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The INEMAR database: a tool for regional atmospheric emission inventory

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Abstract: Within the framework of the Regional Air Quality Plan (PRQA) of the Lombardy Region (Italy) a database named INEMAR (AiR EMission INventory) was developed for the estimation and management of the atmospheric emissions.
The INEMAR system considers emissions of different sources (point, area, biogenic, road transport), and organizes all information needed for their estimation: activity indicators, emission factors, other statistical data necessary on spatial and temporal distribution of emissions.
As the first Italian experience of an emission inventory source code made by a regional authority, INEMAR is a multi-user database that contains all the data for the emission estimates, the procedures that carry out the algorithms utilized for these estimates and the values of calculated emissions. INEMAR's strength is the high resolution (municipality level) of all the emission results, great flexibility (database in 3rd normal form), and the client-server framework suitable for provincial inventories.
The database is accessible by any PC user connected by the regional ISDN network or by Internet, in order to visualize or modify the data in the archive, or for local processing of the data. Output can be also visualized, in client-server mode, with maps, graphs and tables by means of a specific module of Nebula LTK, a GIS-oriented package previously developed by the Lombardy Region.
The use of INEMAR by other Italian Region (i.e. Piedmont Region) and by the provincial offices of ARPA is ongoing.

Keywords: database; emission; inventory; air pollution; Italy

1. INTRODUCTION

Within the framework of management activities related to air quality, more and more attention is being paid to the need for quantitative information on emissions from different sources.

A detailed emission data collection allows the spotting out of contributions of different sources to local and global air pollution, and consequently the assessment of more proper intervention strategies. The emission inventory is thus one of the main instruments necessary to the definition of air recovery policies.

2. THE LOMBARDY REGIONAL AIR QUALITY PLAN (PRQA)

The emission inventory of the Lombardy Region has been carried out within the Regional Air Quality Plan (PRQA) [R.L.-F.L.A., 2000], a three-year project resulting from an agreement signed between the Environmental Quality General Direction of the Lombardy Region and the Lombardy Foundation for the Environment, a non-profit research institution founded by the Lombardy Region, which co-operates with the main Lombard universities.

The PRQA is a research project performed on a regional scale with the aim of reaching a valid assessment of atmospheric emissions which may allow the characterization of critical areas, the estimate of health risks for man and ecosystems and the performance of costs-benefits analysis for the adoption of proper mitigation measures.

3. METHODOLOGY

Within an inventory, emissions can be divided into the following typologies:

"area sources" scattered on the territory and assessed by means of proper indicators and emission factors;
"point sources", pollution sources which can be geographically located, assessed by measured data collected by special census; as for some pollutants which have not been monitored, emissions can derive from estimations carried out as previously mentioned;
"linear sources" such as roads, assessed by means of proper indicators and emission factors, generally by detailed methodologies.

The optimal methodology to set up an emission inventory implies direct quantification of all emissions of different sources typologies for both areas and time of interest through measurements. However, the "analytical" approach can be used exclusively for some specific pollutants typologies (i.e. sulfur dioxide, nitrogen oxides, carbon monoxide) and sources, typically great industrial plants (i.e. thermal power plants, incinerators, cement industries) which usually have major emissions and are therefore checked by means of in-continuous monitoring systems.

It is then necessary to apply the most common approach by emission inventories, which for area sources carries out emissions evaluation by means of an indicator characterizing the activity of the source and its emission factor, specific of the industrial process and of the adopted purification technology. This method bases on a linear relation between the source activity and the emission, following a relation that can be broadly outlined as follows:

$$E_i = A \cdot FE_i \qquad (1)$$

where:
E_i = emission of the pollutant i (g year^{-1});
A = activity indicator, i.e. produced amount, fuel consumption (t year^{-1});
FE_i = emission factor of the pollutant i (g t^{-1} of product).

The reliability of this evaluation depends on the precision of emission factors, so far as one considers in detail each single production process using specific emission factors typical of the plant typology.

COPERT II methodology proposed by CORINAIR [E.E.A., 2000] have been used for road transport emissions, with the basic distinction between non-urban driving (highway and other main roads) and urban driving. Non-urban traffic is the component of road mobility which runs along the roads network by middle or long-term courses, whereas urban traffic uses it for all kinds of courses along municipal roads [Terraria, 2000].

4. THE 1997 LOMBARDY EMISSION INVENTORY: DATA AND RESULTS

4.1 Pollutants

The substances taken into consideration in the 1997 Lombardy Region inventory are acidifiers (SO_2, NO_x, NH_3, CO), ozone precursors (NMVOC), greenhouse gases (CO_2, CH_4, N_2O), heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn). PM_{10} and dioxin have also been considered, although estimates are more uncertain since they have been based mainly on US-EPA emission factors [U.S.-E.P.A., 1998].

4.2 Classification of activities

The SNAP 97 Nomenclature [E.E.A., 2000] used for the CORINAIR (CooRdination Information AIR) project, promoted by the European Union, has been adopted.

The CORINAIR inventory is designed as a common european-wide database which is easily applicable to the setting up of specific inventories in accordance with LRTAP and FCCC guidelines. The SNAP97 system is set up according to three levels:

- the upper level - 11 source categories which features grouping of sources as commonly performed;
- the intermediate level - 75 source sub-categories (45 of which used in the Lombardy Inventory) embodying technological and social-economic criteria;
- the lower level - 416 source activities (198 of which used in the Lombardy Inventory), aiming at an exhaustive enumeration of sources and sinks to spot homogeneous sections in generating emissions.

4.3 Point sources

About 200 huge industrial plants have been selected and emission and other surrogate data (characteristics of the stacks and of the flue gas, etc.), have been collected by means of a form. The surveyed plants are power plants, cement industries, municipal waste incinerators, refineries, landfills and the largest chemical and manufacturing plants. Emission data on most significant macro-pollutants (SO_2, NO_x, dust, CO) are taken from a monitoring system.

Within the framework of PRQA, a computerized network of large plants emission data is ongoing,

and the relative procedural scheme has been defined.

4.4 Area sources

Emissions from smaller industrial plants or, in general, area sources emissions (i.e. emissions from heating plants or agricultural activities) are assessed by the methodology based on indicators and emission factors, previously described.

Emission factors used in this analysis derive from the European Atmospheric Inventory Guidebook [2000], from the U.S.EPA Air CHIEF CD-ROM Version.7 [2000], and from Italian data collected by ANPA [De Lauretis, 2000]; in some cases, specific emission factors have been applied, coming from studies carried out within the framework of the PRQA.

As for biogenic emissions (NMVOC emitted by forests), the algorithm developed by Simpson et. al. [1995], and proposed in the CORINAIR framework has been used. As for landfill emissions, the algorithm based on the IPCC detailed methodology has been used [IPCC, 1996].

As far as urban driving is concerned, a survey on 18 PUTs (Urban Traffic Plan) has been done [Terraria, 2000], collecting information on vehicle mileage and speed, on daily and seasonal traffic variation. A relation between vehicle mileage and population has been adopted to calculate urban traffic emissions for the 1546 municipalities in Lombardy.

4.5 Linear sources

As for non-urban transport emissions, data of temporal vehicle distribution have been considered for 4 seasons, 3 different days, 3 different hours. All available data have been processed within the TRIPS (Equilibrium Traffic Assignment Algorithm) model to calculate both traffic flows and speed on all roads in the Lombardy Region (except for smaller roads with local traffic).

5. THE INEMAR DATABASE

The INEMAR (AiR EMission INventory) database is a multi-user database in RDBMS Oracle environment based on cluster Alpha server; the database is in Oracle version 8.1.7 and the Application Server is in Oracle 9iAS version 1.2.2.

INEMAR contains all data for emission estimates and the procedures to carry out the algorithms used for these estimates:

- activity indicators (i.e. fuel consumption, paint consumption, incinerated amount);
- emission factors;
- other statistical data needed for spatial and temporal distribution of emissions.

The calculated emissions data are stored as a combination of:

- Pollutant name
- Fuel name
- Activity name
- Municipality name
- Emission type

The database is now characterized by more than 1 million of records, it assesses emissions of 18 pollutants, for each of the 1546 municipalities of the Lombardy region, for 198 source activities (referring to 11 groups and 45 sub-categories) and for 20 typologies of fuels. As an example, Figure 1 shows the share of the different sources categories on the pollutants emissions.

The algorithms for data elaboration have been created with PL/SQL procedures, directly memorized into the Server Database.

The database can be reached by any PC user connected on the regional ISDN network or by Internet, in order to visualize or modify data in the archive, or for local data processing.
Data can be reached by two ways:

- by INEMAR 2.0 Client Server
- by INEMAR 3.0 Web

5.1 INEMAR 2.0 Client Server

Forms created in this version have been made using Oracle Forms version 6i.

The INEMAR 2.0 network is represented in Figure 2. The output can be visualized with maps, graphs and tables by means of a specific module of Nebula LTK, a GIS-oriented package previously developed by the Lombardy Region (Figure 3).

From the main menu (Figure 4) the six sections of the database can be reached: point sources, landfills, biogenic sources, residential heating, area sources, road transport.

5.2 INEMAR 3.0 Web

The network of this version, realized with Oracle Portal version 3.0.8.9.8, is represented in Figure 5. The website (R.L., 2002) is the latest INEMAR version: any PC user can access to the data stored in the archive simply by an Internet connection to the homepage (Figure 6).

The site is organized in a public area and in a confidential area. The public area provides information pages on the project, the plan, FAQ, activities in progress, links and download of 1997 emission data.

To extract data from the 1997 archive the user can download files of emissions already assessed or create new files: in the following pages the user is requested to choose for which pollutant, from which group, sub-group or source activity and municipality the emission is to be calculated. After a few minutes the file with the user's emission data could be downloaded to the user's PC.

The access to the confidential area is restricted to qualified users with a username and a password: some users may have access to all data (i.e. control authorities, ARPA - regional agency for protection of the environment) while others may access only to data concerning their facility; the aim of this database is in fact to be accessible by any PC in order to verify, to modify and to update the data in the archive.

6. CONCLUSIONS

The INEMAR system is the first Italian experience of an emission inventory source code developed by a regional authority, thus suitable to implementation and development. As an example, the harmonization of the emission inventory with the IPCC (International Panel on Climate Change) methodologies, and the implementation of the on-line emission survey for the compliance with the IPPC (Integrated Pollution Prevention and Control) Directive (EU, 1996) is ongoing.

INEMAR's strength is the high resolution (municipality level) of all the emission results, which allows to use data to define critical areas for air quality, to define the role of new plants in Environmental Impact Assessment process, as a support to atmospheric pollution modeling (i.e. photochemical models), and as a data framework for the local Agenda 21.

As an example of an INEMAR use for management activities, the availability of non-urban (highway, other main routes) and urban driving emissions at municipality level are mostly significant, and allow the Regional Authority to consider the efficiency of different traffic limitation interventions on a local scale.

The great flexibility (database in 3rd normal form), allows an easy data arrangement for different requirements. The client-server framework, suitable for provincial inventories, gives back the system of great interest as a starting point for inventories in other areas. The use of INEMAR by different Italian Region (i.e. Piedmont Region) and by the provincial offices of ARPA is ongoing.

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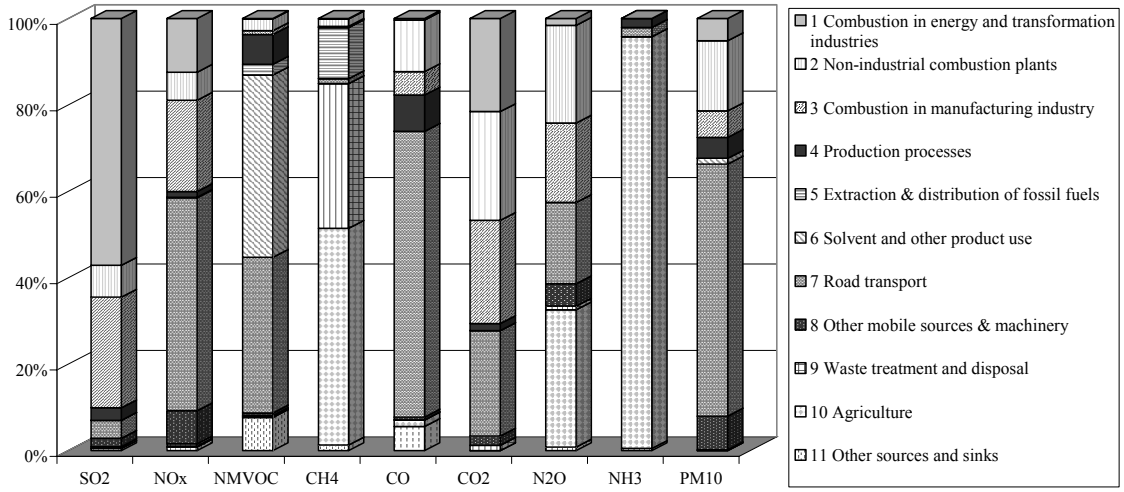

Figure 1

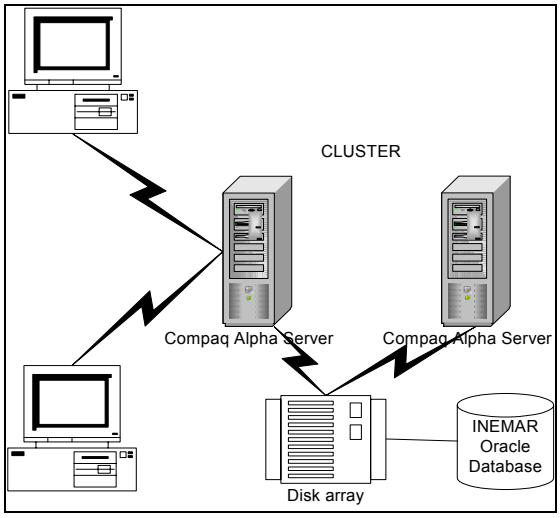

Figure 2

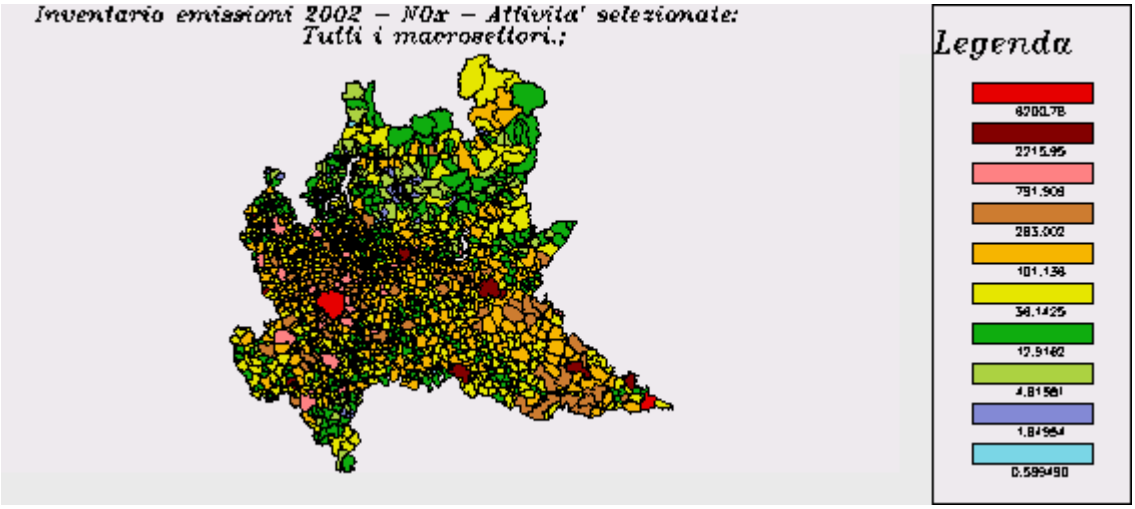

Figure 3

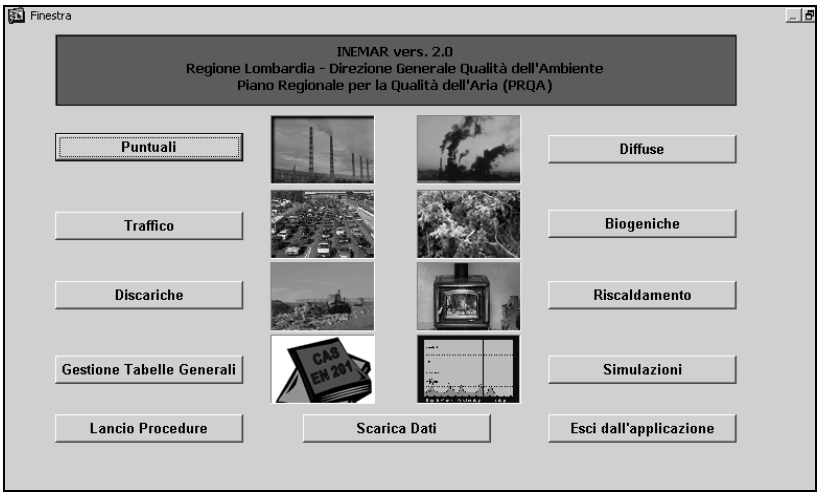

Figure 4

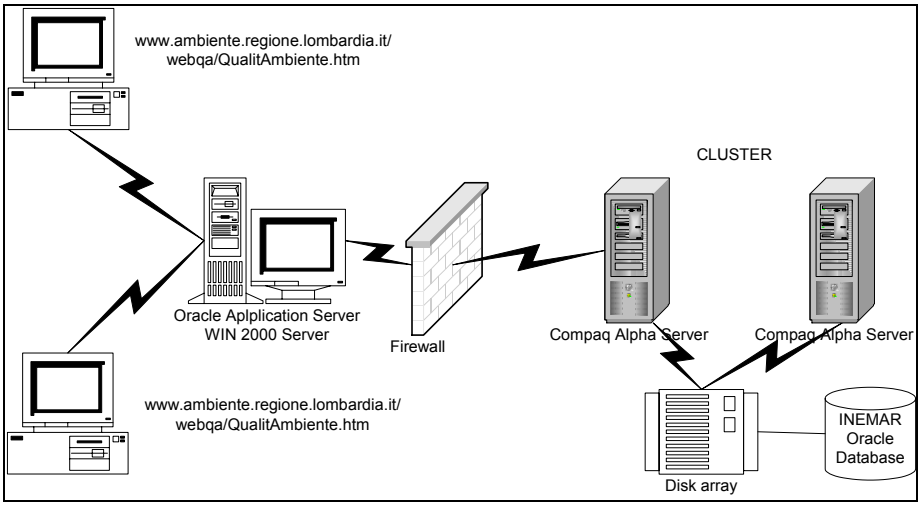

Figure 5

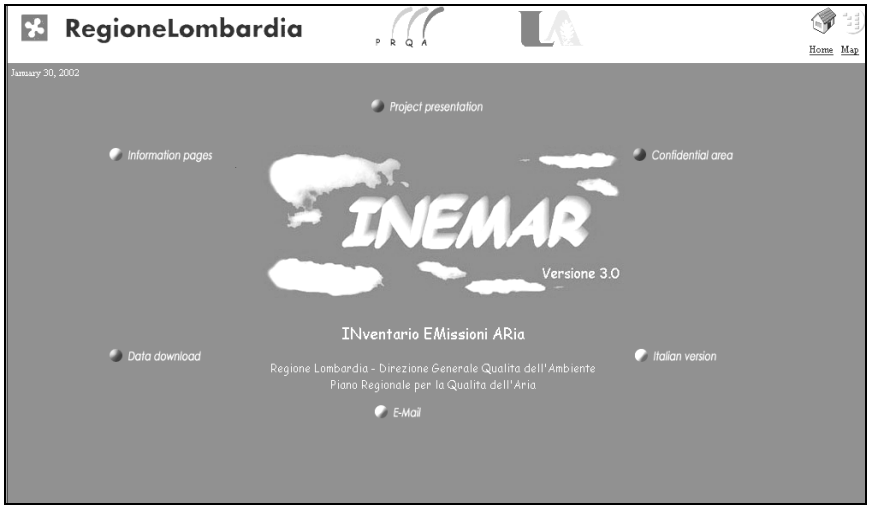

Figure 6