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A methodology to assess the risk of an existing pesticide and potential future pesticides for regulatory decision-making

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ABSTRACT

When a pesticide is banned, in an effort to reduce pesticide-related risk to the public, substitute pesticide(s) with different risks would likely replace the risk from the banned pesticide. This paper provides a framework that may be used as a regulatory decision support tool in studying the effect of banning a pesticide at the national level. A risk analysis of the prevailing pesticide and the potential substitute pesticide(s) must be separately performed and compared before a decision to ban the pesticide is adopted. In this study, an ordinal logistic regression model is developed using 21 pesticides and 99 watersheds to relate pesticide distribution in surface waters with chemical property, watershed property, and pesticide use. The model is used to predict substitute pesticide residue distributions in streams for evaluating intermediate drinking water risks before and after a potential ban of atrazine. About 80% of atrazine will likely be replaced by 2,4-D, bromoxynil, dicamba, and nicosulfuron. We found that banning atrazine will increase the risk from these substitute pesticides, but the cumulative risk from atrazine and the substitutes actually decreased slightly after the ban. Atrazine is a potential carcinogenic pesticide and the prospect that its substitutes are non-carcinogenic and pose less threat to the public warrants further attention. This study provides a scientific framework for decision-making and policy implementation related to banning a pesticide of concern.

1. Introduction

1.1. Background

Concerns over the potential health and environmental hazards of chemicals have resulted in an ongoing investigation of many pesticides. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) determines the regulatory actions of the US Environmental Protection Agency (US EPA) in pesticide management. FIFRA, as amended by the Food Quality Protection Act (FQPA) of 1996 (US EPA, 2003) (http://www.pestlaw.com/x/law/HR1627.htm), requires that all pesticides intended for use in the United States be registered by the US EPA to ensure that they do not cause unreasonable adverse effects on humans or the environment. Important reforms under FIFRA include reviewing pesticide registration at least every 15 years, expediting registration of reduced-risk pesticides, and promoting the use of integrated pest management.

FIFRA requires the US EPA to balance risks and benefits in the pesticide management process. It also authorizes the US EPA to conduct a risk/benefit analysis of pesticides through its special review process. This is performed when new scientific

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evidence and additional data show that a pesticide may pose an imminent hazard to human health or the environment. A special review may result in banning or restricting some or all uses of the pesticide. In cases where the risk for a given pesticide or a set of pesticides exceeds acceptable standards, there is a need to mitigate or manage this risk. Management options may range from reducing the use of the pesticide to completely banning it. From a management viewpoint, the question still remains whether banning of a given pesticide will necessarily eliminate the public health risk or will it merely change the type and/or the magnitude of the risk. Banning a pesticide in an attempt to remove target risk may introduce higher countervailing risks from potential substitute pesticides thus exacerbating the public health risk. It is therefore crucial to predict the trade-off between the prevailing and the countervailing human health risks. In this study, we will investigate the risk trade-off occurring as a result of a complete ban of a controversial pesticide known as atrazine.

Atrazine is slightly or mildly toxic to humans. It causes skin, eyes, nose, and throat irritation. Animal studies have shown that atrazine causes adverse effects to reproductive systems, heart and lungs and changes in liver, kidney, and brain functions (http://ace.orst.edu/info/extoxnet/pips/atrazine.htm) when ingested above the allowable doses. However, recent findings are showing that the environment may not be safe with atrazine even at significantly lower doses. Hayes et al. (2002) found that, at a level as low as 0.1 ppb, atrazine causes sexual deformities in frogs. The maximum contaminant level (MCL) of atrazine is 3 ppb, which is 30 times higher than the level at which the frogs experienced sexual abnormality. MCL is the maximum concentration of a chemical that is allowed in public drinking water systems. At higher levels, frogs developed additional health problems. Kettles et al. (1997) found a statistically significant relationship between the exposure to triazine herbicides and increased breast cancer risk in Kentucky using data on county-wide breast cancer rates. The US EPA has actually classified atrazine as a potential carcinogenic herbicide (US EPA, 2000).

The above studies are indications that ongoing risk assessment of prevailing pesticides is essential in light of improved risk assessment methodologies (Tesfamichael and Kaluarachchi, 2004), better data, and new scientific discoveries on impacts of pesticides on human health and the environment. The possibility that doses of atrazine at 3% of the MCL disrupted frog reproductive organ development has adverse implications for humans. This finding may pose significant problems to the public because atrazine is one of the most frequently detected pesticides in surface water across the country (US EPA, 2001).

Several studies have documented pesticide risk-benefits (Pimentel et al., 1991; Harper and Zilberman, 1992; Ribaudo and Bouzaher, 1994; Liu et al., 1995; Ribaudo and Hurley, 1997; Zilberman and Millock, 1997; Gray and Hammit, 2000; Paul et al., 2002; Tesfamichael et al., 2005). However, most of these studies focus on the economic and health trade-offs of the prevailing pesticide. These studies did not consider the possible countervailing health impacts of banning a pesticide, which is crucial in pesticide management. Banning of heavily used pesticides such as atrazine may introduce other less effective pesticide(s) to the environment. Less intrinsically toxic pesticide(s) will now be heavily detected in surface waters when these are replaced by atrazine. Therefore, it is essential to study not only the risk-benefit trade-off of the prevailing pesticide, but also the risk trade-off between the prevailing and the potential substitute pesticides. There are few studies in the literature that investigated the effect of banning a pesticide from this viewpoint. Gray and Graham (1995) reported that efforts to reduce pesticide-related risks to the consumers and farm workers may exacerbate other risks and thereby partially or completely offset the reductions in the target risk. Countervailing risks may arise from substitute pesticides or pest control management practices. Gray and Hammit (2000) did an exploratory analysis of public health effects of a potential ban on organophosphates and carbamates (OP/Carbamates). Potential risk trade-offs and populations of concern were first identified. The primary health concern of the OP/Carbamate family of pesticides is possible neurotoxic effects on humans. If the whole classes of OP/Carbamate pesticides are banned in an attempt to mitigate neurotoxicity, some of the substitute pesticides may offset the target risk, while others may replace it by another risk. For example, the target risk of neurotoxicity from fonofos will be replaced by cancer risk from a potential substitute pesticide, lindane. In this case, the potential risk of neurotoxicity from OP/Carbamates is only substituted by different sets of adverse health effects as a result of the ban.

An exploratory risk trade-off analysis on a complete ban of OP/Carbamates was shown to have a countervailing effect on the public (Gray and Hammit, 2000). In some cases substitute pesticides may be non-carcinogenic or less toxic and the risk they pose may even be less than the prevailing pesticide thus favoring banning from human health risk considerations. In others, the substitute pesticide may be carcinogenic or more toxic and may pose greater risk to the public. A decision to ban a pesticide must therefore be preceded by risk assessment of the problem and the potential substitute pesticides. This approach may be useful in averting some unforeseen countervailing risks by restricting the use of the substitute pesticides on certain crops or reducing the allowable application rates.

In pesticide risk analysis, the countervailing risks are frequently discussed qualitatively (Gray and Hammit, 2000). One of the reasons why risk trade-offs are often restricted to exploratory analysis is the lack of residue data on substitute pesticides. There is a crucial need to explore methods of estimating environmental concentration distributions of substitute pesticides that is essential for a meaningful risk analysis and predicting the potential countervailing risk ahead of banning. Regression models are therefore developed in this study to predict the surface water concentrations of potential substitutes of atrazine for use in estimating countervailing risks. Several studies have investigated the relationship between residues, physical characteristics of watersheds, and chemical properties (Battaglin and Goolsby, 1997, 1998; Larson and Gilliom, 2001; Kolpin et al., 2002; Battaglin et al., 1999; Twarakavi and Kaluarachchi, 2005). Battaglin and Goolsby (1997) used linear and logistic regression models to investigate the relationship between watershed characteristics and annual mean herbicide concentrations in mid-western rivers. They found a significant relationship between herbicide use in the watersheds and concentration levels in rivers.