Effects of Weed Control on the Environment

W. A. Harvey
Extension Environmentalist
University of California, Davis

The only reason for any weed control practice is to change the environment:

- to change the environment to permit the production of food and fiber in quantities sufficient to feed and clothe our growing population.

- to provide beauty and recreation — attractive lawns, gardens, landscapes, camping sites, fishing, swimming and other outdoor sports.

- to insure safety from fire, from effects of traffic obstructions and from allergy sources — poison oak, ragweed, etc.

Control of vegetation is essential to our health, well being and enjoyment of life. And vegetation control practices change the botanical environment around us — the botanical composition of the flora, the ecology, if you like that term. This is true regardless of the methods used for control — hand pulling, hoeing, plowing, cultivating, burning, etc. It is true for biological control through the use of insects that selectively feed on plant species.

We know, then, that any successful weed control practice must affect the environment. We should expect this. Our concern is with possible effects outside the target area or on non-target organisms. Today, our principal concern is with herbicides, although we can get side effects with other control methods — soil erosion, soil compaction, air contamination with dust or smoke, etc.

We know that certain chlorinated hydrocarbon insecticides have come under heavy criticism due to:

1.) relatively long persistence in the environment
2.) biomagnification through certain organisms
3.) frequent detection in the food chain

Organic herbicides have had relatively little criticism because most of them are low in mammalian toxicity and have short persistence in the environment under most conditions. The major challenge has been the 2,4,5-T uproar which is discussed elsewhere on the program.

Let's review, briefly, what we know about environmental contamination by herbicides under four headings:

1.) Entry into the environment
2.) Persistence in the environment
3.) Residues in the environment
4.) Effects on organisms in the environment

I will list a number of pertinent references at the end of this paper for those of you who may want to go further into the subject.

1. Entry into the environment.

Herbicides, to be effective, must become an intimate part of the environment of the target plants. It is only when they move away from the target site or persist sufficiently to affect later plantings that they become a problem. Herbicides can move by drift of particles at and soon after the time of application, by volatility from a treated area, by leaching, and by surface movement through wind or water erosion.

A. Drift. Small particles produced as the spray solution leaves the nozzle may remain suspended in the air for varying periods of time depending primarily on droplet size. The distance these particles will travel depends primarily on wind velocity. In any spray operation a certain fraction of the liquid will be in small particles or droplets and some drift is inevitable. The effect of this drift depends on the herbicide involved and the proximity of sensitive plants. It should be noted that the damage, if any, is usually confined to the agricultural community and is damage to other plants, not animal life.

Our most spectacular effects of drift have come in the past from the phenoxy herbicides, particularly 2,4-D. This was due to the potency of these herbicides, the high degree of sensitivity of certain plants and the striking symptoms developed by sensitive plants exposed to even minute amounts of phenoxy herbicides. Once this hazard was fully recognized it was possible to minimize drift through proper application techniques and regulations. In recent years only occasional reports of damage from phenoxy drift have been received and these are usually the result of error or accident.

A more recent example of unpredicted drift is that of propanil, sprayed on rice for control of barnyardgrass, reportedly causing symptoms on prune trees some miles away. Again, once the problem was discovered it was possible to minimize or eliminate it. It is an example of an unpredictable development, and while these have been rare they do occur. As our knowledge of air movement and particle behavior improves there is less reason to expect such occurrences.

B. Volatility. Volatility results from movement of materials in a vapor phase from the treated area to other areas by wind or air mass movement. Some of the early forms of 2,4-D were highly volatile and could evaporate from treated fields or plants and contaminate an air mass. This problem was solved through the use of low volatile forms of 2,4-D and other phenoxy's in areas where susceptible crops or ornamentals were grown.

There has been some confusion between drift and volatility but in recent years drift has been more common than volatility and it is rare in California today to find evidence of volatility of herbicides as a cause of environmental contamination.

C. Leaching. Leaching is movement of a chemical down into the soil profile with water movement. Compounds that are highly water soluble, such as sodium TCA, leach readily with rainfall or irrigation whereas compounds such as trifluralin leach to only a limited extent. Our concern in terms of environmental contamination is not with movement in the soil itself but with vertical movement as a potential source of contamination of ground water supplies.

The amount of herbicide at different levels in the soil depends upon several factors. The soil type – sand, silt, clay, muck, etc. determines the depth of water movement in soil and consequently the depth to which any given herbicide will move. In addition the soil type has an effect through its properties for adsorption and holding molecules of the herbicide against leaching forces. Certain clays because of their structure can tightly bind certain of the triazines, and organic matter or carbon particles may retain herbicides against at least moderate leaching forces.

The amount of water entering the soil either from rainfall or irrigation and the solubility of the herbicide in water are also important factors. Even formulation of the herbicide may affect depth of movement as, for example, the amine of 2,4-D moves more readily than ester formulations.

The final factor that affects leaching is the degradability of the herbicide itself from either chemical reactions or biological agents. The more rapidly a herbicide is broken down, the less time there is for leaching.

Because of the number of factors limiting leaching we have so far found no evidence of ground water contamination from field use of herbicides.

D. Surface Movement. A final method by which herbicides might move into the environment is through surface movement by wind or water, usually with soil particles. In field experience, water has been the major element in causing such surface movement.

Factors affecting such movement include:

1.) slope or steepness of the area which affects run-off
2.) permeability of the soil
3.) amount and intensity of the precipitation
4.) formulation of the herbicide (principally solubility)
5.) rate of application
6.) vegetative cover

2. Persistence in the environment.

Herbicides, particularly soil-applied herbicides, must persist in the environment for a long enough time to provide some period of weed control. Here we are faced with something of a dilemma. In crop land we would like weed control during the growing period of the crop. But once the crop is harvested we may want to plant a different crop and perhaps one that is susceptible to the herbicide used in the first crop. So we don't want to jeopardize future crops with herbicide residues and yet we would like weed control throughout the growing period of any treated crop. We often must settle for a period of weed control during the germination and early growth of a crop and epend upon crop competition, cultivation, or repeated herbicide treatments to give season-long control. On non-crop sites we usually want at least one season of weed control per treatment.

A. Soil persistence is usually our major concern, and it is difficult to set exact values on the length of time any herbicide will remain in the soil. We know that herbicides such as the carbamates give weed control for something like six weeks whereas some of the triazines and the substituted ureas may persist for six months or more when used at crop selective rates.

Soil persistence depends on several factors:

1.) rate and formulation of herbicide
2.) soil type
3.) temperature
4.) moisture
5.) organic matter
6.) microbial activity

In general, soil breakdown is most rapid in warm, moist soils with good microbial growth. With some highly water soluble herbicides, leaching below the root zone may cause a rapid loss of immediate toxicity without actual breakdown. Cold soils, dry soils and sterile soils usually inhibit breakdown and prolong persistence.

B. Persistence in water is of concern for those herbicides used for aquatic weed control either when applied into the water itself as for submerged aquatics or when applied for emerged or ditchbank weeds when some portion of the treatment may get into canals or ditches.

There is less information on water persistence of herbicides than on soil persistence, but the literature in this area is increasing. It appears that breakdown in water is mostly microbial with definite evidence of removal from water by precipitation and by adsorption on particulate matter. There is likewise evidence of persistence in bottom mud where anaerobic conditions may reduce activity of the particular microbes responsible for decomposition.

Recent studies show only minute amounts of herbicides appearing in irrigation water from ditchbank spray operations. It would appear that careful ditchbank application of current herbicides present no appreciable hazard to downstream vegetation or crop irrigations. Treatments to the water itself have caused no reported crop loss when used as directed. Most truly aquatic herbicides do affect other aquatic organisms, however, and their use is usually confined to irrigation canals where game fish are not resident.

c. Persistence of herbicides in air has not been widely studied, although drift of 2,4-D has been reported over distances of several miles probably taking some hours of time. A study in Washington State over a period of 106 days during and following the wheat spraying season revealed minute quantities of 2,4-D in 80% of the air samples but the amount averaged in franction ug/M^3. Dilution by air mass and wash out by rainfall probably account for the disappearance of the limited amount of herbicides that get into the air, although decomposition by ultraviolet light has been suggested as an additional factor.

3. Residues in the environment.

The actual amount of herbicides in the environment has been studied in numerous monitoring surveys throughout the United States. We know, of course, that treated soils and waters contain herbicides for some period after treatment; otherwise we would not have weed control. Our concern is with the possibility of appreciable residues for long periods after treatment or the occurrence of herbicide residues in untreated or non-target sites.

Since residues are reported in terms of concentration — parts per million (ppm), parts per billion (ppb) and even parts per trillion (ppt) — it is important to recognize what these figures actually mean in amounts we can recognize. The amount of soil covering an acre, one foot deep (usually called an acre foot of soil) weighs about 3½ million pounds. Thus if we apply 3½ lbs. per acre of an herbicide and mix it throughout the upper foot of soil, the concentration will be 1 ppm. If we mix it only in the top 6 inches of soil the concentration will be higher — 2 ppm. It is the same amount of herbicide but mixed in less soil.

If we are concerned with water we should remember that water weighs 62.4 pounds per cubic foot and 8.33 pounds per gallon. Thus an acre foot of water (enough to cover an acre one foot deep) weighs about 2.7 million pounds and an herbicide application of 2.7 lbs. to an acre foot of water gives a concentration of 1 ppm. In terms of gallons, 8.33 pounds of herbicide are required to give a concentration of 1 ppm in a million gallons of water.

Some concept of the minuteness of 1 ppb can be obtained from a consideration of the population of the whole earth which is between 3 and 4 billion people. Thus 3 or 4 people represent 1 ppb of all the people on the earth today. Residue concentrations need interpretation in terms of amounts as well as concentrations!

A. Residues in soils have been monitored for some time. A detailed study in six areas over several years reported in a publication, ARS, USDA ARS 81-32, 1967, revealed only minor amounts of phenoxy herbicides. Out of 264 samples only 4 contained 2,4-D with an average concentration of 0.032 ppm. Non contained 2,4,5-T. In a series of soil samples from grain fields with a known history of 2,4-D and these at fractional ppm's. In none of these surveys has there been evidence of excessive accumulation of any herbicide in the soil environment.

B. Residues in water have likewise shown no evidence of accumulation. A monthly survey of 11 major streams in the Western U.S. in 1967 revealed no residues of 2,4-D, 2,4,5-T or silvex. A US Geological Survey of 20 sites on Western streams using refined analytical methods showed only fractional parts per billion of 2,4-D, 2,4,5-T and silvex in a limited number of the several hundred samples analyzed. Again, there is no evidence of accumulation of phenoxy herbicides in any of the studies.

C. Residue data in plants are required for registration and breakdown curves and total amounts of residues are the bases for the tolerances set. There are pages of such data in every petition for a tolerance. Spot checks by regulatory agencies rarely reveal residues in crop plants in excess of established tolerances when the use pattern has followed label restrictions. There is no evidence of excessive herbicide residues in any of our food stuffs.

D. Residues in animal products have also been monitored. In 1969, the Consumer and Marketing Service, USDA, analyzed 240 samples of red meat fatty tissue from 44 locations across the U.S. for 2,4-D. More than 96% showed no residue, with only 3 samples showing more than 0.10 ppm and none as much as 1 ppm. There is also no evidence of accumulation in milk even when 2,4-D was fed directly to lactating cows.

E. Residues in the air have had only limited study, but as indicated earlier, drift or volatility may result in air contamination for brief periods. Usually the effects are evidenced on neighboring vegetation and rapidly diminish with distance. A sophisticated study of air samples in Washington State revealed a maximum concentration of about 2 ppm of 2,4-D in the air during the spraying season but considerably less than 1 ppm as an average concentration over a period of days.

4. Effects on organisms in the environment.

Our final consideration is that of effects of herbicides on the living things in our environment. An extensive bibliography on toxic effects of herbicides to a wide variety of organisms was published by the National Agricultural Library in 1968 and many publications cover effects of specific herbicides on specific organisms.

The effects on plants have been discussed. We use herbicides to change the botanical composition of our environment. Even extensive use of herbicides has produced changes in only limited areas and I know of no plant species that has been eliminated through the use of herbicides.

With the exception of a few herbicides such as sodium arsenite and the dinitro compounds which have a high acute toxicity to animals, the majority of current herbicides must be fed in large quantity to produce any toxic symptoms. Extensive feeding tests are run on all herbicides prior to registration and the hazards, if any, are known. The only animal deaths that I can recall in the last two decades in California from herbicide use were from sodium arsenite, the use of which is now strictly regulated in California. This might be contrasted with the many livestock losses from poisonous plants over the same period. Most herbicides are rapidly eliminated from animals in feces and urine. At normal rates of application our current widely used herbicides appear to have no direct effects on wildlife or farm animals. Residues have not appeared in milk or eggs. There is no evidence of wildlife destruction although changes in cover and possibly food plants on limited areas have caused population movements to other untreated areas. There has been only limited use of herbicides in wildlife areas in California.

For man, the only toxic effects have been from the direct ingestion of herbicides for intended suicide or accidental ingestion by children as the result of adult carelessness.

In conclusion, there is no evidence that the use of herbicides in California today contributes to deterioration of our environment.

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