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Okay! So What Happens to All Those Pesticides Applied to Golf Courses?

"Turfgrass areas generally rank second only to undisturbed forests in their ability to prevent pesticides and nutrients from reaching ground and surface water."- Dr. Michael P. Kenna, Dir. USGA Green Section Research

There is growing concern about the use of pesticides and the impact they may have on our environment. Protecting ground and surface water from chemical pollutants is a national initiative, as it should be according to the Turf Resource Center. But what really happens to those pesticides that are applied to golf courses?

The Environmental Protection Agency (EPA) estimates that 1.2 billion pounds of pesticides are sold annually in the United States. About 70 percent of the pesticides applied are used for agricultural production of food and fiber. Only a small fraction of this amount is used on golf courses. Yet, Dr. Michael P. Kenna, Director USGA Green Section Research, comments that there is often a public concern about the chemicals used on golf courses because of the perception that the intense maintenance on golf courses creates the potential for environmental contamination.

Dr. Kenna goes on to state, "In the late 1980's, golf was faced with a dilemma. On one hand, regulatory agencies responding to public concern routinely initiated environmental monitoring programs of ground and surface water. On the other hand, very little public information was available on the behavior and fate of pesticides and fertilizers applied to turfgrass. Probing, sometimes over-zealous federal and state regulators looking for non-point source polluters raised concerns about a recreational game that had relied on the integrity of chemical companies and the EPA to provide products and guidelines that protect the environment. There were lots of questions but few answers."

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The game of golf needed answers to environmental questions, and the USGA wanted these answers based on scientific facts. In 1991 the USGA initiated a three-year study of the fate of pesticides and fertilizers applied under golf course conditions.

The following write up prepared by Dr. Mike Kenna has been reprinted from the USGA Green Section Record. It first briefly describes what is known about the fate of chemicals used on golf courses and provides some supporting documentation to help choose a pesticide. Highlights of the research projects then are summarized, but the articles should be read to learn more about the particulars of each research project.

The Fate of Chemicals Applied to Golf Courses

Do golf courses pollute the environment? No, they do not. At least not to the extent that critics state in undocumented media hype. Golf course superintendents apply pesticides and fertilizers to the course, and depending on an array of processes, these chemicals break down into by-products that are biologically inactive.

In general, there are six processes that influence the fate of chemical products applied to golf courses.

1. Solubilization by water
2. Sorption by soil mineral and organic matter
3. Degradation by soil microorganisms
4. Chemical degradation and photo-decomposition
5. Volatilization and evaporation
6. Plant uptake

The relative importance of each process is controlled by the chemistry of the pesticide or fertilizer and environmental variables such as temperature, water content, and soil type.

Solubility

The extent to which a chemical will dissolve in a liquid is referred to as solubility. Although water solubility is usually a good indicator of the mobility of a pesticide in soils, it is not necessarily the best criterium. In addition to pesticide solubility, the pesticide's affinity to adhere to soils or sorption must be considered.

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Sorption

The tendency of a pesticide to leach or run off is strongly dependent upon the interaction of the pesticide with solids within the soil. The word sorption is a term that includes the process of adsorption and absorption. Adsorption refers to the binding of a pesticide to the surface of a soil particle. Absorption implies that the pesticide penetrates into a soil particle. The adsorbed or absorbed pesticide is often referred to as bound residue and is generally unavailable for microbial degradation or pest control.

Factors that contribute to sorption of pesticides on soil materials include: a) chemical and physical characteristics of the pesticide; b) soil composition; and c) the nature of the soil solution. In general, sandy soils offer little in the way of sorptive surfaces. Soils containing greater amounts of silt, clay and organic matter provides a richly sorptive environment for pesticides.

Adsorption of pesticides is affected by the partition coefficient which is reported as Kd or, more accurately, as Koc. For example, a Koc of less than 300 to 500 is considered low.

Microbial Degradation

Pesticides are broken down by microorganisms in the soil in a series of steps that eventually lead to the production of CO2 (carbon dioxide), H2O (water) and some inorganic products (i.e., nitrogen, phosphorus, sulfur, etc.). Microbial degradation may be either direct or indirect. Some pesticides are directly utilized as a food source by microorganisms. In most cases, though, indirect microbial degradation of pesticides occurs though passive consumption along with other food sources in the soil.

Regardless, microbial degradation is a biological process whereby microorganisms transform the original compound into one or more new compounds with different chemical and physical properties that behave differently in the environment.

Degradation rates are influenced by factors such as: pesticide concentration, temperature, soil water content, pH, oxygen status, prior pesticide use, soil fertility, and microbial populations. These factors change dramatically with soil depth, and microbial degradation is greatly reduced as pesticides migrate below the soil surface.

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Persistence of a pesticide is expressed as the term half-life (DT50), which is defined as the time required for 50 percent of the original pesticide to break down into other products. Half-life values are commonly determined in the laboratory under uniform conditions. On the golf course, soil temperature, organic carbon and moisture content change constantly. These and other factors can dramatically influence the rate of degradation. Consequently, half-life values should be considered as guidelines rather than absolute values.

Chemical Degradation

Chemical degradation is similar to microbial degradation except that the breakdown of the pesticide into other compounds is not achieved by microbial activity. The major chemical reactions such as hydrolysis, oxidation, and reduction are the same. Photochemical degradation is a different breakdown process that can influence the fate of pesticides. It was the combination of chemical, biological, and photochemical breakdown processes under field conditions that was the focus of the USGA sponsored studies.

Volatilization and Evaporation

Volatilization is the process by which chemicals are transformed from a solid or liquid into a gas, and is usually expressed in units of vapor pressure. Pesticide volatilization increases as the vapor pressure increases. As temperature increases, so does vapor pressure and the chance for volatilization loss. Volatilization losses generally are lower following a late afternoon or an early evening pesticide application than in the late morning or early afternoon, when temperatures are increasing.

Volatilization also increases with air movement, and losses can be greater from unprotected areas than from areas with windbreaks. Immediate irrigation is usually recommended to reduce the loss of highly volatile pesticides.

Plant Uptake

Plants can directly absorb pesticides or influence pesticide fate by altering the flow of water in the root zone. Turfgrasses with higher rates of transpiration can reduce the leaching of water soluble pesticides. In situations where the turf is not actively growing, or where root systems are not well developed, pesticides are more likely to migrate deeper into the soil profile with percolating water.

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Good Management Can Make A Difference

A primary concern when applying pesticides is to determine if the application site is vulnerable to ground or surface water contamination (See Tables 1 and 2). In most cases, level areas away from surface waters (rivers, lakes, or wetlands) will not be prone to pesticide runoff and if the depth to groundwater is greater than 50 feet on fine-textured soils, the chances for deep percolation of pesticides is greatly reduced. More attention to the pesticide's characteristics is needed when applications are made to sandy soils with little organic matter, or sloped areas with thin turf and low infiltration rates.

Table 1 Chemical Physical Properties of Pesticides: Values That Indicate Potential for Groundwater and Surface Water Contamination.

Pesticide Characteristic	Parameter Value or Range Indicating Potential for Contamination
Water solubility	Greater than 20 ppm
Kd	Less than 5, usually less than 1
Kc	Less than 300 to 500
Henry's Law Constant	Less than 102 atm m3 mol
Hydrolysis half-life	Greater than 175 days
Photolysis half-life	Greater than 7 days
Field dissipation half-life	Greater than 21 days

From EPA 1988 as reported by Balogh and Walker, 1992.

Table 2 Factors Contributing to Greater Risk for Ground and Surface Water Contamination -- The More of These Conditions Present, the Greater the Risks.

Chemical	Soil	Site	Management
High Solubility	Porous Soil (sand)	Shallow Water Table	Incomplete Planning
Low Soil Adsorption	Low Organic Matter	Irrigated/Sloping land	Misapplication
Long Half-life (persistent)		Near Surface Water	Poor Timing
Low Volatility		Sink Holes/Abandoned Wells	Over Irrigation

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The most important thing a golf course superintendent can do when applying pesticides is to read and follow the label directions. From planning and preparation to storage and disposal, followinglabel directions will significantly reduce the risks of contaminating our water resources. When possible, select a pesticide that poses the least threat of rapid leaching and runoff and is relatively non-persistent.

The Rest of The Story

This is only a very brief overview of the processes that affect what happens to pesticides and nutrients in the environment. The rest of this issue of the Green Section Record is devoted to the USGA sponsored environmental research projects, which were conducted from 1991 through 1994. Compared to agricultural crops, the results not only build on what is known about pesticide and nutrient fate, and often show that turfgrass systems:

- Reduce runoff
- Increase adsorption on leaves, thatch and soil organic matter
- Maintain high microbial and chemical degradation rates
- Reduce percolation due to an extensive root system, greater plant uptake and high transpiration rates.

<u>These results reinforce the view that turfgrass areas generally rank second only to undisturbed forests in their ability to prevent pesticides and nutrients from reaching ground and surface water.</u>

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Highlights from the USGA-sponsored environmental research:

University of Nebraska, Dr. Garald Horst

- After 16 weeks under golf course fairway management conditions, detectable residues of isazofos, metalaxyl, chlorpyrifos and pendimethalin pesticides found in soil, thatch and verdure were 1% or less of the total application amount.

- The average DT90 (days to 90% degradation) of the four applied pesticides was 2 months in fairway-managed turf/soil. Thatch played a significant role in pesticide adsorption and degradation.

Iowa State University, Dr. Nick Christians

- Pesticides and fertilizers applied to Kentucky bluegrass have the potential to leach through a 20-inch soil profile if irrigated improperly.

- Pesticide and fertilizer leaching can be greatly reduced during the four weeks after a pesticide or fertilizer application by irrigating lightly and more frequently, rather than heavily and less frequently.

- The thatch layer in a mature turf significantly decreases the amount of pesticides from leaching into the soil profile.

University of Georgia, Dr. Al Smith

- Data from research on simulated putting greens indicated that the concentration of 2,4-D, mecoprop, dithiopyr, and dicamba in soil leachate was below 4 ppb (parts per billion). According to a leaching prediction model for agriculture (GLEAMS), this leachate should have been 50 to 60 ppb, a significantly higher number. This indicates that current prediction models overestimate the potential leaching of pesticides through turfgrass systems.

- Less than 0.5% of the applied 2,4-D, mecoprop, dithiopyr and dicamba was found in the leachate from the simulated USGA putting greens over a 10-week period.

- No chlorpyrifos or OH-chlorpyrifos (first order metabolite) was detected in the leachate from the simulated putting greens in the greenhouse or field evaluations.

- Small quantities of chlorthalonil and OH-chlorthalonil were found to leach through the greens. However, the amount was less than 0.2% of the total applied.

- Data from fairway runoff plots with a 5 degree slope indicate that there is a potential for small quantities of 2,4-D, dicamba, and mecoprop to leave the plots in surface water during a 2-inch rainfall at an intensity of 1 inch per hour. The runoff was attributed to poor infiltration on a high clay soil.

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Michigan State University, Dr. Bruce Branham

- Nitrate leaching was negligible; less than 0.2% of the applied nitrogen was recovered at a depth of 4 feet below the surface (deepest system among all the studies).

- The nitrogen detected was at least 10 times below the drinking water standard (0.43 ppm nitrate in spring and 0.77 ppm nitrate in fall).

- It is estimated that up to 34% of the nitrogen volatilized.

- Only two (dicamba, triadimefon) of the eight pesticides evaluated were detected in the percolate at four feet (levels of 2 to 31 ppb).

- 2,4-D is potentially very mobile, but did not show up in the percolate.

- Phosphorus leaching potential is very low except in some sandy soils with low adsorption ability, where phosphorus applications require closer management.

- The root zone and thatch had a high biological activity, which enables turf to work like a filter when pesticide and fertilizers are applied.

University of Massachusetts, Dr. Richard Cooper

- Volatile pesticide loss over the two-week observation period ranged from less than 1% of the total material applied for the herbicide MCPP, to 13% of the total applied for the insecticides isazofos and trichlorfon.

- Volatile loss reached a maximum when surface temperature and solar radiation were greatest. To minimize volatility, the best time for application is late in the day.

- Total volatile loss for each compound was directly related to vapor pressure. For all materials evaluated, most of the volatile loss occurred during the first 5 days following application. Volatile residues were undetectable or at extremely low levels two weeks after application.

- Pesticide residues for all materials were rapidly bound to the leaf surface, with less than 1% of all residues dislodging (rubbed with cotton gauze) eight hours after application.

- Irrigating treated plots immediately after application greatly reduced volatile and dislodgeable residues on the first day following treatment

- Volatile losses were far below (up to 1000 times) levels that should cause health concerns.

University of Nevada, Dr. Daniel Bowman

- When the turf was maintained under a high level of management, nitrate leaching from both tall fescue and bermudagrass turf was very low. A total of 1% or less of the applied nitrogen was lost in the leachate.

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- Irrigating the two turfgrasses with adequate amounts (no drought stress) of moderately saline water did not increase the concentration or amount of nitrate leached.

- Higher levels of salinity in the root zone, drought, or the combination of these two stresses caused high concentrations and amounts of nitrate to leach from both a tall fescue and bermudagrass turf. This suggests that the nitrogen uptake capacity of the turf root system is severely impaired by drought, high salinity, or both. Under such conditions, it will be necessary to modify management practices to reduce or eliminate the stresses, or nitrate leaching could be a problem.

University of California, Dr. Marylyn Yates

- Turf maintained under golf course fairway and putting green conditions used most of the nitrogen applied - even with over-irrigation.

- Under the conditions of this study (bi-weekly applications of urea and sulfur-coated urea), little leaching of nitrate-nitrogen (generally less than 1% of the amount applied) was measured. No significant differences were found in the percent leached as a result of irrigation amount or fertilizer type.

- Leaching of 2,4-D was very low in soils that contained some clay, which adsorbs the pesticide; however, up to 6.5% leached from the sandy putting green soil. Irrigation amount did not significantly affect the amount of leaching.

- Less than 0.1% of the carbaryl leached, regardless of soil type. The irrigation amount did not significantly affect the amount of leaching.

- Little volatilization of 2,4-D was measured (£ 1%) from any of the plots, although the difference in the amount volatilized was significantly different between the two turfgrass species used (bentgrass vs. bermudagrass) and the surface characteristics (green vs. fairway).

- Little volatilization of carbaryl was measured (£ 0.05%) from any of the plots.

- Based on uniformly low volatilization results, turf may require different volatility regulations than agricultural crops.

University of Florida, Dr. George Snyder

- A total of 98 to 99% of the insecticide applied stayed in thatch layer.

- Greater movement of the fenamiphos metabolite occurred than expected, and different management practices may be warranted with this product.

- Less than 1% of the applied pesticides were found on cotton cloth immediately after spraying.

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Cornell University, Dr. Martin Petrovic

- More leaching occurred in newly planted turf than in mature, established turf.
- Nitrogen leaching did not exceed EPA drinking water standards.

- During the first year, MCPP leached from a coarse sand with poorly established turf (50 to 60% leached through the profile). This treatment was a "worst case" scenario.

- During the second year, a 7-inch rain (hurricane conditions) immediately after application caused substantial leaching from all soils (_____ need % of total).

Penn State, Dr. Thomas Watschke

- Significant differences between water runoff from ryegrass (more) versus creeping bentgrass (less) occurred because of the presence of more stolons, more organic matter, and higher density in bentgrass.

- Infiltration rate differences did not occur between the two turfgrass species.

- Over time, the increase in thatch resulted in decreased runoff.

- The irrigation rate had to be doubled (6 inches/hr.) in order to produce any runoff and indicates that turf is good at holding water.

- More than half of all the runoff water samples analyzed contained no pesticide. The remaining contained pesticide concentrations of less than 10 ppb of the pesticides.

- All reported nitrogen and phosphorous concentrations in runoff were less than EPA drinking water standards

By Dr. Michael P. Kenna
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