PESTICIDE FATE IN TURF

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A critical issue facing agriculture and the turfgrass industry is the fate of pesticides in our environment. In this context 'fate' means the ultimate disposition of a pesticide after it has been applied. Why all of the concern about chemicals? First, use of pesticides has been increasing steadily since the 1960's. Secondly, the ability of scientists to detect pesticides has increased at least 1000 fold in the last ten years (i.e. in the 1970's limits of detection were in the parts per million (PPM) range, currently levels of detection for organic pesticides are in the parts per billion (PPB) range). There have been many articles in the turf and agricultural literature talking about parts per billion with the general thrust of the articles being that a part per billion is such a tiny amount it can't hurt you. As an example, the average extra strength aspirin tablet contains 500 mg of aspirin per tablet. Dissolving the entire tablet in 1 liter of water (16.8 ounces) would yield an aspirin concentration of 500 PPM. To get an aspirin concentration of 1 PPB would require us to dissolve only 1/500,000 of the aspirin tablet in one liter of water. Thus, a 1 PPB concentration is a very small amount of a toxin but that does not mean it is harmless. The USEPA has recently adjusted the maximum allowable concentration of lead (Pb) in drinking water to 10 PPB. The maximum allowable concentration of atrazine (commonly used corn herbicide) in drinking water is 3 PPB. A third reason pesticides are more of a concern is that scientists have recently begun testing ground water and have been finding pesticides with considerable regularity. Because ground water accounts for almost fifty percent of the drinking water supplies in the United States, protection of this source of fresh water is essential. These three points have focused attention on the use of pesticides. A fourth reason is an undeniable hysteria in the general public over the use of pesticides. The level of risk associated with the use of pesticides is not commensurate with the level of fear of pesticides amongst the general public. Regardless of the extent of the risk caused by using pesticides, it is incumbent upon all who use pesticides to understand the processes that control the fate of these compounds in the environment.

Pesticide Fate Processes

Pesticide fate generally is concerned with the disposition of pesticides after they reach the soil surface. Thus, spray drift is often omitted from discussions of pesticide fate because it is largely controlled by the type of sprayer used and is not dependent upon the physical and chemcical properties of the individual pesticide molecule.

The processes affecting pesticide fate can generally be grouped into two categories: transformation and transportation. Transformation results in the alteration of the chemical structure of the pesticide. This is generally a desirable process since most organic pesticides used today are made less toxic or non-toxic by these processes.

Transportation processes are more of a concern because these fate processes often result in the movement of a pesticide away from the site of application. The transportation and transformation processes are displayed in table 1. Each will be discussed individually.

The most important factor to consider in pesticide fate studies is leaching. Leaching is the downward movement of pesticides through soil. It is the process responsible for ground water contamination. A pesticide fate process that is strongly correlated, in fact one of the three primary determinates of leaching, is adsorption. Adsorption is the physical binding of a pesticide to soil organic matter or clay which are the primary adsorptive sites in soil. Some pesticides are strongly adsorbed to soil and this reduces their availability for leaching. Adsorption, or more accurately, strength of adsorption, plays a critical role in determining whether a pesticide will leach. With some exceptions, most notably paraquat which because it is a positively charged organic molecule is essentially irreversibly adsorbed, most pesticides will slowly leach over time. Thus, two other factors are important in determining susceptibility to leaching, the half life of a pesticide in soil and the water solubility of a pesticide. The half life of a pesticide is the time needed for its concentration to reach one-half of its original value. If a pesticide has a half-life of 2 days then at 2, 4, and 6 days after application, its concentration in soil will be 1/2, 1/4, and 1/8, respectively, of its initial concentration. A pesticide with a short half life degrades rapidly and has little chance to leach. As a rule of thumb, a half life of 30 days or less should mean that leaching will not be a significant problem. The other factor to be considered is water solubility. Most pesticides are organic molecules with varying degrees of water solubility. For example, benefin (Balan) has a reported water solubility of 0.1 PPM while paraquat has a water solubility of 62,600 PPM. If a herbicide is very slightly soluble in water, such as benefin, then its tendency to leach with downward moving water will be very much reduced. Generally, any compound with a water solubility of less than 10 PPM would not be expected to leach readily.

Leaching is probably the biggest environmental concern facing the turf industry. The three factors mentioned above soil adsorption, persistence in soil, and water solubility play a large role in determining the leaching potential of pesticides. Paraquat is very water soluble and has a long half-life in soil but because it is adsorbed so strongly, it has never been detected in ground water and does not leach.

Another important factor in pesticide fate is runoff. Runoff occurs when the precipatation rate exceeds the infiltration rate of the soil. This often occurs during intense rainstorms. This is a serious concern in row crop agriculture where many of the pesticides are applied to bare soil which is not held in place by plants. When runoff occurs from row crops, not only can a pesticide be carried in the runoff water, but water-insoluble pesticides can be carried on soil particles. In turf a different situation exists because the continuous plant cover holds the soil in place preventing any soil erosion. Research by T.L. Watschke et al. (1) at Penn State University has shown that a well maintained turf does an excellent job of reducing runoff and that a turf improves soil permeability over time allowing for greater water infiltration. Watschke's data has shown that runoff from turfed sites is relatively rare and confined to intense rainoff events. Runoff can be considered a minor means of pesticide transport from turf in most situations.

Another means of transporation is volatilization. Volatilization is the transfer of a pesticide from a solid or liquid phase to a gas or vapor. The vapor can then be transported in the air and deposited off the application site. Volatilization is a concern when using broadleaf herbicides that are formulated as esters. Esters are generally volatile and can cause injury to non-target plants if volatilization occurs. The tendency for volatilization to occur depends primarily on the vapor pressure of the pesticide. Temperature and moisture also play important roles in determining the quantity of a pesticide that is volatilized.

Spray drift is technically not a pesticide fate process since it occurs before the pesticide is deposited on the soil or plant surface. However, spray drift is something that should be clearly understood since it is primarily determined by the spraying equipment used. Data in table 2 shows the effects of droplet size on the length of time for the droplets to reach the ground. Droplets smaller than 100 μm in diameter are considered aerosols and tend to settle to the ground very slowly. Droplets of these sizes should be avoided. Droplet size is determined by nozzle orifice size, spray pressure, and spray solution viscosity. The lawn care industry attempts to avoid spray drift by using the Chemlawn gun. This low pressure sprayer has a average spray droplet size of 2200 μm, well above the aersol size limits. These drops are much heavier and fall rapidly to the turf.

The above discussion has centered on transportation processes which can result in the movement of pesticides from the site of application to undesirable sites such as ground water, surface water or non-target plants. We will now discuss the transformation processes which are generally viewed as beneficial since the result is the alteration and/or degradation of the pesticide molecule.

Unlike traditional row crops, all turf pesticide applications are made directly onto plant foliage. The turfgrass community intercepts all pesticide applications and absorbs a fraction of each application. Plant absorption is one mechanism of pesticide transformation since most plants attempt to transform pesticides into more water soluble compounds through biochemical reactions. The extent of plant absorption of various pesticides by turfgrasses has not been well studied and thus the magnitude of this pathway of pesticide removal is not known.

Another means of pesticide degradation that is difficult to quantify is photodecomposition which is the degradation of compounds by light energy. This is difficult to study under natural conditions because it is difficult to tell whether degradation is due to light, microorganisms, volatility or other factors. The dinitroaniline herbicides (e.g. benefin, trifluralin, pendimethalin, and prodiamine) are known to be susceptible to photodecomposition; however, once they are watered into the soil they are assumed to be safe from photodecomposition.

Microbial degradation is the most common means of pesticide degradation Microorganisms are extremely efficient at degrading a wide variety of organic compounds. Microorganisms degrade pesticides by two different processes. Microorganisms which can use a pesticide as a food source are said to metabolize the pesticide. This method of degradation leads to a fairly rapid disappearance of the pesticide. Some microorganisms will alter the structure of the pesticide but are unable to gain any energy from the reaction. This process is called cometabolism. A pesticide degraded by a cometabolic process would tend to persist in the soil for a longer period of time. Microorganisms are extremely diverse and capable of degrading a wide range of organic compounds. Degradation by microorganisms is desireable because it usually results in the detoxification of the pesticide.

This discussion has attempted to identfy the major pathways by which pesticides are transported or transformed in the environment. The issue of pesticides in ground or surface water and public exposure to pesticides will continue to be a major concern for our industry. Understanding the issues and concerns of pesticide use can only benefit our industry.

1) Watschke, T.L., S. Harrison, and G. Hamilton. 1988. Movement of Nutrients and Pesticides in Runoff from turfed slopes. Agron. Absts. 157.

TABLE 1.

FACTORS AFFECTING PESTICIDE FATE

1) Transportation

   A) Leaching
   B) Volatilization
   C) Runoff
   D) Spray Drift
   E) Adsorption

2) Transformation

   A) Microbial Degradation
   B) Chemical Degradation
   C) Plant Uptake
   D) Photodecomposition

TABLE 2.

EFFECT OF SPRAY DROPLET SIZE ON SPRAY DRIFT

Droplet Diameter	Time to Fall 10 Feet	Distance Traveled In 5 MPH Wind
1	28 hr	29,050 ft
10	17 min	7480
50	40 sec	295
100	11 sec	77
400	2 sec	15
1000	1 sec	7

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