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Potential Environmental Impacts of Herbicides used in Agriculture

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ABSTRACT

Herbicide has become the indispensible in weed control in crop production due to increase of wage rates and high unavailability of agricultural laborers. Herbicides are thought to cause many environmental and health hazards. The hazard by herbicides could be caused by its persistence in the environment and its toxic effect after reaching the site of action. The toxicity is indicated by the LD_{50} values of a herbicide and the US EPA classification of pesticides show that most of the herbicides belong to the low to none toxic category. Although some herbicides may cause cancer and other health complications but it must happen due to exposure of the people to the herbicides. This problem can be minimized to some extent by using suitable herbicides and following the appropriate herbicide handling rules. The herbicide may deteriorate soil and water quality if they persist in the environment. The persistence depends on the soil factors, climatic conditions and herbicide properties. Some research reports show that most of the herbicides used in agriculture were not present in soil, water, plant and grain after the harvest of crops. Thus, judicious selection of herbicide and its appropriate handling could help reduce herbicide related environment and health hazards.

Keywords: Persistence, Herbicides, Environmental impacts, Health hazards, Toxicity, Weed control

INTRODUCTION

Herbicides are used as an alternative method of weed control as they are less expensive, often safer, faster and sometimes more selective compared with mechanical weeding by hand or machine. The use of herbicide has recently been increased globally because of increased unavailability of agricultural laborers and higher wage rates. Herbicides are chemicals designed to kill undesired plants in a defined area. However, inappropriate use of herbicide may cause damage to crop plants, especially if too large a dose is used or if spraying is occurred at wrong time when the crop species is sensitive to the herbicide. Herbicides bring change in vegetation in the sprayed site causing changes in habitat of animals such as mammals and birds. This is especially true for herbicide treatment in forest areas. This is an indirect effect of herbicide use as it does not cause any direct toxic effect to most of the animals. Broadcasting by air craft or tractor may cause spray drift beyond the spray site or may deposit onto the intended spray area causing damage to vegetation. People spraying the herbicides may be affected by the chemicals during their spraying if herbicide handling safety rules are not followed. In addition, people may be exposed to herbicides through spray drift or residues on food, and wildlife. The activity of herbicide in the environment and its impact on animal health depends on its persistency in the environment and its toxicity to the animals. The present paper describes the effect of herbicides on environment and suggests the means to alleviate herbicide related environmental hazards.

TOXICITY OF HERBICIDE TO ANIMALS AND HUMAN HEALTH

The main intention of using herbicide is to keep weeds to below some economically acceptable threshold, judged on the basis of the amount of damage that can be tolerated to crops. Most herbicides are specifically plant poisons and are not very toxic to animals, with few exceptions such as paraquat, which is toxic to animals. However, herbicides mainly affect population of birds, mammals, insects and other animals through changes in the nature of their habitat. Herbicides causes change in structure and abundance of non-crop plants in agro-ecosystem affecting food availability of

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granivorous birds, that eat weed seeds, and the food availability of birds that eat arthropods which rely mainly on non-crop plants for nourishment and habitat.

Weed control practices bring about a major shift in the microbial population, rhizosphere and thereby in physico-chemical properties of the soil. The mechanical control keeps the field bare resulting into soil erosion caused by both wind and water. On the other hand, use of herbicides results into evolution of various volatile compounds, fumes, gases and other residues. The entry of the herbicides into the atmosphere by means of application to the soil or plants, drift during spraying and vapor is the most dangerous source of environmental pollution; however its quantity is almost negligible. Although herbicides cause adverse effect on animal biodiversity mostly through indirectly by destruction of non-crop species, there would be continued reliance on herbicide until suitable alternative weed management approach are developed. Therefore, the herbicide is an indispensible part of modern intensively managed agriculture.

Environmental Protection Agency (EPA) classifies all pesticides into general and restricted use categories. General use pesticides are those that will not cause unreasonable adverse effects on the environment and are safe for application by the general public without special training. Most of the herbicides are relatively safe to the user, wildlife and the environment and are classified as general use pesticides. The potential toxicity to the users generally is expressed by the lethal dose (LD_{50}). According to the US - EPA most herbicides fall under low and non-toxic groups [1,2].

LD_{50} is a good indicator of relative toxicity and safety. The majority of herbicides are less toxic than aspirin and DDT. For example, LD_{50} values of aspirin and DDT are 750 and 87 while the LD_{50} value of attrazine, trifluralin, butachlor are 3080, 3700 and 2000, respectively [3]. Many herbicides may cause adverse health effect due to their properties such as carcinogenicity, endocrine disruption, reproductive and developmental toxicity and acute toxicity [4], but these effects are exhibited when chemicals come to the contact to the person at a substantial amount and time. However, the toxic effect of herbicides on human health can be avoided following herbicide safety rules.

Most herbicides are less hazardous to animals and humans because of the following reasons:

1. The toxic effects of herbicides are relatively specific to plant processes. Therefore, they tend to be low in mammalian toxicity.
2. Most herbicides are susceptible to breakdown by microbes, plant tissues and physical processes. Therefore, there are few problems associated with long-term persistence.
3. Herbicides tend to be either water soluble or are susceptible to breakdown. Therefore, there is little or no build-up of herbicides or their residues in the fatty tissues of animals.
4. Most herbicides are of relatively low toxicity to fish and other aquatic organisms. Those compounds with high toxicity tend to be soil adsorbed and seldom move into water systems. Fish toxicity problems develop when chemicals are dumped or disposed of in stream or applied to ditch-banks where runoff can move large quantities of herbicide into the water.

Persistency of herbicides

The herbicides provide their actions as long they persist in the soil and environment. The effective life of an herbicide is considered as its persistence [5]. The residual life of herbicides is expressed in term of their half-life or period of persistence. Herbicides vary in their potential to persist in the soil **(Table 1)**. Longer persistency may be desirable for some long duration crops like sugarcane while short-term persistency is desirable the crops in the intensive cropping systems. Short-term persistency is desirable for escaping the phytotoxicity in the succeeding crops in the intensive cropping systems. Thus, herbicide should be selected based on the crop and cropping system. The herbicide residues may pose adverse effect on the environment by leaching to the ground water, runoff to the water bodies, may remain in the soil to cause phytotoxicity to the next crops and may cause health hazards if present in the plants and food grains. Thus, the detection of herbicide residue in the soil, water, plants and food grains needs to be done to know the potential threats by the herbicides. Sondhia [6] reported that herbicides used in Indian agriculture poses a little hazard to the environment as the residues of most of the herbicides in soil, water, plants and grains were found at lower than the safe levels. This report suggests that most of the herbicides are not much hazardous to soil, water and environment. However, the effect of herbicides depends on soil factors, climatic conditions and herbicidal properties [7].

Table 1. Persistence of some herbicides under tropical conditions in soil.

Herbicides	Persistence in soil (Days)	Herbicides	Persistence in soil (Days)
Attrazine	45-90	Metribuzin	20-100
Alachlor	60-80	Oxadiazone	56-125
2,4-D	45-90	Pretilachlor	30-60
Butachlor	100	Pendimethalin	60-200
Isoproturon	90-120	Thiobencarb	28-60

SOIL FACTORS

Soil physical, chemical and microbial factors affect the persistency of herbicides. Physical factors include soil texture and organic matter content. Chemical properties of soil affecting herbicide persistence include pH, cation-exchange capacity (CEC) and nutrient status. The microbial aspects include type and abundance of microbes present in the soil. Soil composition affects herbicide phytotoxicity and persistence through adsorption, leaching and volatilization. Soil high in clay, organic matter or both increases the potential of herbicide carryover because of increase in adsorption to soil colloids with a corresponding decrease in leaching and loss through volatilization. Thus, soil having high clay and organic matter holds the soil colloid and slows the plant uptake and herbicidal activity. Soil pH affects herbicide persistence. At higher pH, herbicide adsorption in the soil colloid is less and therefore, herbicides mainly remain in the soil solution. Herbicides available in the soil solution are available for plant uptake. Chemical breakdown and microbial degradation of herbicides are slow at higher pH. Certain members of sulfonylurea group (chlorsufuron and chlorimuron) persists for long time in higher pH soils while Low pH affects the persistence of clomazone and the imidiazolineones (imazaquin and imazethapyr). However, soil pH has little effect on the persistence of other herbicides.

The cation exchange capacity (CEC), principally a function of clay type and organic-matter content, is directly involved in herbicide absorption. There is much variation in the effects of cations and nutrients on herbicide activity and breakdown, depending on soil composition, nutrient type and concentration, and chemistry of the herbicide. Soil microorganisms are partially responsible for the breakdown of many herbicides. The type of microorganisms and their relative amount determine the speed of decomposition.

CLIMATIC CONDITIONS

Moisture, temperature and sunlight are the most involved climatic elements in herbicide degradation. Increased temperature and soil moisture enhance both chemical and microbial degradation of herbicides. Cool, dry conditions slow degradation, causing greater carryover potential. Thus herbicide persistence is less likely in warm moist winter than cool dry winter. Many herbicides are subjected to photo-degradation. The dinitroanilines (trifluralin and pendimethalin) are sensitive to light degradation. They may be lost when surface applied if they remain for an extended time without rainfall. Thus degradation is accelerated on very sunny days. This sensitivity to light and loss by volatility are primary reasons for soil incorporation.

HERBICIDAL PROPERTIES

Soil persistence of herbicide depends on its chemical properties. Important factors include water solubility, soil adsorption, vapor pressure and susceptibility to chemical and microbial alteration or degradation. The water solubility of an herbicide helps to determine its leaching potential. Leaching occurs when an herbicide is dissolved in water and moves down through the soil profile. Herbicides that readily leach may be carried away or carried to rooting zone of susceptible plants. Herbicide leaching is determined not only by an herbicide's water solubility but also by its ability to adsorb to soil particles. Additionally, soil texture and available soil water affect herbicide leaching. Herbicides that are low in water solubility, are strongly adsorbed to soil colloids, and exist in dry soils are less likely to leach and have a greater potential to persist. The vapor pressure of an herbicide determines its volatility. Volatile herbicides such as thiocarbamates (EPTC, butylate) must be incorporated immediately to avoid gases losses. The herbicides with high vapor pressure are less likely to persist than herbicides with low vapor pressure. Volatility also increases with temperature.

Herbicides vary in their susceptibility to microbial decomposition. For example, microbial degradation of 2,4-D occurs very quickly in the soil, whereas microbial degradation of atrazine is slow. Chemical decomposition of an herbicide not only depends on the chemistry of the herbicide but also on soil and climatic factors. Chemical breakdown of an herbicide involves reactions such as hydrolysis, oxidation and reduction. The speed of these reactions depends on soil type and climatic conditions. These chemical reactions along with microbial degradations are important processes in the decomposition of herbicides.

Means of avoiding herbicide carryover/persistence

Herbicide carryover problems can be overcome by the following ways.

1. Dose, method and soil type influence herbicide persistence. Thus use of correct rate and method for any herbicide for specific soil and weed problem would reduce persistence.
2. The amount of tillage affects herbicide persistence. Tillage encourages herbicide decomposition indirectly through increased microbial and chemical breakdown.
3. Herbicide combination may reduce the risk of carryover problem. Lower dose of each herbicide may broaden the weed control spectrum and potentially reduce carryover.
4. Herbicide application to the crop determines the toxicity to the succeeding crop. For example, soybean may tolerate a certain level of atrazine residue but application of metribuzon to soybean could increase injury when soybean is grown after atrazine treated corn.
5. Plants absorb herbicides from soil. The removal of plants after harvesting from the field may reduce the risk of herbicide residue carryover.
6. Use of tolerant crops in the rotation may reduce the risk of carryover problem. Generally smaller seeded crops are more likely to herbicide sensitivity than larger seeded crops.

CONCLUSION

In conclusion it should be remembered that all herbicides are poisonous to some degree and must be handles with care. In all cases, the applicator should read and consult the label for specific use and handling procedures. Good common sense always is required when herbicides are being used.

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