USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Herbicide effects on water quality in the Great Plains: mechanisms of selective toxicity in freshwater algae

Duration: Two years (9/97 to 8/99)

Federal Funds Requested: $50,006

Non-federal (matching) Funds Pledged: $100,734

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Congressional District: 01

Statement of Critical Regional or State Water Problems:

Agricultural herbicides such as atrazine constitute the largest amount of all pesticides applied to agricultural land in the U.S. Atrazine contamination of surface waters as a result of agricultural non-point source inputs was identified as a majo r threat to aquatic ecosystems nationwide (EPA 1994). The documented presence of atrazine in surface waters has prompted a large number of studies on its potential adverse effects on nontarget organisms such as freshwater algae, yet our current understand ing of the overall impacts of atrazine is lacking in several key respects' how has atrazine fundamentally affected algal community composition in streams receiving inputs and how will it impact streams previously unexposed? Algae are the most important pr imary producers in aquatic systems and account for nearly the same percentage of total global net primary production of carbon annually as do cultivated plants. In addition, algae represent the basal component of aquatic food webs, since they are consumed by a variety of invertebrates or directly by fish, both of which are consumed by other fish species. These attributes of algae make them fundamentally important to surface water quality and point to the importance of finding solutions to the above questi ons.

It has recently been revealed that different divisions of freshwater algae and even clones of the same algal species may exhibit differential responses to herbicide exposure. Toxic effects of atrazine to a number of freshwater algal species were determ ined recently in our laboratories based on measurements of cell density and chlorophyll a. The inhibition percentage and EC50 values (effective concentrations causing 50% inhibition compared with control) were calculated. It was found that there were sign ificant differences in atrazine toxicity to different algal species, with green algae significantly more susceptible to atrazine than diatoms (Tang et al. in press). The mode of action of atrazine involves a competition with plastoquinone for binding to t he Q _b polypeptide in the photosystem II complex of the chloroplasts (Velthuys 1981). In order to inhibit photosynthesis in freshwater algae, atrazine must be absorbed through the algal cell membrane. Using 14C-labeled atrazine, hi ghly significant correlations were also observed between the uptake capacity (bioconcentration factors) of the algal species studied and the toxicity of atrazine to those algal taxa (Tang et al. in review). The results suggested that different degrees of uptake might account for the differences in the toxicity of atrazine to different algal species and that uptake might be a prerequisite for atrazine toxicity in algae. Clearly, there is a great need to more precisely determine what causes the differential sensitivity of algae to atrazine exposure. Because of the relatively limited number of algal taxa (i.e. Divisions or Phyla) examined to date, it is also necessary to determine the relationship between atrazine bioconcentration and toxicity among a broade r range of algae representatives from streams and rivers throughout the Great Plains, while at the same time defining the relative atrazine tolerances among these Divisions. Lack of such data obviates the formation of acceptable predictive models on the r eal and potential impacts of atrazine and other common herbicides on surface water quality in the Midwest.

The information obtained by this study will include' (1) the relative toxicity of atrazine to five of the most common algal Divisions, and (2) the mechanisms of these differences in atrazine toxicity. The former data will significantly broaden our curr ent understanding of the potential for atrazine to alter algal community composition and abundance in aquatic ecosystems, while the latter information will provide crucial insights regarding the mechanisms of differential toxicity in algae applicable to o ther pesticides and pollutants. Because many aquatic systems in North America receive inputs of atrazine and other soluble herbicides (see for example, Richards et al. 1987, Gregor and Gummer, 1989, Glotfelty et al. 1987), this study addresses a potential problem of significant proportion. In the agricultural Midwest where even higher order streams such as the Platte River have detectable levels of atrazine virtually year-round, it is clearly important to understand how these toxicants currently affect co mmunity structure and biomass production.

Statement of Research Benefits:

A fundamental goal in the ecotoxicology of surface waters in the Great Plains is to predict the effects of pesticide stressors. Our lack of critical knowledge concerning the impacts of pesticides on Midwestern aquatic communities is attributable t o a general lack of understanding of the physiological and biochemical processes that result in the toxicity of herbicides to various algal species and the relative susceptibilities of the dominant algal groups. This study is designed both to investigate the underlying mechanisms of differential algal sensitivity to the most commonly used herbicide in the U.S. and to elucidate the relative tolerances of a much broader range of algae than have been previously examined. Given our initial findings of differe ntial algal toxicities (Tang et al. in press) and the importance of algae as primary producers at the base of aquatic food webs, obtaining more comprehensive information on algal responses to pesticides is clearly warranted and prerequisite to our assessm ent of pesticide impacts on aquatic systems throughout the Region. The proposed study will provide a much more complete understanding of the relative tolerances of the most common algal constituents in streams, lakes, and wetlands, as well as identify the basic underlying mechanisms which explain their differences in atrazine tolerance. Taken together, this approach will allow us to extrapolate our findings to other aquatic systems and to better predict the impact of atrazine on surface water quality in g eneral and on overall ecosystem health. This information will also provide water managers and policy makers with important information on acceptable levels of this ubiquitous toxicant.