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The Fate of Pesticide in the Environment

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ABSTRACT

Pesticides are an essential element of agriculture production. Increased use of pesticides has greatly aided agricultural production, decreased losses of stored grains, and has generally improved man's welfare. However, pesticide usage may lead to undesirable residues as trace contaminats of food, the environment and living tissues. Pesticides are known to move from treated agricultural areas into the broader environment, then they can reach to the non-target organisms. Once pesticides enter the atmosphere, they may be transported long distances. The escape of these chemicals into the atmosphere represents an economic loss to the user, inefficient control of pests, and introduction of possible environmental contamination. With the basis of update references, this article deals with; movement of pesticides from the site of application, environmental behaviour of pesticide and fate of pesticide in the soil-plant system.

Key Words: Fate of pesticides, environmental pathways of pesticide

Pestisitlerin Çevredeki Akıbeti

Özet

Pestisitler tarımsal üretimde ana unsurdur. Artan pestisit kullanımı tarımsal üretime büyük destek olur, ürün kayıplarının azalmasını sağlar ve insanların refah düzeyinin dolaylı olarak artmasını sağlar. Ancak pestisitler gıdalarda, çevrede ve yaşayan diğer canlılarda kalıntılara da sebep olurlar. Pestisitler uygulanan tarımsal alanlardan çok geniş şekilde çevreye dağılırlar ve hedef olmayan organizmalara uluşabilirler. Pestisitler bir defa atmosfere girdikten sonra çok uzun mesafelere taşınabilirler. Bu kimyasalların atmosfere ulaşması, üretici açısından kayıplara, zararlılarla mücadelenin etkisiz olmasına ve çevre kontaminasyonuna sebep olur. Bu çalışma güncel literatürlerle, pestisitlerin uygulandıkları bölgeden haraketleri, pestistlerin çevresel davranışları ve toprak-bitki sisteminde pestisitin akıbeti ile ilgilidir.

Anahtar sözcükler: Pestisitlerin akıbeti, pestisitlerin çevreye giriş yolları

INTRODUCTION

When a pesticide is released into the environment many things happen to it. Sometimes, the leaching of some herbicides into the root zone can give you better weed control. Sometimes, releasing pesticides into the environment can be harmful, as not all of the applied chemical reaches the target site (Figure 1) (Cesna 2009).

Pesticide characteristics (water solubility, tendency to adsorb to the soil and pesticide persistence) and soil characteristics (clay, sand and organic matter) are important in determining the fate of the chemicals in the environment (Anoymous 2009).

Sofuoğlu et al (2004) determined pesticide residues in the ambient air in İzmir. Twenty successive daytime and nighttime air samples were collected and analyzed for 23 currently used and/or banned organochlorine pesticides between 14 and 23 May 2003 in Izmir, Turkey. Average individual organochlorine concentrations ranged from 574 pg m^{-3} (p,p o-dichloro diphenyldichloroethane) to 3917306 pg m^{-3} (chlorpyrifos) and they were within the ranges previously measured at different sites.

Environmentalists, scientists and agriculturalists are all too aware of the long-term effects of pesticides as they seep away to pollute streams and watercourses. Air in field margins may be contaminated with pesticides because of application drift, post-application vapour loss and wind erosion of treated soil. Soil, vegetation and water bodies within field margins may become contaminated through wet and dry atmospheric deposition of pesticides and through surface runoff from pesticide-treated agricultural land (Cessna et al. 2005).

Movement of pesticides from the sites of application to nontarget regions creates three problems. It represents an economic loss to farmers, inefficient control of pests, and possible environmental contamination (Duttweiler and Malakhov 1977, Waite et al. 2002).

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The aim of this study is to present movement of pesticides from the site of application, fate of pesticide in the soil-plant system including soil bound residues, and environmental pathways of pesticide, with the based on update references and our previous work.

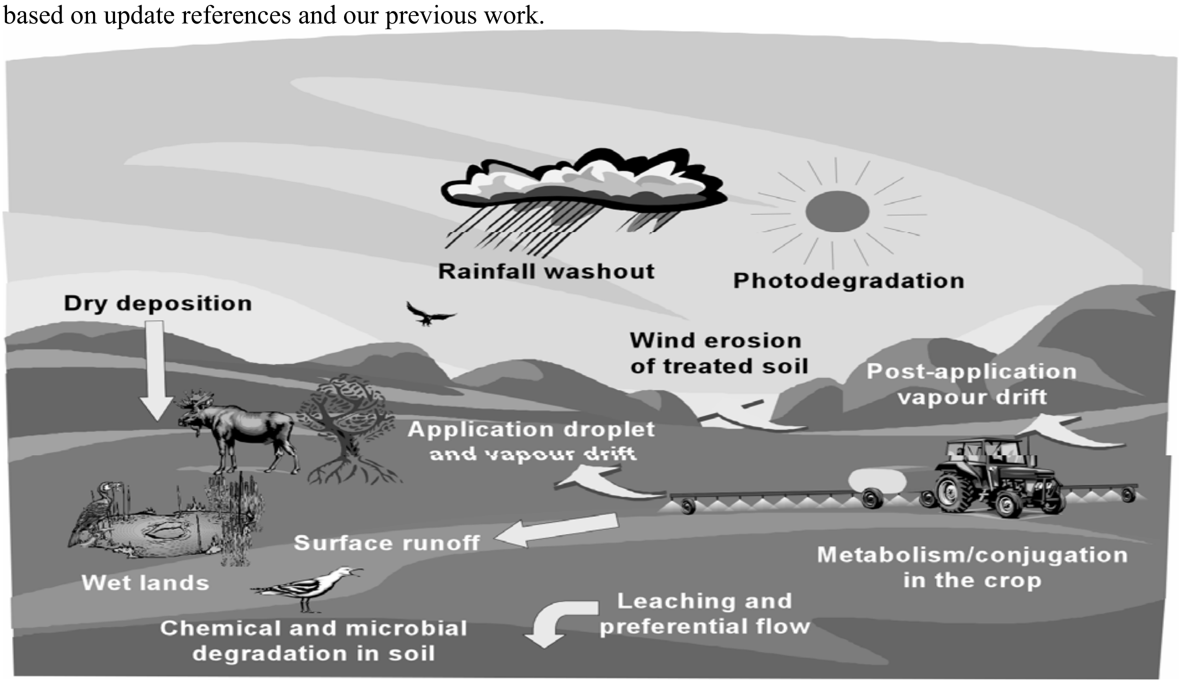

Figure 1. Routes of entry of pesticides into the atmosphere and into surface and ground waters and mechanisms of pesticide transformation in air, soil and plants (Cessna 2009).

INITIAL DISTRIBUTION

Initial distribution describes the proportion of pesticide that is on or in the air, soil, water, plants, and animals after application and affects fate of a pesticide in the environment This amount is determined by the formulation, method, and rate of application, as well as topography, amount and type of vegetation and groundcover, and weather conditions. With time, the pesticide may be redistributed within the application site or may move off site-beyond the edge of the target area or the bottom of the root zone. Pesticides that move off site represent an economic loss and may pollute groundwater or surface water (Figure 2) (Kerle et al. 2007).

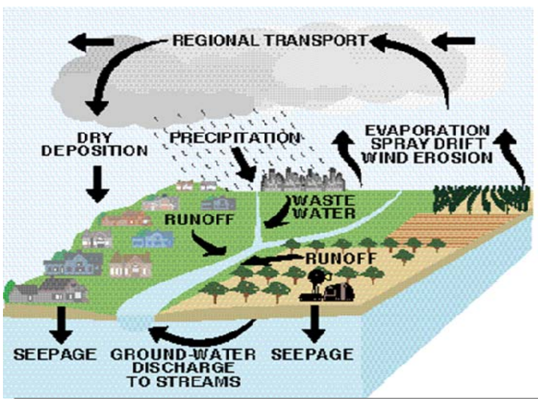

Figure 2. Pathways of pesticide into aquatic system (Kerle et al. 2007).

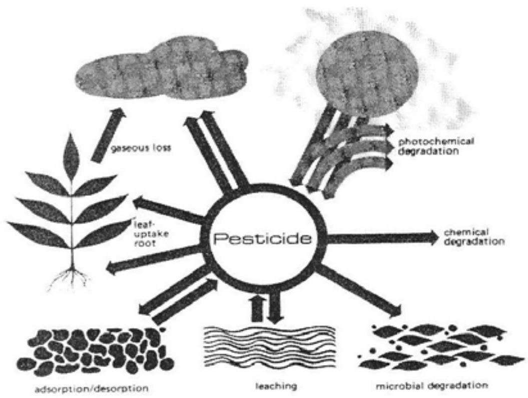

Figure 3. The fate of pesticides in the soil plant system (Führ 1991)

Persistence

Pesticide persistence often is expressed in terms of half-life. This is the length of time required for one-half of the original quantity to break down. For example, if a pesticide has a half-life of 15 days, 50 percent of the pesticide applied will still be present 15 days after application and half of that amount (25 percent of the original) will be present after 30 days. In general, the longer the half-life, the greater the potential for pesticide movement. Pesticides can be divided into three categories based on half-lives: *nonpersistent* pesticides with a typical soil half-life of less than 30 days, *moderately persistent* pesticides with a typical soil half-life of 30 to 100 days, or *persistent* pesticides with a typical soil half-life of more than 100 days (Table 1) (Kerle et al. 2007, Anonymous 2009).

Table 1. The properties of some pesticides useful for predicting environmental fate.

Pesticide	Haf-life (days)	Sorbtion coefficient K_{oc}	Movement rating	Water Solubility mg/l*	Vapor pressure index	Henry's Law Index K_{h**}
Malathion	1	1800	extremly low	130	80	1000
1,3-dichloro-propene	10	32	moderate	2250	290 billion	77 billion
Dicamba	14	2	very high	400 000	0	0
Benomyl	67	1900	low	2	0.001	0.78
Diuron	90	480	moderate	42	0.69	21
Bensulide	120	1000	moderate	5.6	8	3058
Prometon	500	150	very high	720	77.3	130

*Multiplied 10^7 **Multiplied 10^9

Persistence is affected by photodegredation, chemical degredation and microbial degredation. All three processes may participate in the breakdown of a single pesticide. The rate of degradation depends on pesticide chemistry, as well as on environmental conditions. Distribution between foliage and soil, as well as temperature, soil and water pH, microbial activity, and other soil characteristics may affect pesticide persistence.

Mobility

Pesticide mobility may result in redistribution within the application site or movement of some amount of pesticide off site. After application, a pesticide may: (I) attach to soil particles, vegetation, or other surfaces and remain near the site of deposition, (II) attach to soil particles and move with eroded soil in runoff or wind, (III) dissolve in water and be taken up by plants, move in runoff, or leach, (IV) volatilize or erode from foliage or soil with wind and become airborne. Mobility is affected by the pesticide's sorption, water solubility, vapor pressure, and other environmental and site characteristics including weather, topography, canopy, and ground cover; and soil organic matter, texture, and structure (Kerle et al. 2007).

ENVIRONMENTAL EFFECTS OF PESTICIDES

Pesticides effect the environment by point-source pollution and nonpoint-source pollution. The former is the contamination that comes from a specific and identifiable place, including pesticide spills, wash water from cleanup sites, leaks from storage sites, and improper disposal of pesticides and their containers. The latter is the contamination that comes from a wide area, including the drift of pesticides through the air, pesticide run-off into waterways, pesticide movement into ground water (Toth and Buhler 2009).

Environmentally-sensitive areas to the pesticides are (I) where ground water is near surface, (II) near surface waters; (III) heavily populated with people; (IV) populated with livestock and pets; (V) near the habitats of endangered species and other wildlife; (VI) near honey bees; (VII) near food crops and ornamental plants (Toth and Buhler 2009). Sensitive plants and animals as well as the water quality of water bodies in field margins can be affected either directly or indirectly (Cessna et al. 2005).

FATE OF PESTICIDE IN THE ATMOSPHERE

Entry of Pesticides into the Atmosphere

Pesticides enter the atmosphere either by application drift, post-application vapour losses or wind erosion of pesticide treated soil (Figure 1). They and their photodegradation products may be transported long distances before the removal processes of atmospheric wet and dry deposition return them to the earth's surface (Cessna et al. 2005, Cessna et al. 2006).

Application drift

Liquid sprays are applied through nozzles which provide metering, atomization, and uniform distribution of the pesticide mixture. The majority of atomizers use hydraulic pressure as the energy source for breaking the liquid into droplets. The proportion of the total spray volume contained in droplet sizes below 150 μm can be used as an indicator of drift potential, because it is these small droplets that are most prone to movement under windy conditions.

Post-application vapour losses

There are two types of applications. Preemergence applications, applied to the soil surface prior to the emergence of the crop, may be left undisturbed on the soil surface or incorporated by some form of soil disturbance into the upper layer of soil. Post-emergence applications are applied to the crop, a portion of which will penetrate the crop and deposit on the soil surface.

Wind-erosion of pesticide-treated soil

Pesticides on the soil surface may be susceptible to transport through wind erosion of soil in which three processes are considered operative. Large soil particles can roll on the soil surface under the influence of wind and this movement is called surface creep. Smaller particles can become suspended in the air for short periods of time as they move laterally. Since all processes may involve soil particles with adsorbed pesticide, significant amounts of pesticide may be transported from the soil surface with the wind-eroded sediment.

In a study, overall losses for three winter wind erosion events for two soil incorporated herbicides, trifluralin and triallate, were approximately 1.5% of the amounts applied. Simultaneous losses of four postemergence herbicides (2,4-D, mecoprop, bromoxynil, diclofop) applied to the soil surface averaged 4.5%. This study demonstrate the potential for environmental transport of pesticides on wind-eroded sediment and its associated implications for off-site air and surface water quality (Cessna 2009).

PESTICIDES FREQUENTLY DETECTED IN THE ATMOSPHERE

Pesticides frequently detected in the atmosphere are (I) organochlorine insecticides: resistant to environmental degradation, (II) organophosphate insecticides: not long-lived in environment, (III) triazine herbicides: heavily-used herbicides, persistent in environment, (IV) acetanilide herbicides: used heavily, but not as persistent as triazine (Toth and Buhler 2009).

HAZARDS OF ATMOSPHERIC PESTICIDES TO HUMANS AND ENVIRONMENT

Atmospheric pesticides are the source of exposure to pesticides through inhalation and source of contamination of surface/ground water through dry deposition and precipitation. Atmospheric movement may cause (I) transportation of pesticides from application sites to sensitive areas and (II) accumulation of pesticides in the environment (Toth and Buhler 2009).

FATE OF PESTICIDE IN THE AQUATIC SYSTEM

The contamination of water bodies with pesticides can pose a significant threat to aquatic ecosystems and drinking water resources. Pesticides can enter water bodies via diffuse or via point sources. Diffuse-source pesticide inputs into water bodies are the inputs resulting from agricultural application on the field. These are tile drain outflow, baseflow seepage, surface and subsurface runoff and soil erosion from treated fields, spray drift at application, and deposition after volatilization. In contrast, point-source inputs derive from a localized situation and enter a water body at a specific or restricted number of locations. These are mainly farmyard runoff, sewage plants, sewer overflows, and accidental spills. There are also point sources of pesticides from non-agricultural use, e.g. from application on roads, railways or urban sealed surfaces such as parking lots (Reichenberger et al. 2007).

Many factors, such as soil and pesticides properties, and crop management practices, govern the potential for groundwater or surface water contamination by pesticides (Kerle et al. 2007).

SURFACE WATER

Entry of pesticides into surface waters
Pesticides enter surface waters through run-off, wastewater discharges, atmospheric deposition and spills (Cessna 2009).

Atmospheric Deposition
Once pesticides enter the atmosphere either by above mentioned pathway, they are subjected to transport over distances which can range to thousands of kilometres. At any point during transport, they are also subject to the removal processes of wet and dry deposition, both of which contaminate surface waters. In wet deposition, pesticides may be trapped in snow and hail or dissolved in rain. In dry deposition, pesticides sorbed to particles of wind-eroded soil.

Surface Runoff
Surface waters include streams, rivers, lakes, reservoirs and oceans. Streams and reservoirs supply approximately 50% of the drinking water in the world. Surface waters receive a portion of their water from snow melt or rainfall runoff. Pesticides susceptible to surface runoff are those within the runoff-soil interaction zone or the top 0.5 to 1 cm of soil. Several factors may affect the amount of pesticide present within this zone. These include type of pesticide application, soil type, physiochemical properties and formulation type of the pesticide, field half-life of the pesticide, atmospheric deposition of pesticides (Toth and Buhler 2009).

The pollution of aquatic system is depend on water solubility of pesticides. Water solubility describes the amount of pesticide that will dissolve in a known amount of water. It usually is measured in milligrams per liter of water or ppm and measures how easily a pesticide may be washed off the crop, leach into the soil or move with surface runoff (Toth and Buhler 2009).

GROUND WATER

Groundwater may be contaminated if pesticides leach from treated fields, mixing sites, washing sites, or waste disposal areas (Anonymous 2009).

ENTRY OF PESTICIDES INTO GROUND WATERS

Surface runoff and erosion
Runoff is the movement of water over a sloping surface. It can carry pesticides dissolved in water and pesticides sorbed to eroding soil. The pesticides are either mixed in the water or bound to eroding soil. Runoff can also occur when water is added to a field faster than it can be absorbed into the soil. Pesticides may move with runoff as compounds dissolved in the water or attached to soil particles. The amount of pesticide runoff depends on slope, texture of the soil, soil moisture content, amount and timing of a rain-event and type of pesticide used (Anonymous, 2009; Reichenberger et al. 2007, Kerle et al. 2007).

Soil erosion by water consists of two processes: i) the detachment of soil particles from the soil surface, and ii) their subsequent transport downslope. Detachment is caused by raindrop impact and also by the abrasive power of surface runoff, especially when the runoff water flow has concentrated (Le Bissonais et al. 1995). Pesticides lost in runoff and erosion events leave the field either dissolved in runoff water or adsorbed to eroded soil particles. However, for most pesticides losses via runoff are considered far more important than losses via erosion, because the amount of eroded soil lost from a field is usually small compared with the runoff volume (Leonard 1990). Only for strongly sorbing substances with a K_{oc} greater than ca. 1000 L kg^{-1}, erosion is considered as the main loss pathway (Kenaga 1980).

Drainflow
The purpose of installing artificial subsurface drains is to prevent top soil saturation that otherwise would impair crop development, soil trafficability and workability. The main factors affecting pesticide inputs into surface waters via drainage are soil texture, site, drainage system, compound properties, weather, application rate and season (Reichenberger et al. 2007).

Leaching

Leaching is the movement of pesticides in water through the soil. Leaching occurs downward, upward, or sideways. The factors influencing whether pesticides will be leached into groundwater include characteristics of the soil and pesticide, and their interaction with water from a rain or irrigation. Leaching can be increased when: (I) the pesticide is water soluble, (II) the soil is sandy, (III) a rain-event occurs shortly after spraying, and (IV) the pesticide is not strongly adsorbed to the soil (Anonymous 2009). Leaching of water and dissolved pesticides to depth in soil occurs by matrix flow and preferential flow. Matrix flow is the slower transport process in which the simultaneous movement of pesticides with water is determined by the physical-chemical properties of the pesticides (Table 1). Such movement is dependent on its water solubility, vapour pressure, K_h and K_{oc} (Cessna 2009).

Spray drift

Spray drift is the airborne movement of spray droplets away from a treatment site during application. Spray drift is affected by spray droplet size, wind speed and distance between nozzle and target. It can damage nearby sensitive crops or can contaminate crops ready to harvest and may be hazard to people, domestic animals, or pollinating insects. It can contaminate water in ponds, streams, ditches and harm aquatic plants and animals (Anonymous 2009).

Point sources

Point-source inputs of pesticides consist of runoff from hard surfaces, mostly farmyards, storage facilities or roads. The contamination of hard surfaces arises from filling and cleaning of sprayers, improper handling of tank mix left overs, leaking of faulty equipment, incorrect storage of canisters. Of course accidental spills can occur due to leaking tanks on the road to the field to be treated (Reichenberger et al. 2007).

ENVIRONMENTAL IMPACT OF PESTICIDES IN GROUND WATER

Ground water is water located beneath the earth’s surface, usually in rock or soil. Ground water is the primary source of drinking water for 50% of population, 95% of rural residents in the United States. At least 143 pesticides and 21 of their transformation products have been found in ground water, from every major chemical class. Pesticides most frequently detected in ground water are (I) triazine and acetanilide herbicides: used extensively on corn and soybeans, and (II) carbamate insecticide aldicarb: ground water contamination problems, sampled for extensively (Figure 2) (Toth and Buhler 2009).

FATE OF PESTICIDE IN THE PLANT-SOIL SYSTEM

Research in the fields of metabolism and the environmental behavior of pesticides has developed into interdisciplinary cooperation, in which pesticide chemists cooperate with agricultural chemists, soil scientists, microbiologists and plant physiologists. All the process which take place in the soil-plant system after the application of pesticides are of particular interest for agriculture (Figure 3). The ultraviolet fraction of sunlight is absorbed to a considerable extent by many chemical compounds, providing the energy necessary for photochemical reactions. Similar decomposition reactions take place during chemical and biochemical modifications in which microorganisims, plant roots and soil macrofauna are involved. Absorption and fixation processes have a influence on the availability of active substances in the soil for treated cultures and subsequent untreated crops (Führ 1991).

ENVIRONMENTAL IMPACT OF PESTICIDES ON PLANTS

Factors which influence leaf uptake and metabolism of pesticides are physicochemical behavior, formulation, droplet size and application technique, precipitation or rainfall and relative humidity, temperature, sunlight, plant species and pyhsiological differences, e.g. stomata, upper/lower leaf surface, hairs, waxes, and time of application during the vegetative period. Similarly factors which influence root uptake and degradation of pesticides in soil are physicochemical behavior, application method and amount, physicochemical and biochemical reactions in the soil, climatic factors and plant development (Figure 3) (Führ 1991).

The degree of plant uptake is determined partially by the pesticide's water solubility. Plant uptake of pesticides prevents runoff or leaching (Kerle et al. 2007).

Volatilization from foliage

Pesticides also may volatilize or be blown away by the wind. Volatilization from foliage is determined by the pesticide's vapor pressure, which is affected by temperature. The higher, the temperature, the greater the volatilization. Pesticides on foliage are most susceptible to volatilization after application, because over time, pesticides become incorporated into surface waxes. In general, pesticides with vapor pressure index values of less than 10 have a low potential to volatilize (Table 1). Pesticides with vapor pressure index values greater than 1000 have a high potential to volatilize (Kerle et al. 2007).

Absorbtion

Absorption is the uptake of pesticides and other chemicals into plants or microorganisms. Most pesticides break down once they are absorbed. Pesticide residues may be broken down or remain inside the plant or animal and be released back into the environment when the animal dies or as the plant decays. Some pesticides stay in the soil long enough to be absorbed by plants grown in a field years later (Anonymous 2009).

ENVIRONMENTAL IMPACT OF PESTICIDES IN SOIL

Adsorption

Adsorption is the binding of pesticides to soil particles. The amount a pesticide is adsorbed to the soil varies with the type of pesticide, soil, moisture, soil pH, and soil texture. Pesticides are strongly adsorbed to soils that are high in clay or organic matter. Most soil-bound pesticides are less likely to give off vapours or leach through the soil. They are also less easily taken up by plants. For this reason you may require the higher rate listed on the pesticide label for soils high in clay or organic matter (Anonymous 2009, Tiryaki and Aysal 1999).

Sorption

Sorption describes the attraction between a chemical and soil, vegetation, or other surfaces. However, sorption most often refers to the binding of a chemical to soil particles (Figure 3). Pesticides that are sorbed to soil particles are more likely to remain in the root zone where they may be available for plant uptake and microbial or chemical degradation (Kerle et al. 2007*)*.

Sorption is influenced by soil moisture, organic matter content, and texture. Pesticides are more readily sorbed onto dry soil because water competes with pesticides for binding sites in moist soil. Organic matter and clay particles both have plenty of surface area and are chemically active. Soils high in clay and organic matter, have a high potential to sorb pesticides. Clay content is also important for holding organic matter. Sand particles provide less surface area for sorption (Kerle et al. 2007*)*.

Generally, soil bound pesticides increase with time. This in turn corresponded with an idecreas in extractable residues. It means the more pesticide is binding to the soil organic matter, the more time after the application (Tiryaki et al. 1997, Tiryaki and Aysal 1999).

The sorption of a particular pesticide to a soil is measured in a laboratory by mixing water, pesticide, and soil. After equilibrium has been reached, the amount of pesticide remaining in solution is measured. The concentration of pesticide sorbed to the soil in the mixture is divided by the pesticide concentration still in solution. This yields the distribution coefficient, (K_d). Kd(L/kg) is the ratio of a chemical's sorbed concentration (mg/kg) to the dissolved concentration (mg/L). A low K_d indicates that more pesticide is in solution; a higher value indicates that the pesticide is more strongly sorbed to soil.

The K_d determined in the laboratory will vary depending on the ratio of soil to water and the chemical properties of the pesticide and the soil. For this reason, the sorption coefficient (K_{oc}), is used to compare the relative sorption of pesticides. K_{oc} is the distribution coefficient (K_d) divided by the amount of organic carbon in the soil (Kerle et al. 2007*)*. The higher the K_{oc} value, the more strongly the pesticide is sorbed, and therefore, the less mobile it is. In Table 1 dicamba has the lowest K_{oc} (K_{oc}=2) and benomyl has the highest (K_{oc}=1900). Dicamba would be the most mobile, and benomyl would be the most tightly Higher K_{oc} (greater than 1000) indicate a pesticide that is very strongly attached to soil and is less likely to move unless soil erosion occurs. Lower values (≤ 300) indicate it tends to move with water and have the potential to leach or move with surface runoff (Anonymous 2009).

Degradation or breakdown processes

Degradation is the process of pesticide breakdown after application. Pesticides are broken down by microbes, chemical reactions, and light or photodegradation. This process may take anywhere from hours or days to years, depending on environmental conditions and the chemical characteristics of the pesticide (Anonymous 2009).

Microbial degradation is the breakdown of pesticides by microorganisms such as fungi, bacteria, and other soil microorganisms. Soil organic matter, texture, and site characteristics such as moisture, temperature, aeration, and pH-all affect microbial degradation. Microbial activity usually is greatest in warm, moist, well-aerated soils with a neutral pH. Microbial breakdown tends to increase when: temperatures are warm soil pH is favourable, soil moisture and oxygen are adequate, soil fertility is good. Microbial degradation occurs at a higher rate in the surface soil horizons, particularly in areas with high organic matter. Usually, the rate decreases with depth in the soil, where conditions such as moisture, temperature, and aeration are less favorable for microbial activity (Kerle et al. 2007, Anonymous 2009).

Chemical degradation occurs when a pesticide reacts with water, oxygen, or other chemicals in the soil. As soil pH becomes extremely acidic or alkaline, microbial activity usually decreases. However, these conditions may favor rapid chemical degradation. Chemical breakdown is the breakdown of pesticides by chemical reactions in the soil. The rate and type of chemical reactions that occur are influenced by the binding of pesticides to the soil, soil temperatures, pH levels (Kerle et al. 2007***).***

Photodegradation is the breakdown of pesticides by sunlight. All pesticides are susceptible to photodegradation to some degree. The intensity of sunlight, length of exposure, and properties of the pesticide affect the rate of photodegradation. Pesticides that are applied to foliage or to the soil surface are more susceptible to photodegradation than pesticides that are incorporated into the soil. Pesticides may break down faster inside plastic-covered greenhouses than inside glass greenhouses, since glass filters out much of the ultraviolet light that degrades pesticides (Kerle et al. 2007, Anonymous 2009).

Volatalization from the soil

Volatilization is the process of solids/liquids converting into a gas, which can move away from the initial application site. This movement is called vapour drift. Vapour drift from some herbicides can damage nearby crops. Volatilization from moist soil is determined by the moisture content of the soil, and by the pesticide's vapor pressure, sorption, and water solubility. Pesticides volatize most readily from sandy and wet soils. Hot, dry, or windy weather and small spray drops increase volatilization. Where recommended, incorporating the pesticide into the soil can help reduce volatilization (Anonymous 2009). The rate of volatilization of pesticides from soil depends upon properties of the chemical and of the soil. On the other hand post-application volatilization represents further significant pesticide input into the troposphere for several days/weeks after application (Glotfelty et al. 1989).

The dominant factors that affect volatilization from soil and crops are vapor pressure, Henry's law constant (K_h**,** is defined as the concentration of pesticide in air divided by the concentration in water) and water solubility of pesticides, as well as its persistence in the soil or plant surface, and environmental conditions. K_h characterizes the tendency for a pesticide to move between the air and the "soil water." The higher the K_h, the more likely that a pesticide will volatilize from moist soil.

Of the pesticides in Table 1, dicamba, benomyl, and diuron have a low potential to volatilize from moist soil; 1,3-dichloropropene and bensulide have a higher potential to volatilize. In Table 1 K_h values have been multiplied by 10^9 (Henry's law index). In general, pesticides with K_h index values of less than 100 have a low potential to volatilize from moist soil. Pesticides with K_h index values above 10,000 have a high potential to volatilize (Kerle et al. 2007***).***

MOVEMENT OF PESTICIDES IN THE ENVIRONMENT VIA THE SOIL

Erosion

Erosion, soil particles which are transported by wind and water; pesticides attached to soil particles (Toth and Buhler 2009). WP formulations such as those used to apply atrazine and simazine in the present experiment appear to be susceptible to wind erosion when the soil is dry (Glotfelty et al 1989). Soil lost through wind erosion may transport herbicides to nontarget areas. Incorporation may reduce herbicide concentrations at the soil surface, reducing loss on wind-erodible sediment (Clay et al. 2001).

There is potential hazard of environmental transport of herbicides in windblown sediment which may have implications for air and water quality. Wind erosion events affect air quality. If dust containing pesticides is inhaled, there may be an impact on human health. If the dust is deposited in waterways, then there may be a detrimental effect on water quality. Surface applied herbicides are adsorbed to soil particles in the very shallow surface layer which is the first to be removed by wind erosion. Hence the potential for removal of surface-applied chemicals by wind erosion is much higher than soil-incorporated pesticides. Incorporation increases herbicide efficacy. Therefore, potential transport of soil-incorporated herbicides by wind is much lower than that of surface-applied herbicides (Larney et al. 1997). Larney et al. (1999) found that in their studies, overall wind erosion losses of the soil-incorporated herbicides were about three times lower than those of the surface-applied herbicides.

Wind erosion has detrimental effects on the economics of agriculture and the environment. During the dust storms, high amounts of radionuclides, heavy metals and residues of pesticides are transferred by the wind and contaminate the agrolandscapes. Research was conducted on the physical and chemical parameters of soils susceptible to wind erosion. Clay and microagregates <0.01 mm content are the main soil parameters influence the level of erodibility of soil by wind. Increase of clay and microagregates content leads to decrease of erodibility. There are many other problems caused by wind erosion which affect the environment. The behaviour of contaminants such as, remains of fertilizers and pesticides is different in various environments and perhaps depends on the binding of contaminants with soil particles. Some components of agrolandscape increase generation the dust during wind erosion and the dust then has an influence on neighbouring landscape contaminating the soils, water and other resources (Dolgilevich 2009).

Leaching

Leaching is the downward movement of pesticides in the soil through cracks and pores. Soil normally filters water as it moves downward, removing contaminants such as pesticides. Soil and pesticide properties, geography and weather can influence the movement of pesticides (leaching). Pesticides that leach through soils may reach ground water (Toth and Buhler 2009).

Soil properties (organic matter, soil texture and soil acidity), pesticide properties (solubility, adsorption and persistence), pesticide application (rate of application and application method), and weather conditions are the factors of affecting leaching.

As a summary, the behaviour of pesticides in soils is governed by a variety of complex dynamic physical, chemical and biological processes, including sorption–desorption, volatilization, chemical and biological degradation, uptake by plants, run-off, and leaching. These processes directly control the transport of pesticides within the soil and their transfer from the soil to water, air or food. The relative importance of these processes varies with the chemical nature of the pesticides and the properties of the soil (Arias-Estevez et al. 2008).

GUIDE TO REDUCE PESTICIDE IMPACTS ON SURFACE AND GROUND WATER, AND WAYS TO MINIMIZE ENVIRONMENTAL IMPACT OF PESTICIDE

Pesticides have the potential to cause harm to the environment if they are not used safely. It can also keeped groundwater free of contaminants; safeguard the health of your family, neighbors, and livestock; and ensure a clean, healthy environment by: (a) practicing Integrated Pest Management (IPM), (b) only using pesticides that are labeled for the intended crop and pest, (c) considering application site characteristics (soil texture, slope), (d) considering the location of wells, ponds and other water bodies, (e) measuring accurately, (f) maintaining application equipment and calibrating accurately, (g) mixing and loading carefully, (h) preventing backsiphoning and spills, (ı) considering the impact of weather/irrigation, (i) storing pesticides safely and securely, (j) disposing of wastes safely, (k) leaving buffer zones around sensitive areas, (l) reducing off-target drift (Reichenberger et al. 2007, Cessna et al. 2005).

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