Frozen Soil Worsens Pesticide Runoff Problems

By Zachary M. Easton

Winters in the Northeast can be long and cold. Soils are generally frozen during this period (December-March). Significant runoff can occur in the winter due to snowmelt or rainfall on frozen soils, which can contain and transport unused or unbound nutrients and pesticides from turfgrass despite the fact that no compounds were applied in the winter.

Runoff from frozen soils can approach 100 percent of the precipitation and can occur even in the absence of rainfall. Soils become prone to runoff when they are saturated (i.e., all available soil pores are filled with water). When the soil is not frozen, this pore water drains quickly with sands and more slowly with clays (Hillel, 1998). However, when the pore water is frozen, internal drainage occurs slowly or, in extreme cases, not at all.

When no chemicals are applied during the winter, there theoretically should be little nutrient or no pesticide loss from turfgrass. But volatilization, microbial degradation, binding to organic matter, decay, metabolism of pesticides by turf and leaching are slowed or stopped, leaving runoff as the primary loss mechanism. Any pesticide not used or unattenuated when the temperature drops can potentially end up in runoff.

During the growing season, controlling runoff generally reduces pesticide losses as well. A dense stand of turfgrass will reduce and in many cases eliminate runoff. However, when the soil is frozen, water cannot enter the soil profile, which allows runoff from even the densest stand of turfgrass. This runoff has the potential to transport significant quantities of pesticide from a site. Concentrations of the pesticide in winter runoff are usually low, but the sheer runoff volume can contain large amounts of pesticides.

When the upper-most layer of soil is frozen, water is prevented from entering the profile. In central New York, the soil below 4 to 6 inches deep rarely freezes. Runoff during the winter corresponds closely with whether the soil is frozen or not. During the winter of 2000-2001, there was significant runoff due to the soil being frozen. However, during the winter of 2001-2002 there was very little runoff because the soil was rarely frozen.

In the first year, 83 percent of the total runoff was measured during the winter of 2000-2001. In the second year, only 2.5 percent of the runoff occurred in the winter. The soil was rarely frozen, and there was very low rainfall. What rain did fall easily infiltrated the unsaturated and unfrozen soil. As a result, little pesticide loss was recorded in the second year. However, when 83 percent of the runoff occurred in the winter, there were significant pesticide losses (Table 1).

Total pesticide losses from this study were extremely low on average. However, concentrations were, at times, very high. 2,4-D was detected at 1,236 micrograms per liter, or almost 18 times what is allowed in drinking water by the U.S. Environmental Protection Agency (USEPA, 1989). Dicamba was measured in excess of 200 micrograms per liter, the maximum contaminate level (MCL) allowed, and mecoprop at concentration of 27 micrograms per liter, which is nearly four times higher than the allowable levels (USEPA, 1989).

High pesticide concentrations in runoff are much more likely to be detected following pesticide application during the growing season. However, runoff losses during the growing season are generally low. Turfgrass is efficient at removing water from the soil (reducing soil moisture), which creates air-filled pore space in the soil which rainfall or irrigation water can easily enter.

Likewise, the dense growth habit and thatch-forming capabilities slow runoff water by creating a more tortuous pathway, (Krenitsky et al., 1998) and increases soil infiltration. Actively growing turfgrass can also increase the overall porosity of the soil, increasing the potential water storage capabilities of the soil. The interaction of these factors makes runoff during the growing season minimal in all but the most intense storms.

In contrast, when the soil is frozen, the above factors make little difference. Rainfall or snowmelt will generally end up as runoff. The question is, how can pesticides still be detected in runoff after so much time? Numerous pesticide and environmental properties must be considered when assessing the runoff potential of pesticides during the winter.

Pesticides with a long half-life will remain in the environment and are potentially available for transport by runoff. When the temperature is below freezing, the time needed to break down a pesticide increases.

Siduron is one such pesticide. With a half-life of 128 days, significant amounts of the compound would be present in the environment for a long period. Pesticides such as trichlorfon have a short half-life — less than six days — so they would not remain in the environment for long.

Another important pesticide property to consider is how tightly the pesticide is bound once applied. This is measured with the organic carbon partitioning coefficient (K_{oc}). Some pesticides can be easily washed from the turfgrass tissue or soil if they are weakly bound (low K_{oc}), whereas others are relatively immobile once applied (high K_{oc}).

Pesticides such as trichlorfon, dicamba and mecoprop are weakly bound, whereas pesticides such as fenoxaprop and siduron are tightly bound to turfgrass.

For a pesticide to be effective (particularly foliar herbicides), it must attach to the turfgrass tissue. Take siduron for example. It is tightly held to turfgrass tissue, so theoretically should not be detected in runoff, especially in March (which is when most of the pesticide was detected). Since siduron was applied pre-emergently, however, there was little turfgrass in place to immobilize the compound. As a result, siduron runoff from the frozen soil was 26 percent of the total siduron recovered.

Trichlorfon, which controls grubs, is weakly bound to turfgrass tissue. The compound needs to be in the area where grubs are active, which means in the thatch and shallow soil.

To get the pesticide where it is needed, it must be easily transported from the turfgrass tissue to the soil and thatch. The ease of wash-off and the short half-life make extended detection lengths unlikely. In fact, 93 percent of the total measured in runoff was within six days of application. However, any that did remain when the soils became frozen was easily transported.

Clearly, the relationship between runoff and pesticide loss can be complicated. There are many factors affecting the potential for runoff, including rainfall rate and duration, soil type, moisture level, grass type and growth stage. However, if runoff can be controlled, and/or eliminated, pesticide loss can be as well.

When runoff does occur, pesticides may run off at different rates. This is generally a function of the intrinsic pesticide properties, such as the half life and organic carbon partitioning coefficient.

While management practices may have a clear affect on runoff and pesticide loss during the growing season, it is generally the site and environmental conditions which control losses from frozen soils. It is therefore imperative to select pesticides, which pose a low threat to water contamination.

Despite what one may think, runoff on frozen soils can represent the majority of the total yearly runoff and may contain a significant portion of the total pesticide loss.

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TABLE 1

Percent of total pesticide lost during each season (growing or winter)

	Runoff	Percent of pesticide lost during each season			
Season	**(mm)**	**Dicamba[1]**	**2, 4-D[1]**	**Siduran[2]**	**Trichlorfon[3]**
00 Growing Season	1.4	95	51	74	*
00-01 Winter	7.5	5	49	26	*
01 Growing Season	7.1	100	97	0	95
01-02 Winter	0.5	0	3	0	5
02 Growing Season	14.5	*	*	*	0

*No pesticide applied

[1] Applied 9/27/00, 6/3/01, 6/14/01, 9/22/01

[2] Applied 7/22/00

[3] Applied 9/18/01

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