frame of the norms of quality ISO 9001:2000 with the goal to realize an inventory of the emissions more reliable.

The DATA CHECKLIST is articulated in the two models "Ante correction" and "Post Correction", to compile respectively before and after that the eventual errors are corrected. The checklist is subdivided in sections, in which is specified the detail of requirements of the reports to carry out. In such a way the procedure of correction of eventual errors is documented. The evidence of the reports carried out before and after modifications, when corrections are needed, is obtained through reference to online documentation.

The CHECKLIST imposes the control of the reports of the source categories indicators and emissions data from area, linear and point sources and total. In emissions check, main pollutants, heavy metals, greenhouse gases, benzene and IPA are validated.

In the test procedure can be distinguished two cases. In the case of an existing inventory that must be updated, the comparison is carried out on the outputs that the inventory software supplies for the various years under study. In the case of a new inventory, the term of comparison can be an inventory elaborated for similar territory (for example a similar region). In the CHECKLIST, if anomalies were detected for some source categories, at first indicators are compared with the reference inventory and, if no anomalies are evidenced, the emission factors are compared.

Initially emissions data are controlled (since they are the result of the product between the emission factor and the data of source categories and therefore from the analysis of these can be characterized anomalies imputable to both). Once characterized not validate emission data, it is proceeded to the control of source categories indicators and emission factors.

In the model ante-correction, in the relative part to the result of the test, is reported OK if the result of the test is positive, is written NO, with the indication of the found error, if it is negative. In this case the test must be repeated, after to have modified the input data. In the model post-correction, in the relative section to the controlled source category is placed an OK with the error description or, if instead the discrepancy it is revealed imputable not to an error but to an effective variation in data, a comment.

The CHECKLIST previews an ulterior section in which they are specified the modalities of control of the spatial and temporal allocation of the emissions. The first of the two tests, evaluates if the total area source categories indicators is equal to the sum of the values of source categories indicators allocated on square grids. The second test evaluates if the total coincides with the sum of the values of source categories indicators allocated temporarily on the hours of the year.

The last section of the CHECKLIST defines a synthetic statistical index. This is calculated as relationship between number X of the source categories for which the test has supplied positive result and the T total of the evaluated source categories. The elaborated index, allows obtaining one synthetic evaluation on the loading of data in the inventory.

APEX.COM QA/QC TEST PROCEDURES

The new emission inventory software (APEX.com) release includes specific procedures for QA/QC. In particular appropriate interactive and batch QA/QC test procedures are contained in the software. The procedures sequence is first activated by the user and executed sequentially by the system producing a list of test results. The user can analyze the results, correct data and, where applicable, execute all the sequence or selected tests. The iterated procedure allows a complete documentation of QA/QC program.

CONCLUSIONS

In conclusion it can be asserted that the application of the quality plans and of the controls defined, and in particular the final tests through check list, represents the most valid support to the validation of the emission inventories and to obtain a "better" final results in terms of reliability.

Finally must be emphasized the importance, in the case of the compilation of a local emission inventory, of the relation between quality control of the data, obtained for example through the DATA CHECKLIST, and the final results in terms of uncertainty. The control and the validation of data contribute in fact to the reduction of the total uncertainty of the inventory.

It’s therefore obvious that the application of procedures QA\QC in the various processes that directly or indirectly are connected to the data retrieval and the data elaboration activities has a strong impact on the quality of the final product.

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