CORNELL UNIVERSITY TURFGRASS TIMES

CUTT

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Turfgrass Management Influence on Water Quality

Part 1: Pesticides

Concern about sources of agricultural pollution has raised questions about the contribution of turfgrass to water contamination and has motivated research on the role of pesticides and nutrients on contamination of water supplies. Turfgrass, while not the largest acreage crop, is in many cases the most intensively managed ecosystem. However, turfgrass management does not necessarily imply environmental degradation; in fact turf provides many benefits. The functional, recreational and aesthetic benefits provided to humans are unmatched by other crops.

Turf provides sediment reduction, runoff control, flood control, reduction in point- and non-point source pollution, water filtration, heat dissipation, and oxygen production. In many cases turfgrass has been used to remediate harmful chemicals leaving a site. Daniels and Gilliam found runoff transported from agricultural fields and flowing through a grass filter underwent significant sediment and chemical load reductions. In fact, the grass filter was more effective at reducing chemicals and sediments than the use of both a grass and a riparian filter.

Golf courses have been shown to be effective filters of surface water, especially for nutrients such as ammonium (NH_4^+-N) and, in some cases, nitrate (NO_3^--N). To be an effective filter, grass must produce a dense canopy, and deep, fibrous roots, which are capable of removing water from the soil at great depths. A dense canopy will slow and filter chemicals from runoff. Increased plant shoot density will reduce runoff and hence the chemical load leaving a site by creating a more tortuous pathway and increasing soil infiltration of water.

In any case, nutrients and pesticides found in water supplies can cause problems for both humans who rely on clean water for consumption, irrigation and recreation, and organisms that must have clean water for survival. The Environmental Protection Agency (EPA) has established maximum contaminant levels (MCL) for drinking water, above which human consumption is unsafe. The effect of these MCLs on aquatic organisms is generally much greater, suggesting that the use of aquatic toxicities may be a better indicator of water contamination. An in-depth review of the literature reveals a lack of work regarding the specific effect of pes-

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ticide use, differing nutrient sources and management practices on drainage water quality from turfgrass.

Management Systems

There are many management systems in use on turfgrass today, but they are generally a variation on one of three types. Preventative management, which entails pesticide applications made on a preventative, or preemergent basis, and high rates of water soluble fertilizers. In this system, pests are not tolerated, and are generally treated prior to or at first observance. Integrated Pest Management (IPM) is a widely adopted system that utilizes all current practices, including cultural, biological, physical, and chemical practices to reduce pest pressure. Pesticide applications are curative, and made only when viable alternatives do not exist. Nutrient sources range from organic composts to water soluble inorganic sources.

Organic management systems are recently becoming more and more acceptable, as people realize the perceived benefits with going organic. This system does not utilize any synthetic pesticides, but may use organic pesticides, if they exist. Pest pressure is reduced by alleviating the environmental stress on the turfgrass. Nutrient sources include manures, compost and commercial organics, usually exhibiting low solubility. All systems have the potential to contaminate water.

Pesticides

With the increased demand for food, fiber and recreation, pesticide use has increased dramatically. Pesticide use on turfgrass, although a relatively small proportion of total use, is significant, as it is typically the most intensively managed ecosystem. Movement of pesticides off-site can have dire implications for biotic systems. These chemicals negatively impact drinking water quality and organisms living within. Pesticides today are much more selective, and generally less toxic to nontarget organisms than in the past. However, the sheer quantity of pesticides applied makes their detection in water more frequent.

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There is a relationship between the frequency of pesticide detection in water and increased land use of the compound. High detection frequency and concentrations of pesticides were more likely to occur in water near land application sites. The EPA has established threshold levels below which human consumption is thought to be safe. Exceeding these standards can be harmful to human health. However, lower levels have been shown to be problematic for aquatic organisms. Baird, et al, suggest that aquatic toxicities may be a better measurement of dangerous pesticide levels, since they are generally lower than human toxicity levels.

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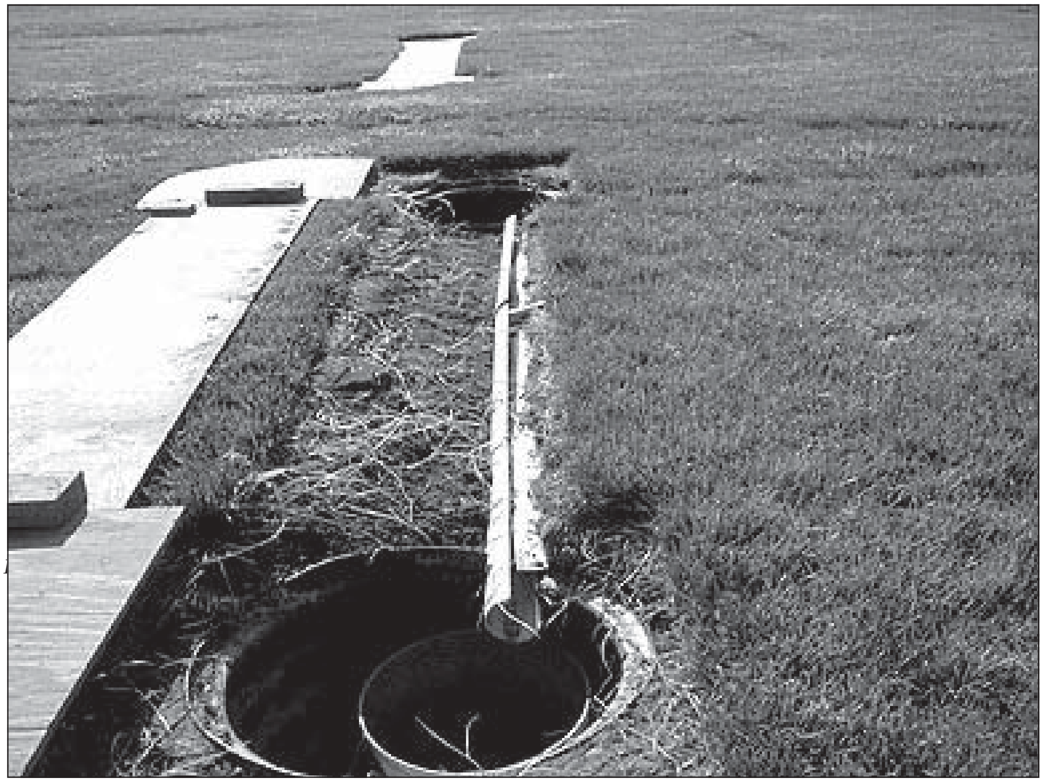
Pesticide movement in the environment is a function of many different factors which interact in multiple ways. Major factors include the composition of the soil, chemical degradation time, thatch composition, application timing, pesticide chemistry, rainfall patterns, soil microbial population, plant uptake and metabolization, temperature, antecedent moisture, pesticide sorption process, and slope. In general, surface movement of pesticides can be grouped into two areas: the properties of the pesticide and the environmental or site conditions. Pesticides found in ground water have several common characteristics: most are highly mobile in the soil, weakly adsorbed, long lived, and applied at high rates or detectable at low levels.

In the past, movement of pesticides to ground water was considered unlikely and insignificant. Dilution, binding, degradation, and metabolism were thought to remove a pesticide from the soil before it could move to and contaminate groundwater. The soil was believed to filter the contaminants and impurities before they could reach water supplies. Little work has been done on the fate of pesticides once they have entered ground water, but degradation of pesticides in aquifers is unlikely, and slow, due to reduced organic carbon and microorganism populations. Many pesticides have been found at detectable levels in ground and surface water. Well water testing yielded detections of sixteen pesticides, many at levels well in excess of mandated MCL.

In a study commissioned by the National Water Quality Assessment (NAWAQ) program, and completed by Barbash, et al, pesticides were detected more frequently, and in higher concentrations in shallow ground water than in deep aquifers. Detection was mainly a function of frequency of use and mobility. Concentrations of pesticides in ground water in a study by Loague, et al, were a function of the soil



Runoff collection study area at the Cornell Turf and Landscape Research Laboratory.

Preferential flow paths have been found to be capable of allowing strongly bound contaminants to be quickly transported to ground water, suggesting that the use of highly toxic compounds should be reexamined in the presence of preferential flow.

depth and soil hydraulic properties. The assumption being that greater depth to the water table allows for greater residence time and increased degradation. This assumption may be valid for uniform, disturbed soils, with no macropore transport (preferential) flow. Soils under no-till management (such as turfgrass) have been found to have a very large macropore flow component.

Macropores and Fingers

Macropores can transmit both adsorbed and non-adsorbed pesticides quickly and deeply into the soil profile. Wilkinson and Blevins found that macropores were responsible for up to 35% of the water flow through a clay soil. These preferential flow paths have been found to be capable of allowing strongly bound contaminants to be quickly transported to ground water, suggesting that the use of highly toxic compounds should be reexamined in the presence of preferential flow. EPA regulatory approval is based on the assumption of uniform transport through the soil which allows the compound time to degrade. The presence of preferential flow dramatically reduces degradation time and increases the likelihood of water contamination.

Sandy soils, such as those used on golf course greens, can form fingers which function very similarly to macropores. Fingers, once formed, can transmit large volumes of water repeatedly. Nektarios, et al, saw average water velocities in fingers on sand-based putting greens approach 0.76 cm min^{-1}, allowing rapid transport of contaminates to ground water, reduced efficacy of applied compounds, and reduced time for degradation, binding, and plant uptake. Once preferential pathways have moved pesticides past the root zone, degradation slows, and in some cases ceases altogether. However, Loague, et al, present evidence that pesticide leaching through an unsaturated profile can be significant, particularly for compounds with long soil half lives, or those that are dangerous at very low levels compared to the amount applied.

Runoff

Clearly, the first runoff event following pesticide application generally contains the highest concentration of pesticides. Ground and surface water face the largest risk in the first 24 hours following treatment.

Clearly, the first runoff event following pesticide application generally contains the highest concentration of pesticides. Ground and surface water face the largest risk in the first 24 hours following treatment. The highest pesticide concentrations in runoff (800, 800, and 360 $\mu g\ L^{-1}$ for mecoprop, 2,4-D and dicamba respectively) were seen by Shuman, et al, 24 hours after application. Drying time and foliar adsorption require at least 24 hours to effectively bind the pesticide and prevent excessive off site movement. Ma, et al, found an average of 73% of pesticide loss is from the first runoff event

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Research found that 70% of the dicamba present on the foliage was lost in a rainfall event occurring 8 hours after application.

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following application, 24.5 % of applied for dicamba. Mecoprop and 2,4-D had observed losses of 19.9 and 18.9% respectively.

In a separate study, Ma, et al, found high levels of atrazine, approaching 500 µg L^{-1}, in runoff from the first event following application, which in some cases accounted for 89% of the total loss. Concentrations in runoff water declined rapidly after application. Carroll, et al, saw 70% of the dicamba present on the foliage lost in a rainfall event occurring 8 hours after application. Watschke, et al, measured mecoprop concentrations in runoff of >4700 µg L^{-1} 24 hours after application. However, concentrations declined rapidly, undergoing a 99.5% reduction in 14 days. In the same study, mecoprop levels in leachate were high initially following application, >600 µg L^{-1}, but declined to below detectable levels with in 2 months.

In a study conducted by Baird, et al, 2,4-D and mecoprop mass losses in runoff varied from 0 to 15% of applied, and were generally a function of solubility and K_{oc}. Smith and Bridges found very high levels of 2,4-D, dicamba and mecoprop (810.7, 279.2, and 820.0 µg L^{-1} respectively) in runoff water less than 24 hours after application. They also found that only samples collected over the first week contained any significant concentration (i.e. above minimum detection levels) of pesticides in runoff. In the same study, they saw low levels of the same pesticides in lysimeter leachate water, <3µg L^{-1}, presumably due to good water soil contact (the soil was disturbed, so macropores did not likely exist or contribute to flow). These results were verified in a similar lysimeter study conducted by Smith and Tilloston. They saw 2,4-D levels generally below detection limits (5 µg L^{-1}), despite a sand-based rooting mix. Evert concluded that soils repacked into lysimeters in laboratory experiments effectively remove the macropore flow component from the equation.

Leaching

In a leaching study carried out by Carroll, et al, thatch was found to be an important component in reducing pesticide leaching over bare soil. Supporting this finding is a study by Cisar and Snyder which found that the majority of applied pesticides (90-100%) remained in the thatch, leaving little to be transported in runoff or leachate. However, the remaining 10% of a pesticide could cause significant damage to water bodies. Observed levels in leachate were <1% of applied. The organic carbon present in the thatch layer is very effective at binding and ultimately removing a pesticide from potential transport. However, pesticide chemistry can determine its ability to be bound. A pesticide is a threat to ground water if it has K_{oc} <1900 L kg^{-1}, water solubility >3mg L^{-1}, or a soil half life >610 days.

Many of the pesticides used in turfgrass have all or some of the above characteristics, yet do not leach significantly. This is perhaps further evidence that environmental conditions play a major role in pesticide transport, detention and degradation in ecosystems. However, pesticide mobility is a significant issue when making direct comparison of compounds. Both dicamba and 2,4-D are considered potential leachers, but Dicamba is more mobile than 2,4-D. In fact, despite only 10% as much dicamba as 2,4-D was applied, nearly the same quantities of each was leached.

Season was found to significantly affect the leaching of dicamba in a study by Roy, et al. High evapotranspiration rates (Et_o) were found to reduce total leaching losses in the summer, but losses in the fall approached 1000 µg L^{-1} dicamba, because of reduced plant uptake, high application rate and reduced soil and microbial degradation from lower soil temperatures. A large portion of pesticide mass loss occurs in the winter despite little or no pesticide application. Runoff and leachate losses are greater in the winter months due to reduced evapotranspiration and increased rainfall. Cooler weather results in reduced degradation and metabolization of pesticides as well as reduced turfgrass growth, leaving more pesticide to be transported to water. Pesticide formulation can have a significant impact on water quality. Harrison, et al, measured the acid form of 2,4-D at concentrations greater than 200 µg L^{-1}, while the ester form was below detection levels.

How Pesticides Move

Transport of pesticides can follow a number of paths. Pesticides can move from the soil surface via runoff, in the soluble form, or attached to sediments (negligible with established turfgrass). Ma, et al, discovered that pre-wetted sites were much more prone to pesticide loss via runoff. Much of the transport from established turfgrass is of the soluble form. Smith and Tilloston state that the formulation of 2,4-D, dicamba, and MCPP normally applied has a high average water solubility (<50 mL g^{-1}), allowing it to move rapidly through a soil profile. Toranio, et al, found pesticides had a greater potential to leach if the K_{oc} was less than 1900 mg L^{-1}. However, rooting can affect pesticide mobility greatly. Deeply rooted turfgrass has a greater influence on subsurface water movement than shallow rooted turf. Branham, et al, state that pesticide applications to turf reduced leaching losses over bare soil.

Golf course greens have the potential to allow large pesticide losses. The sand-based rooting mix has low organic matter content, metal oxides and an open matrix which all combined to reduce the interaction of a pesticide with the soil, thereby reducing potential attenuation and binding. The coarse, sandy soil allows for rapid water movement and little potential attenuation because of a low cation exchange capacity. Over-application of water will cause pesticides to be transported through the soil to ground water. Greens are generally watered heavily which increases leaching. However, pesticide movement with the water can be greatly reduced by thatch which binds and degrades large quantities of pesticides. Runoff is usually negligible on sand-based golf greens. Concentrations of a compound may be high in runoff, but mass losses are low. They observed 2,4-D concentrations as high as 314 µg L^{-1}, but runoff depth was minimal.

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Editors Note: Zach is currently pursuing his Ph.D. with Professor Marty Petrovic investigating landscape, watershed and water quality issues. This is the first of a three part series on the current status of water quality research as it relates to turfgrass management.

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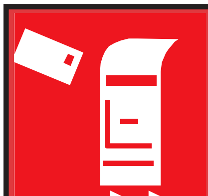

Please Note:

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sionalism are but a few of Joann's many fine attributes. [She is] a tireless individual who goes above and beyond in her work and dedication to the industry and her profession. A most deserving individual for this prestigious award."

It is clear that Joann Gruttadaurio is deserving of the 2003 Citation of Merit Award. Congratulations Joann, and thank you for all of the contributions you have made to our association and community.