ENVIRONMENTAL FATE AND AQUATIC IMPACTS OF HEXAZINONE APPLIED AT A HIGH RATE FOR PLANTING SITE PREPARATION

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Introduction

Most environmental fate and impact concerns associated with the use of forest herbicides are related to offsite movement during and after application. The environmental fate and ecosystem impacts of forest herbicides are governed by movement and transformation in the atmosphere, above ground vegetation, soil surface, soil rooting zone, surface water, and groundwater. Herbicides and their breakdown products are transported within ecosystems mainly through the water cycle, but drift, volatilization, photodecomposition, and other forms of degradation also affect movement directly or indirectly. Precipitation and evaporation are the principal driving forces in the processes of runoff, leaching, and plant uptake and they have been discussed in great detail for forest watersheds by Hewlett (1982), Anderson et *al.* (1976), and Crossley and Swank (1987). Many herbicide fate studies have been conducted in the southern pinery of the United States of America (USA). Those studies have been reviewed by Michael and Neary (1993).). However, few studies exist in the literature that have examined the potential impacts of forest herbicides to stream biota.

To address environmental concerns, a process was established for registration of pesticides in the USA. Herbicides used in the USA must be registered for specific uses by the U.S. Environmental Protection Agency (USEPA) which requires a forest dissipation study be conducted for forest herbicides. In addition, the Federal Insecticide, Fungicide, and Rodenticide Act Section 3(g) as amended in 1978 also directed the USEPA to reregister previously registered pesticides using current registration standards.

This study was designed to address environmental fate and impact concerns, and for use in partial fulfillment of the USEPA reregistration requirements. Rate of dissipation of hexazinone (the active ingredient in Velpar(RTM) Herbicide) in plant tissue, litter, and soil; off-site movement of hexazinone in water and sediment; and impacts of that movement on aquatic macroinvertebrate and fish populations were determined. Principal metabolites of hexazinone were also monitored.

Materials and Methods

Velpar(RTM) L (25% water dispersible liquid) and Velpar(RTM) ULW Herbicide (75% water soluble granule) were applied to representative watersheds in the Piedmont of Alabama at the rate of 6.72 kg ai ha-' for the normal practice of planting site preparation. An adjacent untreated watershed was maintained as a control which did not receive the test substance.

Water, sediment, foliage, litter, and soil samples were collected on at least 14 sampling dates (-1, 0, 1, 3, 7, 14, 30, 45, 60, 90, 120, 180, 270, and 365 days after treatment). All samples were frozen as soon after collection as possible and maintained that way until analyzed.

All samples were analyzed by HPLC using reversed-phase gradient elution and programmed wavelength UV detection. Hexazinone detection limits based on method blanks and detector response were: water, 2 μg L^{-1}; plants, 17 μg kg-'; litter, 16 μg kg-'; soil, 4 μg kg-'; and sediment, 15 μg kg-'. Recovery of hexazinone ranged from 8697% in the various matrices analyzed.

Benthic (bottom-dwelling) macroinvertebrates were sampled on 6 dates (-3, 7, 41, 69, 139, and 307 days after treatment) using modified rapid bioassessment techniques (Plafkin *et al.* 1989; Barbour *et al.* 1996). In each stream, riffle and run microhabitats with current velocities exceeding 10 cm s^{-1} were sampled with D-frame nets (mesh size of about 1 mm). Rocks, woody debris and leaf packs were disturbed upstream of the net and macroinvertebrates were washed into the net by the current. Two biologists each collected one sample from each stream. Netting effort in each stream was timed to standardize collecting effort. Community metrics (biocriteria) used to measure differences among streams included the Hilsenhoff Biotic Index (HBI), a measure of organic pollution (Hilsenhoff 1987); the Shannon-Weaver diversity index; and species (taxa) richness, both total and the number of pollution-sensitive Ephemeroptera-Plecoptera-Trichoptera taxa (EPT Index).

Fish were sampled in each stream on 4 dates (-5, 50, 76, and 344 days after treatment) using a backpack electroshocker. Fish were identified, weighed and measured in the field and most were released alive. A subsample was preserved for taxonomic verification and reference. Any physical abnormalities were noted and an Index of Biotic Integrity (IBI) was calculated from the collections (Karr 198 1).

Results and Discussion
Hexazinone dissipated readily from both watersheds with similar half-lives computed for respective matrices in the two treatments (Velpar ULW vs. Velpar L Herbicide). Half-lives in plants were somewhat longer for plants from the ULW site (26-59 days) than for the same species from the Velpar L Herbicide site (19-36 days). Dissipation in the litter and soil was similar for the two sites (55-77 days half-life) except for soil under litter on the Velpar L Herbicide site which had a half-life of 275 day4 Dissipation of hexazinone to background levels was complete by 365 days in all other matrices except sediment. Movement in the soil was consistently detected to 30-45 cm, but was rarely detected above background levels in the range 60-75 and 75-90 cm. Movement to this depth may occur, but is often attributed to macropore transport (movement in rotted root channels, stump holes, rodent burrows, etc.).

Off-site movement in storm runoff was not significantly greater than observed in some studies with this and other forest herbicides applied at one third the rate used in this study. Maximum stream concentrations were observed during application (422 μg L^{-1} on the ULW site, 473 μg L^{-1} on the Velpar L Herbicide site) and were generally diluted 3-5 times 1.6 km downstream.

Hexazinone was generally not present significantly above the detection limits in water after about 6 months. Monitoring of streams continued for another 6 months after this end point.

Off site movement on sediment followed a bimodal curve for the ULW site and an exponential curve for the Velpar L Herbicide site. Dissipation in sediment was nearly complete by 180 days after treatment on both sites, but rose again toward the end of the study as very large amounts of sediment began to move through the flumes on the treated watersheds. Within a week after this peak ULW sediment concentrations decreased to 0.6 mg kg-'. Sampling was not continued after this time. The sediment at this time differed significantly in composition from the loamy fine organic matter collected in the beginning of the study. The sediment collected at the end of the study was a very friable rock material resembling coarse sand. The hexazinone carried in this wave of sediment near the end of the study did not give rise to concurrent and significant elevation of hexazinone concentrations in streamflow at or below the flume sites.

Metabolites A, C, and E were infrequently detected by HPLC in the matrices sampled, but Metabolites B, D, G, and H were detected. However mass spectrometry did not confirm presence of Metabolite G. Dissipation of these metabolites generally followed the same, but delayed, pattern observed for the parent compound. Analyses of Metabolites D and G were considered more unreliable than analyses for the other metabolites due to coextractabies which interfered with the analyses, but presence of metabolite D was confirmed by mass spectrometry.

Stream bioassessments based on the HBI across all dates indicated significantly higher water quality in the control stream than that found in the Velpar L strearn, but not the ULW treatment. However, these differences were not detected on individual dates following hexazinone application. Total taxa richness and diversity differed little among streams and the pollution-sensitive EPT Index showed no evidence of hexazinone toxicity among streams. No changes in benthic community structure were evident from the application of hexazinone to the two watersheds.

Fish abundance and diversity were low in all three first-order streams. An IBI could not be calculated based on only four families of fish, and eight species among the three streams. The dominant species in each stream was the creek chub, *Semotilus atromaculatus*. This species is common in small headwater streams (Dycus 1972). Based on the few changes observed in fish communities in the two treated watersheds, hexazinone had no adverse impacts on fish.

References

Anderson, H.W., *et al.* 1976. USDA Forest Service Gen. Tech Rep. PSW-18,115 pp.
Barbour, M. T., *et al.* 1996. J. N. Am. Benthol. Soc. 15: 185-211.
Crossley, D.A. and W.T. Swank (ed.), 1987. Springer-Verlag, New York, NY.
Dycus, D. L. 1972. Master's thesis, Samford University, Birmingham, AL.
Hewlett, J.R., 1982. University of Georgia Press, Athens, GA. 183 pp.
Hilsenhoff, W. L. 1987. Great Lakes Entomol. 20: 3 1-39.
Karr, J. R.. 1981. Fisheries 6: 21-27.
Michael, J.L. and D. G. Near-y. 1993. Environ. Toxicol. Chem. 12: 405-410.
Plafkin, J. L., *et* al. 1989. US EPA. EPA/444/4-89-001.