REVIEWING SOME ORIGINS OF PESTICIDE PERCEPTIONS

Robert Krieger, Extension Toxicologist, University of California, Riverside and winner of the American Chemical Society's International Award for Research in Agrochemicals at the 229th National Meeting March 13 – 17, 2005 in San Diego, California summarises his award lecture in which he described the origins of public perceptions of pesticide risk and the difficulties associated with countering these views

Keywords
pure food, DDT, risk perception, exposure, arsenic, lead, pesticide residue, pesticide illness

Spectacular benefits have been derived from chemical technologies in medicine, agriculture, pesticides, nutrition, and the manufacturing of an immense variety of industrial products and consumer goods. In recent times, benefits have often been blurred by hypothetical risks. The schism between common experience and the perceived threat of adverse effects affects no class of chemical technologies more than pesticides. Public perceptions of risk have been studied for more than 25 years, and in those studies pesticide use has consistently been scored as among "risky activities" (Slovic, 2001).

Origins of that perception are not easy to identify. Slovic (2001) suggests Rachel Carson's *Silent Spring* and the characterization of pesticides as "elixirs of death" played a major role. Perhaps, but that alone was not enough. Carson characterized pesticides as follows: "They have immense power not merely to poison, but to enter the most vital processes of the body and change them in sinister and often deadly ways." The impact of *Silent Spring* with respect to pesticide use must not be overestimated – still most persons have not read the book and utilize poorly informed media personalities to form their dire perspectives.

As powerful as Carson's words were in moving the US into an intense era of Environmentalism, there seems to be more to the story. What occurred during the preceding years? Can additional events be identified that made persons so receptive to *Silent Spring*? Several factors attract attention and warrant consideration as contributing causes of uneven perceptions of pesticide technologies.

Pesticides

No other group of chemicals is used so extensively as part of a continual human struggle to maintain a balance of advantage over competitors for food, fiber, and health and welfare. The thousand plus active ingredients designated pesticides include (1) any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest, and (2) any substance or mixture of substances intended for use as a plant growth regulator, defoliant, or desiccant. Application of pesticides is inevitably associated with a measure of direct or indirect exposure; however, when the amounts of exposure are benign, the exposures should be considered chemical exposures rather than "pesticide" contact (Krieger *et al.*, 1992). The simple definition of the pesticide class and the reality of exposure are not sufficient to generate health concern, but, in cases where the purity of the food supply, drift, and control of disease vectors is concerned, persons frequently express concern that, from a scientific perspective, bears little or no relation to the possibility of harm.

Early Pesticide Residues

During the second half of the 19th Century, economic conditions resulted in the emergence of a rapidly growing national agriculture. Pesticide use became more common, and concerns existed about possible health effects of fruit and vegetable pesticide residues. The chemicals of concern were primarily arsenicals.

A. J. Cook of Michigan reported results of the first official tests of arsenicals that considered consumer exposure in 1880 (Porter & Fahey, 1952). Cook concluded that Paris green and London purple did not represent a danger to health. Eleven years later C. P. Gillette at the Iowa Agricultural Experiment Station also studied arsenicals on food and concluded that an individual would have to eat 30 cabbages dusted with Paris green to get enough arsenic to cause illness. Such projections serve to confirm the presence of residues to those who are opposed to pesticide use, and reinforce the pro-pesticide positions of those already convinced of their value. There are probably few cross-overs based upon such common sense data.

A more extensive pesticide residue survey was conducted 1915 to 1919 in response to intensified patterns of insecticide use by the Bureau of Chemistry enforcing the Federal Foods and Drugs Act. Hundreds of samples of peaches, cherries, plums, apples, pears, grapes, cranberries, tomatoes, celery, and cucumbers were tested for lead, arsenic, and copper. Little chemical residue remained on produce treated according to standard recommendations of the Department of Agriculture, but other samples treated with excessive amounts or too close to harvest had higher residues. The possibility of cumulative effects over a period of time also emerged in discussion of the significance of food residues at this time.

Trace residues remain a characteristic of food protected with pesticides in both organic and conventional farming. Both practices can be associated with pesticide residues. In both cases, the dose associated with ingestion of residues are a small fraction of toxic levels. Systemic toxicity is not an issue; nonetheless, some persons opt to purchase organic foods as part of a fad that has only perceived benefits.

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The Food and Drugs Act of 1906

There were major new trends in American life at the beginning of the 20th Century, particularly the move toward urban life and increasing federal regulation. Urban workers and families did not agitate for passage or enforcement, but some of their protectors launched strong protests. Coppin and High (1999) relate several important observations concerning the 1906 Act. No public outcry over food was ever heard. Further, there was no general outbreak of disease or death from food in the cities. The authors suggest that the impetus for the food purity movement came from "food commissioners, agricultural chemists, manufacturers of expensive foods, representatives from rural agricultural states, and a small number of middle-class women" representing the professional classes.

Harvey W. Wiley, M. D., who championed pure food and served as Chief of the Bureau of Chemistry, Department of Agriculture, barely mentioned arsenic residues on apples in two popular 1907 and 1911 editions of *Foods and Their Adulteration*. The book described the history, preparation, and subsequent adulteration of basic foodstuffs. Wiley presented pesticide residues as an unavoidable accompaniment to the necessary practice of spraying fruit, and implied they were of little consequence for health (Whorton, 1974).

Still there was much controversy regarding purity of the food supply. Ruth deForest Lamb (1936) later considered that weak laws, rather than enforcement, limited government's ability to prevent harmful effects of foods, drugs, and cosmetics. The longest chapter of *American Chamber of Horrors* (1936) was entitled, "How Much Poison is Poisonous." Lamb highlighted the history of apple-spray regulations that were dominated by political and economic factors. Again, the times did not feature a general outbreak of disease linked to arsenical spray programs, but concern about acute arsenic and lead had been better defined.

DDT

DDT, the first of the chlorinated organic insecticides, was originally prepared in 1873, but it was not until 1939 that Paul Muller of Geigy Pharmaceutical in Switzerland discovered the effectiveness of DDT as an insecticide. He was awarded the Nobel Prize in medicine and physiology in 1948 for this discovery. DDT was perceived as a "wonder drug." "DDT – Our War Famed Bug-Killer." In 1946, the Nebraska Farmer reported, "After winning a glorious victory during the World War II over the insidious insect foes of G. I. Joe, DDT has shucked its military clothes, wrapped up its world-wide service bars, and come back home to take over the No. 1 spot in America's bug battle Ganzel, (2005)." Still DDT's greatest use was in public health for controlling malaria. There were several particulars including the following: 1) kill of a "broad spectrum" of insects, 2) environmental persistence so it did not have to be reapplied too often, 3) low water solubility to minimize wash off, 4) relatively cheap and easy to apply. Uses multiplied in urban and agricultural settings, DDT was ineffective against some pests and some flies became resistant, and residues in milk became an important regulatory issue by 1949. Later, DDT became a "dreaded environmental pollutant" and, in spite of volumes of scientific evidence, DDT was banned about 20 years later by the Environmental Protection Agency. Biomagnification, long persistence in the environment and carcinogenicity became perceived general attributes of pesticides in the minds of some persons.

Premarket Toxicology and the Delaney Clause of the 1950s

The wholesomeness of the food supply and the need for premarket testing was perceived as a particularly important responsibility of the Department of Agriculture. In 1954, the "Miller amendment" to the Food, Drug, and Cosmetics Act required toxicity and residue by the manufacturer of any new pesticide to be used as the basis for a residue tolerance. A Select Committee of the House of Representatives chaired by James Delaney of New York published policy in 1958 about regulating chemicals added to the food supply. The clause specifies: "No additive shall be deemed to be safe if it is found to induce cancer when ingested by man or animal, or if it is found, after tests which are appropriate for the evaluation of the safety of food additives, to induce cancer to a greater percent in man or animal." Testing protocols have been continually evaluated and modified during the subsequent 50 years. Toxicity data have proliferated at a remarkable rate, but their usefulness for pesticide safety evaluation is highly variable .

How does the public perceive testing? Men (49%) and women (35%) were in general agreement about animals being predictors of human reactions to chemicals, but when animal testing found evidence of cancer, higher agreement about cancer predictability was reported by both men and women (ca. 70%) (Slovic, 2001). However, when toxicologists were asked to respond to the same pair of questions, they expressed less confidence in the predictability of carcinogenicity from animal tests. These observations seem to illustrate an important difference in the interpretation of testing between toxicologists and the public (Slovic, 2001). In some cases testing may intensify concern, rather than mitigate it, by clarifying chemical determinants of disease.

Possible cancer hazards have been the most debated health issue related to pesticide use for more than 50 years. The public perceives pesticides in food are a serious cancer risk (Opinion Research Corp., 1990) in spite of epidemiologic studies that indicate the major preventable risk factors are smoking, dietary imbalances, endogenous hormones, and inflammation (chronic infections) (Gold *et al*. 2001). Ecological correlations, indirect exposure estimates, small sample size and lack of control are confounding factors. In spite of the considerable research, including many lifelong carcinogenicity tests of pesticides, none is listed as a human carcinogen (NIEHS, 2005). Given dose and exposure time considerations, that situation is unlikely to change. This is remarkable given the lay perception of the link between pesticide toxicology and carcinogenicity (Slovic, 2001).

Cancer and food emerged as a public issue in the

Cranberry Scare of 1959 that resulted from sensitive chemical analysis and inept risk communication. The scare evolved from the occurrence of minute levels of aminotriazole herbicide — a chemical in the total diet at 0.5-1% that produced thyroid cancer in rodents. At a press conference, the Secretary of Health, Education & Welfare urged consumers "to be on the safe side" and to refrain from buying "contaminated" cranberries. The comparable human dose was daily consumption of 15,000 pounds of tainted cranberries per day for several years — the human risk of cancer, if not zero, was very close to it. This episode marked the emergence of the modern wave of "chemophobia." It predated *Silent Spring* by three years and had a substantial impact on food and environmental safety.

Other events of the late 1950s and 1960s, including the recognition of global transport of radiation from atmospheric nuclear weapons testing, thalidomide phocomelia in Europe, the environmental occurrence of chlorinated hydrocarbon insecticides, sanctions against chemicals as carcinogens based on rodent testing, and oil spills, contributed to growing environmental fear and anxiety.

Rachel Carson

The above actions predated Rachel Carson's polemic and seem to include some factors that often cause some persons to be remarkably wary of pesticide technologies. The major challenge to public confidence in chemical technologies came from the 1962 publication of *Silent Spring*. Rachel Carson's book launched public and regulatory furor, and it ultimately earned recognition as a landmark book of the 20th Century. She made many unscientific claims regarding pesticide exposure and the biological fate of pesticides, particularly DDT. Carson promoted public skepticism by casting synthetic chemicals as "Elixirs of Death", and her "load of toxic chemicals" was perceived as a biological dead end rather than subject to dynamic processes of exposure and elimination.

Recently modern day chemophobes have popularized the "body burden" concept as a health risk. Measures of body burden are said to reflect health status or the susceptibility to disease. The Center for Disease Control and Prevention (2005) has recently published a listing of 148 chemicals in urine and/or blood. More than half of the listed "Pesticides" are actually metabolites of environmental origin or breakdown products in blood or urine. As a result of this misclassification, CDC findings are not "pesticide body burden." The chemicals detected by CDC in trace amounts in blood or urine, excepting lead and urinary cotinine, are best regarded as trace chemical signatures of 21st century life rather than as a signal of a risk to health.

Current View of Pesticides and Human Health

What about alleged human mortality and morbidity? Is pesticide use as high risk as regarded in the minds of many and much public policy? There is no objective means to clarify the issue, but review of human illness data can be used to establish an indication of their relative threat to health within the chemical domain. Case definitions will differ, but each of the sources of exposure or illness and injury data contain extensive data for persons seeking more details. Three examples will be considered here.

Table 1. Unintentional Injuries at Work by Industry in the US

Injury Division	Workers x 10^3	Deaths 2003	Deaths per 10^5 Workers
Agriculture	3,340	710	20.9
Mining	539	120	22.3
Construction	9,268	1,060	11.4
Manufacturing	17,708	490	2.8
All industries	138,988	4,500	3.2

National Safety Council, 2004

Table 2. Leading Causes of Death in the US: Unintentional Injuries Including Poisoning

Cause	Number	Deaths per 10^5 Deaths
All unintentional injuries	101,537	35.6
Motor-vehicle	43,788	15.4
Falls	15,019	5.3
Poisoning	14,078	4.9
Pesticide	7	0.0025
Choking	4,185	1.5
Drowning	3,281	1.2
All other	21,186	7.4

National Safety Council, 2004

National records of extreme unintentional injuries are regularly collected by the National Safety Council (2004). Unintentional injury deaths in the US numbered 101,500 in 2003 and 103,500 in 2002. Table 1 lists the top 4 leading causes of unintentional injury deaths including agriculture. Discussions of the potential health impacts of pesticides frequently list agriculture without citation of the actual contribution of pesticides to deaths in agriculture. The 710 deaths attributed to agriculture in 2003 resulted in a rate of 20.9 deaths per 100,000 workers. Since there were a total of 7 pesticide deaths in all occupations (Table 2), pesticide use in agriculture accounts for a small fraction. Taken in context, those deaths are a measure of real (as opposed to theoretical) risk from pesticides (Ross *et al.*, In press)

Pesticide deaths are particularly remarkable when taken within the context of all unintentional injuries (101,537). This category includes motor vehicles, falls, poisoning, choking, drowning, and all other miscellaneous causes. The poisoning deaths included only 7 attributable to pesticides. Hazards of pesticide exposure from animal testing are not represented under conditions of pesticide use.

Pesticide illness and injury surveillance provides a means to assess their impact on human health. California has collected such health data for about 50 years (DPR, 2004). The state's agriculture is the largest in the nation and utilized 151 to 203 hundred million pounds of active ingredients annually from 1999 to 2003. Mortality and morbidity data are included in a detailed annual report and are used here as an index of health. Data from the last 5 years demonstrate

Table 3. Five Year Summary of California Pesticide Illness and Injury Data Classified by Definite, Probable, and Possible Exposures[1]

		Relationship of Illness or Injury to Pesticide Exposure					
		Definitely or Probably			Possible		
Year	Total cases	Cases	Hospitalized	Lost work time	Cases	Hospitalized	Lost work time
1999	1,629	830	32	126	371	2	51
2000	1,144	637	33	144	256	3	51
2001	979	430	27	78	186	2	25
2002	1,859	924	19	106	291	6	42
2003	1,232	614	8	70	188	1	42

[1] *Definite: Signs and symptoms would be expected from exposure described. Probable: Close correspondence. Possible: Some correspondence.*

year-to-year variability, and the outcomes of cases definitely-probably and possibly related to pesticide exposure (Table 3). Data such as these have had a significant impact on pesticide policy-making in California and at the national level.

The health issue can also be scaled by review of accidental poisoning and exposure data of the American Association of Poison Control Centers (Watson *et al.,* 2003). The case definition is extremely broad to capture "informational" telephone inquiries as well as cases involving contact and absorption of chemicals, including pesticides. A very small percentage of over 2.4 million Human Exposures Cases reported result in hospitalization or medical follow-up. Table 4 includes substances involved in pediatric cases (children under 6 years of age) that accounted for 52% of all cases. Of 1.2 million pediatric cases, pesticides ranked 8th among 15 categories, behind plants and ahead of vitamins. The listing clearly indicates that availability rather than hazards dictates the rank order of causes of exposure cases in children.

Recognizing Perspectives on Risk Assessment

With the above issues and events as background, it is not surprising that pesticide use is often contentious whether food, agriculture, residences, rights-of-way, or public health are involved. The divisions among personal viewpoints are not easily described, but a simple classification scheme may be used to distinguish views on chemical exposures. The scheme for recognizing perspectives on risk assessment (Fig. 1) captures several concepts developed by Slovic (2001) in his pioneering work on risk perception.

Table 4. Substances Most Frequently Involved in Children Under 6 Years-of-age

Substance	Number x 10^5	Per Cent
Cosmetics and personal care products	1.7	13.4
Cleaning substances	1.2	9.7
Analgesics	1.0	7.8
Foreign bodies	0.92	7.4
Topicals	0.92	7.4
Cough and cold preparations	0.68	5.5
Plants	0.58	4.6
Pesticides	0.51	4.1
Vitamins	0.45	3.6
Antimicrobials	0.35	2.8
All other	1.5	11.2
Total	12.5	–

American Association of Poison Control Centers, 2003

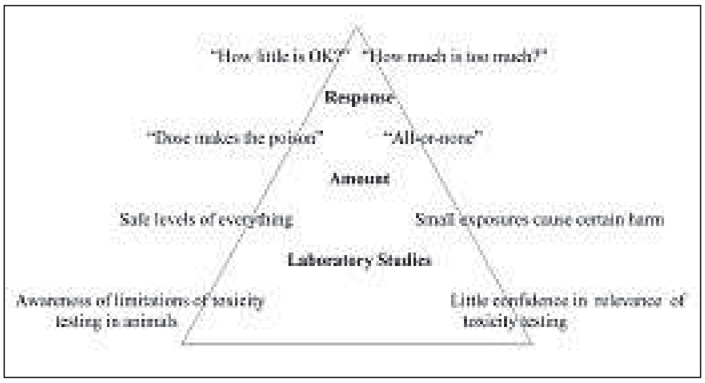

Figure 1. Views of Chemical Exposures

Persons in the pro-chemical technology sector focus upon the reality of exposure and "How little is OK?" In doing so, they subscribe to the fundamental principle of "Dose makes the poison" or there is a safe level of everything. These issues also include the reality that animal testing is a means to obtain information about potential health effects in humans.

Others take a negative, more arbitrary position in their opposition of use of chemical technologies, pesticides in particular. The central question is "How much is too much?" This is a much more narrow question than it first appears since "All or none" responses are envisioned if exposure occurs. Traditionally this question concerned the magnitude of exposure, but more recently small exposures are linked to certain harm demonstrated by rudimentary hazard identification studies. In that case, results of hazard identification studies are adopted as an endpoint of concern with little or no regard for dose and the likelihood and magnitude of human exposure. This position is capped by lack of confidence (Slovic, 2001) in the relevance of testing to human health.

Conclusion

Here some factors have been considered that seem to erode confidence in the relative safety of pesticides, the most thoroughly tested chemical technology in common use. As was the case of the pure food movement about 100 years ago, there has been no general outbreak of disease or death from either food or pesticide exposure. The potential for adverse effects of pesticides when used as directed is minimal, but it is continually overestimated by most persons. Better understanding of the general uncertainties surrounding development, regulation and use of pesticides would probably have substantial benefits.

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Robert Krieger is an Extension Specialist in Toxicology, Department of Entomology, University of California, Riverside, California. Baccalaureate and Ph. D. degrees were obtained at Pacific Lutheran Univ. and Cornell Univ. He is a fellow of the Academy of Toxicological Sciences. Residential and agricultural human pesticide exposure is studied in diverse settings using whole body dosimetry and biological monitoring. Public communication of fundamental toxicology of natural and synthetic everyday chemicals presents a continual challenge in risk communication.

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