# 3I: Forest Chemical Management

### *Forest Chemical Management*

Use chemicals when necessary for forest management in accordance with the following to reduce nonpoint source pollution effects due to the movement of forest chemicals off-site during and after application:

(1) Conduct applications by skilled and, where required, licensed applicators according to the registered use, with special consideration given to effects to nearby surface waters.

(2) Carefully prescribe the type and amount of pesticides appropriate for the insect, fungus, or herbaceous species.

(3) Prior to applications of pesticides and fertilizers, inspect the mixing and loading process and the calibration of equipment, and identify the appropriate weather conditions, the spray area, and buffer areas for surface waters.

(4) Establish and identify buffer areas for surface waters. (This is especially important for aerial applications.)

(5) Immediately report accidental spills of pesticides or fertilizers into surface waters to the appropriate state agency. Develop an effective spill contingency plan to contain spills.

## Management Measure Description

Chemicals used in forest management are generally pesticides (insecticides, herbicides, and fungicides) and fertilizers. Since pesticides can be toxic, they have to be mixed, transported, loaded, and applied correctly and their containers disposed of properly to prevent potential nonpoint source pollution. Since fertilizers can also be toxic or can shift the ecosystem's energy dynamics, depending on the exposure and concentration, it is important that they be handled and applied properly.

Pesticides and fertilizers are occasionally used in forestry to reduce mortality of and favor desired tree species and improve forest production. Many forest stands or sites never receive chemical treatment, and for those that do receive treatment, typically no more than two or three applications are made during an entire tree rotation (40 to 120 years).

Even though few applications are made, forestry chemicals can enter surface waters and precautions can be taken to prevent water contamination.

A number of studies conducted before 1990 demonstrate the importance of following current state and federal guidelines for forest chemical applications for protecting surface waters and groundwater. Norris and others (1991) compiled information from multiple studies that evaluated the peak concentrations of herbicides, insecticides, and fertilizers in soils, lakes, and streams (see Table 3-37). These studies were conducted from 1967 to 1987. Norris (1968) found that application of 2,4-D to marshy areas led to higher-than-normal levels of stream contamination. When ephemeral streams were treated, residue levels of hexazinone and picloram greatly increased with storm-generated flow. Glyphosate was aerially applied (3.3 kg/hectare) to an 8-hectare forest ecosystem in the Oregon Coast Range. The study area contained two ponds and a small perennial stream. All were unbuffered and received direct application of the herbicide. Glyphosate residues were detected for 55 days after application with peak stream concentrations of 0.27 mg/L. It was demonstrated that the concentration of insecticides in streams was significantly greater when the chemicals were applied without a buffer strip to protect the watercourse. When streams were unbuffered, the peak concentrations of malathion ranged from 0.037 to 0.042 mg/L. When buffers were provided, however, the concentrations of malathion

**Table 3-37. Peak Concentrations of Forest Chemicals in Soils, Lakes, and Streams After Application (Norris et al., 1991)**

| Chemicals[a] and System[b] | Application Rate (kg/hectare) | Concentration (mg/L or mg/kg*) | | Time Interval[c] | Time to Non-detection | Source[d] |
|---|---|---|---|---|---|---|
| | | Peak | Subsequent | | | |
| **Herbicides** | | | | | | |
| 2,4-D | 2.24 | 0.001-0.13 | | | 1-168 h[e] | 17 |
| Marsh | 2.24 | 0.09 | | | | 17,18 |
| 2,4-D BE | | | | | | |
| Built pond | 23.0 | | | | | 1 |
| Water | | 3.0 | 1.0 | 85 d | | |
| | | | 0.2 | 180 d | | |
| Sediment | | 8.0* | 4.0* | 13+ d | | |
| | | | 0.4–0.6* | 82–182 d | | |
| Aquatic plants | | | 206* | 7 d | | |
| | | | 8* | 82 d | 182 d | |
| 2,4-D AS | | | | | | |
| Reservoir | | 3.6 | 0 | 13 d | | 7 |
| Picloram | | | | | | |
| Runoff | | 0.078 | | | | 19 |
| Runoff | | 0.038 | | | | 23 |
| Ephemeral stream | 2.8 | 0.32 | | 157 d | 915 d | 9 |
| Stream | 0.37 | | | | | 3 |
| Hexazinone | | | | | | |
| Stream (GA) | 1.68 | 0.044 | | 3–4 m | | 11 |
| Forest (GA) | 1.68 | | | | | 14 |
| Litter | | 0.177* | <0.01* | 60+ d | | |
| Soil | | 0.108* | <0.01* | 90 d | | |
| Ephemeral stream | | 0.514 | | 3 d | | |
| Perennial stream | | 0.442 | | 3 d | | |
| Atrazine | | | | | | |
| Stream | 3.0 | 0.42 | 0.02 | 17 d | | 16 |
| Built ponds | | | | | | 10 |
| Water | | 0.50 | 0.05 | 14 d | | |
| | | | 0.005 | 56 d | | |
| Sediments | | 0.50* | 0.9* | 4 d | | |
| | | 0.50* | 0.25* | 56 d | | |
| Triclopyr | | | | | | |
| Pasture (OR) | 3.34 | 0.095* | 0.09 | 5.5 h | | 20 |
| Glyphosate | | | | | | |
| Water | 3.3 | 0.27 | <0.01 | 3 d | | 15 |
| Dalapon | | | | | | |
| Field irrigation water | | 0.023–3.65 | <0.01 | Sev h | | 5 |

**Table 3-37. (continued)**

| Chemicals[a] and System[b] | Application Rate (kg/hectare) | Concentration (mg/L or mg/kg*) | | Time Interval[c] | Time to Non-detection | Source[d] |
|---|---|---|---|---|---|---|
| | | Peak | Subsequent | | | |
| **Insecticides** | | | | | | |
| Malathion | | | | | | |
| Streams | 0.91 | | | | | 24 |
| Unbuffered | | 0.037–0.042 | | | | |
| Buffered | | 0–0.017 | | | | |
| Carbaryl | | | | | | |
| Streams & ponds (E) | | 0–0.03 | | | | 24 |
| Streams, unbuffered (PNW) | | 0.005–0.011 | | | 48 h | 24 |
| Water | 0.84 | 0.026–0.042 | | | | 8 |
| Brooks with buffer | 0.84 | 0.001–0.008 | | | | 22 |
| Rivers with buffer | 0.84 | 0.000–0.002 | | | | 22 |
| Streams, unbuffered | 0.84 | 0.016 | | | | 22 |
| Ponds | 0.84 | | | | | 6 |
| Water | | 0.254 | | | 100-400 d | |
| Sediment | | <0.01–5.0*[f] | | | | |
| Acephate | | | | | | |
| Streams | | 0.003–0.961 | | 1 d | | 4 |
| Pond sediment & fish | 0.56 | 0.113–0.135 | 0.013-0.065 | 14 d | | 21 |
| **Fertilizers** | | | | | | |
| Urea | 224 | | | | | |
| Urea-N | | | | | | |
| Forest stream (OR) | | 0.39 | 0.39 | 48 h | | 12 |
| Dollar Cr (WA) | | 44.4 | | | | 13 |
| $NH_4^+$-N | | | | | | |
| Forest stream (OR) | | <0.10 | | | | 12 |
| Tahuya Cr (WA) | | 1.4 | | | | 13 |
| $NO_3^+$-N | | | | | | |
| Forest stream (OR) | | 0.168 | | | | 12 |
| Elochoman R (WA) | | 4.0 | | | | 13 |

[a] 2,4-D BE = 2,4-D butoxyethanol ester; 2,4-D AS = 2,4-D amine salt + ester.
[b] E = eastern USA; Cr = Creek; GA = Georgia; PNW = Pacific Northwest; OR = Oregon; R = River; WA = Washington; buffer = wooded riparian strip.
[c] d = day; h = hours; m = months; sev h = several hours. Intervals are times from application to measurement of peak or subsequent concentration, whichever is the last measurement indicated.
[d] 1 = Birmingham and Colman (1985); 2 = Bocsor and O'Connor (1975); 3 = Davis et al. (1968); 4 = Flavell et al. (1977); 5 = Frank et al. (1970); 6 = Gibbs et al. (1984); 7 = Hoeppel and Westerdahl (1983); 8 = Hulbert (1978); 9 = Johnsen (1980); 10 = Maier-Bode (1972); 11 = Mayack et al. (1982); 12 = Moore (1970); 13 = Moore (1975b); 14 = Neary et al. (1983); 15 = Newton et al. (1984); 16 = M. Newton (Oregon State University, personal communication, 1967); 17 = Norris (1967); 18 = Norris (1968); 19 = Norris (1969); 20 = Norris et al. (1987); 21 = Rabeni and Stanley (1979); 22 = Stanley and Trial (1980); 23 = Suffling et al. (1974); 24 = Tracy et al. (1977).
[e] Normally less than 48 h.
[f] One extreme case: 23.8 mg/kg peak concentration, 16 months to nondetection.

were reduced to levels that ranged from undetectable to 0.017 mg/L. The peak concentrations of carbaryl ranged from 0.000 to 0.0008 mg/L when watercourses were protected with a buffer, but they increased to 0.016 mg/L when watercourses were unbuffered.

Moore (1971), as cited in Norris et al. (1991), compared nitrogen loss from a watershed treated with 224 kg urea-N per hectare to nitrogen loss from an untreated watershed. The study demonstrated that the loss of nitrogen from the fertilized watershed was 28.02 kg/hectare whereas the loss of nitrogen from the unfertilized watershed was only 2.15 kg/hectare (Table 3-38).

**Table 3-38. Nitrogen Losses from Two Subwatersheds in the Umpqua Experimental Watershed (OR) (Norris et al., 1991)**

| Loss Locus or Statistic | Urea-N | $NH_3$-N | $NO_3$-N | Total |
|---|---|---|---|---|
| | Absolute loss (kg/hectare) | | | |
| Watershed 2 (treated) | 0.65 | 0.28 | 27.09 | 28.02 |
| Watershed 4 (untreated) | 0.02 | 0.06 | 2.07 | 2.15 |
| Net loss (2-4) | 0.63 | 0.22 | 25.02 | 25.87 |
| | Proportional loss | | | |
| Percent of total | 2.44 | 0.85 | 96.71 | 100.00 |

Riekerk and others (1989) found that the greatest risk to water quality from pesticide application in forestry operations occurred from aerial application because of drift, wash-off, and erosion processes. They found that aerial applications of herbicides resulted in surface runoff concentrations roughly 3.5 times greater than those for application on the ground.

The Riekerk and others (1989) study results also suggested that tree injection application methods would be considered the least hazardous for water pollution, but would also be the most labor-intensive. Hand application of herbicides usually poses little or no threat to water quality in areas where there is no potential for herbicides to wash into water-courses through gullies. Providing buffer areas around streams and water bodies can effectively eliminate adverse water quality effects from forestry chemicals.

Megahan (1980) summarized data on changes in water quality following the fertilization of various forest stands with urea. The major observations from this research are summarized below:

- Increases in the concentration of urea-N ranged from very low to a maximum of 44 ppm, with the highest concentrations attributed to direct application to water surfaces.
- Higher concentrations occurred in areas where buffer strips were not left beside stream banks.
- Chemical concentrations of urea and its by-products tended to be relatively short-lived due to transport downstream, assimilation by aquatic organisms, or adsorption by stream sediments.

Based on his review, Megahan concluded that the effects of fertilizer application in forested areas could be significantly reduced by avoiding application techniques that could result in direct deposition into the water body and by maintaining a buffer area along the stream bank. Other researchers have presented information supporting Megahan's conclusions (Hetherington, 1985; Malueg et al., 1972).

## Cost of Forest Chemical Applications

The cost of chemical management depends on the method of application (Table 3-39). Generally, chemicals are applied by hand, from an airplane or helicopter (aerial spray), or mechanically. When forest chemicals are applied mechanically, it is most common to use a boom sprayer.

**Table 3-39. Average Costs for Chemical Management (Hansit, 2000; Holburg, 2000)**

| Application Practice | Average Cost |
|---|---|
| Hand application | $100/acre |
| Aerial application | $55–$70/acre |

## Best Management Practices

- ◆ *For aerial spray applications, mark and maintain a buffer area of appropriate width around all watercourses and water bodies to avoid drift or accidental application of chemicals directly to surface waters (Figure 3-45).*

Buffer width is determined by taking into considerations the altitude of application, weather conditions, and drop size distribution (Ice and Teske, 2000). Careful and precise marking of application areas for aerial applications helps avoid accidental contamination of open waters.

Models are available to help the forest manager calculate pesticide application details. The Spray Drift Task Force, in collaboration with EPA and USDA, co-developed AgDRIFT, a new model, to provide estimates of spray drift deposition under different pesticide application and meteorological conditions (see www.agdrift.com). The Forest Service Cramer-Barry-Grim (FSCBG) spray dispersion model analyzes data on aircraft,

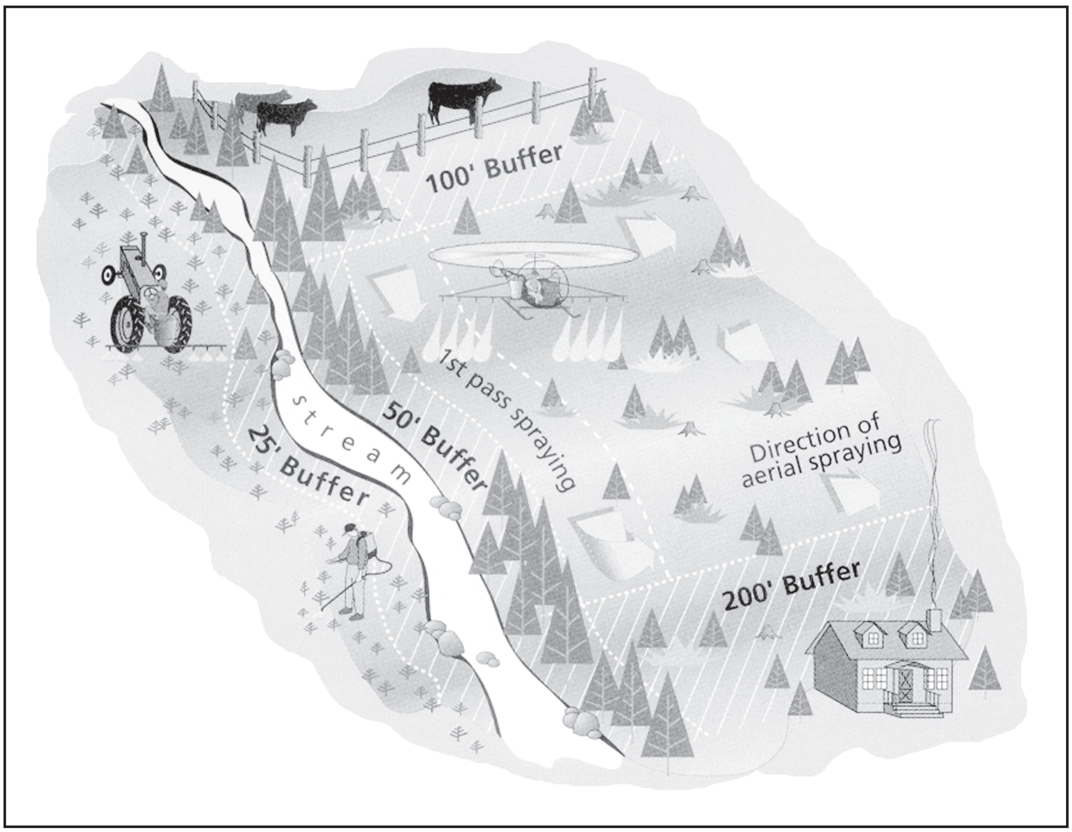


**Figure 3-45. Establish buffer zones of appropriate width during aerial applications of forest chemicals to protect water quality, people, and animals (Washington State DNR, 1997).**

meteorology, pesticides, and target areas to predict deposition and drift (see www.fs.fed.us/foresthealth/technology). A personal computer version of the model is available that combines and implements mathematical models to assist forest managers in planning and implementing aerial spray operations.

◆ *Apply pesticides and fertilizers during favorable atmospheric conditions.*

Do not apply pesticides when wind conditions increase the likelihood of significant drift. It is also best to avoid pesticide application when temperatures are high or relative humidity is low because these conditions influence the rate of evaporation and enhance losses of volatile pesticides.

◆ *Ensure that pesticide users abide by the current pesticide label, which might specify whether users be trained and certified in the proper use of the pesticide; allowable use rates; safe handling, storage, and disposal requirements; and whether the pesticide may be used only under the provisions of an approved State Pesticide Management Plan.*

Consistency between management measures and practices for pesticides and those in the approved State Pesticide Management Plan helps ensure consistency in the method and means of use.

◆ *Locate mixing and loading areas, and clean all mixing and loading equipment thoroughly after each use, where pesticide residues will not enter streams or other water bodies.*

◆ *Dispose of pesticide wastes and containers according to state and federal laws.*

◆ *Take precautions to prevent leaks and spills.*

◆ *Develop a spill contingency plan that provides for immediate spill containment and cleanup, and notification of proper authorities.*

Maintain an adequate spill and cleaning kit that includes the following:

- Detergent or soap.
- Hand cleaner and water.
- Activated charcoal, adsorptive clay, vermiculite, kitty litter, sawdust, or other adsorptive materials.
- Lime or bleach to neutralize pesticides in emergency situations.
- Tools such as a shovel, broom, and dustpan and containers for disposal.
- Proper protective clothing.

◆ *Apply slow-release fertilizers when possible.*

This practice reduces potential nutrient leaching to groundwater, and it increases the availability of nutrients for plant uptake.

◆ *Apply fertilizers during maximum plant uptake periods to minimize leaching.*

◆ *Base fertilizer type and application rate on soil and/or foliar analysis.*

Conduct foliar analysis approximately once per year to diagnose nutrient toxicities or deficiencies and to determine the correct fertilization program to follow. Foliar analysis is the process whereby leaves from trees are dried, ground, and chemically analyzed for their nutrient content. Compare the results of foliar analysis to available nitrogen, phosphorus, potassium, and sulphur in the soils to be treated and to the requirements of the species.

- ◆ *Consider the use of pesticides as only one part of an overall program to control pest problems.*

Integrated Pest Management (IPM) strategies have been developed to control forest pests without total reliance on chemical pesticides. The IPM approach uses all available techniques, including chemical and nonchemical. An extensive knowledge of both the pest and the ecology of the affected environment is necessary for IPM to be effective.

- ◆ *Base selection of pesticide on site factors and pesticide characteristics.*

These factors include vegetation height, target pest, adsorption (attachment) to soil organic matter, persistence or half-life, toxicity, and type of formulation.

- ◆ *Check all application equipment carefully, particularly for leaking hoses and connections and plugged or worn nozzles. Calibrate spray equipment periodically to achieve uniform pesticide distribution and rate.*

- ◆ *Always use pesticides in accordance with label instructions, and adhere to all federal and state policies and regulations governing pesticide use.*