

HERBICIDES AND CHEMOPHOBIA

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Abstract. Data support the use of chemicals as herbicides as a low-risk procedure when compared to the human health risks caused by other every-day activities. Because of their use as defoliants, specific herbicides, such as 2,4-D and 2,4,5-T, have come to the public's attention. These chemicals have a relatively low toxicity and high biodegradability and their overall effectiveness has helped the world overcome pestilence and poverty in many areas. Contrary to the myths that surround them, herbicides do not cause cancer when applied properly.

Chemistry can be mastered from books alone only at the most elementary level. For the journey to the frontiers of knowledge, an experienced and willing master is needed as a guide.

adapted from E. Borek

Development of Chemophobia

For roughly the past two decades, scientists have been complaining about the image of chemistry beset by a biased press and irrational environmentalists. This constant whining in the midst of ever-occurring environmental "disasters" accomplished very little. It neither aided the misinformed public on complex science issues nor slowed down the all-too-eager journalists seeking sensationalism to sell their news. Lately, however, chemists with sound scientific evidence are becoming involved in the dissemination of information so that the public can make better choices on the risks versus the benefits of chemical use.

For centuries, the chemist has been portrayed as a cold, calculating person, but this image never seemed to arouse a "fear-of-chemicals" syndrome until the appearance of *Silent Spring* in 1962 (5). In this book the initial pesticide/herbicide scare was presented. After its publication, even the most uninformed person could recognize places and names such as Times Beach, Love Canal, Bhopal, acid rain, asbestos, radon, PCBs and so on. The list goes on interminably and is recognized by a majority of the public as disasters caused by technology and science—specifically, chemistry. This fear of chemistry and the development of

chemicals was described most recently in the article, "Chemophobia," by Kauffman (9). Many of the concerns and thoughts expressed by Kauffman are expanded on and reinforced by this presentation.

Necessary at this point is informing the public and the public servants (politicians) of the real risks involved in using specific chemicals. This task can be accomplished by supplying strong scientific information to compete with information used to develop the perceived risks which have been supported by news media misinformation.

It is well known that one aspect of determining the risk of a particular chemical is hazard identification. This aspect requires epidemiological studies, animal bioassays, in-vitro effects, and comparison of molecular structure. Added to this hazard identification are dose response, exposure, and risk characterization; only after these complicated procedures can one arrive at a reasonable risk assessment. It requires only common sense to recognize that epidemiological studies, which are the most convincing evidence of human risk, may not be available.

In addition, animal assays, as well as in-vitro tests, are not always applicable to the human experience. Benarde's text provides a clear description of the factors involved in risk assessment as well as providing tabulated data for many of the so-called "environmental hazards" as related to every-day experiences (2). It is written in such a way that most of it can be understood by the lay person, and it includes a multitude of scientifically sound references. Benarde contends that the safety of an event, chemical or otherwise, is an individual choice and that the only thing scientists can provide is a risk assessment.

Therefore, it is imperative that the public be properly informed in order to make personal choices. For proper choices to occur, responsible scientists should present the risk assessment

1. Presented at the annual conference of the International Society of Arboriculture in Philadelphia in August of 1991.

data to the public through as many forums as possible, including radio, television, newspapers, periodicals, professional conferences, local community groups, and more. Only then will the feeling of helplessness conveyed to the public by misinformed emotional environmentalists, various government organizations, and mass media sensationalists be squelched.

To put things in perspective—the risk of cancer from the pesticide DDT cannot be assessed with accuracy since no cases of cancer caused by DDT have been documented. This is true even though DDT is known to cause cancer in mice, and many industrial workers have been exposed to greater concentrations than the average person. To put it bluntly—scientific risk assessment data conclude that the risk of dying from cancer over a lifetime from exposure to pesticides at or below the world and federal standards is one in 100,000 to one in 1,000,000.

Toxicity: Science or Myth

All chemicals, natural and synthetic, are toxic—it simply depends on the dose. Several myths exist concerning toxicity: the first is that artificially made chemicals, not naturally occurring chemicals, are toxic; the second is that toxic chemicals are carcinogenic, and the third is that certain chemicals used for generations, such as table salt and aspirin, are much less toxic than herbicides or pesticides. These three statements are erroneous and are the result of misinformation. If one compared the LD₅₀ values for a variety of chemicals (Table 1), it is obvious that even table salt has a toxicity on the same order of magnitude as certain herbicides; in fact, calcium chloride, a chemical commonly used to wet road surfaces, is more toxic than most chemicals.

The amount of material in milligrams of substance per kilogram of body weight administered orally to white rats (and that kills fifty percent of them) is termed the LD₅₀ value. The lower the LD₅₀ value, the more toxic the substance. To most of the public, the number is meaningless. What people want to know is whether or not they will get cancer if exposed to it. Although this may seem obvious to some, the public must be informed that the toxicities of a substance and its cancer causing potential in

Table 1. Acute toxicity of selected pesticides

Pesticide	LD ₅₀ mg/kg (white rats-oral)
picloram	8200
atrazine	3080
DDD	3000
malathion	2800
sodium chloride	2500
carbaryl (Sevin)	540
2,4-D	500
2,4,5-T	300
cupric sulfate	300
rotenone	132
DDT	113
calcium chloride	88
dieldrin	60
nicotine	55
parathion	10

animals or humans are not directly related.

Three essential pieces of information are necessary for understanding the effect of chemicals on human health: the toxicity data on animals, the carcinogenic data on animals, and the epidemiological data on humans. Only the last piece of information is realistic and, unfortunately, is not always available. Herbicides 2,4-D and 2,4,5-T are specific examples in which all data are available.

According to Reuber, there can be little doubt that these herbicides cause various kinds of cancer in animals although the inevitable presence of dioxin impurities was not eliminated as a cause (15). Reuber's implication, however, is unrealistic in stating that any evidence which indicates the induction of cancer in male and female rats by a specific chemical is sufficient to ban its use in the environment and that a zero level is the only level to be tolerated. If zero tolerance level were enforced, the world would need to ban many of its food products which contain chemicals that cause cancer in laboratory animals at lower dosage levels than those observed with 2,4-D and 2,4,5-T.

In Jay Lehr's manuscript *Toxicological risk assessment distortions*, he deals most eloquently with this issue (11). With specific examples, such as EDB fumigant studies on rats, he illustrates the fallacy of relating chemically induced cancer in

laboratory animals to a similar prognosis in humans. Lehr has been a leader in formulating a Safe Drinking Water Act and goes to great lengths to show the ridiculous use of the laws to "rile the public into an atmosphere of unnecessary fear."

In addition to toxicological data and the observed chemically induced cancer in male and female rats, epidemiological data on 2,4-D and 2,4,5-T were obtained from Wolfe's studies on Vietnam veterans (17). This work concluded after a twenty-year assessment that there was no increase in melanoma and systemic cancer when compared to the general population. With this evidence in hand, it is improbable that the general public, who are exposed to an order of magnitude less than the exposure to Vietnam veterans, would suffer any significant health risks.

Environmental Concerns

The mention of herbicides and the environment elicits an immediate negative response from the average person. A July 1991 spill of weed killer (methamsodium) into the Sacramento River and its subsequent entry into Lake Shasta have only fueled the fire of environmentalists. People fail to ask what the risks and benefits are when confronted with this mass media information.

The benefits of weed killers are substantial and the adverse effect of weeds on the public is staggering. Loss of 2 million acre feet of water per year at a cost of \$100 million/year because of excessive weed expansion, as well as the loss of work days due to poison ivy and other poisons, are only a few of the many situations documented by Chandler (6). The estimated monetary loss in vegetable crops annually from 1975 to 1979 was approximately \$600 million.

If one considers field crops, fruit crops, and others, the monetary loss is enormous. What would be the effect of eliminating chemical herbicides as part of weed-control technology? Common sense dictates that it would be disastrous to American food production capability. Does this mean that farmers should apply a greater tonnage of herbicide? The obvious answer is no.

More research is necessary to determine the type of technology needed to control weeds, especially those that have become resistant to cer-

tain herbicides. LeBaron and McFarland have tabulated the weeds that have become resistant, and they point out that this area of research needs to be understood so that the development and control of weed-resistant genes can be part of the future course of agricultural management (10). This is not to say that chemicals should be eliminated as a method of control, but that more than one method must be available to maintain pest management.

Of major concern today is the persistence of herbicides in the environment. The transformation or degradation of herbicides to CO₂ and small harmless molecules has been studied. Smith documents the herbicide classes and their degradation products (16). He concludes that studies on newer herbicides are better documented than those on older herbicides and that more studies should be done on the transformation of chlorinated anilines, amides, ureas, and thiocarbamates.

Since herbicides represent the largest amount of pesticide use today, particular attention has been paid to their toxicity. It can be said with only few exceptions that herbicides are essentially non-toxic to humans; however, because of their appearance in small amounts in water, concern has developed over long-term exposure.

What must be clarified is that a one-time exposure at a non-toxic level to a toxic chemical is not always detrimental and bioaccumulation or storage is a misunderstood concept. Ottoboni explains how the body can and does reduce storage as the exposure level is reduced and she explains clearly how the dose level makes the poison (12). There can be no doubt that even the so-called "safe" chemicals can kill at high dose levels.

It should also be made quite clear that the dose level received by the average person from environmental contamination is well below the toxic level for all herbicides used. This is not to say that the use of herbicides is completely safe. To be fair to the anti-chemical side, accidental poisoning and chronic, long-term exposure cause health effects. Pimentel has documented an enormous amount of information on ecological and social costs, as well as the economic impact of reducing pesticide use (13).

Health Effects

Everything people do in life involves some risk. What is the real risk associated with the use of herbicides? Because of the lack of epidemiological data on most herbicides, it is impossible to determine the real risk as compared to other daily activities. A look at acute toxicity data as illustrated in Table 1 would predict that only those people who are directly involved with the preparation and application of specific herbicides (high exposure levels) are potentially at risk. Again, Pimentel attempts to assess the environmental and social costs of pesticide misuse and overuse (14). Although his references show health risks with massive levels of exposure, very little risk is associated with low-dose exposure to herbicides.

The most important concern to the lay person is whether or not he or she will get cancer from exposure to herbicides in drinking water, in the air, or in the food supply. No simple yes or no can be given. Presently, scientists are arguing and trying to decide what level of substances causes cancer in humans. Because science does not use humans in experimentation, the real answer is impossible to know.

Scientists use a battery of chemical tests and animal studies to evaluate a particular chemical. If a chemical fails any of the tests, it is labeled as mutagenic, tetratogenic, or carcinogenic. Once a chemical is tagged with one or more of these terms,

it is doomed. "Environmentalists" insist on zero-level concentration; government regulators dictate unrealistically low-level tolerance based on the assumption that if a high level causes ill effects, a low dose will cause the same illness in a linearly reduced manner. As it turns out, if this were true, humans would be in extreme danger from natural chemicals in food. Ames, who developed chemical tests for carcinogenicity, points out that many chemicals in food show a greater tendency to cause cancer than most of the artificially made chemicals, and he estimated that humans are exposed to 10,000 times more natural than synthetic pesticides (1). Table 2 gives several examples of natural carcinogens.

Although not the subject of this paper, many halogenated chemicals made in nature are structurally related to artificially produced herbicides and are released at quantities that far exceed the amounts released into the environment by industrial chemical companies. This does not mean that these chemicals are harmless; in fact, many of the naturally occurring chemicals are more toxic and harmful to humans than the most toxic substances made in laboratories.

The question still remains: what about herbicides? Bond, et al., reported epidemiological studies on phenoxy herbicides and cancer which included data from Sweden, New Zealand, and the United States (3). They stated that "the total weight

Table 2. Some natural rodent carcinogens

Carcinogen	Source	ppm
5-/8-methoxypsoralen	parsley	14
	parsnips	32
sinigrin (converted to allyl isothiocyanate)	cabbage	35-590
	cauliflower	12-66
	brussel sprouts	110-1560
d-limonene	orange juice	31
caffeic acid	apples, carrots, celery	50-200
	cherries, eggplant, grapes, lettuce, pears, plums	
	potatoes, coffee	1800
	apples, apricots, broccoli	50-500
neochlorogenic acid (converted to caffeic acid)	brussel sprouts, cabbage	
	cherries, kale, peaches pears, plums	

of evidence currently available does not support a conclusion that the phenoxy herbicides present a carcinogenic hazard to humans." In an earlier work by Bond, which studied 878 chemical workers exposed to 2,4-D between 1945 and 1983, the following conclusion was reached: "There were no patterns suggestive of a causal association between 2,4-D exposure and any particular cause of death" (4).

The last important consideration is food chain accumulation which could pose health effects because of concentration that could reach toxic levels. Isensee has documented many studies which have been done on bioconcentration factors (BCFs) (8). Most of the existing herbicides have short half lives and therefore low BCFs. Since there are no examples of food chain accumulation of herbicides at this writing, it is highly unlikely that this phenomenon will be of concern in the future because the trend is to use chemicals with very short half lives and to apply less herbicide in conjunction with alternative methods of weed management.

Summary

There are risks for everything humans do to sustain existence, and therefore, there is a health risk for the use of herbicides. All chemicals are toxic and ingestion of large quantities of herbicides can cause illness and death; however, the risk of this occurring is very low. From the current documented literature, there exist no causal cancer links in humans from exposure to herbicides. When applied in a responsible manner, herbicides pose little or no threat to humans or animals. Because of a recent syndrome known as "Multiple Chemical Sensitivity", described by Hileman, (7) the judicious use of all natural and artificially made chemicals is a wise decision.

Literature Cited

- Ames, B.N., Profet, M, and Gold, L.S. Proc. Natl. Acad. Sci. U.S.A. 87: 7777.

- Benarde, Melvin A. 1989. *Our Precious Habitat*, John Wiley and Sons New York.
- Bond, G.G., Bodner, K.M., and Cook, R.R. 1989. *Fundam. Appl. Toxicol.* 12: 172.
- Bond, G.G., Wetterstroem, N.H., Rousch, G.J., McLaren, E.A., Lipps, T.E. and Cook, R.R. 1988. *Brit. J. Ind. Med.* 45: 98.
- Carson, R. 1962. *Silent Spring*, Faucett, Greenwich, CT.
- Chandler, J.M. 1991. Estimated Losses of Crops to Weeds in the CRC Handbook of Pest Management in Agriculture, Vol 1, CRC Press, Inc., Boca Raton, FL.
- Hileman, B. 1991. *Chemical and Engineering News* 69(29): 26.
- Isensee, Allan R. 1988. *Bioaccumulation and Food Chain Accumulation. Environmental Chemistry of Herbicides*, Vol. II, ed. R. Grover CRC Press, Inc., Boca Raton, FL.
- Kauffman, George B. 1991. *Chemistry in Britain* 27 (6): 512.
- LeBaron, H.M. and McFarland, Janis. 1990. *Herbicide Resistance in Weeds and Crops*, In ACS Symposium Series Managing Resistance to Agrochemicals, the American Chemical Society, Washington, DC.
- Lehr, Jay H. 1990. Toxicological risk assessment distortions, the American ground water trust, from the journal *Ground Water*, January through June.
- Ottoboni, M. Alice . 1984. *The Dose Makes the Poison*. Vincente, Berkeley, CA.
- Pimentel, David, et al. 1991. *The CRC Handbook of Pest Management in Agriculture*, Vol. II, Boca Raton, FL.
- Pimentel, D. 1991. *Chemistry in Britain*, 646 July.
- Reuber, Melvin D. 1983. *The Science of the Total Environment* 31: 203.
- Smith Allan. 1988. *Environmental Chemistry of Herbicides*, Vol. I, ed. R. Grover, CRC Press, Inc., Boca Raton, FL.
- Wolfe, W.H. et al. 1990. *J. Amer. Med. Assoc.* 264: 1824.

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Résumé. Les informations appuient l'emploi de substances chimiques comme étant une procédure à faibles risques pour la santé humaine en comparaison avec les activités de tous les jours. En raison de leur utilisation comme défoliants, des herbicides spécifiques, comme le 2,4-D et le 2,4,5-T, ont été portés à l'attention du public. Ces composés chimiques présentent une toxicité relativement faible et une biodégradation élevée, et leur efficacité d'ensemble a aidé le monde à triompher de la peste et de la misère en plusieurs régions. Contrairement aux mythes les entourant, les herbicides ne causent pas de cancer lorsque appliqués correctement.