

Chapter 5

Pesticides and Cancer in Adults

Introduction:

Most pesticide exposure is clinically silent and goes unnoticed. Exposure may result from legal use that does not cause any apparent illness, leading to false assumptions of safety. It is a challenge to study pesticides as a risk factor for cancer in adults since the period of time between exposure and development of disease (clinical latency) is years long. There is also exposure to a large number of pesticides with use patterns changing over a. Other factors to consider are alcohol, tobacco, drugs, and other exposures. In studying agricultural pesticide use on farms, possible contributing factors include exposures to dusts, animals, and fertilizer, among others. Many pesticides are classified as possible or probable human carcinogens (see Appendix G), and little is known the risk of chronic low-level exposures over a working life-time.

Most studies of chronic health effects of pesticides are groups with occupational exposure, such as farmers, farm workers, exterminators, pesticide formulators and factory workers. Fewer studies focus on non-occupational sources of exposure including home, lawn, and garden use, and drift from living near crop growing areas, or near pesticide factories.

This chapter summarizes studies of pesticides as a risk factor for cancer in adults (cancer in children is discussed in Chapter 7). Study findings summarized in Tables 1-7 are listed by the country where they were done, and with the most recent studies listed first.. See Appendix F for an explanation of how the studies are done and what the numbers and abbreviations mean. There are many factors that can affect study results. See the citations in the reference section for full details.

If the type of cancer is rare or infrequent, or the number of people in the study is small, it may be difficult to find an association between pesticide exposure (increase or decrease), even if it exists. In many of the studies cited in this discussion, increases in risk were found but were not statistically significant. For example, one study found a 30 to 45% increase in risk of non-Hodgkin lymphoma for pesticide illness or pesticide spills on clothing, but it was not statistically significant¹³⁶. Only statistically significant results, and some of borderline significance, are included in this summary.

Occupational Pesticide Exposure
Agricultural
Farmers
Farm workers
Ground applicators
Aerial applicators
Nursery, greenhouse workers
Non-agricultural
Exterminators (pest control operators, PCOs)
Formulators
Factory workers
Turf, lawn care workers
Gardeners, landscapers
Road side sprayers
Mosquito, vector control

Because the source and type of exposure can affect the risk of cancer, the summary discusses cancer as follows:

- Table 1-A Occupational Agricultural Pesticide Exposure - Increased Risk
- Table 1-B Occupational Agricultural Pesticide Exposure - Increased Risk
- Table 1-C Occupational Agricultural Pesticide Exposure - Increased Risk
- Table 2 Occupational Agricultural Pesticide Exposure - Decreased Risk
- Table 3 Non-Agricultural Occupational Pesticide Exposure - Increased and Decreased Risk
Pest Control Operators (PCOs), Exterminators
- Table 4 Pesticide Manufacturing and Formulation Exposure - Increased Risk
- Table 5 Pesticide Manufacturing and Formulation Exposure - Decreased Risk
- Table 6 Environmental, Drift, and Other Non-occupational Pesticide Exposure - Increased Risk
- Table 7 Environmental, Drift, and Other Non-occupational Pesticide Exposure - Decreased Risk

Bladder Cancer

Chlordimeform, a cotton insecticide banned by the EPA in 1988, metabolizes to a known bladder carcinogen 4-chloro-o-toluidine. Factory workers manufacturing this pesticide have a strikingly high risk of bladder cancer (SIR 89.7, SIR 53.8, SIR 35.0)²⁰⁰. A much lower, but significant, increased risk was found in agricultural researchers (OR

9.3)⁴¹, and workers manufacturing chlorinated hydrocarbons (SMR 7.1)²⁰¹. Farmers^{38,41,42}, farm workers³⁹, agricultural extension agents⁴³, pest control operators^{187,188}, and people living in wheat crop areas in the midwest²⁵⁰ are also at increased risk. Several studies found a decreased risk in farmers, both males^{42,103}, and females^{148,163}.

Bone Cancer

While no associations have been reported in U.S. farmers or farm workers, increased risk was reported in people living in wheat growing areas of the Midwest²⁵⁰. Increased risk was found in female farm workers in Denmark (SIR 6.25)⁴⁵, and male farm workers in Japan (SR 1.62)⁴⁶.

Brain Cancer

There are reports of increased brain cancer risk in all pesticide exposed groups except factory workers. The highest reported risk in adults is a 670% increase in women living near cranberry bogs in Cape Cod, Massachusetts (OR 6.7)²⁵⁴. High risks were found in Chinese female grain farmers (SIR 6.5)⁵³, agricultural researchers in Ireland (OR 4.69)⁴⁰, and farm workers in Italy (OR 5.0)⁵. A lower increase was found in agricultural extension agents (PMR 2.08)⁴³, pest control operators (SMR 2.7)¹⁸⁹, and golf course superintendents (PMR 2.3)¹⁹⁰. Decreased risk was found in seed disinfection workers²³⁹.

Breast Cancer (female) - Occupational

Increased risk was found in North Carolina farm women who applied pesticides (OR 1.8), which increased by % if they did not use protective equipment (OR 2.0)⁶¹, and in crop farmers⁶⁰. Most other studies of agricultural exposures report a decrease in risk, including U.S. migrant farm workers¹²⁹, apple orchard workers¹⁶⁶, Japanese farm workers⁴⁶, and Swedish farmers¹⁶³. An increased risk was found in ethylene oxide factory workers (OR 2.55)²⁰⁶, and a borderline increase in herbicide manufacturers in Germany (SMR 2.15)²⁰⁴, and in an international cohort of herbicide factory workers (SMR 2.16)²⁰⁵. A decreased risk was found in pest control operators in Florida¹⁹⁶.

A recent survey from Canada reporting a 900% increase in risk of breast cancer in farm women was not included in the table. The study participants were not a random sample, but self selected, with breast cancer patients more likely to be included. The numbers were small, and the comparison was to other cancer patients, with no cancer free controls^a.

Breast Cancer (male) - Occupational

Breast cancer is rare in men. The American Cancer Society predicts that in 2003, there will be 1,300 cases, compared to 211,200 in women^b. Non-significant increase in risk of male breast cancer was found in U.S. farmers in 23 states⁵⁸, and in Danish farmers and farm employees⁴⁵. A U.S. case-control study²⁴⁰, and an international cohort study²⁰⁹, found no association with herbicide and pesticide exposure.

Breast Cancer (female) - Environmental

The possible relationship between pesticides and breast cancer has been the focus of many studies. Most have been of DDE, the persistent metabolite of DDT that is most prevalent in human tissues. Some studies are done by grouping the women with breast cancer into several categories (usually quartiles (four groups), or quintiles (five groups)), based on the lowest to highest amount of pesticides in the blood or tissue. If the breast cancer rate increases with increasing levels of DDE, and the women with the highest levels of pesticides also have the highest rates of breast cancer, there is an association between the DDE and breast cancer if the findings are statistically significant. Other studies compare the DDE levels between women with and without breast cancer. If the levels are higher in the women with breast cancer there is association with breast cancer if the findings are significant (see Appendix A for an explanation of statistical significance). Studies reporting an increase in risk are shown in Table 9; those reporting a decrease in risk in Table 10.

One investigator concludes that "...exposure to persistent, hormonally active organochlorines during adulthood is not associated with breast cancer risk. The possibility that some organochlorines and especially p,p'-DDE may increase breast cancer aggressiveness deserves further attention"²⁵⁵. The American Cancer Society has issued the following

^a Brophy JT, Keith MM, Gorey KM, et al. 2002. Occupational histories of cancer patients in a Canadian cancer treatment center and the generated hypothesis regarding breast cancer and farming. *Int J Occ Env Hlth* 8(4):346-353.

^b Cancer Facts and Figures 2003. American Cancer Society.

statement: “While some of these compounds may have other adverse environmental or health effects, organochlorine exposure is not believed to be causally related to breast cancer. Women concerned about possible organochlorine exposure can be reassured that available evidence does not suggest an association between these chemicals and breast cancer.”^c

Colorectal Cancer

High risk of rectal cancer was found in one of the few studies of female pesticide applicators (RR 4.63)⁶², and in farmers licensed more than 10 years (OR 4.22)⁶³. Pesticide factory workers are at increased risk, including those manufacturing the herbicide alachlor for five years or more (SIR 4.3)²⁰⁵, and females manufacturing arsenicals (SMR 6.7)²⁰⁶. Lower increases were found in farmers^{41,55}, agricultural extension agents⁴³, forest conservationists⁶⁹, and golf course superintendents¹⁹⁰. An increase in rectal cancer was found in men living in pesticide use areas²⁵⁰. A national study of migrant farm workers¹²⁹, and aerial applicators⁸⁷ found a decrease in risk.

Eye Cancer

There are reports of high risk in Midwest farmers (OR 6.5, PMR 3.75)^{44,64}, in women living near agricultural pesticide use areas (SRR 5.77)²⁷⁸, and in a pesticide manufacturing cohort (OR 2.3)²⁰⁷. Non-significant increased risk of uveal melanoma was found for agricultural occupation and self reported pesticide exposure^{REF}.

Hodgkin’s Disease

Hodgkin lymphoma is not as strongly associated with pesticides as non-Hodgkin type (see below). The highest reported risk is in creosote factory workers (OR 10.7)²⁰⁸, and in farmers exposed to herbicides for more than 10 years (RR 8.7)⁶⁶. A doubling or more in risk was found in farmers^{42,45,65}, and agricultural extension agents⁴³.

Kidney Cancer

The highest reported risk is in forestry soil conservationists (OR 9.0)⁶⁹, and pentachlorophenol factory workers (RR 4.16)²¹⁰. Increases were also found in farmers^{63,67,68}, and in men living in wheat production areas²⁵⁰.

Leukemia

Leukemia is frequently associated with pesticide exposure. The highest risk reported is in factory workers manufacturing the herbicide alachlor at a Monsanto facility in Iowa (SIR 28.6)²⁰⁵. Among farmers the highest risks were found in New Zealand (OR 10.4)⁷⁹, and in Iowa/Minnesota (OR 11.1)⁸⁴. At high risk are female pesticide applicators (SIR 5.6)⁶², aerial applicators (RR 3.35)⁸⁷, and agricultural extension agents (PMR 5.4)⁴³. Lower risks were found in pesticide users in Denmark⁷¹, France⁷³, Italy⁷⁴⁻⁷⁸, Sweden⁸¹, and the U.S.^{84-86,89}. Farm workers were found to have an increased risk of 59% in California⁵⁴, and 90% in Sweden⁸⁰. But most studies of farm workers find a non-significant small increase, no association, or a decrease in risk (see Table 5). There are reports of increased risk in people living near pesticide use areas in Australia²⁷², Canada²⁷³, the Philippines²⁷⁴ and the U.S.²⁷⁵.

Liver and Biliary Cancer

The highest reported risk is in pest control operators (SMR 5.7)¹⁸⁹, and factory workers (SMR 3.9)²⁰¹. At lower increased risk are farmers^{45,92-94}, malaria sprayers¹⁹², grain millers⁹¹, and women living in wheat production areas²⁵⁰.

Lung Cancer

Several studies report decreased risk in farmers^{dk42, 82,151,163}, and farm workers^{174,175}. Other studies found an increased risk in farmers^{95,97}. Factory workers are at higher risk, with increases reported from DBCP^{e 216}, arsenicals²⁰⁶, and a 22% to 46% increase (some borderline, see Table 7) from herbicides, chlordane, and diatomaceous earth^{209,211,213-215,217}. A national cohort study of pest control operators found a 35% increase¹⁹⁴, and a Florida study a borderline significant increase¹⁹³.

Malignant Melanoma (Skin)

The highest reported risk is in black farmers in North Carolina (PMR 6.3)⁸⁹. Increased risk was also found in

^c Calle EE, Frumkin H, Henley SJ, et al. 2002. Organochlorines and breast cancer risk. *CA Cancer J Clin* 52(5):301-309.

^d Farmers as a group smoke less than the general population.

^e Soil fumigant dibromochloropropane (DBCP), a known animal carcinogen, banned continental U.S. in 1979, and Hawaii in 1989.

Australia / Scotland⁹⁸, male banana workers in Costa Rica⁹⁹, and in Scandinavia^{55,100}.

Multiple Myeloma

The highest reported risk is an 820% increase in herbicide applicators (SMR 8.2)¹⁹⁵. Multiple myeloma is more frequently reported in farm workers than other cancers, with a 20% to 80% increase in risk^{101-102,105-106,110}. A 340% increase in risk was found if the farm workers were exposed to pesticides (OR 5.2), with a further 270% increase if exposed ten years or more (OR 7.9)¹¹⁰. Multiple myeloma is frequently reported in females, who are at greater risk than males^{45,53,58,103} (see Table 4b). There are reports of a 23% to 80% increase in farmers^{41,100-101,104,111}, rising further with pesticide exposure¹⁰⁷⁻¹⁰⁹. Younger farmers are at greater risk than older farmer¹⁰⁷. Increased risk was also found in pest control operators¹⁹⁶, golf course superintendents¹⁹⁰, malaria eradication sprayers¹⁹², and agricultural extension agents⁴³. No increase in risk has been reported in factory workers or people living near pesticide use areas.

Nasal Cancer

High risk is reported in workers manufacturing chlorophenols for ten years or more (RR 9.07)²²¹, in female farmers (SPIR 7.4)¹¹², for daily burning of insecticide coils (OR 7.8)²¹⁹, and in workers manufacturing formaldehyde (OR 6.2, OR 4.0)²¹⁸⁻²¹⁹, chlorophenols (OR 5.9)²²⁰, or herbicides (SMR 4.92)²¹¹. Farm workers¹¹³⁻¹¹⁴, farmers¹¹⁵, and females who live near pesticide use areas (SRR 3.35)²⁷⁸ were also at increased risk. There are no reports of increases in pest control operators.

Nervous System Cancer

The mortality of pesticide-exposed workers linked to the 1986-1994 National Health Interview Survey found increased risk for nervous system cancers, RR 2.4 (1.3-4.6)

Non-Hodgkin Lymphoma

Non-Hodgkin lymphoma is the cancer most frequently associated with pesticide exposure. The highest reported risk is in factory workers manufacturing the herbicide alachlor at a Monsanto facility in Iowa (SIR 18.6)²²⁵. High risks are also found in workers manufacturing creosote (OR 9.4)²⁰⁸, and arsenicals (SMR 8.53)²⁰⁶. A 200-500% increase in risk was found in workers manufacturing phenoxy herbicides^{208,222-224}, and pentachlorophenol²²⁴.

A study finding an 800% increase in risk of non-Hodgkin lymphoma in Kansas farmers using 2,4-D (OR 8.0)¹⁵², resulted in this cancer being one of the most studied in agriculture. The focus on phenoxy herbicides was driven by concerns about the potential long term health effects of Agent Orange, a 50-50 combination of 2,4-D and 2,4-5-T used as a defoliant in Vietnam from 1965 to 1972. Studies confirming the association found increased risk in farmers in Illinois⁸², Iowa^{149-151,153,155}, Kansas^{152,153,155}, Minnesota^{151,153,155}, Nebraska^{153,155,159,160}, Washington state¹⁶¹, Wisconsin^{44,162}, and in a 24 state cohort¹⁵⁶. There were also increases in agricultural extension agents⁴¹, soil /forestry conservationists⁶⁹, forest herbicide applicators¹⁶¹, and flour/grain mill workers^{90,91}. Other countries reporting an increased risk in farmers are Canada¹³⁶⁻¹⁴⁰, France^{141,142}, Italy^{66,77,143}, New Zealand¹⁴⁵, and Sweden^{80,146-148} including hairy cell type^{6,147}. See Table 4c for specific pesticides related to the increases.

Non-agricultural workers at increased risk are lawn care applicators (SMR 7.1)¹⁹², and golf course superintendents (PMR 2.4)¹⁹¹. There are reports of increased risk from living near crop production areas in Australia²⁷², Canada²⁵², Finland²⁷⁶, Italy²⁷⁷, and the U.S.^{235,279}.

Ovarian Cancer

There are no reports of ovarian cancer in any occupational group with pesticide exposure. Two studies in Italy in the 1980s found an increase in women living in high atrazine use corn producing areas (RR 2.7)²⁸², (RR 4.28 bs^g)²⁸³. A more recent study in Kentucky of women living in areas with high atrazine use on corn found a decrease in risk³⁰¹.

Pancreatic Cancer

The highest reported risk is in factory workers manufacturing nitrofen (RR 12.0) and DDT (RR 7.8). In the same factory a 400-500% increase²²⁸, and 30-60% increase²²⁶⁻²²⁷ was found with other pesticides (see Table 7). High risk was found in gardeners (OR 6.7)¹¹⁶, in pesticide licensed farmers (OR 5.2)⁶³, and a lower 10-40% increase in other farmers^{44-45,58,92,118}. A doubling or more of risk was found in aerial pesticide applicators⁸⁷, and grain/flour mill

¹ Hairy cell leukemia is a rare subtype of non-Hodgkin lymphoma.

^g Borderline significant.

workers⁹⁰⁻⁹¹. People living in midwest wheat producing areas were at increased risk²⁵⁰, as were Californians living in the high pesticide use counties of Fresno, Kern, and Tulare. The only pesticide for which the increase was significant was 1,3-dichloropropene^{REF}. A nonsignificant 60% increase was found in Australian outdoor workers^{REF}. A decrease was found in a national study of U.S. migrant farm workers¹²⁹. No associations were found in pest control operators.

Prostate Cancer

Most risks of prostate cancer from agricultural pesticide exposures are low, from a 12-70% increase in farmers¹²⁰⁻¹²⁴, a 22-45% in farm workers^{46,53}, and 50% in agricultural extension agents⁴³. One study found a doubling of the risk (RR 2.23)¹¹⁹. A recent report from the Agricultural Health Study found a 14% increased risk in Iowa and North Carolina farmer applicators. The pesticide significantly associated with increased risk in all farmers was methyl bromide in those with high level exposure. In those with a family history of prostate cancer, butylate, chlorpyrifos, coumaphos, fonofos, and phorate in those with a family history of prostate cancer. A study in North Dakota found mean survival in prostate cancer patients was for those without. Another recent study in Italy found increased risk in farmers exposed to, whose effects could not be well separated. Increased risk was found in black workers manufacturing DDT²²⁹. No associations were found in pest control operators^{REF}, or in people living near a pesticide use area^{REF}.

Soft Tissue Sarcoma

The highest risks reported are in a cohort of factory workers manufacturing herbicides (OR 10.3)²³¹, in a cohort of herbicide sprayers (SMR 8.2)¹⁹⁷, and in U.S. chlorophenol workers (OR 7.78)²³⁷. A 300-680% increase was found in other herbicide manufacturing workers^{197,230,233-236}, in gardeners¹²⁵ and in orchard / greenhouse workers⁵³. Other studies of farmers^{42,146}, and farm workers⁴⁶, found a lower increased risk, and others a decrease in risk or no association (see Table 7). A high risk of this rare cancer was found in people living in an area of chlorophenol contamination in Finland (RR 8.9)²⁷⁹, and in men living near a pesticide factory in Spain (SIR 5.5)²⁵². Men living in rice crop areas had a lower increase in risk²⁸⁰.

Stomach Cancer

Most risks of stomach cancer in agriculture are low, ranging from a 25-69% increase in farm workers^{45-46,54-55,128-129}, to a 24-88% increase in farmers^{44-45,58,92,149}. Higher risks were found in forestry workers (OR 4.3)¹²⁷, and pesticide licensed farmers (OR 2.62)⁶³. Although aerial pesticide applicators were found to have a 32% decrease in risk, all three gastric cancer deaths were in pilots with the most flight hours (more than 1,280)¹⁸⁰. Factory workers manufacturing pentachlorophenol²¹⁰ and phenoxy herbicides¹²⁸ were at increased risk. Hungarian men living in a high pesticide use village were at increased risk (RR 3.2)²⁸⁷, as were people living in Midwest wheat producing areas²⁵⁰. No associations were found in pest control operators, or people living in California's Central Valley where drinking water wells were contaminated with DBCP^{(g)313}

Testicular Cancer

There are few studies of pesticides as a risk factor for testicular cancer. Unlike earlier studies in Texas reporting a high risk in farmers (OR 6.27) and farm workers (OR 5.1)¹³⁵, most find less than a doubling of the risk^{53,130-134}, or a decreased risk^{130-134,184-185}. An increase in risk was found in pest control operators (SIR 2.5)¹⁹⁶, and factory workers manufacturing methyl bromide²¹⁷. No associations have been reported for people living in high pesticide use areas.

Thyroid Cancer

Thyroid cancer is infrequently reported in association with occupational pesticide exposure. There are reports of an increase in Midwest farmers (SMR 2.9)⁴², and a 60% increase in female farmers in Denmark (RR 1.6)⁴⁵. No association have been reported in pest control operators or factory workers. An unusual finding is an increased risk in males, but not females, exposed to hexachlorobenzene from living near a solvent factory in Spain (SIR 6.7)²⁵², in an area of pesticide use²⁷⁸, and in wheat producing areas²⁵⁰.

Table 1-A
Occupational Agricultural Pesticide Exposure - Increased Risk
(See Appendix F for explanation of the table)

Bladder Cancer		Kidney Cancer	
France vineyard farmers ¹	RR 1.17	Canada men pesticide, herbicide exposure ³⁶	OR 1.6, 1.8
France agricultural workers ²	OR 4.6	Denmark men ≥ 20 yrs expos. insect/herbicides ³⁷	OR 3.9 bs
Ireland agricultural research workers ³	OR 9.31	Italy copper sulfate exposure ³⁸	OR 2.7
US agricultural extension agents ⁴	PMR 2.72	Italy farmers pesticide licensed ³⁰	OR 2.0
US Iowa, North Carolina farmers ⁵	SMR 2.9	Italy farmer/farm employee females ⁸	OR 4.23
US Iowa farmers ⁶	SMR 1.37	Male farmers/farm employees	OR 1.46
US Wisconsin farmers ⁷	PCMR 1.55	US Iowa farmers ⁶	OR 1.22
Bone Cancer		US soil conservationists ≥ 15 years in forestry ³¹	OR 9.0
Denmark female farmers/farm employees ⁸	SIR 6.25	US 23 states white male farmers ²³	OR 1.10
Japan male agric. wrkrs (incl.soft tiss. sarcoma) ⁹	SPR 1.62	Leukemia	
Brain Cancer		Canada British Columbia farmers ³⁹	PCMR 1.22
Canada farmers fuel use - trend significant ¹⁰	OR 2.11 bs*	Denmark male gardeners pesticide exposed ⁴⁰	SMbR 2.75
France farmers exposed to pesticides ¹¹	RR 1.10	Denmark female farmers/farm employees ⁸	SIR 2.22
Ireland agricultural research workers ³	OR 4.69	France farmers pesticide exposed ⁴¹	SMR 1.33
Italy farmers pesticide licensed ¹²	SIR 2.1	France herbicide exposure more than 10yrs ⁴²	OR 6.0
Italy agricultural workers (after 1960) ¹³	OR 5.0	Insecticide exposure more than 10 yrs	OR 4.0
New Zealand male livestock farmers ¹⁴	OR 2.59	Italy male farmers pesticide licensed ⁴³	SMR 2.43 bs*
All farmers	OR 1.38	Wives of licensed farmers	SMR 3.14
Norway grain farmers ¹⁵	RR 1.51 bs*	Italy farmers pesticide exposed ⁴⁴	OR 4.9
Shanghai female grain farmers ¹⁶	SIR 6.5	Italy farmers/breeders insecticide exposure ⁴⁵	OR 2.46
Pesticide exposed	SIR 3.6	Carbamate exposure	OR 3.08
Sweden (glioma) farm supervisor - male ¹⁷	RR 2.34 bs	Organophosphate exposure	OR 2.9
Forestry supervisor - male	RR 1.63	Italy animal breeding workers ⁴⁶	OR 1.79
Horticultural worker - male	RR 1.75	Italy women pesticide exposed ⁴⁷	OR 4.4
Agricultural worker - female	RR1.22 bs	New Zealand livestock farmers ⁴⁸	OR 3.0
US agricultural extension agents ⁴	PMR 2.08	Acute monocytic 65 yrs and older	OR 10.4
US California UFW union members ¹⁸	MbOR 1.57 bs*	Norway male dairy farmers ¹⁵	RR 1.76
US California farm workers non-white ¹⁹	PCMR 1.55	Sweden farmers (ANLL) ⁴⁹	SIR 5.0
US Meta-analysis 33 studies ²⁰	RR 1.30	Gardeners (CML)	SIR 4.0
US Missouri agric production male ²¹	OR 1.5 bs*	Agricultural workers (CML)	SIR 1.9
US 4 states farm women pesticide exposed ²²	OR 1.2	Sweden farmers DDT exposed (CLL) ⁵⁰	RR 6.1
US 23 states white male farmers ²³	PCMR 1.15	US aerial pesticide applicators ⁵¹	RR 3.35
US 24 states women crop farmers ²⁴	PMR 1.9	US agric. extension agents (lymphocytic) ⁴	PMR 5.4
Breast Cancer (female)		US farmers 23 states white males ^{(b)23}	PCMR 1.27
Canada British Columbia crop farmers ²⁵	Increase	US farmers 26 states white males (lymphocytic) ²⁴	PMR 1.14
Canada Ontario women >55 who ever farmed ²⁶	OR 9.05	US flour mill worker 10 to 20 years ⁵²	SMR 1.94
Serbia women pesticide exposed ²⁷	RR 4.25	US California UFW ^(a) union members ¹⁸	OR 1.59
US N. Carolina farm women applied pesticides ²⁸	OR 1.8	US Illinois farmers ³²	OR 1.51
Colorectal Cancer		US Iowa farmers (CLL) ⁵³	OR 1.70
Iceland all pesticide applicators ²⁹	SIR 2.94	US Iowa, Minnesota farmers OP use ⁵⁴	OR 2.2
Licensed users only	RR 4.63	Ever handle crotoxyphos	OR 11.1
Italy farmers pesticides licensed >10 years ³⁰	OR 4.22	Ever handle dichlorvos	OR 2.0
US agricultural extension agents ⁴	PMR 1.46	Ever handle pyrethrins	OR 3.7
US California farm owners/managers ¹⁹	PCMR 2.2	Used DDT on animals	OR 2.1
US Iowa farmers ⁶	SMR 1.22	US Iowa, Minnesota farmers dichlorvos use ⁵⁵	OR 1.8
US soil conservationists ³¹	PMR 1.5	US Iowa, Minnesota farmers herbicide use ⁵⁶	OR 1.86
15 years or more in forestry	OR 1.9	Insecticide exposure	OR 1.50
Eye Cancer		US Nebraska farmers born after 1900 ⁵⁷	OR 1.24
US Illinois farmers ³²	OR 6.5	High insecticide use counties	OR 1.95
US Wisconsin farmers ⁷	PMR 3.75	US North Carolina black farmers ⁵⁸	PMR 1.2
US agricultural expos. (uveal melanoma) ³³	OR 2.18 ns	US Wisconsin farmers ⁷	PMR 1.10
Hodgkin Disease		Liver and Biliary Cancer	
Italy male farmers/farm employees ⁸	OR 2.91	Canada British Columbia farmers ⁵⁹	PCMR 1.73
Italy farmers pesticide exposed ³⁴	OR 3.2	Denmark female farmers/farm employees ⁸	SIR 2.66
Italy agricultural herbicide exposure >10 yrs ³⁵	RR 8.7	Sweden grain millers ⁶⁰	SIR 2.38
Norway orchard/greenhouse workers ¹⁵	RR 1.85 bs*	US New Jersey agricultural production ⁶¹	RR 2.08
US agricultural extension agents ⁴	PMR 2.72	US 5 states pesticide exposed farmers ⁶²	RR 2.4 bs*
US Iowa, North Carolina farmers ⁵	SMR 2.9	* bs = borderline significance	
US Iowa farmers ⁶	SMR 1.37	(a) United Farm Workers (b) PCMR 1.45 in females borderline sig.	
US Wisconsin farmers ⁷	PCMR 1.55	continued in Tables 1-B, and 1-C	

Table 1-B
Occupational Agricultural Pesticide Exposure - Increased Risk
(See Appendix F for explanation of the table)

Lung Cancer		Prostate Cancer	
Canada farmers herbicide exposure ⁶³	Increase	Canada farmers pesticide exposed ⁹³	RR 2.23
China farmers ⁶⁴	OR 1.6 bs*	Canada Alberta farmers ⁹⁴	OR 1.31
China men exposed to pesticides ⁶⁵	OR 3.29	Canada British Columbia farmers ⁷⁰	PCMR 1.13
US Missouri farmers pesticide exposure ⁶⁶	OR 2.3	England / Wales farmers ⁹⁵	PMR 1.12
Malignant Melanoma (Skin)		Italy applied agric. pesticides ⁹⁶	OR 1.7
Australia, Scotland pesticide exposure ⁶⁷	RR 3.6	Italy farmers organochlorine insecticides ⁹⁷	OR 2.5
Costa Rica male banana workers ⁶⁸	SIR 1.97 bs	DDT exposure, Dicolof exposure	OR 2.1, 2.8
Norway agricultural pesticide exposure ¹⁵	RR 1.37	Japan agricultural work ⁹	SPR 1.22
Sweden farmers ⁶⁹	SMR 1.39	Netherlands agric. pest. expos. ⁹⁸	Increase
US N. Carolina black farmers ⁵⁸	PMR 6.3	Norway orchard/greenhouse workers ⁵²	RR 1.45
Multiple Myeloma		Sweden agric. pesticide applicators ⁹⁹	SIR 1.12
Canada farmers, prairie provinces ⁷⁰	RR 1.69	US agricultural extension agents ⁴	PMR 1.5
Denmark farmers/farm employees male, female ⁸	SIR 3.3, 1.57	US Calif. white farmers/managers ¹⁹	PCMR 1.22
England agricultural workers ⁷¹	RR 1.8	US Missouri farmers ¹⁰⁰	OR 1.33
France farmers ¹	SMR 1.59	US Illinois farmers ¹⁰¹	OR 1.15 bs
Italy female farmers ⁷²	RR 2.4	US Iowa, North Carolina farmers ¹⁰²	SIR 1.14
Italy female farm workers, tree fruit ³	OR 1.75	Methyl bromide high exposure group	OR 3.4 7
Any chlorinated pest.expos., DDT exposure	OR 1.6,2.6 bs	Butylate, Chlorpyrifos exposure	OR 1.93, 1.65
New Zealand farmers diagnosed < age 65 ¹⁴	OR 2.2	Coumaphos, Fonofos exposure	OR 2.58, 2.04
Norway farmers/agricultural workers ¹⁵	RR 2.61	Phorate exposure	OR 1.64
Sweden forestry workers ⁴⁹	SIR 3.6	US N Dak farmers pest expos. median surv. ¹⁰³	11.3 months
Sweden farmers ⁷⁴	SIR 1.4	No pesticide expos. median survival	20.1 months
Sweden farm workers ⁷⁵	SIR 1.4	US forestry soil conservationists ³¹	PMR 1.6
Sweden agricultural workers ⁷⁶	SMR 1.2	US farmers 26 NOMS ^(a) states ,blacks ¹⁰⁴	OR 1.4
US agricultural extension agents ⁴	PMR 1.9	US farmers 23 states whites ²³	PCMR 1.18
US national farming herb/pest. expos. (trend ns) ⁷⁷	OR 4.3	Soft Tissue Sarcoma	
US Iowa farmers ⁶	OR 1.5	Denmark male gardeners ⁴⁰	SMbR 5.29
US Wisconsin farmers ⁷	PMR 1.23	Japan male agric. workers (includes bone) ⁹	SPR 1.62
US Wisconsin farmers insecticide areas ⁷⁸	OR 1.9	Norway female orchard/grnhse workers ¹⁵	RR 3.9
US 4 states farmers pesticide exposed ⁷⁹	RR 2.6	Sweden farmers, gardeners ¹⁰⁵	OR 5.1, 4.1
US 4 states farm workers pest. expos. ≥ 10 yrs ⁸⁰	OR 7.9	US Iowa, N Carolina farmers, spouses ⁵	SMR 1.6, 1.1
Employed in forestry	OR 2.5	US Kansas farmer pesticide applicators ¹⁰⁶	OR 1.9
US farmers 23 states white males, white females ²³	PCMR 1.15, 1.78 bs	Stomach Cancer	
US farmers 26 states white male s, livestock ²⁴	PMR 1.29	Canada British Columbia farmers ⁵⁹	PCMR 1.36
US farmers meta-analysis 32 studies ⁸¹	RR 1.38	Italy forestry workers ¹⁰⁷	OR 4.3 bs*
Nasal Cancer		Italy farmers pesticide licensed >10 yrs ³⁰	OR 2.62
Denmark female farmers ⁸²	SPIR 7.4	Italy farmers/farm employees males ⁸	OR 1.25
Europe male, female orchard workers ⁸³	OR 3.72, 1.69	Japan farm workers female s ⁹	SPR 1.37
France farm workers males, females ⁸⁴	OR 2.2, 4.9 bs*	US California UFW ^(a) union members ¹⁸	MbOR 1.69
Sweden farmers died 1974-79 ⁸⁵	RR 2.1	US Calif. white farmers, farm workers ¹⁹	PCMR 2.02, 1.34
Nervous System Cancer		US Iowa farmers ⁶	OR 1.3
US National Mortality 1986-1994 ⁸⁶	RR 2.4	US Michigan agriculture white males ¹⁰⁸	OR 2.6
US 4 states females insecticide/fungicide expos. ⁸⁷	OR 1.2	US Wisconsin farmers ⁷	PMR 1.24
<i>(Non-Hodgkin Lymphoma See Table 1-C)</i>		US farmers 23 states non-white females ²³	PCMR 1.88
Pancreatic Cancer		US farmers 24 states migrant workers ¹⁰⁹	PCMR 1.22
Canada British Columbia farmers ³⁹	PCMR 1.2 bs*	White workers only	PCMR 1.38
Finland male gardeners ⁸⁸	OR 6.7	Testicular Cancer	
Italy farmers pesticide licensed vs non-licensed ³⁰	OR 5.18	England, Wales farm owners/managers ¹¹⁰	OR 1.85
Licensed vs entire cohort of farmers	OR 3.78	England, Wales farm owners, managers ¹¹¹	OR 1.89 bs*
Italy male farmers/farm employees ⁸	OR 1.42	Norway orchard /greenhouse workers ¹⁵	RR 1.63
Spain pesticide exposure ⁸⁹	OR 3.17	Sweden farmers (embryonal) ¹¹²	OR 3.1
US aerial pesticide applicators ⁵¹	RR 2.71	Farmer use of deet repellent	OR 1.7
US flour mill workers ≥ 25 years ⁵²	OR 2.2	Sweden agricultural pesticide applicators ¹¹³	SIR 1.55 bs*
US grain millers ⁹⁰	PMR 1.91	US black farmers who grew up in the South ¹¹⁴	OR 1.4
US Iowa farmers ⁵³	SMR 1.23	US Texas farming, agricultural work ¹¹⁵	OR 6.27
US Louisiana farmers pesticide exposed ⁹¹	OR 1.39	Thyroid Cancer	
US Wisconsin farmers ⁷	PMR 1.20	Denmark female farmers/farm employees ⁸	SIR 1.6
US 3 states (GA,MI,NJ) pest. expos. trend sig ⁹²	OR 1.4	US Iowa, North Carolina. farmers ⁵	SMR 2.9
Fungicide exposure blacks, whites	OR 1.5, 1.4 bs		
US farmers 23 states males white, black ²³	PCMR 1.13, 1.2 bs		

* bs = borderline signif. (a) National Occupational Mortality Surveillance
Continued Table 1-C

Table 1-C
Occupational Agricultural Pesticide Exposure - Increased Risk
(See Appendix F for explanation of the table)

Non-Hodgkin Lymphoma		DDT use	
Canada farmers raising bison/elk/ostriches ¹¹⁶	OR 3.26	US farmers 4 midwest states handled DDT ¹³⁰	RR 1.5
4 to 15 years living on a farm	OR 2.15	Handled DDT ≥ 5 days/year (Nebraska)	OR 1.6
More than 13 head of swine	OR 1.96	US farmers 23 states white males ²³	OR 2.6
Diesel fuel/exhaust exposure	OR 1.52	US farm managers 24 states ¹³¹	PCMR 1.2
Canada farmers herbicide use ¹¹⁷	OR 1.38	US farmers 4 states organophosphate use ¹³²	OR 2.8
2,4-D, Dicamba use	OR 1.32, 1.88	US farmers 26 NOMS ^(a) states white ♂ livestock	PMR 1.17
Mecoprop, malathion use	OR 2.33, 1.83	US farmers meta-analysis 6 studies ¹³³	RR 1.34
Organophosphate, carbamate use	OR 1.73, 1.92	US farmers meta-analysis 36 studies ¹³⁴	RR 1.10
Aldrin, carbaryl, DDT, lindane use	OR 2.11	Central US farmers only	RR 1.26
Amide fungicides, CCl ₄ fumigant use	OR 2.42	US flour mill workers after 25 years ⁵²	SMR 9.4
Canada farmers 8 provinces herbicide use ¹¹⁸	OR 1.3 bs*	US grain millers ⁹¹	PMR 2.02
Canada farmers heavy herbicide use ¹¹⁹	RR 2.1	US soil conservationists ≥ 15 yrs in forestry ³¹	OR 11.2
Canada farmers herbicide use ≥ 100 acres ¹²⁰	RR 2.14	US Illinois farmers Winnegabo county ¹³⁵	SMR 2.65
France pest. users (hairy cell leukemia ^a) ¹²¹	OR 1.5	US Iowa farmers ¹³⁶	OR 1.3
Organophosphate exposure (non-smokers)	OR 7.5	US Iowa farm women ¹³⁷	RR 1.89
France farmers (hairy cell leuk. ^a) males, females ¹²²	OR 2.0, 2.7	US Iowa, Minnesota farmers DDT use ¹³⁸	OR 1.5
Italy animal breeders ⁴⁶	OR 1.79	Chloramben use	OR 2.2
Italy farmers triazine herb. exposure > 18 yrs ¹²³	OR 9.3 bs*	US Iowa, Minnesota exposure methyl bromide ⁵⁶	OR 2.82
Italy male farmers/farm employees ³	OR 1.59	Herbicide exposure	OR 2.06
Italy agriculture herbicide exposure 1-10 yrs ³⁵	RR 2.6	Insecticide exposure	OR 1.90
Herbicide exposure 10 years or more	RR 5.2	US Kansas farmers mix/apply herbicides ¹³⁹	OR 8.0
New Zealand orchard farmers ¹²⁴	OR 3.7	Herbicide exposure > 20 days per year	OR 6.0
New Zealand farmers < age 65 ¹²⁵	OR 1.76	US Missouri farmers ¹⁰⁰	OR 1.4
Sweden fungicide use ¹²⁶	OR 3.11	US Nebraska female farmers pest. exposed ¹⁴⁰	OR 4.5
Glyphosate herbicide use	OR 3.04	Pesticide use dairy cattle	OR 3.0
MCPA herbicide use	OR 2.62	Organochlorine use	OR 1.6
Wood preservative use	OR 1.88	US Nebraska farmers organophosphate use ¹⁴¹	OR 1.9
Any herbicide use	OR 1.75	Carbamate use	OR 1.8
Any insecticide use	OR 1.43	US Nebraska 2,4-D use >20 days/year ¹⁴²	OR 3.0
Sweden farmers (hairy cell leuk. ^a) fungicide use ¹²⁷	OR 3.8	US Utah farmers diagnosed 1952-65	OR 6.6
Herbicide use	OR 2.9	Diagnosed 1966-1971	OR 3.1
Insecticide use	OR 2.0	US Washington state farmers ¹⁴³	OR 1.33
Sweden female animal breeders ⁸⁰	SIR 5.3	Forest herbicide applicators	OR 4.8
Sweden dairy workers ¹²⁸	SIR 1.8	DDT exposure	OR 1.8
US agricultural extension agents ⁴¹	PMR 2.3	US Wisconsin farmers insecticide use ¹⁴⁴	OR 6.6
US farmers methyl bromide use ¹²⁹	OR 2.82	Wheat farmers, general agriculture	OR 4.4, 3.2
Chloramben use	OR 2.2	Farmers younger than 65 at diagnosis	OR 1.67
Herbicide use	OR 2.06		
Insecticide use	OR 1.90		
Pentachlorophenol use	OR 1.86		

* bs = borderline significance

(a) Hairy cell leukemia is a rare subtype of non-Hodgkin lymphoma.

(b) National Occupational Mortality Surveillance

Table 2
Occupational Agricultural Exposure – Decreased Risk or No Association Found
(See Appendix F for explanation of the table)

Bladder Cancer		US Iowa farm women ¹⁵¹	RR 0.32
Italy farmers ⁶⁸	RR 0.6	US Iowa, North Carolina farmers ⁴²	SMR 0.3
US Iowa, North Carolina farmers ⁵	SMR 0.57	US Illinois farmers ⁸⁶	SMR 0.82
US Iowa farm women ¹¹⁹	RR 0.33	US Washington apple orchard workers ¹⁵⁷	No association
Bone Cancer		Non-Hodgkin Lymphoma	
US Wisconsin farmers ⁴⁴	No association	Canada agricultural pesticide exposure ¹⁵⁸	No association
Brain Cancer		Italy farmers pesticide licensed ⁷⁴	SMR 0.90
Europe farm workers ¹⁴⁵	OR 0.66	Italy farmers ¹⁵⁹	No association
Europe farm animal contact ¹⁶³	No association	Sweden female farmers ¹⁶³	SIR 0.78
Italy farmer pesticide licensed ⁶³	No association	US female farmers ¹⁶¹	RR 0.93
US farmers ,CNS ^(a) lymphoma ¹⁴⁶	No association	US Iowa, North Carolina farmers spouses ⁴²	No association
Breast Cancer		US North Carolina farmers/farm workers ¹⁶⁰	No association
Denmark gardeners ⁷¹	No association	High pesticide use counties	No association
Japan farm workers ⁴⁶	SPR 0.73	Multiple Myeloma	
Sweden female farmers ¹⁶³	SIR 0.83	Canada British Columbia farmers ⁹²	No association
US 24 states migrant workers ¹²⁸	Decrease	US aerial pesticide applicators ⁸²	RR 0.23
US female applicators using PPE ^(b) 147	OR 0.8	Nasal Cancer	
US Washington apple orchard worker ¹⁴⁸	OR 0.75	Sweden farmers ¹⁷⁶	RR 0.42
Colorectal Cancer		Pancreatic Cancer	
Italy farmers ⁶⁵	RR 0.6	US 24 states non-white migrant workers ¹²⁸	Decrease
Sweden male farmers ¹⁴⁹	SIR 0.8	Prostate Cancer	
Females	OR 0.9	US Iowa farmers ¹⁶¹	No association
Sweden female farmers ¹⁶³	OR 0.86	US California farm workers ⁵⁵	No association
US aerial applicators ⁸²	RR 0.51	Stomach Cancer	
US 24 states migrant workers ¹²⁹	Decrease	US aerial pesticide applicators ¹⁶²	SMR 0.68 ^(d)
Hodgkin Disease		Soft Tissue Sarcoma	
Canada farmers pest. expos >10 hrs/yr ¹⁵⁰	OR 0.85	England/Wales farming/forestry workers ¹⁶³	No association
Potential pesticide exposure	OR 0.96	Italy farm employment ¹⁶⁴	OR 0.8
Italy farmers pesticide licensed ¹⁵¹	No association	Pesticide exposure	OR 0.4
US Kansas farmers ¹¹²	No association	Italy male rice weeders, herbicides ¹⁶⁵	OR 0.91
Kidney Cancer		Sweden female farmers ¹⁶³	SIR 0.62
Finland farmers ¹⁵²	Decrease	Sweden farming, forestry workers ¹⁰⁶	OR 0.9
Sweden female farmers ¹⁶³	SIR 0.81	US Kansas farmers ¹¹²	No association
Sweden pesticide applicators ¹⁵³	SIR 0.53	Testicular Cancer	
US California farmers ⁵⁵	No association	Canada farmers ¹⁶⁶	OR 0.89
US Wisconsin farmers ⁴⁴	No association	England/Wales farm workers ¹³⁰	OR 0.9
US 24 states migrant workers ¹²⁸	No association	US Washington farmers, gardeners ¹⁶⁷	RR 0.6
Leukemia		US currently a farmer ¹³⁴	OR 0.6
Canada poultry farmers ¹⁵⁴	No association	Ever a farmer	OR 0.9
US 16 states back farmers ¹⁵⁵	OR 0.7	Thyroid Cancer	
Liver and Biliary		Sweden horticultural workers ¹⁶⁸	Decrease
Japan farm workers ⁴⁶	SPR 0.64		
Lung Cancer			
Brazil farm workers ¹⁵⁶	No association		
Sweden female farmers ¹⁶³	SIR 0.46		

- a Central nervous system
b Personal protective equipment (mask, gloves etc.)
c All three gastric cancer deaths occurred in those with the most flight hours (more than 1,280)

Table 3
Non-Agricultural Occupational Pesticide Exposure - Increased and Decreased Risk
Pesticide Applicators, Pest Control Operators (PCOs), Exterminators
(See Appendix F for explanation of the table)

Increased Risk		Decreased Risk	
Bladder Cancer		Breast Cancer (female)	
England/Wales PCOs ^(a) 6 ¹⁶⁹	OR 2.4 bs	US Florida licensed PCOs ^(a) 179	Decrease
US 40 states applicators ¹⁷⁰	SMR 2.77	Colombia DDT exposure ²⁵⁸	Decrease
Brain Cancer		Kidney Cancer	
Italy PCOs ¹⁷¹	SMR 2.7	Sweden applicators ¹⁷²	SIR 0.53
US golf course superintendents ¹⁷²	PMR 2.3	Non-Hodgkin Lymphoma	
Colorectal Cancer		Finland herbicide applicator cohort ¹⁸¹	SMR 0.42
Iceland pesticide applicators entire cohort ²⁹	SIR 2.94	US Florida licensed PCOs ^(a) 178	No association
Licensed users only	RR 4.63	Liver and Biliary Cancer	
US golf course superintdents ¹⁷²	OR 1.75	Sweden applicators ¹⁷²	OR 0.45
Leukemia		Lung Cancer	
Iceland female applicators only ²⁹	SIR 5.6	Italy PCOs ^(a) 171	SMR 0.5
Australia outdoor workers (myeloid) high expos. grp ¹⁷³	SMR 20.9	Sweden applicators ¹⁷²	OR 0.50
Liver and Biliary Cancer		Pancreatic Cancer	
Italy PCOs ^(a) 171	SMR 5.7	Sweden applicators ¹⁷²	SIR 0.5
Sardinia malaria sprayers ¹⁷⁴	PMR 2.4	Soft Tissue Sarcoma	
Lung Cancer		Sweden applicators ¹⁸²	RR 0.9
US Florida exterminators less than age 40 ¹⁷⁵	OR 2.4 bs [†]	US Florida licensed PCOs ^(a) 197	No cases
US national cohort PCOs ^(a) 176	SMR 1.35		
Lymphoma			
US lawn applicators more than 3 years ¹⁷⁷	SMR 7.1		
US golf course superintdents ¹⁷²	PMR 2.4		
Multiple Myeloma			
Netherlands herbicides ¹⁷⁸	SMR 8.2		
Sardinia malaria sprayers ¹⁷⁴	PMR 3.4		
US Florida licensed PCOs ^(a) 179	SIR 2.5		
US golf course superintendents ¹⁷²	PMR 2.9		
Pancreatic Cancer			
Australia outdoor workers DDT exposed ¹⁷³	SMR 5.3		
Soft Tissue Sarcoma			
International cohort herbicide sprayers ¹⁸⁰	SMR 8.2		
Testicular Cancer			
US Florida licensed PCOs ^(a) 179	SIR 2.5		

a Pest control operators, exterminators

Table 4
Pesticide Manufacturing and Formulation - Increased Risk
(See Appendix F for explanation of the table)

Bladder Cancer		Non-Hodgkin Lymphoma	
Denmark chlordimeform ¹⁸³	SIR 35.0	Germany cohort phenoxy herbicide workers ²⁰⁶	SMR 3.26
Germany (East) chlordimeform ¹⁶⁹	SIR 89.7	20 years or more since first exposure	SMR 4.25
Germany (West) chlordimeform ¹⁶⁹	SIR 53.8	Sweden herbicide workers ²⁴⁷	OR 3.7
US organochlorines ¹⁸⁴	SMR 7.1	MCPA	OR 2.7 bs*
US agricultural chemicals ¹⁸⁵	OR 3.3	Phenoxy herbicides	OR 1.5 bs*
Breast Cancer (female)		Sweden phenoxy herbicides ²⁰⁷	OR 5.5
Germany herbicides ¹⁸⁶	SMR 2.15 bs*	Pentachlorophenol	OR 4.8
International cohort herbicide workers ¹⁸⁷	SMR 2.16 bs*	Phenoxy herbicides	OR 4.9
US New York ethylene oxide ¹⁸⁸	SMR 2.55	Creosote	OR 9.4
Colorectal Cancer		US Iowa alachlor factory workers ²⁰⁸	SIR 18.6
US Iowa alachlor factory ¹⁸⁹	SIR 4.3	US Maryland male arsenate workers ²⁰⁸	SMR 8.53
5 years since first exposure	SIR 5.2	US ethylene oxide males ²⁰⁹	Increase
US Maryland female arsenates workers ¹⁹⁰	SMR 6.7	Pancreatic Cancer	
Eye Cancer		Spain all pesticide workers ¹¹⁷	OR 3.17 bs*
US pesticide factory workers ¹⁹¹	OR 2.3	Arsenical exposure only	OR 3.4 bs*
Formaldehyde workers	OR 2.9	US 24 states formaldehyde cohort ²¹⁰	OR 1.2-1.4
Hodgkin Disease		US Philadelphia nitrofen ²¹¹	RR 12.0
Sweden creosote workers ¹⁹²	OR 10.7	DDT	RR 4.8-7.8
Kidney Cancer		Ethylan	RR 5.0
International herbicide cohort ¹⁹³	SMR 1.6	Nitrophenol	RR 4.5
US Michigan pentachlorophenol workers ¹⁹⁴	RR 4.16	DDD	RR 4.3
Leukemia		Carbon tetrachloride	RR 4.1
England phenoxy herbicides ¹⁹⁵	SMR 1.7 bs*	Dinocap	RR 4.1
US Iowa alachlor workers ²⁰⁷	SIR 25.0	Prostate Cancer	
Most heavily exposed	SIR 28.6	US black DDT workers ²¹²	Increase
Sweden ethylene oxide ¹⁹⁶	SIR 2.44	Soft Tissue Sarcoma	
Liver and Biliary Cancer		US chlorophenol workers ²¹³	OR 1.79
US organochlorines ²⁰²	SMR 3.9	Exposed for 10 years or more	OR 7.78
England phenoxy herbicide cohort ²¹³	SMR 1.15	Sweden phenoxy herbicides ²¹⁴	OR 3.0
Lung Cancer		International herbicide ²¹⁵	OR 10.32
England 4 pesticide factories ¹⁹⁷	SMR 1.34	Denmark herbicide work more than 10 years ²¹⁶	SIR 6.4
England phenoxy herbicide cohort ²¹³	SMR 1.15 bs*	US Alabama herbicide factory ²¹⁷	SMR 4.84
International herbicide cohort ²¹¹	SMR 1.12 bs*	Europe herbicide worker 10-19 yrs ¹⁹⁸	SMR 6.06
US diatomaceous earth workers ¹⁹⁸	SMR 1.4	Sweden chlorophenols ²¹⁸	RR 5.25
US Michigan DBCP workers ¹⁹⁹	OR 3.3	Pentachlorophenol	RR 3.85
US Illinois chlordane/others ²⁰⁰	SMR 1.22	2,4,5-T	RR 2.94
Increasing years of exposure	SMR 1.46	Phenoxy herbicides	RR 1.80
US Maryland male arsenate workers ²⁰⁸	SMR 2.65	Sweden phenoxy herbicide ²¹⁹	RR 6.8
US Michigan/Arkansas pesticide factories ²⁰¹	SMR 1.31 bs*	New Zealand herbicide workers ²²⁰	RR 1.3
Nasal, Sinonasal Cancer		Stomach Cancer	
England herbicide cohort ²¹³	SMR 4.93	Sweden all herbicides ²²¹	OR 1.56
Europe female formaldehyde workers ²⁰²	OR 6.2	Phenoxy herbicides	OR 1.70
Males	OR 3.0	US Michigan pentachlorophenol ²¹²⁹	RR 3.63
Phillippines formaldehyde ²⁰³	OR 4.0	Testicular Cancer	
US chlorophenol workers ²⁰⁴	OR 5.9	US Michigan /Arkansas pesticide factories ²¹⁹	SMR 17.99 ^(a)
US chlorophenol workers ²⁰⁵	OR 1.94		
Exposed 10 years or more	OR 9.07		

* bs = borderline significance

a Two deaths in workers with methyl bromide as the only exposure in common.

Table 5
Pesticide Manufacturing and Formulation - Decreased Risk or No Association
(See Appendix A for information on using this table)

Brain Cancer		Pancreatic Cancer	
Sweden seed disinfection workers ²²²	Decrease	US ethylene oxide ^(a) workers ^{229,230}	Decrease
Breast Cancer (male)		US ethylene oxide ^(a) workers ²²⁷	Decrease
US male pesticide workers ²²³	Decrease	Soft Tissue Sarcoma	
Leukemia		Sweden chlorophenol exposure ²³³	No association
England/Wales ethylene oxide ^(a) workers ²²⁴	Decrease	Netherlands cohort herbicide workers ²³¹	No cases
Germany ethylene oxide workers ²²⁵	Decrease	Stomach Cancer	
US ethylene oxide workers ²²⁷	Decrease	England/Wales ethylene oxide ^(a) 243	Decrease
Liver/Biliary Cancer		US ethylene oxide ^(a) 227	Decrease
Netherlands dieldrin exposure ²²⁶	No association	US herbicide and other pesticide workers ¹²⁷	No association
Lung		US male ethylene oxide ^(a) workers ^{207,208}	Decrease
US Illinois chlordane workers ²²⁷	Decrease ^b		
Non-Hodgkin Lymphoma			
Sweden insecticides ²²⁸	No association		
International cohort herbicide workers ¹⁹⁸	No association		
US female ethylene oxide ^(a) workers ²²⁷	Decrease		

a A gas used to sterilize hospital equipment.
b A later study found a significant increase²¹⁸

Table 6
Environmental, Drift, and Other Non-occupational Pesticide Exposure - Increased Risk
(See Appendix F for explanation of the table)

Bladder Cancer		US California two fireman ^{(d)260}	Case report
US chlorinated water users ²³²	OR 1.43	US Minnesota females in wheat crop areas ²⁶¹	SRR 1.35
Bone Cancer		US Michigan males in pesticide use areas ²³⁵	OR 3.8
US 4 states ^(a) wheat areas ²³³	Increase	Females	OR 1.9
Brain Cancer		Malignant Melanoma - Skin	
Canada living in pesticide use area ²³⁴	Increase	US Georgia pesticide exposure ²⁶²	OR 3.56 bs*
Spain males living near HCB ^(b) factory ²³⁵	SIR 2.7 bs*	Nasal/Sinonasal Cancer	
Sweden living near farm pesticide area ²³⁶	OR 2.4 bs*	Phillippines insecticide coil burning ²²¹	OR 7.8
US Cape Cod females near cranberry bog ²³⁷	OR 6.7	US Minnesota females in pesticide areas ²⁷⁹	SRR 3.35
US states ^(a) males living wheat crop areas ²⁵¹	Increase	Ovarian Cancer	
Breast Cancer (female)		Italy flower workers adult children ¹²¹	SRR 3.35
Canada DDE levels (invasive, large size) ²³⁸	OR 3.5	Italy live corn crop/atrazine use areas ²⁶³	Increase
Canada DDE fat levels ER ⁻²³⁹	OR 2.4 bs*	Italy live corn/herbicide use areas ²⁶⁴	RR 4.28
Colómbia Bogotá DDE levels ²⁴⁰	OR 1.9	Pancreatic Cancer	
Denmark dieldrin decreased survival ^{241,242}	OR 2.6	Spain DDE levels and K-ras mutations ²⁶⁵	OR 8.8
Denmark dieldrin levels ²⁴³	OR 2.2	US California DDE serum levels ²⁶⁶	Increase
Finland β-HCH ^(c) fat levels ²⁴⁴	OR 10.5	US Calif.live hi use county 1,3-dichloropropene ²⁶⁷	OR 1.89
Germany p,p'-DDT fat levels ²⁴⁵	Increase	US Michigan self reported ethylan use ²⁶⁸	Increase
Mexico DDE levels - trend significant ²⁴⁶	OR 3.8	US 4 states ^(a) living in wheat crop areas ²⁵¹	Increase
US Connecticut DDE fat levels ²⁴⁷	OR 1.5	Prostate Cancer	
US Kentucky herbicide area ²⁴⁸	OR 1.2	Canada Montreal home use ²⁶⁹	OR 2.3
US Buffalo NY mirex levels ³⁰²	2.42 bs*	US 4 states ^(a) males in wheat crop areas ²⁵¹	Increase
US New York DDE levels ²⁴⁹	OR 4.0	US Minnesota males in pesticide areas ²⁷⁹	SRR 1.12 bs*
US North Carolina DDE levels blacks ²⁵⁰	OR 3.8 bs*	Rectal Cancer	
US HCB fat ER+ post-menopausal ²⁵¹	OR 7.1	US 4 states ^(a) males in wheat crop areas ²⁵¹	Increase
US DDE levels ER+ ²⁵²	Increase	Soft Tissue Sarcoma	
US DDE fat levels ²⁵³	Increase	Finland chlorophenol water ²⁷⁶	RR 8.9
Eye Cancer		Italy men living in rice crop areas ²⁷⁷	SMR 1.8
US self reported expos. (uveal melanoma) ³³	OR 1.36 ns	Spain men living near HCB ^(b) factory ²⁵³	SIR 5.5
US 4 states ^(a) females in wheat crop areas ²⁵¹	Increase	US self-reported herbicide use ¹⁹⁵	OR 2.9
Kidney Cancer		Stomach Cancer	
US 4 states ^(a) males in wheat crop areas ²⁵¹	Increase	Hungary males in high pesticide use village ²⁷⁰	RR 3.20
Leukemia		US 4 states ^(a) living in wheat crop areas ²⁵¹	Increase
Australia females living sugar cane area ²⁵⁴	OR 1.54	Thyroid Cancer	
Canada Quebec live pesticide use area ²⁵²	Increase	Spain males living near HCB ^(b) factory ²⁵³	SIR 6.7
Italy flower workers adult children ¹²¹	Increase	US 4 states ^(a) males in wheat crop areas ²⁵¹	Increase
Phillippines males living rice crop areas ²⁵⁵	SMR 4.8	US Minnesota males in pesticide use areas ²⁷⁹	SRR 1.12 bs*
US Michigan living pesticide use areas ²⁵⁶	SIR 1.4		
Liver and Biliary Cancer			
US 24 states fat DDE- whites ²⁵⁷	Increase		
US states ^(a) females in wheat crop areas ²⁵¹	Increase		
Non-Hodgkin Lymphoma			
Australia females living sugar cane area ²⁷²	SMR 1.54		
Canada Quebec live pesticide use area ²⁵²	RR 1.6-3.7		
Finland chlorophenol water ²⁵⁸	RR 2.8		
Italy men living in rice crop areas ²⁵⁹	RR 2.07		
Women	RR 1.28		

* bs = borderline significance

- a Minnesota, North Dakota, South Dakota, Montana
- b Hexachlorobenzene.
- c Hexachlorocyclohexane (lindane)
- d Both developed lymphoma 6 years after helping

Table 7
Environmental, Drift, other Non-occupational Pesticide Exposure - Decreased Risk or No Association
(See Appendix F for explanation of the table)

Breast Cancer (female)			
Brazil, Rio DDE levels ²⁷¹	OR 0.79	Vietnam DDE/DDT levels ²⁹³	No association
Denmark DDT fat levels ²⁷²	No association	Endometrial Cancer	
Europe ^(a) DDE fat levels ²⁷³	OR 0.48	Sweden DDE, HCB levels ²⁹⁴	No association
Germany β -HCH ^(b) fat levels ²⁶³	Decrease	beta-HCH ^(b)	OR 0.9
Mexico HCB ^(c) levels ²⁷⁴	OR 0.46	US five regions DDE levels ²⁹⁵	RR 0.7
Norway pesticide ^(d) levels ²⁷⁵	No association	Liver and Biliary	
Sweden DDE fat levels ²⁶⁹	No association	US 24 states DDE levels blacks ²⁷⁵	No association
US California DDT levels ²⁷⁶	OR 0.90	Non-Hodgkin Lymphoma	
US Calif. DDE serum levels ²⁷⁷	No association	Australia males in sugar cane areas ²⁷²	SMR 0.49
US Cape Cod live near cranberry bogs ²⁵⁵	No association	US 24 states DDE fat levels ²⁷⁵	No association
US Connecticut DDE levels ²⁷⁸	OR 0.96	Multiple Myeloma	
US Connecticut oxychlordane ²⁷⁹	OR 0.7	US South Carolina pesticide areas ²⁹⁶	No association
US Connecticut DDE, DDT fat levels ²⁸⁰	OR 0.9, 0.8	US 24 states DDE fat levels ²⁷⁵	No association
US Connecticut HCB fat levels ²⁸¹	No association	Ovarian Cancer	
US Connecticut β -HCH ^(b) levels ²⁸²	No association	US Kentucky live atrazine use area ²⁹⁷	Decrease
US Kentucky atrazine exposure ²⁸³	Decrease	Pancreatic Cancer	
US Missouri DDT levels ²⁸⁴	No association	US 24 states fat DDE levels ²⁷⁵	No association
US North Carolina DDE levels, whites ²⁸⁸	OR 0.98	Soft Tissue Sarcoma	
US Buffalo NY HCB levels ²⁸⁵	OR 0.82	Italy females living in rice crop areas ²⁷⁷	SMR 0.9
US New York DDE serum levels ²⁸⁶	No association	Stomach Cancer	
US New York DDE, transnonachlor ²⁸⁷	No association	US California DBCP contamination ²⁹⁸	No association
US 24 states DDT fat levels ²⁷⁵	Decrease		
US DDE, DDT tissue levels ²⁸⁸	No association		
US DDE meta-analysis 5 studies ²⁸⁹	No association		
US DDE levels Nurses' Study update ²⁹⁰	OR 0.82		
US DDE1974 serum levels ²⁹¹	OR 0.5		
US DDE serum levels ²⁹²	OR 0.72		

- a Germany, Netherlands, Northern Ireland, Spain, Switzerland.
b Hexachlorocyclohexane (lindane)
c Hexachlorobenzene
d β -HCH, heptachlor epoxide, oxychlordane, transnonachlor, p,p'-DDE, dieldrin

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