How Herbicides Work, Part III: Fate and Environmental Impact

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Introduction

This is the third and final part of the series "How Herbicides Work". The first installment described the various classes of herbicides, while the second discussed efficacy. Why is it important to understand herbicide fate? From a weed control standpoint, residual activity determines length of control and influences overseeding options. Most post-emergent herbicides have a very short period of activity as they are meant to quickly eliminate weeds, though they may persist in the soil for several weeks after application which delays overseeding. Pre-emergent herbicides stop weeds from germinating but selecting a product with short residual may require a second application to obtain season-long control. In other cases herbicide fate may affect efficacy.

These days it is especially important to understand herbicide fate because of the societal debates regarding pesticide usage. The Environmental Protection Agency (EPA), designed to safeguard the national interest, in theory determines the types and uses of pesticides allowed for use based on scientific data which balances their benefits and risks. In reality the EPA is subject to indirect political pressure driven by public attitudes and perceptions. Local pesticide practices and regulations are determined by politicians and community officials acting directly on the basis of public perception and goodwill. As professional turf managers it is the responsibility of every superintendent to be able to understand pesticide fates. I recently sent out a notice on the Noernet asking users if an EPA-proposed cancellation of the pre-emergent herbicide DCPA would cause any hardships: if so, we had an opportunity to seek an exemption for turf (I received no responses). Understanding herbicide fate is important not only to ensure safe and proper use of the chemicals but also to educate the public when it is necessary. Without your input the turf industry will continue to be regulated by those without the proper understanding of the turf ecosystem.

Herbicide Fates

Pesticides, including herbicides, dissipate (disperse) in the environment through volatilization, drift, plant/soil adsorption, runoff, and leaching. Volatilization occurs when pesticide is dissolved in water, thus, volatilization is reduced at low humidity because the product dries faster on the plant or soil surface. Drift occurs when winds (usually greater than 5 mph) carry pesticide away from the target site, eventually depositing the pesticide in unintended areas. Spraying when the wind is low, using large droplet sizes, and shielded sprayers can help reduce drift.

Most of the herbicide is adsorbed (stuck) to foliage and/or soil. The abundance of turf leaves and thatch can adsorb a significant amount of herbicide, potentially decreasing the effectiveness of some pre-emergent herbicides by preventing their movement to weed seeds in the upper soil surface (Branham, 1994). Herbicides absorbed by plants are degraded (broken down) by plant enzymes. In some case the breakdown products are more toxic to the plants than the whole compound. If the plant does not completely degrade the herbicide, microbes and soil reactions generally degrade the remaining product. Most of today's synthetic herbicides are ultimately degraded to relatively harmless products such as hydrogen, carbon dioxide, and water.

Pesticides are degraded beginning the minute they leave the applicator unit through photolysis (degradation by sunlight), plant metabolism, soil degradation, and especially microbial degradation (primarily bacteria and fungi). The degree of each type of degradation depends on many factors. In general, microbes appear to degrade the greatest part of herbicides that aren't absorbed and degraded in the plant, followed by photolysis and soil degradation. Soil degradation occurs when herbicides come into contact with naturally-occurring compounds such as organic acids that may catalyze reactions to break apart the pesticide. The proportion of each type of fate depends on the type of chemical and the environment.

The half-lives of chemicals are most useful for determining pesticide persistence. The half-life is the amount of time required for a compound to degrade to one-half its original amount. Thus, if a compound has a half-life of 40 days, half of the original quantity would degrade in 40 days, with half of the remainder degrading the following 40 days, and so on. Enhanced biodegradation can occur at sites where applications are routinely made over time. With enhanced biodegradation, microbial populations shift to take advantage of the presence of the pesticide, in essence degrading the compound faster and faster with each application. This should not be too surprising given the high number of microbial species that exist in our environment and their proclivity to adapt and thrive in many conditions. The actual half-life of any compound will depend on its formulation and environment, including temperature and soil type. The half-lives of several turf herbicides are listed in Table 1.

Table 1. Half-lives of several commonly used turf herbicides (adapted from Branham, 1994).

Post-emergent Herbicide	Half-life (days)	Pre-emergent herbicide	Half-life (days)
Dicamba, salt	14	Benefin	40
2,4-D, ester	10	Trifluralin	60
2,4-D, salt	10	Pronamide	60
MCPP, salt	21	Pendimethalin	90
MCPA, salt	25	Siduron	90
Triclopyr, salt	46	Bensulide	120

Occasionally herbicides may move in sufficient amounts to the soil profile and leach past turf root systems, potentially contaminating groundwater supplies. This is especially likely with thin or non-existing turf, sandy soils, near-saturated conditions (often with continuing heavy precipitation), and highly water-soluble herbicides. Numerous studies have been conducted during the past 20 years to determine the extent to which turf-applied herbicides may runoff or leach. Studies conducted with older products such as DDT insecticide, fungicides based on heavy metals, or even the Vietnam-era herbicide 2,4,5-T do not provide valid comparisons for today's herbicides. Unfortunately it is often examples of these older chemistries which are used to incite public fear and regulations.

Herbicide leaching potential is greatest when applications are made to bare soil. Turf, contrary to most agricultural situations, poses an impressing barrier to pesticide movement into and through soil. An established Kentucky bluegrass turf may have over 450,000 roots per gallon in the top 6 inches of soil (Beard, 2000). The roots act as a third barrier after leaves and thatch. Herbicides with a high water solubility are potentially most at risk including phenoxy herbicides such as 2,4-D. However, the organic carbon partitioning coefficient, or Koc, must also be considered when evaluating leaching or runoff of pesticides. The Koc determines the binding capacity of a substrate, typically organic matter, for a particular herbicide. Clay, loam, and soils with high organic matter have better herbicide-binding capacity than sandy soils. When bound to soil, herbicides are not moving into groundwater or runoff, and microbes may "feast away at will". In general, due partly to the presence of foliage, extensive roots, and thatch, the likelihood of turf herbicides leaching seems to be less than that of runoff.

Urban runoff is often identified as a primary source of nonpoint water pollution, especially in Wisconsin, and it would not be surprising to see legislation aimed at curbing or prohibiting use of turf pesticides in the near future. Data show that pesticide runoff from turf is greatest when water-soluble pesticides are applied to saturated soils within 24 hours prior to heavy precipitation (usually greater than 1 inch per hour). An

Oklahoma study showed up to 15% of mecoprop (MCPP) ran off-site following a 3 inch/75 minute simulated rainfall on a soil having 25-30% moisture by volume (Baird et al., 2000). In nature, precipitation of such an amount occurs rarely, especially when a soil is at or near saturation. Furthermore, the chances of having applied an herbicide to a saturated soil followed closely by a once-in-a-year intense rainstorm are extremely low. Given the timing of most herbicide applications, turf cover, and Koc of even water-soluble herbicides, the maximum herbicide runoff from turf is likely to be at or near zero percent (Petrovic et al., 1994; Watschke and Mumma, 1989). For example, although dicamba is extremely water-soluble (850,000 ppm) and has a low Koc, its leaching and runoff capacity is typically low due to its short half-life of 17-32 days. Microbes are responsible for degrading 90% of the dicamba that reaches soil (Smith, 1973). In our own research at the O.J. Noer Turfgrass Research and Educational Facility we found zero post-emergent herbicide in naturally-occurring turf runoff in 1999 and only 0.009 % herbicide runoff in 2000 (Stier and Williamson, 2003). Pre-emergent herbicides have low water solubility and thus limited leaching and runoff potential (Watshke and Mumma, 1989).

There are some genuine concerns. A recent study from Washington state showed clopyralid, one of the active ingredients in Confront herbicide, did not readily decompose in a lawn waste compost pile. Since lawn waste compost is sometimes used to mulch home gardens, home lawn uses for products containing clopyralid were voluntarily dropped from product labels by the distributors rather than fight the EPA. Dicamba has long been known to be capable of injuring juniper trees and other species of *Taxus* if sufficient dicamba is applied to and moved through the soil. Some herbicide labels do not allow use of a particular product near a well or in sandy soil. Several agricultural chemicals such as atrazine have been found in groundwater supplies throughout the U.S. The average citizen cannot be expected to distinguish between agricultural sources of atrazine and turf applications of 2,4-D. They often can, however, see lawn applications occurring but not agricultural applications. In addition, turf is an "easy target" for anti-pesticide groups to attack. Agriculture production is comparatively attacked very little for three reasons: 1) pesticides are being used to produce food, 2) many people still have at least an indirect family link to farming (e.g., cousin or grandparent), 3) agriculture has active political groups with a strong lobbying effort. Of the three reasons, it may seem easy to write off the first reason as acceptable because food production is obviously necessary. That does not, however, justify banning turf pesticides. Overall, scientific data do not indicate that properly used turf herbicides significantly degrade environmental quality. It is, however, easy for local officials and politicians to ban application of turf chemicals in order to demonstrate their environmental commitment to the public, while avoiding the sticky issue of agricultural chemicals. Eventually the turf industry is going to have to do two things if it wants to maintain control over its management practices. **First, funds and efforts will have to be developed to support lobbying efforts.** Lobbying is currently done on a small scale nationally through Responsible Industry for a Sound Environment (RISE) but is insignificant compared to lobbying from agricultural groups. Lobbying alone though is not enough. **Secondly, and even more important in the long run, the turf industry will have to educate the public on the benefits versus risks of turf management practices.** This will be a long battle, but one well worth fighting.

Conclusion

Turf herbicides pose little environmental threat when properly used. Water solubility and partitioning coefficients help determine the potential for an herbicide to leach or move off-site in runoff. Turf itself intercepts most or all of the herbicide. Most turf herbicides have relatively short half-lives, with the bulk of herbicide degraded by plants and microbes.

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