VALUATION OF HUMAN DEATHS AND ILLNESSES RESULTING FROM PESTICIDE USES IN THE UNITED STATES

By

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Introduction

The Executive Order (EO) 12291 of 1981 requires all federal agencies to evaluate costs and benefits of significant regulatory actions to ensure that such actions are issued only when the benefits outweigh the costs. Even if the EO 12291 requires a cost-benefit analysis only for regulatory actions which have economic impacts of at least $ 100 million, many federal agencies including the U.S. Environmental Protection Agency (EPA) have rigorously conducted cost-benefit analyses for regulations that have economic impacts of less than $100 million to provide policy-makers with economic consequences of such regulations in the policy-making processes.

For the environmental rules and programs related to air and water, the industry costs of reducing air and water pollution were compared to the public health benefits of the same actions to enhance the effectiveness of the environmental policies. A number of studies have attempted to measure the costs and benefits of environmental polices. The EPA study (US EPA, 1999) assessed the benefits and costs of the Clean Air Act Amendments (CAAA) during the period from 1990 to 2010. The study showed that the annual estimate of social benefits ($71 billion in 2000) that include improved human health, ecological environment, and productivity outweigh the compliance costs ($19 billion in 2000) incurred by industry to control air emissions required by the CAAA. EPA is currently preparing a new cost-benefit analysis for the Safe Drinking Water Act, as amended in 1996 (US EPA, 2006).

Economic information necessary to enhance the effectiveness of pesticide regulations in the United States is different from those for other polluting matters such as air and water. Although pesticides may pose some risk because they are toxic substances to control pests such as insects, weeds, and rodents, they also provide substantial benefits to society. Therefore, EPA's Office of Pesticide Programs (OPP) evaluates pesticides to ensure that they will not pose unreasonable adverse effects[1] on humans or the environment, and conducts a risk-benefit analysis to balance risks and benefits in registering a pesticide.

While pesticide uses may have adverse effects on human health and environment, they have positive economic effects on farmers and rural community, and also provide nutrition to consumers in an economical way. More efficient crop production with the use of pesticides improves grower's profitability. A few studies have attempted to quantify benefits of pesticide uses. For the 50 crops studied the Crop Protection Research Institute (CPRI) estimated the annual costs to farmers associated with fungicide use to be $575 million in the U.S. production while the use of these fungicides increased farmer's annual income by $13 billion in 2005 (CPRI, 2005). The CPRI also estimated that an expected loss of $21 billion would occur in the absence of fumigants due to yield loss and increased labor cost in the U.S. production in 2003 (CPRI, 2003).

In 1993, the American Farm Bureau Research Federation (AFBRF) estimated that more than 60% of the nation's fresh fruit and vegetable production would have been lost if fungicides were not available (AFBRF, 1993). Studies published by the United States Department of Agriculture (USDA) estimated that yield losses in the absence of herbicides are 50% for cranberries produced in Massachusetts (Susan Mahr et. al. 1994), 55% for strawberries in Florida (Kenneth Sorenson. et. al. 1997), and 60% for carrots in

[1] The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) states that "the unreasonable adverse effects on human or environment means any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of the pesticides" (FIFRA, 1997).

Washington (Michael Davis. et. al. 1999). Herbicides are most cost-effective way to control many types of weeds and used for a range of vegetable and fruit production in the United States.

Taylor and Smith (1999) used the U.S. food demand system developed by Huang (1993) to estimate potential effects of pesticide regulations on food consumption and nutrition. They concluded that eliminating organophosphates and carbamates would lower fruit and vegetable yields, leading to higher market prices. As a result, consumers would reduce their consumption of fruit and vegetables, and this negatively affects public health.

Pesticides are well known to harm human health and environment. Pesticides pose health risk to humans: both for consumers and farm workers. The health effects vary by the type of pesticides. People can be exposed to pesticides from consuming food and drinking water that contain pesticide residue. Pesticides could cause a wide range of symptoms from eye irritation to severe intoxication that could lead to a death (EPA/OPP, 2006). In particular, organophosphates and carbamates could disrupt endocrine system in the body. Human cancer can be caused by exposure to carcinogenic pesticides.

Only a few studies have attempted to estimate the public health costs resulting from pesticide use (Primental 1992; Primental 2005). Pimentel (2005) attempted to measure public health impacts of pesticide use in the Unites States. In his study, the total cost of hospitalization, outpatient treatment, lost-work hours, treatment of pesticide-induced cancers, and deaths associated with pesticide exposure was estimated at $1.23 billion per year. His estimates, however, were not based on actual health incidence data available by the American Association of Poison Control Centers (AAPCC). Pimental used 10,000 pesticide cancer cases and 45 accidental deaths in estimating the economic costs of human pesticide poisonings in the United States each year, but the AAPCC shows that on average only 550 major-effect cases and 6 unintentional deaths associated with pesticides were reported per year. His study was not based on the reported health incidence data and was likely to overestimate the human health costs of pesticide uses.

The objective of this study is to measure the costs associated with the unintentional human deaths and acute illnesses resulting from pesticide uses. This study extends the work by Pimentel in two ways. First, the aggregate costs of unintentional human deaths and acute illnesses due to pesticide uses per year were estimated by the six types of pesticides: fumigant, fungicide, herbicide, insecticide, repellent, and rodenticide based on the actual health incidence data reported to the AAPCC. In addition, the health effects are disaggregated into the five clinical severity levels defined by the Toxic Exposure Surveillance System (TESS).

Second, the health cost per 1,000 pounds of pesticide use was estimated for the 6 selected pesticides for which use and incidence data were available. This provides a measure of comparative health costs among alternative pesticides that can be used for a certain crop. In considering registration or reregistration of a pesticide, EPA spends a great deal of effort on estimating risk and benefit of the individual pesticides, but the comparative health costs of alternative pesticides have not been considered. Thus, this information would contribute to the EPA’s decision making in its registration process.

Method and Data

Since 1983, the TESS by the AAPCC has reported deaths and acute illnesses associated with toxic chemicals that include 6 different types of pesticides: fumigants, fungicides, herbicides, insecticides, repellents, and rodenticides. Toxicology specialists at more than 60 poison control centers around the country reported the death and acute illness incidences data during their consultation with callers and also collected detailed data on patient outcomes (AAPCC, 2006). The TESS contains an estimated 98.8 percent of all poison exposures reported to poison centers in the United States, but this data might account for only a quarter of the total cases that occur, especially those requiring inpatient or outpatient treatment[2].

The cases of unintentional deaths and illnesses are characterized into the five clinical severity levels defined by the TESS: no effect, minor effect, moderate effect, major effect, and death (AAPCC 2006). No effect indicates a patient who reported a pesticide exposure did not develop any symptoms or illnesses. However, the TESS data show that 23 percent of the no-effect cases still incurred medical expenses for hospital visits. Minor effect indicates a patient developed some minor symptoms or illnesses, which can be resolved without permanent disability and did not require hospitalization of the patient. Moderate effect indicates a patient developed symptoms or illnesses as a result of the pesticide exposure that were more severe than minor symptoms, but still did not require hospitalization of the patient.

[2] Chafee-Bahamon et al. (1983) found that only 24% of 19,544 inpatient or outpatient cases in Massachusetts in 1979 were referred to the State's PCC. Harchelroad et al. (1990) also found that 26% of identified 470 toxic exposures in Pennsylvania were referred to the local PCC in 1988.

Major effect indicates a patient developed symptoms or illnesses that were life-threatening and required hospitalization of the patient. Finally, death indicates a patient died as a result of the pesticides exposure. Table 1 shows the estimated annual number of exposure cases for each severity level by pesticide type. These estimates are the averages of the annual exposure counts for the period 2001 to 2004.

For each severity level of no effect, minor effect, moderate effect, and major effect, the health cost per case was measured as the sum of the unit costs for outpatient visit, inpatient hospitalization stay, and lost wage.

1) $$HC_i = OutPC_i + InPC_i + LW_i$$

where,

HC_i : health cost per case per each severity level i, i=1,…,4.

$OutPC_i$: unit cost for an outpatient visit for each severity level i.

$InPC_i$: unit cost for an inpatient hospitalization stay for each severity level i.

LW_i : lost wage for each severity level i.

The unit cost for an outpatient visit for each severity level was estimated by multiplying the percentage of cases requiring outpatient visits by the outpatient benchmark cost (table 3). The percentage of cases visiting health care facilities for each severity level was obtained from the TESS. The outpatient benchmark cost is the average physician consultation fee for a patient with symptoms that require a straightforward medical decision-making (myhealthscore, 2006).

2) $$OutPC_i = OutP\%V_i * OutPBC$$

where,

$OutP\%V_i$: percentage of cases requiring outpatient visits per each severity level i, i=1,…,4.

OutPBC: benchmark cost for an outpatient visit.

The unit cost for inpatient hospitalization stays was estimated by multiplying the percentage of cases requiring hospital stays by the benchmark hospitalization cost. Note that only major effect cases involve hospitalization. The hospitalization benchmark cost represents the inpatient cost per case for the diagnosis-related group, “Other Injury, Poisoning & Toxic Effect.” (myhealthscore, 2006).

3) $$InPC = InP\%H * InPBC$$

where,

InP%H : percentage of cases requiring inpatient hospitalization per each major effect

InPBC : benchmark cost for an inpatient hospitalization for each major effect

To calculate the value of lost wages, *LWi*, the average hours of work per day was estimated at 5 hours with an average gross wage rate of $16 per hour from the Bureau of Labor Statistics (BLS, 2006), which resulted in the lost wage of $80 per day. The total lost wage per case was then calculated by multiplying $80 by the average duration of illness for each severity outcome. Based on the TESS, an average duration of clinical illness was generated for each severity level (table 2). The wage loss is directly proportional to the time spent with the illness. The unit health cost associated with premature mortality was based on the "value of a statistical life" (VSL) approach[3].

Finally, the total annual health costs resulting from pesticide uses are the sum of the total costs of illnesses and deaths. The total cost of illnesses are estimated by multiplying the per case health costs by the number of cases for each severity level and summing across severity levels. The value of premature mortality was estimated by multiplying a VSL estimate in the year 2005 dollars ($6.42 million) by the number of deaths:

4) $$THC = \sum_{i=1}^{4} (N_i * HC_i) + (ND * \$6.42\ million)$$

where,

THC : the total annual health cost

N_i : the number of cases by severity level i, i=1,..,5.

HC_i : health cost per case by severity level i, i=1,..,5.

ND : the number of deaths due to pesticide exposures

Health cost of a pesticide use per 1,000 pounds was estimated for selected pesticides for which use information was available. Table 4 shows the 6 selected pesticides and total pounds use and the health incidences per year. Average health cost of a pesticide per 1,000 pounds was calculated by dividing the total health costs for the pesticide by the total use of the pesticide per year.

[3] For more information on VSL, please see Kkuho Kochi, Bryan Hubbell, and Randall Kramer (2005).

5) $AHC_j = THC_j \div TPU_j$

where,

AHC_j = Average health cost per 1,000 lbs use per year for each pesticide j, j=1,…,6.

THC_j = total annual health cost for pesticide j.

TPU_j = total pesticide use in 1,000 lbs per year for pesticide j.

Results

The annual total cost of human deaths and illnesses resulting from pesticide uses in the United States is estimated at $38.83 million. Table 3 shows annual number of cases, unit costs, and annual total costs for each severity level. Fifty-five percent (50,580 cases per year) of all the incidences of pesticide exposures reported to the APCCC did not develop any sign of symptoms, but 23 percent of the no-effect case (11,633 cases per year) still incurred outpatient cost of $45.75 for health facility visit. Therefore, the average outpatient cost per no-effect case is $11 and the total health cost for all no-effect cases was estimated at $0.53 million per year.

For the 33,851 minor-effect cases per year, 30 percent of such cases incurred outpatient cost of $45.75 for health facility visit, resulting in the average outpatient cost per minor-effect case of $14 ($45.75×0.30). Wage loss of $20 was also incurred per minor-effect case due to the average duration of illness for 0.25 day ($80×0.25). The average health cost per minor-effect case is $34 ($14+$20). For the 10155 minor-effect cases per year, the total health cost is estimated at $1.14 million per year.

Seventy-one percent of the 6,140 moderate-effect cases per year incurred outpatient cost of $45.75 for health facility visit and the average duration of illness is 1 day. As a result, the average health cost per moderate-effect case is $112, which is the sum of the average outpatient cost of $32 ($45.75×0.71) and wage loss for one day ($80). For the 4,359 moderate-effect cases per year, the total health cost is estimated at $0.69 million.

Only 550 incidences were reported per year as major-effect cases, but because symptoms as a result of such exposure are often life-threatening or severe, 81 percent of the major-effect cases incurred outpatient cost of $45.75 for health facility visit, resulting in the average outpatient cost per major-effect case of $37 ($45.75×0.81). Wage loss of $152 was also incurred per major-effect case due to the average duration of illness for 1.9 days ($80×1.9). In addition, inpatient hospitalization cost of $1,916 was added to the average health cost per major-effect case. As a result, the average health cost per major-effect case is $2,105 ($37+$152+$1,916). For the 550 major-effect cases per year, the total health cost is estimated at $1.16 million per year.

The cost associated with unintentional death cases of 6 per year was estimated at $35.3 million, which accounts for about 91 percent of the total costs because of the high unit cost of $6.42 million for VSL. It is also noted that although much fewer number of people (550 cases) suffer major effects than minor effects (33,851 cases) the monetary costs associated with each category are of the approximately same magnitude because of much higher unit costs involved with major effect cases.

Table 5 shows the annual total costs by pesticide type and severity level. Both fungicides and fumigants appear to have small health costs due to exposure incidences: $61,322 for fungicides and $36, 353 for fumigants. The total health costs associated with herbicides and insecticides uses are much higher mainly due to unintentional death incidences: $16,393, 864 for herbicides and $19,806,987 for insecticides. However, higher numbers of incidences of illnesses were also reported for herbicides and insecticides as well.

The health cost per 1,000 pounds of pesticide use was estimated for 6 pesticide that includes 2,4,D, diquat, glyphosate, metaldehyde, metam sodium, and paraquat (table 6). 2,4,D, Diquat, glyphosate, and paraquat are herbicides that are widely used to control many types of broadleaf weeds on production acres for field crops such as corn, cotton, wheat, and barley, and pasture and rangelands. Metaldehyde is insecticide to control slugs and snails on vegetable and ornamental crops in the field or greenhouse. Metam sodium is used as a fumigant to treat soils prior to planting crops to control weeds, nematode, and soil-borne pathogens and it is well known as an alternative to methyl bromide which was phased out in 2005.

Table 6 shows the comparison of average health effect for the selected 6 pesticides. Even if the four herbicides are used to control broadleaf weeds and could be alternatives to each other for different crops, their average health cost per 1,000 pounds use varies widely. It ranges from $.40 for 2,4,D to $23,128 for diquat.   The average health costs per 1,000 pounds use are $93.19 for glyphosate and $8,369 for paraquat. The reason that the average health costs are high for diquat and paraquat is mainly because there were more unintentional deaths associated with these two herbicide uses, while their uses are less than those for 2,4,D and glyphosate. More morbidity incidences were also consistently reported for both diquat and paraquat as well.

More than half of all the exposure incidences reported to the AAPCC were associated with insecticides. In particular, 71 percent of moderate-effect cases and 62 percent of major-effect cases are insecticide exposures. The average health cost per 1,000 pounds use of metaldehyde was estimated at $163.47. However, this estimate is much lower than those for diquat and paraquat because no unintentional death was reported for metaldehyde.

When a pesticide is registered by EPA, human health risk and ecological risk are examined and compared to benefit of a pesticide to growers. However, the results in this study show that registered pesticides to control same types of weeds or pests could have significantly different effects on human health. This might stem from the fact that the actual application rates and methods for a pesticide applied to crops can be different from what is required by the label for the pesticide. In addition, the Agency's risk assessment is still largely based on animal studies which might not fully represent human health risk. This measure provides information on comparative health costs of alternative pesticides that can be used in EPA's registration process.

Conclusion

The approach presented in this paper represents an attempt at monetizing human health costs associated with pesticide uses and may contribute to the regulatory decision-making process and have potential application in other environmental valuation contexts. The total health cost of human deaths and illnesses resulting from pesticide uses in the United States was estimated at $38.83 million per year. The average health costs per 1,000 pounds pesticide use vary widely from $.40 for 2,4,D to $23,128 for diquat.

More than 90 percent of the total health cost is from 6 deaths per year. Because the unit mortality value of $6.42 million does not account for the potential variations by socioeconomic characteristics such as age, gender, and income, it might not accurately measure the health costs of unintentional deaths associated with pesticide uses. This study focused only on unintentional deaths and acute illnesses. Although important, chronic health effects of pesticide uses were not included in the estimation due to the lack of data. Also excluded were the heath effects that might be caused by environmental degradation (e.g., drinking water contamination) by pesticides. Further, results in this study are based on the reported exposure cases to the Poison Control Centers. It is likely that the total pesticide exposure incidences are greater than the number of cases actually reported to the Poison Control Centers. Therefore, the results of this study should be interpreted as such.

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Table 1: The estimated annual number of exposure cases for each severity level by pesticide type for 2001-2004.

Pesticide type	None	Minor	Moderate	Major	Death
Fungicides	544	693	150	7	0
Fumigants	191	314	81	7	0
Herbicides	3,850	4,426	643	39	3
Insecticides	21,928	21,209	4,372	339	3
Repellents	7,061	6,202	461	34	0
Rodenticides	17,007	1,007	433	124	0
Sum	50,580	33,851	6,140	550	6

Source: AAPCC 2001-2004

Table 2: Percentage of cases requiring medical treatments, benchmark cost, and average duration of illness

	Percent of cases requiring medical treatment	Benchmark cost	Average duration of illness
None	0.23	45.75	0
Minor	0.30	45.75	0.25
Moderate	0.71	45.75	1
Major	0.81	45.75	1.9
Death	NA	NA	NA

Source: Toxic Exposure Surveillance System (TESS), 2001-2004; Myhealthscore, 2006

Table 3: Annual Number of Cases, Unit Costs, and Annual Total Costs (2005 dollars)

						Total Costs
Severity Level	Estimated Number of Cases per Year (E)	Outpatient (A)	Inpatient (B)	Lost Productivity (C)	VSL (D)	E*(A+B+C+D)
No Effect	50,580	$11	$0	$0	$0	$532,228
Minor Effect	33,851	$14	$0	$20	$0	$1,141,622
Moderate Effect	6,140	$32	$0	$80	$0	$690,684
Major Effect	550	$37	$1,916	$152	$0	$1,158,313
Unintentional Death	6	$0	$0	$0	$6,420,000	$35,310,000
Total	91,127					$38,832,847

Table 4: The total pounds use and health incidences per year for the selected pesticides

Pesticide	Total pounds used per year (1000 lb/year)	Health incidences per 1,000 pounds pesticide used				
		None	Minor	Moderate	Major	Death
2, 4, D	8,017	0.00390	0.00396	0.00087	0.00006	0.00000
Diquat	278	0.30216	0.32014	0.08273	0.00540	0.00360
Glyphosate	104,119	0.01019	0.01079	0.00092	0.00006	0.00001
Metaldehyde	22	2.95282	0.82192	0.07610	0.04566	0.00000
Metam sodium	33,563	0.00007	0.00014	0.00007	0.00001	0.00001
Paraquat	1,535	0.00391	0.01026	0.00635	0.00130	0.00130

Source: AAPCC 2001-2004; USDA/NASS 2001=2004

Table 5: Annual total health costs by pesticide type and severity level.

Pesticide type	None	Minor	Moderate	Major	Death	Total
Fungicides	$5,718	$23,373	$16,869	$15,361	$0	$61,322
Fumigants	$2,006	$10,591	$9,150	$14,605	$0	$36,353
Herbicides	$40,503	$149,293	$72,294	$81,805	$16,050,000	$16,393,864
Insecticides	$230,680	$715,372	$491,792	$714,144	$17,656,000	$19,806,987
Repellents	$74,281	$209,198	$51,838	$71,638	$0	$406,956
Rodenticides	$178,914	$33,965	$48,724	$260,761	$1,605,000	$2,127,364
Sum	$532,208	$1,141,622	$690,684	$1,158,313		$38,832,847

Table 6: The comparison of average health effect for the selected pesticides

Pesticide	Total pounds used per year (1000 lb/year)	Average health cost per 1,000 pounds pesticide use					
		None	Minor	Moderate	Major	Death	Total, all severity levels
2, 4, D	8,017	0.041	0.134	0.098	0.131	0.00	$ 0.40
Diquat	278	3.179	10.797	9.306	11.358	23,093.53	$ 23,128.17
Glyphosate	104,119	0.107	0.364	0.103	0.121	92.49	$ 93.19
Metaldehyde	22	31.071	27.719	8.560	96.121	0.00	$ 163.47
Metam sodium	33,563	0.001	0.005	0.008	0.016	47.82	$ 47.85
Paraquat	1,535	0.041	0.346	0.715	2.743	8,365.64	$ 8,369.48