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ENVIRONMENTAL RISK STUDIES APPLIED TO URBAN MANAGEMENT OF WATER RESOURCES. CASE STUDY: AZUL, BUENOS AIRES PROVINCE, ARGENTINA

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In spite of international efforts in the last decades, access to safe water supply cannot be guaranteed in many regions of the world. As a result, waterborne diseases are the single, most common cause of death throughout the world. In low-income countries, the lack of properly trained human resources and funds are major drawbacks in evaluating the risks to human health from drinking unsafe water, let aside making decisions on how the local water resources are to be managed. This paper presents a simple methodology for evaluating the environmental risk associated with a potentially unsafe water supply. The methodology takes into account the concentration of harmful substances in water, the rate of daily water consumption, the weight of humans exposed (adults and children), as well as the reference dose of each given compound. Simple combinations of these parameters are used to evaluate the risk, with results that can then be converted into risk maps. The methodology has been applied in Azul City, Buenos Aires Province, Argentina, a medium-size town with partial coverage of water supply and sanitation services. Taking the block as the unit area, the results are quite useful to illustrate the potential risk and, eventually, to show the path for much needed preemptive measures by the local authorities.

INTRODUCTION

Risk may be defined as the probability that a given action or a particular compound produces an adverse effect to any sensitive element (human or ecological) under certain exposure conditions (Paustenbach, 1995). Its assessment includes the characterization of potential adverse effects in order to identify, evaluate, select, and carry out actions aimed at reducing them through management systems (CRARM, 1997).

Risk studies, mainly applied to health-related issues, are regularly employed in environmental management in the United States, Canada, and many of the European Union countries (Paustenbach, 1995), but its use as a basis for the decision-making process is rarely encountered in emerging-economies countries.

Given the variety of environmental conflicts linked to water resources in a middle-size town of the Argentine Pampas, it may be suggested that the application of an environmental risk methodology gives rise to options on which decisions can be more thoroughly justified (Peluso et al., 2001). Such studies should not be constrained to purely toxicological aspects that may affect human health or ecosystems. Social, legal, and economic issues, as well as those aspects that lead to an integral assessment (USEPA, 2000) are to be looked at, to ultimately help on the selection of options in the framework of the prevalent management system (CRARM, 1997).

This paper presents an environmental risk methodology and verifies its applicability for water resources management within a context of scarce economic resources. It implies the commitment of local authorities, scientifically backed by human resources regionally available (Usunoff et al., 2000), and taking as the study case a medium-size town of a developing South American economy. The city selected is Azul (50,000 inhabitants), Buenos Aires Province, Argentina.

GENERAL METHODOLOGY

The risk analysis methodology is based on the systematic use of available information in order to determine how likely a given event may occur and the magnitude of its consequences (Australian Standards, 1999). Such an evaluation goes beyond the usual relationships between a pollutant and its effect on humans. It adds risk-related aspects pointing towards including social issues in order to define more precisely what is actually risky (CRARM, 1997).

The general methodology for environmental risk analysis has four main elements (NRC, 1994):

1) Identification of a hazardous source, that determines whether a given compound is causally related to negative effects on human health.

2) Evaluation of exposure, that looks into the pathways of contact between the hazardous source and the target (humans).

3) Evaluation of dose/response, that focuses on the relationship between the degree of exposure and the probability of having negative effects on human health.

4) Risk characterization, which describes the nature and extent of the actual risk by properly processing the information from the above elements.

The exposure evaluation is a measure of the type and quality of contact between the hazardous source and the targets (USEPA, 1992). For exposure to chemical species in water supplies, given that the study does not include carcinogenic substances, the exposure evaluation can be expressed by a model that calculates the mean daily dose (MDD) as follows (modified from USEPA, 1992):

$$MDD = C \,.\, Ir / Bw \tag{1}$$

where

C = concentration of the species in the source (water supply)

Ir = rate of daily consumption of water

Bw = weight of target (humans)

To make use of the exposure evaluation as applied to risk analysis, the reference dose (RfD) may be used. Such a concept represents an estimate of the daily exposure by human beings (including highly sensitive subgroups, such as children or the elderly) that would not produce any adverse effects during a human-life time span (Barnes, 1988). Therefore, a measure of the risk to exposure (R) to a given chemical can be obtained by calculating the excess of MDD with respect to the RfD.

$$R = MDD / RfD \tag{2}$$

Equations 1 and 2 are applied to single individuals. Notice that the risk analysis can be expanded to an entire population, by estimating how many individuals are facing a given hazardous situation (USEPA, 1992), as will be presented below.

APPLICATION OF THE RISK ANALYSIS METHODOLOGY

The objective of the methodology is to determine the spatial distribution of population risk to assess whether homogeneous areas can be identified and if these areas can be assigned a degree of seriousness. The potentially hazardous source is the chemical composition of the water supply (pumped from domestic wells), not including carcinogenic compounds.

Equations 1 and 2 are used to take into account spatial discrete units (blocks) and the number of people in each block who share the same conditions as far as the exposure to the source. The study assumes that the risk affects two population segments, children and adults, with differences in calculation as will be shown below.

The multi-personal risk per unit area (block) can then be expressed as:

$$MPR = R \,.\, N \tag{3}$$

where

N=Number of people per block (children and adults) exposed to the source

Layout of calculations

Inasmuch as the information on chemical analyses of water supply is rather scarce, the available data was processed so as to cover the domain by interpolation using a widely known computer code (Golden Software Inc., 1994), and assuming representative values corresponding to the center of each block.

Extensive polls were carried out to determine whether the householders had a domestic water supply well and how much of the pumped water was used for human consumption. Results revealed that the daily amount of water consumed (2 liters for adults and 1 liter per child) were normal or slightly below normal (USEPA, 1997). Taking into account the most common case encountered, it was possible to estimate the daily rate of water consumption (Ir) per block.

The N value (children and adults) come also from polls, whose results were extrapolated to the entire block in those cases where it was not feasible to survey all houses in the block. The average weight of adults was taken to be 70 kg., and 15 kg. for children.

Finally, Equation 3 is applied at each area unit (block). In Azul, the number of blocks is about 1400 (Figure 1).

The primary variables and those from the calculations were mapped, recalling that each block is characterized by a unique value.

To produce more appropriate material for the decision-making purposes, values of risk obtained were converted into a chromatic scale ranging from zero (null risk: black) to 10 (high risk: red). Such a conversion is done in two steps: (1) the level of risk at each block is divided by a default value of R = 1 and N = average number of people per block for the whole town; and (2) the difference between the maximum and minimum values so obtained is divided by 10, and a color is assigned to each number for generating the chromatic scale. Figure 2 depicts the results obtained for a segment of Azul City.

Discussion of the methodology

Many arguments have been raised about the weaknesses of environmental risk analyses given their uncertainties, such as the variable response by humans to the same pollutant dose, the variability in the daily amount of water consumed, the blind extrapolation to humans of RfD values obtained in experiments with animals, and many others (CRARM, 1997).

In that sense, the methodology applied in this paper does not eliminate or reduce such uncertainties. However, such weaknesses may be disregarded in the context of preliminary environmental risk studies, particularly in those cases where financial resources are either scarce or nil. Even so, some parameters can be continuously updated, such as the RfD values that can be retrieved via Internet. As far as on-site specific values, it should not be infeasible or highly expensive determining the mean average weight of the locals, their rate of water consumption, and so on.

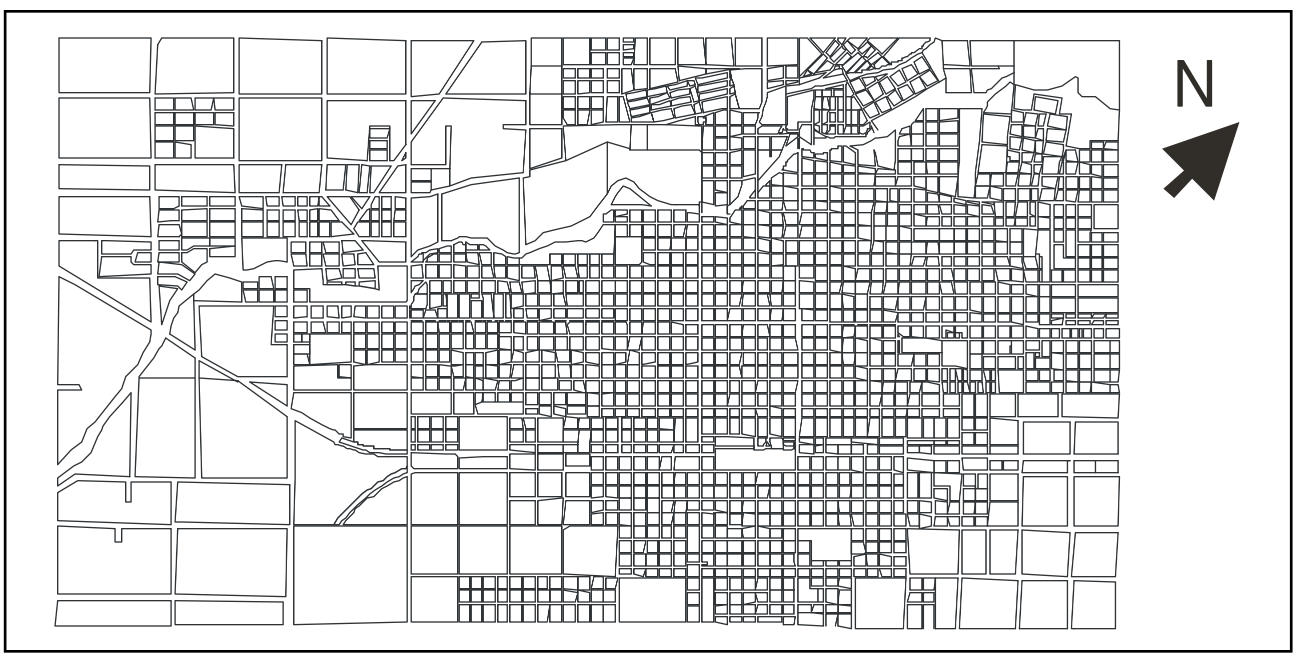

Figure 1: Azul City urban map with detailed division in blocks (unit area in this study).

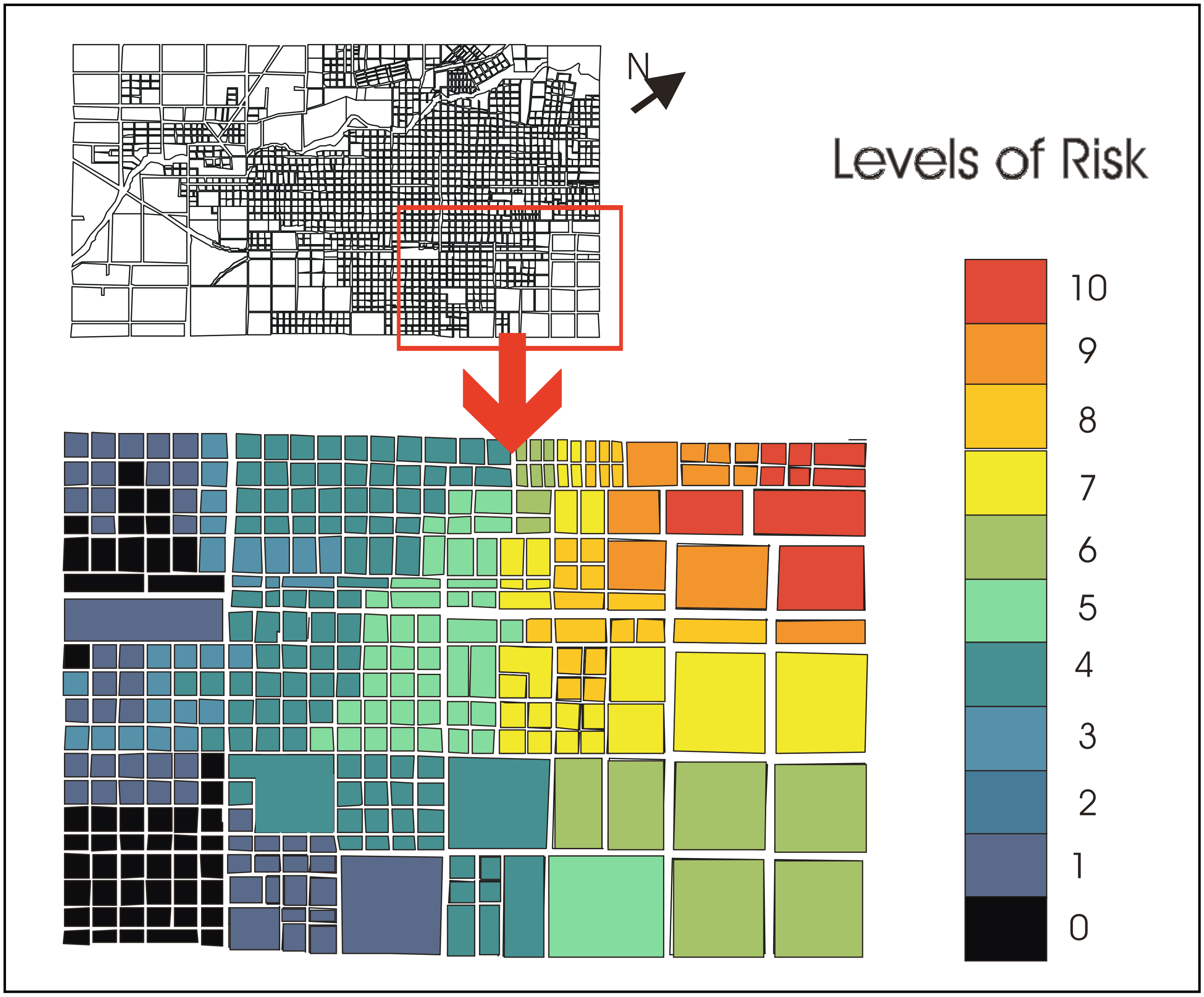

Figure 2: Risk levels from potentially hazardous water supply sources.

On the other hand, the methodology has some strong aspects worthy of consideration: simplicity, ease of operation, trivial updating whenever new chemical data or population growth data are available, and perhaps most important, communication of results to nontechnical stakeholders.

Methodology: Operational requirements

Basically, the methodology can be applied as long as some data/elements are available:

· Digitized map of the domain (city)

· Polls with data on population and water consumption rate

· Water quality from chemical analyses of water wells

· Access to databases containing the RfD values for different substances

· Software for: interpolation, worksheet for numerical calculations, and visualization (GIS)

It is also possible to use even simpler approaches:

If polling is not feasible, data from national agencies may be retrieved. In Argentina (and many similar countries), governmental agencies regularly publish the results of population and household data and statistics (INDEC, 1992). Although the unit area is variable (about 15 blocks in Azul City as shown in Figure 3), data can still be used. Obviously, the degree of uncertainty is higher. At the local level (municipalities), digitized maps of real estate can also be very helpful.

Updated data on RfD can be freely downloaded from several sites in Internet, for example the home page of IRIS (Integrated Risk Information System): http://www.epa.gov/iris.

As far as the availability of GIS, many sites in Internet offer downloadable free copies or demos (see for instance, SPRING: http://www.dpi.inpe.br/spring). Yet, the risk calculation can be done on any commercial worksheet and the results can be translated (colored) onto a digitized map using widely known graphing programs. This alternative was used with excellent results in earlier studies (Peluso et al., 2001).

Access to bibliography dealing with risk (human, ecological) has low or no cost. For example, full reports on the subject are ready to be downloaded from the Environmental Protection Agency web page: http://www.epa.gov.

Those few examples show that the application of the methodology presented here can be highly facilitated by the availability of resources free of charge, which is undoubtedly a very desirable situation given the financial constraints of many countries in the world.

Methodology: Its value for the community environmental management

Counting on an environmental risk study based on water resources as the risk source is not only an essential element from the point of view of integrated water resources management (Usunoff et al., 2000), but also provides a valuable tool for sanitation planning purposes (expansion of services, city growth limitations, educational activities).

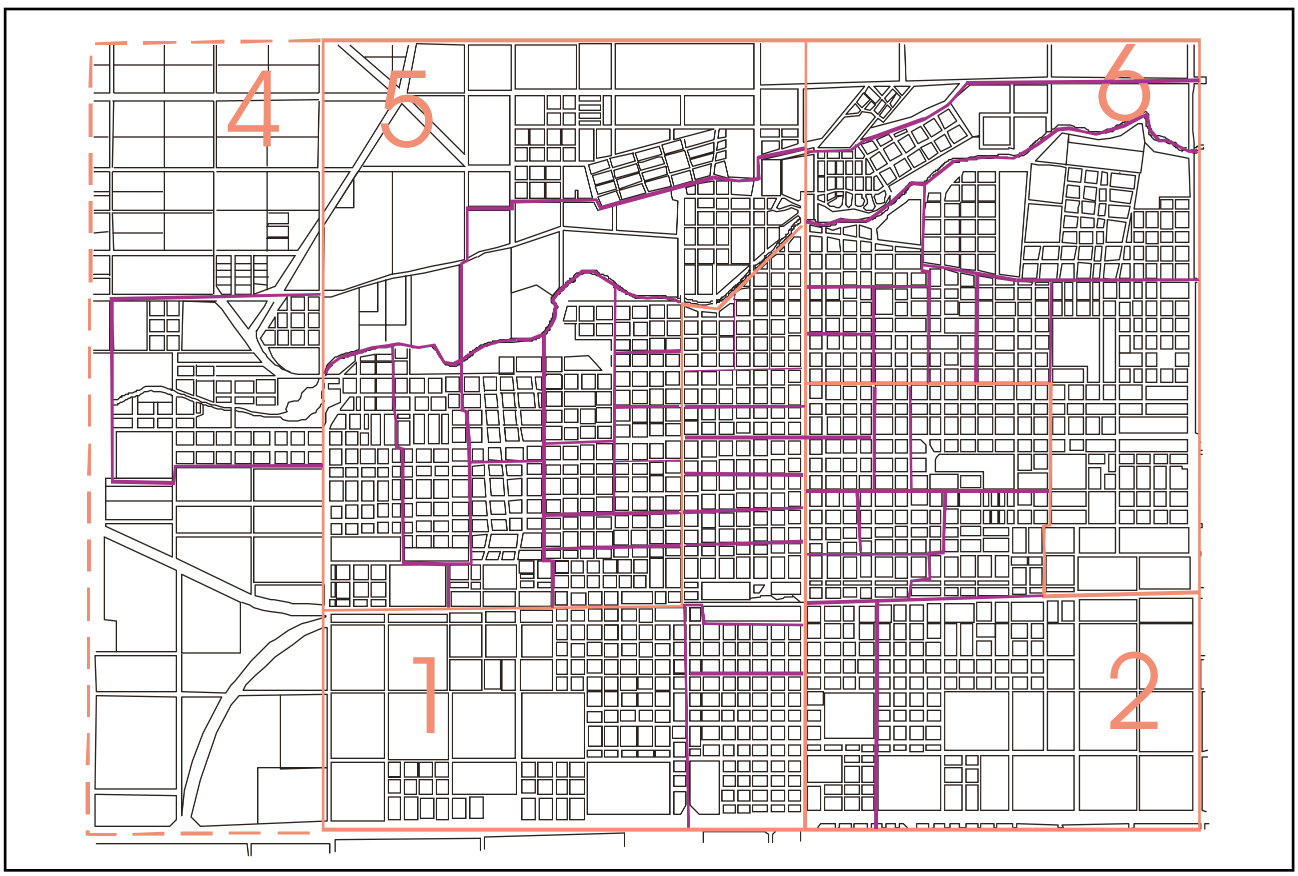

Figure 3. Census radii (red numbers) at the urban domain of Azul City.

Management of a given resource can be defined in terms of the guidelines, norms, laws, rules, and actions aimed at sustaining, preserving, protecting, reclaiming, and regenerating the resource (Custodio, 1994). Although contamination is a central issue concerning water resources management, it has to be viewed in a larger framework that includes social, technical, legal, and economic components (IDB, 1999). If so, all aspects dealing with evaluation and monitoring of water resources imply a heavy commitment of local (municipal) authorities because they have the knowledge on the real environmental conditions (Peluso et al., 2001). To this fact, the scientific know-how and the equipment of local or regional research institutions can be added, from routine services to much more complex research programs (Peluso et al., 2001). That is at the heart of the methodology here presented, where a simple tool has been derived which is powerful enough to back up decisions related to policies that prevent potential negative effects on human health. It should be highlighted that this initiative has been carried out at virtually no cost, and the results can be easily transferred to the local municipality.

CONCLUSIONS

The methodology described here points towards generating a tool to analyze the risks on human health that may come from exposure to a local water supply. It does not attempt to reduce the uncertainties of any risk analysis method. However, it is able to provide a preliminary evaluation that may prove to be useful in shaping management policies. It does not have many technological or informative requirements for its application, and the communication of results is easy and quite understandable by all stakeholders. It is expected that the use of this methodology can lead to identification of high human health risk areas and promote rapid actions to preserve the quality of local water resources.

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