HERBICIDES IN SOUTHERN FORESTRY - IMPROVING WATER QUALITY.

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ABSTRACT

Environmental interest groups have traditionally equated herbicide use with degradation of water quality. If the entire water quality picture is rationally analyzed. the conclusions are quite the contrary. Use of herbicides compared to mechanical site preparation improves or maintains water quality. Short-duration pulses of residues may appear in streamflow. but data from forest ecosystem studies indicates that these residues are generally not significant to aquatic ecosystems. The herbicides currently being used in southern forestry are low in toxicity and do not persist in the environment. Herbicide use significantly reduces the major, but frequently ignored, water quality problem, sediment. Site preparation with herbicides maintains watershed hydrologic conditions close to that of undisturbed stands and does not aggravate storm runoff, which can transport large amounts of sediment into streams. In addition, herbicide use does not produce adverse soil disturbance. which can lead to compaction and markedly increased soil erosion. Sediment displaced in streams produces significant and long-term changes in aquatic systems and can adversely affect stream biota and water quality large distances downstream.

INTRODUCTION

Passage of the Water Pollution Control Act of 1972 resulted in the focusing of considerable scientific effort on the sources and effects of nonpoint source pollution. Water pollution, any undesirable change in water quality, from nonpoint sources originates from a broad landscape rather than a single point. Types of nonpoint source pollution include sediment, nutrients, pesticides, toxic metals, livestock and sewage wastes, and atmospheric products. Of these, sediment comprises the greatest volume of pollutants and the single biggest problem (4). In-stream and off-stream damages from soil erosion and resulting sediment amount to $6 billion per year in the United States (5). Despite 14 years of research and implementation of best land management practices, nonpoint source pollution remains one of this nation's main water quality problems (20).

Forestry generally results in less nonpoint source pollution than agriculture due to a smaller land area. less intensive treatments, infrequent harvests and less frequent nutrient and pesticide applications. However, maintaining the quality of forest streams is a high priority since these waters have the best quality, are used frequently for municipal water supplies, support cold water fisheries, and provide recreational opportunities. Localized nonpoint source pollution problems can arise due to silvicultural activities, so most states have implemented best management

† The authors would like to acknowledge USDA Forest Service Southern Region. National Agricultural Pesticide Impact Assessment Program, Dow Chemical USA. and E.I. duPont de Nemours and Co., Inc. for their support of research mentioned in this paper.

practices to protect the quality of forest lakes and streams (11). In all southern states silvicultural nonpoint source pollution is recognized as a localized problem affecting less than 50 percent of each state's waters. However, in North Carolina it is more of a widespread problem affecting over 50 percent of the water resources (1).

One of the best management practices that is being implemented more frequently in southern forestry is the use of herbicides for site preparation. For many years environmental Interest groups have been arguing that use of herbicides in forest watersheds automatically equates to water quality degradation. However, when the whole nonpoint source pollution picture is analyzed objectively, the main water quality problem with silviculture is, like agriculture, sediment and soil erosion. The careful and professional use of herbicides in forestry can be a major factor in reducing nonpoint source pollution within forest watersheds.

The purpose of this paper is to briefly review the water quality implications of herbicide use in southern forestry. Water quality in its broadest sense of anion/cation chemistry, pesticide loading, aquatic habitat, and sediment loading will be considered. The question that ultimately will be addressed is, "Does herbicide use degrade, maintain, or improve water quality?"

WATER QUALITY- HERBICIDE RESIDUE CONTENT

Forestry herbicides can affect water quality at several phases in the use cycle. These phases consist of 1) transportation, 2) storage, 3) loading and mixing, 4) application, 5) equipment cleanup, and 6) container disposal. During application, the movement of residues into water is generally in the form of a diffuse nonpoint source. It is during application that most adverse public reactions and concerns for water quality arise. Thus, most of the environmental research in the past 10 years has focused on off-site movement during and after application. The other phases usually deal with concentrates, constitute potential point sources of pollution, and have historically caused the most problems for water quality.

During herbicide application in forest watersheds, movement of residues into surface or subsurface water occurs on a broad landscape scale. The main movement mechanisms are drift, leaching, and surface stormflow. Drift can be controlled by selecting appropriate application equipment, use of granular formulations, utilizing adequate buffer strips along streams, adding anti-drift adjuvants into spray mixes. and avoiding windy conditions or inversions. Leaching can be minimized by selecting the appropriate herbicide for individual soils and hydrologic conditions. Off-site movement in stormflow can likewise be minimized by careful application techniques.

The fate and movement of herbicides in forest ecosystems are governed by a complex interaction of physical, chemical, biological. and hydrologic processes. These include herbicide characteristics, climatic and hydrologic conditions, soil and microbiological processes, vegetation response, and application parameters. Some of the important application conditions include frequency of use, rate, application system, and timing. Rainfall, temperature, sunlight, and evapotranspiration are key climatic processes in determining herbicide residue and fate. Herbicide chemical-physical characteristics such as solubility, volatility, and photodegradability are also important in determining residue fate.

Soil characteristics such as infiltration capacity, organic matter content, microbiological activity, structure, and texture mediate transport within and off-site. Vegetation uptake. degradation, and recycling of herbicide residues can also be key processes in determining herbicide fate. In a given situation, herbicides with the highest water solubilities, most resistance to physical, chemical, and biological degradation, lowest affinities for adsorption onto organic matter, and the highest application rates have the greatest potential for movement in the environment (16). The potential exists for herbicide residues to enter surface or subsurface water. The Important questions are, "At what concentration, for how long, and of what importance?"

There are a number of studies on the fates of forestry herbicides in southern forests, but It is beyond the scope of this paper to address all of these. Several studies on hexazinone will be used to illustrate the range of water quality effects associated with herbicide application in southern forest watersheds.

Hexazinone residues in streamflow have been studied under operational-use conditions in several southern forest watersheds. Miller and Bace (10) reported high hexazinone concentrations (up to 2.400 ppb) from direct fall of pellets into a perennial forest stream. The hexasinone pellets were dropped when a helicopter overflew a streamside buffer zone. Concentrations fell to 110 ppb within 24 hours and to <20 ppb after 10 days. Concentrations of 1,000 ppb are needed to impact the most sensitive aquatic plants, and levels of 370,000 ppb are needed to have toxic effects on fish species such as bluegill sunfish. In another aerial application in Tennessee, hexazinone pellets were applied to 18 percent of a 440 ha (1056 ac) watershed at a rate of 1.7 kg/ha a.i. (1.5 lb/ac), but no streams were overflown (12). Hexazinone residues were never detected in streamflow during a 7-month period following the application.

In a more detailed study in the upper Piedmont of Georgia, four watersheds were treated with hexazinone at a rate of 1.7 kg/ha (1.5 lb/ac) (14). For the next year, 26 storms ware sampled to determine hexasinone and metabolite concentrations in surface storm runoff. Residues peaked in the first storm after application (442 ppb) and declined with subsequent storms. Loss of hexazinone in stormflow averaged 0.53 percent of the applied herbicide, with two storms accounting for 59 percent of the chemical lost In runoff. Subsurface movement of hexazinone was detected 3-4 months after application in stream baseflow (concentration <24 ppb). but was short in duration (<30 days). Hexazinone residues were never high enough to adversely Impact sensitive aquatic organisms (9).

Hexazinone was applied to a forest watershed in Arkansas to determine mobility and persistence of residues (3). The application rate was slightly higher than the Georgia study (2.0 kg/ha or 1.8 lb/ac), and the herbicide was not applied to intermittent stream channels. Consequently, the maximum hexazinone concentration did not exceed 14 ppb. However, low level residues presisted in streamflow for a year after application. The amount of herbicide transported out of the watershed amounted to 2 to 3 percent of the applied chemical.

A study, currently in progress, is investigating hexazinone movement in watersheds treated by injecting trees with the liquid formulation. Monitoring of streamflow after operational applications in Alabama, Georgia, Tennessee, and Kentucky has not detected any hexazinone residues in streamflow.

From the studies mentioned above, it can be seen that residues detected in streamflow are generally low and short-term in nature. Since herbicide applications occur only once or twice in a stand's rotation, residue loadings on forest watersheds are small. Less than 3 percent of large forest watersheds would be treated in any one year, so in-stream dilutions are large. Thus, the water quality impact of forestry herbicide residues is minimal to none at all.

WATER QUALITY--NUTRIENTS

Any disturbance to forest ecosystems usually results in short-term increases in nutrient losses. These disturbances include logging, burning, site preparation, herbicide application, and insect and disease outbreaks. Data on this aspect of water quality in southern forests is limited as far as herbicide treatments is concerned. In a study reported by Neary et al. (15), application of hexazinone for site preparation produced short-term nitrate nitrogen increases that exceeded those measured for other forest disturbances in the South (7, 8, 18, 19). However, the peak concentration never exceeded the water quality standard and persisted for only 2 years.

Other anion and cation concentrations were elevated but were within the range of variations for forested watersheds in the region (15). The duration of the water quality response was small and short due to minimal soil disturbance and herbaceous plant recovery the second year after herbicide appliation.

Again, the downstream impacts of the increased nutrient outputs measured after herbicide application were small and not significant. This was due to the small magnitude of the measured increases and due to large dilutions from surrounding untreated watersheds. Thus, water quality was not adversely affected.

WATER QUALITY--SEUIMENT

It was stated earlier in this paper that sediment was the main nonpoint source pollutant in the United States. This holds for forestry land uses as well as other types. Once sediment is displaced off-site and into streams it becomes a long-term problem and can have considerable downstream impact. Herbicide residues transported into streams can still be degraded, but sediment remains in the stream and near channel alluvial areas. It is in this aspect of water quality that herbicides can improve water quality by reducing sedimentation of forest streams. In erosion sensitive areas. use of herbicides should be considered as a best management practice.

Mechanical site preparation has been utilized in southern forestry to improve regeneration success. The purposes of site preparation have been to 1) prepare the site for planting, 2) control weeds, and 3) improve microsite. The first has become less important in recent years with clean harvesting. The second, weed control, can be done more efficiently at a lower cost and with considerably less environmental impact by using modern herbicides.

Undisturbed forest watersheds normally have annual sediment yields of 3 to 700 kg/ha (3 to 640 lb/ac), depending on soils and physiographic region (Table 1). Herbicide application in the Piedmont increased sediment yield by 254 percent mainly as a result of increased water yield (15). Suspended sediment concentrations were only slightly elevated above undisturbed conditions, and bedload sediment was minimal. Mechanical site preparation in the Piedmont has produced very large (3,500 to 14,250 kg/ha) and significant first year increases in sediment loss (6). These losses approach agricultural levels and are often on soils less tolerant of sediment loss. Many forests in the South were established on eroded and abandoned agricultural land. These soils have begun to recover from past abuse, so good forestry would argue for management practices that protect the soil resource as well as water quality. Using herbicides for site preparation can eliminate the large sediment losses indicated in Table 1.

Another aspect of water quality that sediment can affect is the quality of aquatic habitat. Sediment displaced into forest streams can seriously affect habitat, spawning areas, and food sources as well as directly damage fish and invertebrates. Stream reaches choked with sediment have inherently lower species diversity and abundance (9).

CONCLUSIONS

Water quality can be adversely affected by inputs of sediment, nutrients, pesticides, toxic metals, livestock and sewage wastes, and atmospheric products. This paper has briefly examined the effects of herbicide "se in forestry on water quality. Through examination of the whole water quality picture, it has been found that herbicide "se can improve water quality by reducing the major nonpoint source water pollution problem, sediment. Problems can occur locally with herbicide residues in streams or lakes; but careful, well planned applications can eliminate any adverse effect on water quality. The positive water quality aspects of herbicide use in southern forestry have often been overlooked by the public, so foresters need to make more efforts to ensure that the real story on herbicides is told.

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Table 1. Sediment and water yields from site prepared forest watersheds in the South.

Reference	Treatment	Sediment Loss: Mass (kg/ha)	Sediment Loss: % of Control	Water Yield: Ares-Depth (cm)	Water Yield: % of Control	Physio-graphic[1] Province
Nesry et al. 1986	Control	67	--	3.4	--	P
	Herbicide	170	254	9.2	271	
Douglass and Van Lear. 1983	Control	39	--	15.5	--	P
	Burned	44	113	19.4	125	
Douglass and Goodwin. 1980	Control	35	--	4.0	---	P
	Kg, disk, grass	720	2057	8.7	218	
	KG	3501	10000	11.1	278	
	KG, disk	9730	28700	38.5	963	
Bessley, 1979	Control	620	---	2.9		UCP
	Chop	12540	2023	50.8	1752	
	Shear	12800	2065	45.1	1555	
	Bed	14250	2298	50.7	1748	
Riekerk, 1982	Control	3	--	7.6		LCP
Nesry et al., 1982	Burn,bed	7	233	12.9	170	
	window, bed	36	1200	21.4	282	

[1] P = Piedmont; UCP - Upper Coastal Plain; LCP = Lower Coastal Plain