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River pollution from non-point sources: a new simplified method of assessment

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Abstract

Assessment of the pollution of water bodies from non-point sources is a complex data- and time-consuming task. The potential non-point pollution index (PNPI), is a new tool designed to assess the global pressure exerted on rivers and other surface water bodies by different land uses. The main feature of PNPI is the wide availability of its input data. Very detailed input maps, often lacking over many areas, are not needed for PNPI calculation. As a consequence of the input data used, the modelling of physical reality and of processes is heavily simplified. The authors counterbalanced such a simplification using an 'expert system' approach. The system bypasses the accurate representation of the physical reality to assess globally the pollution potential of different land uses according to the judgement of scientists.

The scientific community proposes many models for depicting the dynamics of pollutants coming from diffuse sources. Most of them can be grouped into two broad categories: statistical models and physically based models. PNPI belongs to neither of the above-mentioned groups.

PNPI is a GIS-based, watershed-scale tool designed to inform decision makers and public opinion about the potential environmental impacts of different land management scenarios. PNPI applies the multicriteria technique to pollutant dynamics and water quality. The pressure exerted on water bodies by diffuse pollution coming from land units is expressed as a function of three indicators: land use, run-off and distance from the river network. They are calculated from land use data, geological maps and a digital elevation model (DEM). The weights given to different land uses and to the three indicators were set according to experts' evaluations and allow calculation of the value of the PNPI for each node of a grid representing the watershed; the higher the PNPI of the cell, the greater the potential impact on the river network. The output of the calculation is presented in the form of maps that highlight areas that are more likely to produce pollution. Last, possibilities, strategies and results of the validation of the PNPI are described.

In the authors' view, the explicit link between land use and potential pollution on which PNPI is based, together with its high communication potential, make it particularly interesting for a participatory and integrated approach to land management and environmental protection.

Keywords: Non-point pollution; Multicriteria approach; GIS; Surface water bodies

1. Introduction

The EU directive (EU, 2000/60) concerning the ecological quality of waters is an innovative integrated approach to the management of the aquatic environment, and also the Italian legislation on waters (Italy, 1999; 2000) is now moving towards an integrated approach. The EU directive (European Union, 2000/60) stems from the concerns amongst Member States of the EU over the disparate ways in which water is protected within the Community and reflects the moves toward integrated environmental management outlined in the environmental action

Abbreviations EINECS, European inventory of existing chemical substance; PNPI, potential non-point pollution index; LCI, land cover indicator; ROI, run-off indicator; DI, distance indicator; EEA, European environment agency; FA, flow accumulation; CLC, corine land cover.

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programmes of the Community. Water management policy as set out in the Directive is focused on water as it flows through river basins to the sea, and its provisions apply to all waters: inland surface waters, groundwaters, transitional (estuarine) and coastal waters. An integrated approach based on river basins is introduced for water quality and quantity matters and for surface and groundwater issues. Water is thus seen as a coherent whole. The overriding objective of the policy is the achievement of 'good status' in all waters. The Directive sets the framework for a wide range of activities and issues related to river basin management: definition of river basin districts and relevant characteristics, programme of measures, river basin plans, ground water, waters requiring special protection, priority substances, monitoring and economic instruments. In this framework, many scientific studies have addressed various aspects related to integrated water management.

Some studies have investigated the actual extent of water monitoring in Europe (De Zwart, 1995; Water Researce Center, 1996; European Environment Agency, 1999a; ANPA, 2000; Ministero Ambiente, 2001) other reports illustrate 'integrated models of study' for aquatic environments (United States Environmental Protection Agency, 1996, 2000; SEA, 2000). Particular attention has been paid to diffuse pollution from nutrients, namely nitrogen and phosphorus (Haycock et al., 1993; European Environment Agency, 1999b; Crouzet, 2000; Schilling and Libra, 2000). On the other hand, the number of chemicals released into surface water bodies is extremely large; their dynamics are complex and it is difficult to measure the global impact.

The European inventory of existing chemical substance (EINECS) identified more than 100,000 chemicals, but there is not satisfactory knowledge of their routes of entry into surface waters yet. Furthermore, EINECS is likely to have underestimated the number of pollutants, for it does not take into account all by-products deriving from physical, chemical and biological degradation. The management of non-point pollution of rivers and its prevention are priority factors in water monitoring and restoration programmes.

The aim of this study is to provide a new tool that could contribute to the design of such restoration and monitoring plans. This tool is a GIS based system that is able to detect and display areas that are likely to produce pollution due to their land use, geomorphology and position with respect to the river network. The tool focuses on the driving forces of pollution instead of on the impacts. In this way, point and non-point sources can be clearly separated.

Several indicators and indexes of ecosystem health and quality are used as assessment tools in integrated approaches to aquatic ecosystem management and in environmental planning (Karr, 1999; Lorenz et al., 2001). A major drawback of statistical or physically based models for non-point pollution is the large amount of data required both as input and for calibration and validation of the model. Other possible problems are long computing time, modelization complexity and the highly skilled operators required for using them. PNPI aims to overcome those problems. It only requires widely available data, it is easy to calculate and it is supported by a user-friendly interface. Yet, the most important feature of the tool is that it is able to synthesize into highly communicative maps the experiences and skills of many scientists involved in different aspects of the environmental protection of rivers.

2. Materials and methods

The physical reality of the watershed is represented by few input data: land use maps, geological maps and digital elevation models (DEM).

The method for calculating PNPI follows an approach quite similar to the environmental impact assessment. In this case the potential pollution coming from land parcels is expressed as a function of three indicators:

- LCI (land cover indicator), which refers to the potential generation of non-point pollution due to the land uses of the parcel
- ROI (run-off indicator), which takes into account pollutant mobility and possible filtering with respect to terrain slope, land cover and geology
- DI (distance indicator), which translates hydraulic distance into a kind of pollution dumping coefficient.

In Fig. 1 the calculation pathway of PNPI (potential non-point pollution index) is shown.

The LCI indicator is the most important of the set. Environmental consequences of different planning scenarios can be assessed by means of the LCI contribution to the PNPI. For the LCI calculation each land use was given by experts a coefficient depending on the polluting potential: densely built areas and intensively cultivated fields were given the highest coefficients whereas natural and unaltered zones were placed at the opposite end of the scale. Land use types and their geographic distribution were taken from CORINE land cover (CLC) digital maps. The European Commission implemented CLC from 1985 to 1995. During this period, the information system on the state of the European environment was created (the CORINE system) and nomenclatures and methodologies were developed and agreed upon. This was by far the greatest effort for the creation of a common land use classification system at the European level. Following the European Council decision to set up the European environment agency (EEA) and the establishment of the European environment information and observation network (EIONET), the responsibility for the CORINE databases has fallen on the EEA.

CLC is currently being updated and CLC2000 maps over Italy were released in November 2004. This new project covered both EEA Member States and 10 accession