Regional environmental pressure indicators
geographical information system

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Abstract

In the paper the project for a new information system for evaluating regional environmental pressure indicators on a geographically very disaggregate basis is introduced and discussed. The system is based on the Determinant–Pressure–State–Impact–Response (DPSIR) approach and is the natural evolution of multimedia pollutants emissions inventory computer systems.

First the general concept of the DPSIR approach to analysing the state of the environment is briefly reviewed. The DPSIR model was developed by the European Environment Agency (EEA) and the Statistical Office of the European Communities (Eurostat).

Next the general concept of the integrated emissions inventory are introduced. In the last few years air pollutant emissions inventories have been widely developed around the world and more recently multimedia pollutant emissions inventories have been developed as an instrument for characterizing the different roles played by the various emission sources in the different environmental media.

The design of the information system is consequently introduced. In the system the indicators are classified based on the topology of the structure that produces the pressure. In particular, point, linear, area concentrated and area distributed pressure elements are introduced. Finally, the information contents of the driving forces and pressure databases are finally discussed.

1 Introduction

In the paper the project for information system for evaluating regional environmental pressure indicators on a geographical disaggregate basis is introduced and discussed.
In the past was used various international frameworks of environmental statistics and indicators [1], in particular:

- the Pressure-State-Response (PSR) framework of the Organization for Economic Cooperation and Development (OECD)

The general approach is based on the concept that human activities exert pressures on the environment and change its quality and the quantity of natural resources. Society responds to these changes through environmental, general economic and sector policies. The responses form a feedback loop to pressure through human activities. In a wider sense, these steps form part of an environmental policy cycle that includes problem perception, policy formulation, monitoring and policy evaluation.

Driving forces of pressure component are the social, demographic and economic developments in societies and the corresponding changes in life styles and overall levels of consumption and production patterns. The major driving forces are population growth and changes in needs and activities of individuals. The driving forces provoke changes in overall levels of production and consumption and thereby exert pressure on the environment. The exerted pressure may manifest itself in various ways, e.g., the excessive use of natural resources; changes in land use; and emissions (of chemicals, waste, radiation, noise) to air, water and land.

The Pressure component therefore gives information on emissions, application of chemical and biological agents, and the use of land and other resources. The pressures exerted by society's patterns of production and consumption is subsequently transformed in a variety of natural processes that may result in changes in the state of the environment.

In the following the Driving Force-Pressure-State-Impact-Response model (DPSIR) of the European Environment Agency (EEA) and the Statistical Office of the European Communities (Eurostat) was followed [2, 3].

In Figure 1 a schematic description of the model is reported. With reference to the picture:

**Driving forces** are underlying factors influencing a variety of relevant variables. Examples: the number of cars per inhabitant; total industrial production; GDP.

**Pressure** indicators describe the variables that directly cause (or may cause) environmental problems. Examples: toxic emissions, CO2 emissions, noise etc. caused by road traffic; the parking space required by cars; the amount of waste produced by scrap cars.

**State** indicators show the current condition of the environment. Examples: the concentration of lead in urban areas; the noise levels near main roads; the global mean temperature.
I Impact indicators describe the ultimate effects of changes of state. Example: the percentage of children suffering from lead-induced health problems; the mortality due to noise-induced heart attacks; the number of people starving due to climate-change induced crop losses.

R Response indicators demonstrate the efforts of society (i.e. politicians, decision-makers) to solve the problems. Examples: the percentage of cars with catalytic converters; maximum allowed noise levels for cars; the price level of gasoline; the revenue coming from pollution levies; the budget spent for solar energy research.

Figure 1: Driving Force–Pressure–State–Impact–Response model of the European Environment Agency and the Statistical Office of the European Communities.

In the paper main attention will be devoted to the pressure and to the relations between driving forces (or drivers) and pressure. Main pressure indicators definition can be extracted by the second edition of ‘Environmental pressure indicators for the EU’ by Eurostat and cover several sectors: Resource Depletion, Waste, Dispersion of Toxic Substances, Water Pollution, Marine Environment and Coastal Zones, Climate Change, Air Pollution, Ozone Depletion.

2 Integrated emissions inventory experience

The information system is an evolution of the approach to specific pressure indicators developed in the last years: integrated emissions inventories [4].

In the last years air pollutant emissions inventories are widely developed around the world. Emission sources are usually divided into point, area and linear/node ones. All emissions sources for which it is useful to define exact geographical localization are called point sources, for this sources emissions are
evaluated for single source and physical properties of release (flue gases volume and temperature, stacks height and area) are defined. Regarding mobile sources, the term linear/node source indicates the main communication ways for which the emissions are estimated by single line or node. All other sources are defined area sources. These sources are evaluated collecting statistical indicators on activity and using emissions factors. The emissions factors can be found in the literature (principally by CORINAIR TFEI [5] or US EPA[6]) and integrated with experimental data, available at local level.

In the last years there was a growing attention in the realization of multimedia pollutants emissions inventories as an instrument to characterize the different role played by the various emission sources in the different environmental media and consequently as a basic tool to define criteria for remediation plans.

Regarding point sources, European Council Directive 96/61/EC of 24 September 1996 concerning Integrated Pollution Prevention and Control (IPPC) provides that "an inventory of the principal emissions and sources responsible shall be published every three years by the Commission on the basis of the data supplied by the Members". The Commission Decision of 17 July 2000 on the implementation of a European Pollutant Emission Register (EPER) requires Member States to report the Commission on emissions to air and water from all individual facilities with one or more activities for which "threshold values" are exceeded; both activities, pollutants and threshold values are specified in the Decision.

The Directive concern activities selected in several sectors: energy industries, production and processing of metals, mineral industry, chemical industry, waste management, pulp, paper and board, fibers or textiles, tanning of hides and skins, slaughterhouses, animal and vegetable food products, milk, disposal or recycling of animal carcasses and animal waste, intensive rearing of poultry or pigs, surface treatment using organic solvents, carbon (hard-burnt coal) or electro graphite (by means of incineration or graphitization).

Regarding area and mobile sources, the "activity data" used for the realization of air emissions inventories can be also used for other media (water, wastes, noise, soil) emissions inventories. A lot of emissions factors are available, or can be evaluated, for area and mobile sources emissions inventory in other media (water, wastes, noise, soil).

Previous papers have described the software tools used in the development of emissions inventories in Italy [7] and to build the emissions inventory in different environmental media (air, water, soil, wastes, noise, radiation) [4]. The APEX system was originally developed as an air pollutant emissions computer system in the Windows environment with object-oriented ORACLE CARD tool [8] and with Visual Basic language [7], and was available with an ORACLE or ACCESS database; the system contains an emission factors data base and tools and data to estimate grid and municipal emissions from more aggregated data; the system uses ArcView or Mapinfo for thematic map. APEX 4.0 extends the capabilities of the original system to allow the emissions estimate, and the sources characterization, in the different media.

APEX was designed to:
• manage input data for emissions estimate, spatial, temporal and chemical disaggregation and sources description;
• produce reports about input data and emissions estimates;
• produce graphics about input data and emissions estimates;
• interface to geographic information systems.

3 General design of a new information system

The new Regional Environmental Pressure Indicators Geographical Information System (REGPIGIS) is based on Determinant–Pressure–State–Impact–Response approach and is the natural evolution of multimedia pollutants emissions inventory computer systems.

The information system is divided in two main sections, the first one devoted to store information about driving forces and the second one to evaluate pressure. In the following the two components are described (Figure 2).

![Figure 2: Information system logical scheme.](image-url)
4 Driving forces and pressure geographical definition

The information system allows the evaluation of environmental pressure indicator on a very detailed geographical basis. In the following the indicators are classified based on the topology of the structure that produce the pressure.

The information related to the driving forces and pressure can profitably be structured by the logical point of view with the following typologies of structure that induces the driving force and pressure:

- point
  - typically indicators related to a plant with pressure through a pipes, or a similar structure (for instance an industrial plant that emits in atmosphere through windows, a deposit of fuels);
  - the single plants are generally, but not obligatorily organized in the establishments (or groups of plants);
  - the pressure can simultaneously be directed in the different environmental media (air, water, soil, noise, wastes, ...);
  - the pressure on the environment by the single plant is remarkable, that is superior to preset thresholds (diversified for the different media and for pollutants);

- line
  - typically indicators related to an infrastructure of transport (both it a highway, a water body, a seaway line, a railway line, a power line) with consequential emissions from mobile sources, or that however produce a pressure on the environment (electromagnetic radiations, noise, etc.);
  - the infrastructures are generally divided in sections (anywhere the pressure it is different among the different sections as for instance in the different highway lines);
  - the pressure can simultaneously be directed in the different environmental media (air, water, soil, noise, wastes, ...);
  - the pressure on the environment by the single infrastructure is remarkable, that is superior to preset thresholds (diversified for the different media and for pollutants);

- area concentrated
  - typically indicators related to an infrastructure of transport (both it a port, an airport, a railway area, a truck interport) or a spatially confined area (for example a waste disposal site) with consequential emissions from mobile or fixed sources, or that however produce a pressure on the environment (emissions in atmosphere, noise, water discharges);
  - the pressure can simultaneously be directed in the different environmental media (air, water, soil, noise, wastes, ...);
  - the pressure on the environment by the single infrastructure is remarkable, that is superior to preset thresholds (diversified for the different media and for pollutants);

- area distributed
  - typically indicators related to an area;
  - the indicators are, at first, evaluated at municipal level or with direct
municipal indicators or using a lot of proxy variables known at the municipal level to allocate regional values on a municipality basis; proxy variables allow obtaining information on a certain spatial resolution assuming that it is known for larger spatial resolutions; municipal level in Italy corresponds to level 5 of NUTS (Nomenclature of Territorial Units for Statistics) classification scheme established by Eurostat and widely used in Community legislation since 1988; the municipal level seems to be the most reliable defined to estimate indicators;

- inside the municipality a square grid mesh (1km x 1km) is built-up to represent indicators on a very detailed scale, to disaggregate indicators from the municipal level to the mesh level, the methodology of proxy variables is used; example of proxy variable are: urban; agricultural; industrial and commercial; modeled artificial; mining, permanent crops, arable land, deciduous forests; coniferous forests.

5 Driving forces data base

The driving forces database contains all the information finalized to define driving forces and to evaluate the data on a very detailed geographical and temporal level.

Socioeconomic information

In this area of the database on driving forces are stored the data directly linked to the driving forces.

The information related to the driving forces (socioeconomic data) is:

- point driving forces (plants):
  - registry information,
  - plant engineering information (sections, boilers, pipes, stacks, pylons, of the plant etc.),
  - information related to the capacity or power of the plant,
  - time dependent information related to the driving forces connected with the structure such as:
    - production of goods (for example: production of electric energy, production of heat, production of coke, steel production, etc.),
    - consumptions (for example: consumptions of raw materials, consumptions of electric energy, consumptions of fuels, etc.);

- line driving forces (infrastructures of transport):
  - registry information,
  - infrastructure engineering information (typology of the infrastructure, height from the ground, section, width, etc.),
  - information related to the capacity or power of the infrastructure,
  - time dependent information related to the driving forces connected with the infrastructure (for example: number of vehicles/day, transported energy, water's volumes transported, average speeds, transported
wastes, quantity of commodities transported, quantity of passengers transported, etc.);
- area concentrated driving forces (spatially confined infrastructures):
  o registry information,
  o infrastructure engineering information (typology of the infrastructure, width, etc.),
  o information related to the capacity or power of the infrastructure;
  o time dependent information related to the driving forces connected with the infrastructure (for example: number of vehicles/day, quantity of commodities transported, quantity of passengers transported, dumped wastes, etc.);
- area distributed driving forces:
  o typically a driving force expressible through time-dependent statistic information (for instance population, consumptions of raw materials or fuels, circulating vehicles, equivalent inhabitants, used agricultural surface, etc.); information are typically assignable to an area the commune or in its absence, the province or the region.

**Temporal profiles information**
In this area of the database on driving forces are stored the data linked to the temporal profiles, for the allocation of the driving forces and the pressures on hourly, daily, monthly bases. The information consists in monthly profiles, daily profiles (weekly type), and hourly profiles (daily type) related to several socioeconomic or meteorological driving forces (for instance: business hours, temperature, urban traffic, consumption of drinkable water, electric power loads, etc.).

**Territorial profiles information**
In this area of the database on driving forces are stored the data linked to the territorial profiles, for the allocation of the area distributed driving forces on square grid meshes (for example: 0.5 km x 0.5 km, 1 km x 1 km, 5 km x 5 km, 10 km x 10 km). The information will primarily consist parameters from land use maps.

**Geographic information**
Regarding geographic information the system will contain:
- the geographic coordinate of the alphanumeric information described in precedence, and particularly all the linear, punctual and area structures, both to the goals of the interrogation of the information and to its restitution in thematic maps;
- the information of geographical character related to specific typologies (for instance: maps of temperature, land use, etc.).
6 Pressure data base

The pressure database contains all the information finalized to evaluate pressure on a very detailed geographical and temporal level.

Alphanumeric information
The information related to the pressures can profitably be structured by the logical point of view individualizing the following typologies of information:

- the environmental compartment in which the pressure is practiced:
  - superficial waters
  - sea waters
  - atmosphere
  - noise
  - electromagnetic fields
  - wastes
- the information related to the pressure:
  - punctual pressure:
    - time dependent information related to the quantities produced of total effluents in the different environmental compartments (total air effluents, total water effluents, total radiations, total wastes):
    - time dependent information related to the concentration of chemicals (pollutants, greenhouses gases) or physical components (for instance radiations in the different ranges of frequency) in the produced effluents,
    - factors of generation of the pressure, if used to estimate pressure;
    - time dependent value of the pressure (on annual or hourly base);
  - linear pressure:
    - factors of generation of the pressure;
    - time dependent value of the pressure (on annual or hourly base);
  - area concentrated pressure:
    - factors of generation of the pressure, if used to estimate pressure;
    - time dependent value of the pressure (on annual or hourly base);
  - area distributed pressure:
    - factors of generation of the pressure;
    - time dependent value of the pressure (on annual base);

Geographic information
Regard to geographic information the system will contain the geographic coordinate of the alphanumeric information described in precedence, and particularly all the linear, punctual and area structures, both to the goals of the interrogation of the information and to its restitution in thematic maps.

7 Case studies

The new system design was developed in the frame of the planning of environmental information systems for Liguria Region in Italy. The migration of
the actual Advanced Pollution Emissions Computer System for the realization of integrated emissions inventory [4] toward a Regional Environmental Pressure Indicators Geographical Information System is in progress.

8 Conclusion

In the paper the project for a new information system for evaluating regional environmental pressure indicators on a geographical very disaggregate basis is introduced and discussed. The system is based on Determinant–Pressure–State–Impact–Response approach and is the natural evolution of multimedia pollutants emissions inventory computer system.

The information system is divided in two main sections, the first one devoted to store information about driving forces and the second one to evaluate pressure. In the paper the two components are described with reference to information about structures that generate the pressure: point (plants), line (infrastructures of transport), area concentrated (spatially confined infrastructures), area distributed. Work is in progress to develop the software for the system.

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References


