PESTICIDES AND TOXIC SUBSTANCES IN THE ENVIRONMENT[1]

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Abstract. Uses of pesticides have been regulated under the authority of the Federal Insecticide, Fungicide, and Rodenticide Act since 1948. In 1972, the Act was amended to include particular emphasis on the protection of public health and the environment. One result of these amendments has been an increased awareness of monitoring activities. Monitoring data are critical factors in an exposure assessment and thus are important elements in quantitative evaluations of hazard and risk. Monitoring is a general term used to describe a wide variety of efforts. Basically, monitoring is an activity in which specimens of selected human and environmental components are sampled and then analyzed for evidence of chemical residues indicative of potential human, animal, or plant exposure.

Human and environmental monitoring programs for pesticides and selected toxic chemicals have been conducted for over 15 years. The initial ambient monitoring systems were designed to determine average concentrations of pesticides and related chemicals in human and environmental media on a nation-wide basis and determine changes in these concentrations over time. The results of these surveys showed that almost all of the general human population and various environmental components contained low concentrations of organochlorine pesticides. After the Environmental Protection Agency restricted many uses of certain chlorinated pesticides, the organophosphorous and carbamate insecticides which replaced them and some other commonly used pesticides were not as easily monitored by ambient surveys. Special monitoring studies had to be done more frequently to produce data on these compounds which were not as persistent or accumulative in the environment.

Since 1948, uses of pesticides in the United States have required registration under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Registration activities were carried on first by the Department of Agriculture and, since 1970, by the Environmental Protection Agency (EPA). In 1972, the pesticides law was amended to require EPA to monitor for pesticide residues in humans and the environment. This monitoring requirement was based on the premise that an agency which approves the use of a chemical also should be responsible for determining the consequences of that approval. The requirement states:

Section 20(c): Monitoring—The Administrator shall undertake such monitoring activities, including, but not limited to, monitoring in air, soil, water, man, plants, and animals, as may be necessary for the implementation of this Act and of the national pesticide monitoring plan. The Administrator shall establish procedures for the monitoring of man and animals, and their environment for incidental human and environmental pesticide pollution and the secular trends thereof, and identification of the sources of contamination and their relationship to human and environmental effects. Such activities shall be carried out in cooperation with other Federal, State, and local agencies.

Monitoring data are critical factors in an exposure assessment and thus are important elements in quantitative evaluations of hazard and risk. Studies in laboratory animals indicate actual or potential adverse biological activity (toxicity) of a chemical, while monitoring data are used to assess the exposure of selected human and environmental components to the chemical. Data from monitoring activities also are useful in determining the environmental pathways through which pesticide chemical residues move from their application orbit. Further, monitoring studies contribute substantial information about the intermediate and final environmental fate of pesticides and other toxic chemicals.

The objectives of this report are to describe the pesticide monitoring activities sponsored by the U.S. government since the 1970s and to present and discuss some resulting data and residue trends.

Monitoring Procedures

The FIFRA monitoring amendment which required the monitoring of pesticides actually gave

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legislative recognition to a cooperative pesticide monitoring effort among some Federal agencies that had operated for several years. These programs have been described in detail elsewhere and a summary of these activities is presented in Table 1. These monitoring activities were begun in the mid-1960s by a directive from President John F. Kennedy in 1963 to implement specific recommendations of the President's Science Advisory Committee that appropriate federal agencies develop a continuing network to monitor pesticide residue levels in air, water, soil, humans, wildlife, and fish (9). The Department of Agriculture began to monitor pesticides in agricultural soils and crops nationwide in 1966, and other departments soon followed with monitoring programs in their respective areas of responsibility. The National Pesticide Monitoring Program, as it was called, had nine component networks—air, water (surface water and bottom sediment), soil (agricultural and urban), estuarine organisms (finfish and shellfish), freshwater fish, wildlife (migratory and non-migratory birds), processed foods and animal feed, red meat and poultry, and humans (10). These were considered "ambient" monitoring activities, that is, they involved widely distributed, repeated specimen collection of human or environmental components within a well-defined, statistically based sampling frame, so that trends in pesticide residue concentrations over a broad geographic area could be measured (11).

Table 1. Pesticide monitoring programs in the United States in the 1970s.

Program	*Matrix collected*
Environmental Protection Agency	
National Human Monitoring Program	Human adipose tissue Human blood serum Human urine
National Soils Monitoring *Program*	*Agricultural soils* Raw agricultural crops Urban soils
National Surface Water toring Program	Surface water Bottom sediment
National Estuarine Monitoring Program	Estuarine finfish Estuarine shellfish
National Air Monitoring Program	Ambient air
Suburban Air Studies	Ambient air in suburban locales
Food and Drug Administration	
Market Basket Survey	Processed, ready-to-eat food
Food and Feed Survey	Raw foods and animal feed
Department of Agriculture	
Red Meat and Poultry Surveillance	Red meats and poultry
Department of the Interior	
Freshwater Fish Survey	Freshwater fish
Bird Monitoring Programs	Starling (non-migratory) Mallard ducks (migratory

Discussion

The pesticide monitoring programs in the United States began to generate a body of data that revealed a significant degree of low-level environmental contamination by many organochloride pesticides (Tables 2-6). This information, as well as results of many other scientific studies on these persistent pesticides and growing public concern, prompted EPA to cancel or suspend many previously registered uses of several pesticides, including DDT, aldrin, dieldrin, mirex, chlordane, and heptachlor.

Data from the ambient monitoring networks were used in the resulting legal hearings to show the chemicals' persistence, occurrence, and movement in humans and the environment. The ambient monitoring networks also detected decreases in mean concentrations of these chemicals after some uses were discontinued. This helped demonstrate the effectiveness of chemical use restrictions in reducing exposure

Table 2. Selected pesticide residues found in human adipose tissue and blood serum samples from the general population[1]

Pesticide exposure origin	*Chemical detected*	*Adipose tissue[2]*	*Blood serum[2]*
DDT	*DDE*	×	×
Chlordane and heptachlor	*Oxychlordane*	×	×
	Heptachlor epoxide	×	×
	trans-Nonachlor	×	×
	Heptachlor	-	×
Benzene hexachloride	*beta*-Benzene hexachloride	×	×
Aldrin and dieldrin	Dieldrin	×	×
Hexachlorobenzene	Hexachlorobenzene	×	×

1. Data from reference 11
2. A check (×) denotes a finding in excess of 1% of the general population. A dash (-) denotes no quantifiable finding.

Table 3. Frequency of selected pesticide residues in urine from persons 12-74 years, United States, 1976-1980.[1]

Pesticide origin	Chemical detected	Frequency of detection (%)
Pentachlorophenol, lindane, and hexachlorobenzene	*Pentachlorophenol*	*71.6*
Chlorpyrifos	*3,5,6-Trichloro-2-pyridinol*	*5.8*
2,4,5-Trichlorophenol (disinfectant use or as a metabolite of certain insecticides	*2,4,5-Trichlorophenol*	*3.4*
Methyl and ethyl parathion	*para*-Nitrophenol	2.4
Dicamba	Dicamba	1.4
Malathion	*alpha*-Monocarboboxylic acid	1.1
	Dicarboxylic acid	0.5
2,4-D	2,4-D	0.3

1. Based on specimens collected via the Health and Nutrition Examination Survey II (NHANES II), National Center for Health Statistics.

Table 4. Summary of ambient air monitoring data for selected pesticides at 10 U.S. locations, 1980[1]

Pesticide	Positives[2] (percent)	Nanograms/cubic meter maximum	Nanograms/cubic meter mean conc.
alpha-Benzene hexachloride	42.3	154.0	4.0
beta-Benzene hexachloride	0.3	2.4	0.1
Chlordane	11.4	7.3	0.4
Chlorpyrifos	11.4	100.0	2.1
DEF	0.8	95.0	7.7
Diazinon	48.0	23.0	2.1
Dimethoate	3.3	18.0	0.3
Disulfoton	0.8	4.7	0.1
EPN	0.8	4.6	0.1
Lindane (*gamma*-Benzene hexachloride	0.8	1.5	0.1
Malathion	50.0	220.0	7.5
Methyl and ethyl parathion	12.2	160.0	2.9

1. Locations sampled: Columbia, SC; Lubbock, TX; Huntsville, AL; Pasadena, CA; Miss. State, MS; Harlingen, TX; Houston, TX; Fresno, CA; Helena, MT; Pekin, IL.
2. Out of 123 samples.

levels of persistent synthetic chemicals. Additional chemical analyses were added to several of the monitoring programs to produce data on polychlorinated biphenyls (PCBs), heavy metals, and some non-pesticidal toxic chemicals with industrial uses.

Table 5. Summary of pesticide residues detected in surface water, National Surface Water Monitoring Program[1]

Chemical detected	Occurrence (%)	Maximum value (nanograms/liter)
Chlordane	*1.1*	*0.2*
Dieldrin	*2.4*	*0.6*
Endrin	*0.1*	*0.1*
o,p'—DDT	0.1	0.4
o,p'—DDE	0.3	0.5
p,p'—DDT	0.5	0.7
p,p'—DDE	0.7	0.6
Toxaphene	0.1	1.7
Diazinon	1.2	2.4
Malathion	0.3	0.2
Silvex	0.1	0.5
2,4-D	1.6	1.9
2,4,5-T	0.4	12.9
Atrazine	6.8	7.7
Simazine	0.4	1.1

1. 1976-1980.

Table 6. Summary of pesticide residues detected in bottom sediments, National Surface Water Monitoring Program[1]

Chemical detected	Occurrence (%)	Maximum value (nanograms/gram)
Chlordane	*15.3*	*2,964.0*
Dieldrin	*21.7*	*5,300.0*
Endrin	*1.3*	*2.9*
o,p'—DDT	2.9	7.2
o,p'—DDE	0.5	1.3
p,p'—DDT	13.2	110.6
p,p'—DDE	22.7	163.0
Toxaphene	1.8	814.5
Diazinon	0.5	7.1
Malathion	ND[2]	ND[2]
Silvex	0.2	6.3
2,4-D	0.2	14.9
2,4,5-T	0.2	9.1
Atrazine	0.7	11.9
Simazine	0.2	0.1

1. 1976-1980.
2. Not Detected.

The substitutes for the organochlorine pesticides were primarily organophosphorous and carbamate compounds which were not as persistent, accumulative, or mobile in the environment; however, neither were they as easily monitored with ambient surveys (Table 3). Therefore, special monitoring studies had to be done more frequent-

Table 7. Concentrations of dibromochloropropane (DBCP) in drinking water from selected areas of the United States, 1979.[1]

Location	*Water Source*	*DBCP concentration (micrograms/liter)*
Madera Co., CA	Private well	0.8
Madera Co., CA	Private well	0.4
Riverside Co., CA	Municipal supply	0.1
Riverside Co., CA	Municipal supply	0.1
San Joaquin Co., CA	Private well	0.9
San Joaquin Co., CA	Private well	9.4
Stanislaus Co., CA	Municipal well	0.1
Stanislaus Co., CA	Private well	0.1
Stanislaus Co., CA	Private well	10.8
Darlington Co., SC	Private well	0.1

1. 10 of 127 water specimens analyzed in California, Arizona, Texas, South Carolina, and Alabama contained detectable concentrations of DBCP.

Table 8. Aldicarb concentrations in Soil
Sampling location: Hillsbourough County, FL
Soil: Loamy, siliceious, thermic, grossarenic paleudult
Treatment: Temik applied once, 12 months prior to sampling at a rate of 67.2 kg formulated product/ha.

Soil depth, cm	*Residual aldicarb (micrograms/gram, dry weight)*
0 - 7.6	ND[2]
7.6 - 31	ND
31 - 61	ND
61 - 91	ND
91 - 122	6
122 - 152	25
152 - 183	81
183 - 213	87

1. Detected as aldicarb sulfone.
2. ND = Not Detected. MDL = 1 microgram per gram. All values corrected for recovery (64%).

ly to provide the required data on residue occurrence from specific pesticide uses. Such "special" studies are limited in comparison to ambient monitoring surveys—that is, there may be no repeated sample collection, the study encompasses a limited geographic area, and there is only a single chemical or a few chemicals monitored, or a single sample medium involved. Tables 7 to 9 present results from a few of these kinds of monitoring studies.

Table 9. Aldicarb concentrations in Soil.
Sampling Location: Washington County, MS
Soil: Fine-loamy, mixed, thermic, mollic hapludalf
Treatment: Temik 10G at 5.0 kg a.i./ha/year for 2 years and Temik 15G at 3.4 kg a.i./ha/year for 5 years.

Soil depth, cm	Residual aldicarb[1] (micrograms/gram, dry weight)
0 - 7.6	ND[2]
7.6 - 31	ND
32 - 61	ND
62 - 91	ND
92 - 122	ND
123 - 153	ND
154 - 183	ND

1. Detected as aldicarb sulfone.
2. ND = Not Detected. MDL = 1 microgram per gram. All values corrected for recovery (64%).

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