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ECOLOGICAL RISK ASSESSMENT OF ATRAZINE IN NORTH AMERICAN SURFACE WATERS

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The article "The ecological risk assessment of atrazine in North American surface waters" [1] is one of the few among the 100 most cited articles in *Environmental Toxicology and Chemistry* to specifically address risk and/or assessment of risk, and it was the first to use probabilistic approaches for a pesticide. As with all science, it was one of many steps in the refinement of procedures for characterizing and assessing risks. Today, we understand that risk must always be expressed as a probability; but, in the general sense, this concept was a late arrival in the area of ecotoxicology. Ecotoxicological risk assessment, as we use it today, traces its scientific origins to risk assessment for the protection of human health, but even that was a relatively recent adoption. Although humans have faced risks since the dawn of society, risk assessment was purely empirical, descriptive, and anecdotal. The concept of risk in mathematical terms became possible only though the adoption of the Hindu-Arabic numbering system by Western society approximately 800 years ago [2]. Risk was studied quantitatively only during and after the Renaissance through the work of Chevalier de Méré, Blaise Pascal, Jacob Bernoulli, and Abraham de Moivre, who suggested the structure of the normal distribution. This concept was further refined by Swiss mathematician Carl Fredrick Gauβ and many others, resulting in the process used today.

The risk assessment of atrazine [1] typifies the breadth of expertise that is needed to undertake ecotoxicological risk assessment; it was the work of a panel of 12 authors, each contributing equally important and essential components to the process. The final product was brought together in a collegial and nonconfrontational process and the paper prepared for publication by one panel member. This model worked well and has been emulated in many subsequent assessments.

The assessment of risks of adverse effects from atrazine in the environment was not completely novel, but it was an important step forward in the development of the concepts of risk in ecotoxicology. The probabilistic characterization of toxicity data was not new. In the arena of human health, this process was suggested for components of food [3], which then led to the use of the threshold of toxicological concern [4] as an important screening tool, an approach now advocated for use in ecotoxicology [5]. From the environmental point of view, distributions of toxicity values were used to distinguish between more tolerant or resistant and more susceptible populations of ectoparasites of animals [6], but the notion of using these distributions for setting environmental quality guidelines originated from early work in the Netherlands (N. van Straalen, 1982, personal communication) that was further developed in Europe [7] and the United States [8]. These probabilistic methods are now used worldwide for setting guidelines for environmental quality.

Though the probabilistic analysis of toxicity was not novel, the ecological risk assessment for atrazine demonstrated how data for toxicity and exposure could be combined into a probabilistic characterization and unified expression of risk. This was a significant advancement over the use of simple quotients based on worst-case values. However, this was also not entirely new, it had been conceptualized in the work of the Aquatic Risk Assessment Dialogue Group [9], a process that was organized in part by the Society of Environmental Toxicology and Chemistry (SETAC) and also involved several authors of the article on the risk assessment for atrazine.

The publication of "The ecological risk assessment of atrazine in North American surface waters" was likely the catalyst for a number of joint activities between academia, industry, and regulators, such as the Ecological Committee on Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Risk Assessment Methods (ECOFRAM [10]) in the United States and the European Framework for Probabilistic Risk Assessment of the Environmental Impacts of Pesticides EUFRAM [11] in the European Union. Both of these have led to the further development of probabilistic assessment of ecotoxicological risks. One such development was the use of the joint probability distribution, first suggested in a computer program developed by the Cadmus Group and refined by ECOFRAM [10] for use in graphically displaying risks and, more recently, using these graphical displays for decision making (see Fig. 4 in [12]). Several of the refinements of probabilistic assessment of risk were incorporated in a more comprehensive, larger, and updated evaluation of atrazine that

All Supplemental Data may be found in the online version of this article. See Table S1 for the number of citations and rank of all the "Top 100" papers, which in this essay is reference [1].

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was published as a SETAC book [13], which included significant advances in the modeling of concentrations in surface waters. Probabilistic methods, such as those pioneered in these and subsequent risk assessment authored by others, are likely to become more widely used, particularly for chemicals for which large sets of data are available. A spreadsheet model, the probabilistic risk assessment tool (PRAT) has been developed to aid in the probabilistic assessment of chemicals in the environment [14].

Another feature of the risk assessment for atrazine that probably contributed to the number of citations is the large amount of data that it provided about one particular chemical, which is an important herbicide used in production agriculture. The reason for the inclusion of these data in the paper was twofold: first, the paper was partly a review of the biological and physical properties of atrazine; and second, the authors wished to be as transparent as possible in providing the scientific basis for the conclusions reached in the paper. As has been noted [15], transparency is very important in communicating the results of risk assessments and should be an integral part of the assessment and the decisions that result therefrom. Hopefully, with the ability to include supplemental information in journal articles, such transparency will become the standard for risk assessments in the future.

SUPPLEMENTAL DATA

Table S1. (45 KB PDF).

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