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Management of a river basin: a demo-software for the identification of the potential source of pollutants.

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Introduction

In recent years the correct management of all natural resources became a very urgent need. The new attitude of living at the present while looking at future time has generated the ethical problem of our responsibility towards future generations. As a result, new concepts such as "sustainable development" and "integrated management of the resources" were proposed. However, a new value was attributed to natural resources in general, and to water in particular.

Water has always been considered a precious good. Nevertheless, since the beginning of the industrial era, the water resource has undergone an irrational use and excessive exploitation worldwide. The demographic growth and the increase of the industrial and agricultural production have had so far negative consequences on the environment, especially on the river areas. Fortunately, in the last years the environmental protection and the conservation of water resources have had a high priority in all national and international programs, and this has prevented some more negative consequences.

Rivers are dynamic systems made of a succession of habitats, different from the source to the mouth. Such complex system allows the life of a large variety of animals and plants. Also, the river environment has many uses and is characterized by the presence of various human activities. Like the sea-coast, the river is much exposed to the pressure of such human activities.

As mentioned above, the “sustainable development” concept leads to the sustainable use of resources so to make them available for the future generations. The protection of water resource requires that regulations are respected in order to avoid the environmental degradation. The constant monitoring of water basins: the systematic collection of data may allow the understanding of the environmental dynamics. Such knowledge should promote the implementation of actions that may prevent irreversible damages to the water resource and guarantee that biodiversity is maintained. The new attitude has produced new Laws such as

the italian D.Lgs 152/2006, (European Directive 2000/60) relevant to water protection from chemical and bacteriological pollution and the maintenance of the river quality. The main target is to avoid the depletion of the biological processes that sustain the natural self-depuration of a river.
The ecosystem structure of a river depends on its relationship with the surrounding environment, and this is true from the source down to the mouth of the river in conjunction with the continuous natural transformations there occurring. The various sectors and branches of the river are characterized by a variability of the flow and turbulence, by different sediment typology and chemical composition of the water and by morphological difference of the river bed (straight, winding, wide, etc.). The different sectors of the river are also characterized by different water depth and bed type that contribute to influence, together with other factors, the interrelation and the exchange between the upper layer and the sediment. Additionally, the erosive action of water and the ability to deposit sediments contribute to model and to transform the territory.
The river is an "alive organism", in a slow and continuous transformation under very complex equilibrium conditions that are easily alterable. The whole ecosystem is vulnerable by actions such as:

- Construction of barriers (dikes, bridles, cemented river bed etc.) that in general interrupt the spatial continuity.
- Excessive external inputs produced by human activities, in a “point” or “diffuse” mode.
    - Kinds of “diffused” sources of pollutants are the acid rains, the draining water from agricultural soils, traffic and similar. The diffused sources are difficult to monitor and identify because the pollutants cannot be followed from the source to the water basin.
    - Kinds of “point” sources are factories, water treatment plants, mines, oil wells, reservoirs for oil and some specific agriculture applications. They can be easily located and traced.

The various anthropic activities influence the equilibrium of a river basin as they are sources of several polluting substances that reach the water.
In table 1 some polluting substances are listed.

Table 1 - Kinds of pollutants

Degradables Pollutants	Sulphides, Sulphites, Sulphates, Ammonia, Fats, Oils and some kinds of Soaps	Such substances cause modification of water pH, colour, smell and they also affect the sediment and increase the need of O_2 for the biochemical and chemical oxidation (BOD, COD)
Toxic Contaminants, non Degradable Organics	Aluminum, Barium, Cr (III), Copper, Iron, Nickel, Zinc, Chlorine, some Surfactants	
Toxic Contaminants, non Degradable that may cumulate in water, in soil and in the food chain	Arsenic, Cadmium, Cr (VI), Mercury, Lead, Selenium, Phenols, Pesticides, PVC, Organoalogenates, Plastics	

As a matter of fact, the numerous human activities can produce several different polluting substances, but some of them are characteristic of a given activity.
Table 2 shows the variety of activities and anthropogenic emissions that can influence a river basin.

Table 2 - Anthropic activities and their emissions

INDUSTRIAL POLLUTION
CHEMICAL, PETROCHEMICAL AND PHARMACEUTICAL INDUSTRY
Emission on ground and in water: Oils, Hydrocarbons, Tars, Acids, Bases, Catalysts, Metals (Fe, Cu, Cr, Zn), Sulphides, Polymers, Phenols, Organochlorinated compounds, Paraffins, Solvents (hexane, benzene, dichloromethane, others), culture broths etc. Immission into the atmosphere: Oxides of N, C, S, some Pb and Hg compounds, volatile organic compounds, PCB, etc.
MINING, METALLURGICAL, GALVANO-PLASTIC INDUSTRY
Metals (Cu, Zn, V, Al, Mo, Fe, Ni, Pb, Cd, Hg); Acids (nitric, sulphuric, hydrochloric, perchloric); Salts (nitrates, nitrites, cyanides); Polymers.
TEXTILE AND TAN INDUSTRY
Dyes, Solvents, Soaps, Catalysts, Metals, Acids, Bases.
FERMENTATION AND EXTRACTION INDUSTRY (BEER, WINE, VINEGAR, DISTILLERIES, SUGAR, OIL)
Microrganisms, Organic degradable substances with high COD and BOD, Solvents
FOOD INDUSTRY, SLAUGHTERHOUSE, ZOOTECHNIC BREEDINGS
Organic products and putrescible substances (a pigsty of 10.000 heads, pollutes like a city of 30.000 - 40.000 inhabitants).

URBAN POLLUTION
Waste water
Accumulation of organic and inorganic compounds, hardly degradable substances
Smokes and vapours from combustions, Pb, Hydrocarbons, Oxides of N and C, SO_2.
AGRICULTURAL POLLUTION
Due to the practice of intensive agriculture. The increase of high quality production requires the control of the illness of plants and parasites by means of pesticides and fertilizers. Compounds accumulating in the environment are particularly dangerous.

Exogenous substances may cause the modification of the morphology and the alteration of the natural ability of the river (self-depuration action) to metabolize the organic (natural and anthropogenic) compounds released from the surrounding territory. The substances that are not metabolized cause alteration of the ecosystem.
Examples of the toxic activity of two important classes of pollutants are presented in table 3.

Table 3 - Toxic activity of two classes of pollutants

HYDROCARBONS	METALS
The heavy aliphatic hydrocarbons are easily degradables. Lighter aliphatic hydrocarbons are more toxic. The aromatic compounds can be carcinogenic (benzopyrene, anthracene, benzoanthracene, etc.). In water, these substances cause surface alteration, arrest of the photosynthesis, O_2 depletion, death or contamination of the fish fauna making them not edible.	They can be present in waters and in t he ground as i ons (usually the most toxic form), organic complexes, precipitates (oxides or sulphides). Cu, Zn, Pb, Cd, Hg in io nic form have acute toxicity. Fishes suffer irritating action of the lamellar structures of the gills. This leads to the alteration of the oxygenation and then to death. Metals are often organicated and made liposoluble by the microrganisms present in water or ground. Under this form they cause more easily chronic toxicity since they can cross cellular membranes and reach sensitive organs (e.g. brain).

The sustainability principle demands the conservation of the biodiversity and of the ecosystems.
The human society should avoid river degradation by limiting those impacts that may produce irreversible effects. This requires to maintain a constant level of the water quality with decisions that may reduce the pressure on the river system through a modification of the economic use of the basin.

Figure 1 - System scheme of the entities and their complex relationship relevant to the management of a river basin.

A sustainable use of the river areas optimizes the equilibrium between the social and economic benefits.
Figure 1 shows the relationships among the social-economic-ecology (SEE) aspects of the management of a river basin. The actors involved in the management and the effects of the actions are shown.
One of the key issues in the SEE Scheme is the usability of the data collected through analy-

ses of samples of water. It may happen that such data find a limited (if any) use in the decision process because they are too technical and the information they contain cannot be used by decision makers or their consultants. One of the most complex problems to solve is the lack of links of the figures representing the pollution level to the pollution sources. The work done in this Project was performed in the direction of building a handy tool that may help in finding the source of pollutants and to link the potential source to production activities within the territory.

The Metea Centre contribution to the "RiverNet" Project

The aim of the work developed by the Centro Interdipartimentale METEA of the University of Bari within the RIVERNET Project is summarized in this paragraph. It has been intended to provide a suitable technical tool to a competent organization implicated in the management of hydro-basins in the context of a Strategic Environmental Assessment (SEA).

Based on the model DPSIR of the European Agency for the Environment, the METEA activity has been focused on the evaluation of the Driving Forces that influence the quality of the river water resource.

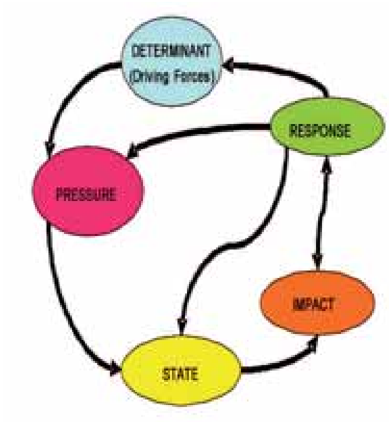
Scheme 1 shows the DPSIR model by The European Agency for the Environment (EEA), that takes into account a model proposed by the OECD. The DPSIR model connects the different classes of environmental indicators.

These classes are divided in:

- **Primary generating causes** (Driving forces): are primary anthropic activities as agriculture, industry, transport, etc.
- **Pressures**: as the discharge in water, production of waste, etc.
- The Pressure determines changes of **State** of the environment and particularly of its quality (changes of water quality, of the biodiversity of the ecosystem).
- The pressures produce an **impact** on the ecosystem and, eventually, on human health.
- The **responses** of the society against modifications of

ecosystems consist of a set of rules and plans of intervention which reduce the pressures. Such measures are aimed at the safeguard of the environmental resources (i.e. water use, fish resources) preventing irreversible damages.

DPSIR model



Sheme 1 - The DPSIR model connects the different classes of environmental indicators. For example: Determinant (Driving Forces): population - economy - uses of the territory - social development in the specific industry and manufacturing sector - energy - agriculture - domestic transport-sector - tourism - recreational activity. Pressure: immission into the air, water and ground - waste production/disposal - use of natural resources. State: quality of waters, ground and air – influence on biodiversity. Impact: on ecosystems, human health, other functions of natural systems. Response (Political Decision): directives and prescriptions - measures and environmental politics.

The knowledge of the environmental dynamics and of the driving forces is useful to define the territorial distribution of the load ability and the environmental sensibility.
The environmental sensibility is the whole of the characteristics of a bio-ecological or physical system. These characteristics determine the greater or smaller vulnerability under external Pressures (produced by the Driving Forces). Therefore, the vulnerability of an environmental system depends not only on its intrinsic sensibility to the external pressure, but also on its recovery capacity.
The sensibility of a system is a multidimensional quality and it is strictly related to the kind of the applied pressures. As a matter of fact, the same pressure applied to two different systems, produces different effects related to the specific sensibility of the systems.
Environmental sustainability is the association between the vulnerability of the system and the economical and social development. One should also consider that a natural environment is a dynamic system. Therefore, the peculiar characteristics of the territory and its vulnerability should be analyzed.
Principles of sustainability are implemented according to the following methods of investigation and intervention policies:

1. An extensive and detailed description of the environmental conditions of a territory is necessary and the thresholds of sustainability must be defined. The knowledge of the environmental conditions and of the social and economical context in which the water basin is inserted, is needed as a basis for investigation, assessment and decision making.
2. Critical sensitive components of the environmental

system (vulnerabilities) and factors of pressure must be defined.

3. Relations cause–effect between the anthropogenic drivers and the change of the ecosystem must be quantified.
4. Anthropic activities should be installed and managed taking into account the environmental sustainability of a territory.
5. Appropriate methodologies must be identified for the evaluation of the ecological, economic and social aspects, for a sustainable development.
6. The cause-effect relationship between the stress agents and their impacts (biodiversity, erosion, anoxia, evolution of trophic chains) must be quantified.
7. The identification and use of the correct political tools (regulations, territorial planning) is at the basis of decisions about economical incentives, or persuasive actions aimed at the implementation of the environmental sustainability.
8. The timely development of strategies and specific indicators for the cost-benefit or cost-efficiency analysis is a need in order to implement an ex-ante evaluation of decision processes for the correct management of the environment.
9. The river community should be mostly involved. It is essential that the community is informed about the quality of the river basin so that people may constructively collaborate to reaching the sustainability objectives.

An important source of information about the quality of a river basin is the water analysis. The key point is that if the chemical or microbiological analyses of samples point out to a poor quality of the river system, the causes of the degradation must be timely identified and a political action must be taken in order to modify the economical and social asset and future development of the area, so that irreversible effects on the water resource are avoided.

Most data are usually very little informative because it is

Figure 2 - Issues considered for a sustainable planning

hard to go back to the causes of the pollution due to the difficulty of identifying the sources and the dynamics of a river system. The work done at METEA within RIVERNET has been aimed to provide a tool for linking the analytical data to potential sources of the identified pollutants. It is obvious that should the sources of pollution be identified the decisional making process is made easier.

Also, if it turns out that it is impossible to set a link between the pollutants and the sources as the latter are not present among the anthropic activities within the river basin, then there is enough reason for suspecting an illegal disposal.

Finally, the knowledge of the Driving Forces and of possible evolutionary trends of a river water quality facilitate the discovery of environmental criticities, providing tools for the correct planning and management of the territory.

Figure 2 schematically shows the path and key points that should be considered in the decision process for guaranteeing a sustainable management of a river basin.

Activity developed by the Research Centre METEA

METEA is an Interdepartmental Research Centre devoted to developing innovative methodologies and environmental technologies. The Centre is composed by several Research Units of the University of Bari having a variety of competences (chemistry, informatics, biology, geology, applied mathematics, etc.). The mission of METEA is to deal with and solve complex environmental problems, using a multi-disciplinary approach.

The core action of the RiverNet project is the sustainable management of a river basin. The activity of the METEA Research Centre inside the RiverNet project, as mentioned above, has been to develop a tool that might be used in supporting ecological, social and economical assessments for implementing a policy of sustainability within the river area.

Moreover, the METEA Research Unit had a fruitful collaboration with the Ecology Group of the University of Lecce for a combined chemical–biological analysis on water samples of the IDRO river at Otranto.

Inside this collaboration, the METEA has carried out chemical analyses of the samples, while the Ecology Group has investigated the biological properties.

The METEA work within the RiverNet project has been oriented to:

- develop cause-effect correlation as a tool that may be used, in conjunction with others, for a correct management of complex ecosystems;
- Identify social necessities and promote the environmental sustainability by improving the relationship between science and politics.
- Build infrastructures for an effective prevention, by fostering the international and multidisciplinary integration.

For developing such tool, the METEA Centre has taken into consideration the many anthropic activities that may produce pressures on a river basin. A software was developed that may be used for identifying Driving Forces that may cause a given pollution.

The analysis of potential Driving Forces brings to identify the main anthropic sources of pollutants through the identification of:

1. Macro areas of anthropic activities
2. Sorting of the main factors of pressure inside each of the macro areas

3. Searching of available databases
4. Harvesting data on the environmental impact of different pressures.

Based on such analysis, an operational software was developed that may be used as a decisional support for the evaluations of the Driving Forces and their effects.

The demo software for linking pollutants to sources

The DPSIR model

The guidelines traced by the DPSIR model of the European Environment Agency, were described above. Such model requires a deep knowledge of the external factors producing the environmental pressures.

Figure 3 identifies six macro areas that can influence the ecosystem of a river basin:

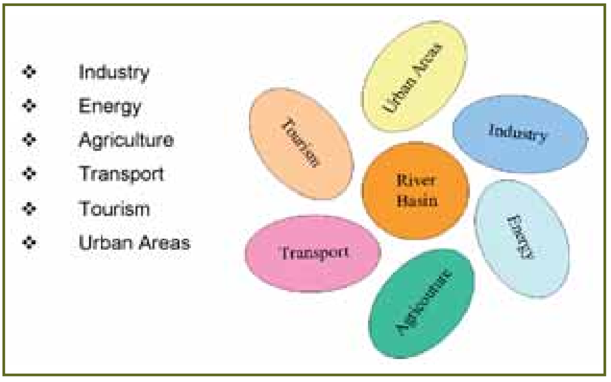


Figure 3 - Macro Areas that influence a river basin

Each macro area produces a set of pressures (in the form of waste or compounds released to the atmosphere or hydrosphere) that cause changes of the environmental quality. In some cases the emissions are a kind of "fingerprint" of the activity. Therefore, a list of substances released by each macro area has been prepared. Such substances may be released as flue gases into the atmosphere or as liquid waste or as disposed solids.

The search of the pollutants produced by each macro area was carried out with the help of databases. The data collected have importance for their environmental pressure. The Databases utilized in this work were:

- Database of the National Informative Service of the Italian Agriculture Ministry, containing data about Agrochemicals;
- The EPER Database - The European Pollutant Emission Register (Register of the Pollutant Emission in Europe);
- The Australian Government Database - National Pollutant Inventory.

Sources of Data

The Database of the National Informative Service of the Italian Agriculture Ministry correlates phyto-drugs to different crops for which they are used. The information present in the Agrochemicals Database are provided by the Experimental Institute for the Vegetal Pathology in Rome. The enquiry of the database is feasible either on the basis of active substances/principles or searching for an agrochemical product specific for a given cultivar. Selected data were assembled in our software and can be now used as an "identification marker" for targeted productive activities of the macro area "agriculture".

The European Register of the Pollutant Emissions allows different searches such as: an enquiry for "industrial activities" or for "polluting agent". Depending on the particular enquiries, it is possible to get an information about, for example:

- The industrial activities that emit the same polluting agent.
- The industrial sectors producing a particular set of emissions.
- The emissions of pollutants grouped on the basis of the industrial activity.
- The percentage weight of various pollutants related to a single productive activity.
- The weight of the European emission per each single member State.

The data obtained from the above Database have been used for setting the reference frame for the macro area

“Industry” and for that of “Energy”. Unfortunately the European Register contains only data about pollutants produced by large companies within the European Union; it does not take into consideration the pollution derived from Urban areas and Transports.

To find the emissions of the two latter macro-areas we have searched the Australian Government Database. In this specific case, only qualitative and not quantitative data were used for a correlation between the different pollutants and their sources. In fact, the style and standard of life in Australia may be quite different from that of European Contries and, consequently, numerical values contained in the Databases may not be correct for the EU and, thus, have not been considered.

The list of parameters contained in all the searched Databases was adapted to the national/local territory.

Table 4 shows examples of the possible relationship between sources and pollutants.

Table 4 - Relationship source - pollutants

INDUSTRY	POLLUTANT
PAPER FACTORIES	Chlorides, Ammonia, Carbon dioxide, Arsenic, Nitrogen, BOD, Cadmium, COD, Halogenated organic compounds, etc....
TANNERIES	Nitrogen compounds, BOD, total organic carbon, chrome and its compounds, pH, etc....

CROPS	PHYTOIATIC ACTIVITY	AUTHORIZATION	ACTIVE PRINCIPLE
CITRUS FRUITS	ACARICIDE	NO	AZOCICLOTIN CIEXATIN
		YES	DICOFOL ETOXAZOLE
CITRUS FRUITS	HERBICIDE	NO	FLORASULAM PYRAFLUFEN ETHYL
		YES	DIQUAT DIURON
APRICOT	FUNGICIDE	NO	CLOROTALONIL FENARIMOL
		YES	CAPTANE CIPROCONAZOL

Unlike other macro areas, where only the direct link between the "Typology of Source" and the "Pollutants" exists, the Agriculture area emissions are organized on the basis of the:

- Nature of the active principle
- Phytoiatic activity of the agrochemical used
- Kind of crops for which a given agrochemical is best suited

- Need to have a specific authorization for the use of compounds.

The "active principles" mentioned here are the substances commercially used for fighting, preventing and/or curing plant diseases. Moreover, such substances are used to fight or to eliminate undesired weeds. Such chemicals are grouped by categories of "Phytoiatic Activity" – i.e. insecticide, acaricide, herbicide, etc.. and can be linked to the specific kind of crops (citrus fruit, cereals, apricots, etc.) for which they are used. Besides such link, an information is included that says if there is or not a need to have a specific authorization for the use of such active principles. Table 5 shows an example of classified information.

Table 5 - Example of classifical Information

CROPS	PHYTOIATIC ACTIVITY	AUTHORIZATION	ACTIVE PRINCIPLE
CITRUS FRUITS	ACARICIDE	NO	AZOCICLOTIN CIEXATIN
		YES	DICOFOL ETOXAZOLE
CITRUS FRUITS	HERBICIDE	NO	FLORASULAM PYRAFLUFEN ETHYL
		YES	DIQUAT DIURON
APRICOT	FUNGICIDE	NO	CLOROTALONIL FENARIMOL
		YES	CAPTANE CIPROCONAZOL

The whole information can be used with a double function:

- To correlate the information obtained through the analyses of water samples to the potential sources of pollutants.
- To verify that the river basin includes within a given territorial extension the potential source of pollutants.

For instance, the typology of dominant crops in a territory will give a list of active principles that could potentially be found in water samples. Obviously further information must be gathered through an enquiry within the considered area concerning the:

- list of active principles really applied to agricultural crops in the territory;
- quantitative information on their market;
- environmental diffusion of such substances.

The collected data allow also to identify eventual illegal

activities such as spilling or disposal of pollutants in a territory.
The acronym of the software is **LIPTOS** (**L**ink **P**ollutants **TO S**ource). It results to be an useful tool for managers of the river basin. In fact, it allows a direct, simple and rapid consultation for checking the link between pollutants identified through the analysis of samples of water and potential Driving Forces or human activities responsible for the emission.

The operative software LIPTOS

The operative software **LIPTOS** (a copy of which is attached to this book as a CD) allows to quickly relate a particular pollutant to a source. The software facilitates the identification of the anthropic activity that produces such pollutant (classified on the basis of the driving forces).
The used software is a DaeQP tool running on a Java platform. Therefore, a relevant application (also included in the CD or downloadable from Internet) is required for using the software.
Polluting substances are related to anthropic activities. The list of pollutants, is divided in four categories of Driving Forces: Industry, Urban area, Transports and Agriculture (for the latter, the moment being, only phytosanitary substances have been considered).

How LIPTOS works

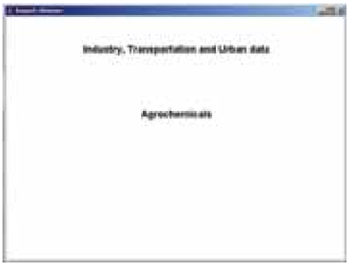
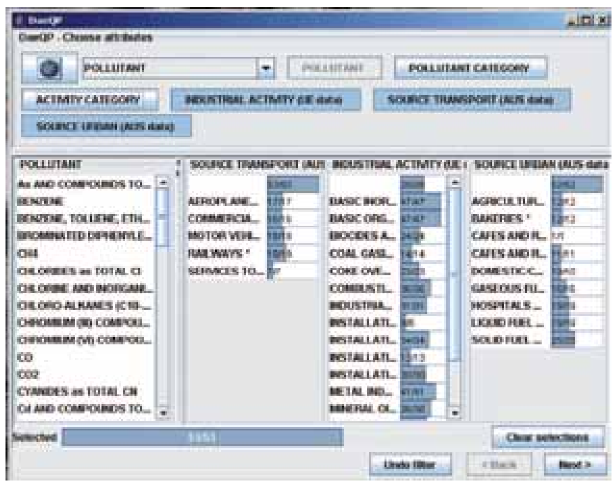


Figure 4 - First page of the Operative DaeQP Software

After opening LIPTOS, a first choice is possible among the four macro areas: one can select either "Agriculture" or one area among Industry-Transport-Urban Areas. (Fig. 4 shows the magnified window).
In the Agriculture macro area, phytosanitary substances are related to categories as Phytoiatic Activity, Kind of crop, Authorization. Polluting substances in other categories of driving forces (Industrial Activity, Transport, Urbanization) are related to different categories.
In the following window (Fig. 5) of LIPTOS, a choice is possible for linking a pollutant to different sources.

Figure 5 - Second window of the Software.

Figure 6 - Third window of DaeQP in which several parameters can be selected



Once such choice is made, a new window will open, in which a list of selected primary attributes is shown on the extreme left (i.e. Pollutants), while secondary attributes are shown on the right (Fig.6). Initially the first column has a narrow field, so it should be manually widen. In order to select a species, it is enough to type its name in the field "SEARCH" that is on the top of the first column. The selection of an item (i.e. in the column "POLLUTANT") will filter further items in the other columns.

A click on the "right key" of the mouse in correspondence of each of the secondary attributes allows to select an option that gathers the items filtered in the upper part of the list. Horizontal bars placed on each of the single items

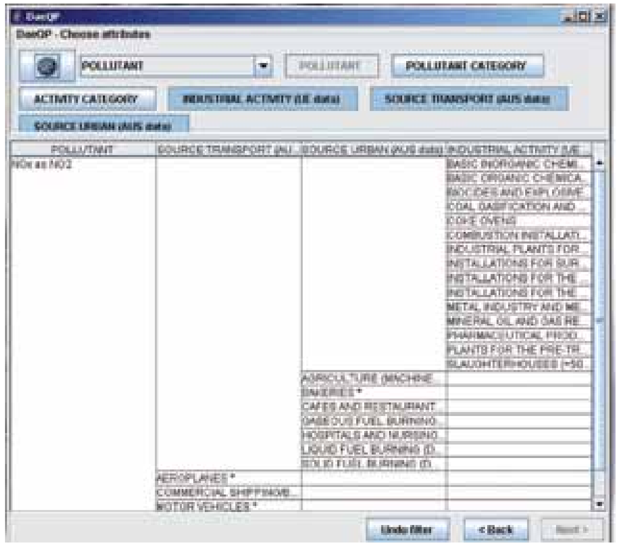


Figure 7 - Fourth window of DaeQP for a more effective visualization of the selected parameters.

of the secondary columns present some numbers (X/Y):

- X indicates the number of filtered items
- Y indicates the totality of possible items of connection.

The "NEXT" key allows to open a fourth window in which the data are better shown (Fig.7).

The "UNDO FILTER" key allows to remove the filter deselecting the considered parameters. At this point it is possible to start again with a new selection.

The described software is demonstrative. It is undergoing further setup and upgrades such as:

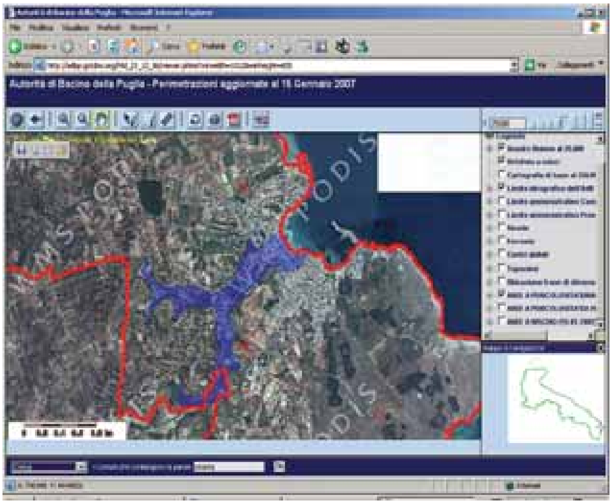
- The unification of all worksheets employed in the structure of the software in a single worksheet;
- The completion of useful information with the insertion of other data (i.e. by adding Fertilizers in the macro area of Agriculture);
- The connection between the gathered information and geographical maps for a spatial analysis of the existing cultures/industries and the localization of a potential source of the pollutants.

Applicative use of LIPTOS

The software has been tested by using real data from a river basin and shown to be quite informative.

The information obtained by using LIPTOS must be integrated with the search for the presence or absence of the specific productive activities indicated by LIPTOS in the considered territory. To this end a "Map of the Economic Activities of the Basin-MEAB" (from the source to the mouth of the river) should be built per each territory under analysis (Fig.8).

Figure 8 - Map of the Idro River Basin



The scheme in figure 9, summarizes the use of the software described above, when applied for the identification of the pollutant sources present in the river basin.

The cross-link of LIPTOS with MEAB allows:

- to correlate a pollutant to a specific productive activity;
- to discover possible illegal release/discharge of pollutants, in the case the analytical data do not have any correspondence with the productive activities existing in the territory.

In conclusion the integrated information derived from:

- the knowledge of the ability and limits of self-depuration of the river basin;
- its actual level of stress;
- the anthropic activities present in the river basin;
- the social demand for an economic development of the area;

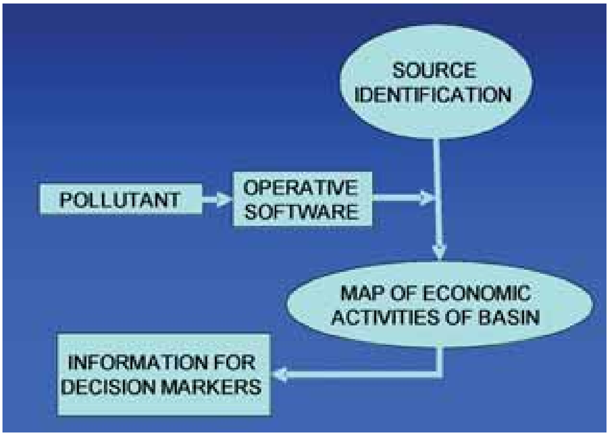


Figure 9 - Summary of the applicative use of LIPTOS

- the information derived from the use of LIPTOS (as a decisional support),

would allow the managers of the river basin to be able to plan a sustainable and optimized use of the territory, while guaranteeing the good quality of the water.

References

Informations used in building the operative software are derived from:

Internet site of Servizio Informativo Agricolo Nazionale Italiano – http://www.sian.it –containing a Database of Phytodrugs;

Internet site of EPER – The European Pollutant Emission Register - http://eper.cec.eu.int

Internet site of Australian Government - http://www.npi.gov.au/ - National Pollutant Inventory.