

GE Study of 7,075 Capacitor Workers *

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*Worked for at least 3 months between
January 1, 1946 to June 15, 1977

Mortality in Male and Female Capacitor Workers Exposed to Polychlorinated Biphenyls

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A mortality study was conducted in workers with at least 90 days' exposure to polychlorinated biphenyls (PCBs) between 1946 and 1977. Vital status was established for 98.7% of the 7075 workers studied. In hourly male workers, the mortality from all cancers was significantly below expected (standardized mortality ratio [SMR] = 81; 95% confidence interval [CI], = 68 to 97) and comparable to expected (SMR = 110; 95% CI, 93 to 129) in hourly female workers. No significant elevations in mortality for any site-specific cause were found in the hourly cohort. All-cancer mortality was significantly below expected in salaried males (SMR = 69; 95% CI, 52 to 90) and comparable to expected in salaried females (SMR = 75; 95% CI, 45 to 118). No significant elevations were seen in the most highly exposed workers, nor did SMRs increase with length of cumulative employment and latency. None of the previously reported specific excesses in cancer mortality were seen. This is the largest cohort of male and female workers exposed to PCBs. The lack of any significant elevations in the site-specific cancer mortality of the production workers adds important information about human health effects of PCBs.

Polychlorinated biphenyls (PCBs) are complex mixtures of 209 different chlorinated biphenyl congeners. They were used extensively in the United States from the 1930s through 1977 in a variety of industrial applications. PCB mixtures have several chemical and physical properties that made them extremely versatile, including resistance to acids and bases as well as oxidation and reduction; compatibility with organic materials; and thermal stability and nonflammability. The major volume usage of PCBs was in capacitors and transformers as dielectric fluids, but they were also used as lubricants and sealants; as additives in paint, plastics, newspaper print, and dyes; as extenders in pesticides; and as heat transfer and hydraulic fluids. More than 95% of the liquid-filled electrical capacitors and transformers produced before the early 1970s contained PCBs. PCBs are persistent chemicals and have bioaccumulated in the environment. They continue to be detected in air, soil, water, and sediment. Trace amounts are also present in the tissues of wildlife, domestic animals, and humans; however, the levels of PCBs in the environment are declining.

The potential for adverse human health effects of PCB exposure has been a concern since the early 1970s and resulted in the Environmental Protection Agency's ban of the production of PCBs in 1978. Current knowledge regarding the human health effects of PCBs is limited, inconsistent, and difficult to interpret. Occupational mortality studies of capacitor workers have reported

From the Institute for Evaluating Health Risks, Washington, DC.

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DSW 189732

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Strengths of Study

- Largest cohort (7,075 workers)
- Highest number of person years (212,778)
- Only 1.3% of workers lost to follow-up
- Largest number of deaths with 1,195 death certificates
- Advisory committee of experts

Overview

- Methodology

Assemble the cohort

Assure completeness of cohort

Determine number of dead people and
obtain death certificate

Verify that the remainder of the cohort
is truly alive

- Results

Exposure

SMR (Standardized Mortality Ratio) analysis

Establishing the Cohort

- Copied worker histories from NIOSH and GE files
- Created paper record for each worker with ID number
- Abstracted records into electronic file
- Corrected errors in electronic file

Completeness of Cohort

- Review of pension records
- Review of Social Security Administration 941 Forms = quarterly earning reports
- Review of GE employee profile data base

Determining Death

- Equifax: Social Security mortality tapes
- National Death Index since 1979
- Obituaries tapes
- Tapes of the Veterans Administration
- Private investigator

Vital Status Search

- GE pension records
- Equifax (insurance plus claims information)
- Polk directories
- Voter registration records
- Telephone directories
- Private investigator
- Asking long-term worker

Data Entered

- Name
- Social Security Number
- Birth Date
- Start and end dates of employment
- Start and end dates for each job during employment
- Job codes
- Dates and reason absent from work

(Problem: difficult to read records)

Demographic Characteristics*

DSW 189740

<u>Characteristic</u>	<u>Hourly</u>		<u>Salary</u>		<u>TOTAL</u>
	<u>Male</u>	<u>Female</u>	<u>Male</u>	<u>Female</u>	
Number of workers	2984	2544	1078	469	7075
Number of deaths	586	380	177	52	1195 (17%)
Number lost to follow-up	33	52	7	3	95 (1.3%)
Mean years worked	6.2	5.8	5.7	4.8	
Number ever highly exposed	1268	352	87	10	1717
Number ever undefinably exposed	2031	133	407	9	2580
Number ever low exposed	2343	2468	831	459	6101
Mean years of follow-up	28	30	32	34	
Percent attended college	15	7	73	26	

*Inclusion criteria: must have worked for at least 3 months between 01/01/46 - 06/15/77.
Total person years 212,778

Deaths¹ in 2,984 Hourly Males,² 2,544 Hourly Females,³
1,078 Salaried Males⁴ and 469 Salaried Females⁵

DSW 189741

Cause of Death	HOURLY				SALARY			
	Males Obs/Exp	SMR (95% C.I.)	Females Obs/Exp	SMR (95% C.I.)	Males Obs/Exp	SMR (95% C.I.)	Females Obs/Exp	SMR (95% C.I.)
All Causes	586 / 699	83.8** (77-91)	380 / 420	90.4* (82-100)	177 / 328	53.9** (46-62)	52 / 75	69.0** (52-91)
All Cancers	128 / 158	81.1* (68-97)	150 / 136	109 (93-129)	56 / 81	69.1** (52-90)	19 / 25	75 (45-118)
Cancer of Tongue	1 / 0.9	103 (3-576)	2 / 0.4	483 (59-1745)	0 / 0.1	—	1 / 0.1	1346 (34-7498)
Other Cancer of Buccal Cavity	2 / 1.1	178 (22-642)	2 / 0.5	365 (44-1317)	0 / 0.5	—	1 / 0.1	1021 (26-5690)
Cancer of Pharynx	4 / 2.0	199 (54-509)	2 / 0.7	253 (31-915)	0 / 1.0	—	0 / 0.1	—
Cancer of Esophagus	5 / 3.8	131 (42-304)	1 / 1.1	87 (2-482)	1 / 2.0	49 (1-272)	0 / 0.2	—
Cancer of Stomach	4 / 5.9	68 (18-173)	4 / 3.0	132 (36-339)	1 / 2.7	36 (0.9-200)	0 / 0.5	—
Cancer of Intestine	8 / 14.0	57 (25-112)	20 / 12.7	157 (96-242)	7 / 7.1	98 (40-203)	1 / 2.2	44 (1-247)
Cancer of Rectum	3 / 3.4	87 (18-255)	4 / 2.2	169 (46-434)	3 / 1.6	185 (38-540)	0 / 0.4	—
Cancer of Biliary Passages & Liver	2 / 2.5	80 (10-289)	2 / 2.2	89 (11-321)	1 / 1.2	79 (2-439)	0 / 0.3	—
Cancer of Pancreas	9 / 7.8	116 (53-219)	7 / 5.9	117 (47-241)	6 / 3.9	150 (55-327)	0 / 1.1	—
Cancer of Larynx	3 / 2.0	147 (30-428)	1 / 0.4	215 (5-1198)	0 / 1.0	—	0 / 0.1	—

Cause of Death	HOURLY				SALARY			
	Males Obs/Exp	SMR (95% C.I.)	Females Obs/Exp	SMR (95% C.I.)	Males Obs/Exp	SMR (95% C.I.)	Females Obs/Exp	SMR (95% C.I.)
Cancer of Trachea, Bronchus & Lung	42 / 54.5	77 (56-104)	32 / 25.2	127 (87-179)	12 / 29.6	40.5** (21-71)	5 / 4.7	104 (34-244)
Cancer of Breast	—	—	25 / 30	82 (53-121)	—	—	6 / 5.7	104 (38-226)
Cancer of Cervix Uteri	—	—	6 / 4.7	128 (47-277)	—	—	1 / 0.9	112 (3-622)
Cancer of Other Parts of the Uterus	—	—	5 / 3.8	131 (43-306)	—	—	0 / 0.6	—
Cancer of Ovary, Fallopian Tube, Broad Ligament	—	—	8 / 9.3	85 (37-168)	—	—	2 / 1.7	115 (14-415)
Cancer of Prostate	12 / 10.9	110 (57-192)	—	—	3 / 5.3	56 (5-136)	—	—
Cancer of Kidney	3 / 4	75 (15-219)	2 / 2.1	94 (11-341)	0 / 2.1	—	—	—
Cancer of Bladder & Other Urinary Organs	3 / 3.8	77 (16-226)	2 / 1.3	151 (18-545)	1 / 1.8	54 (1-300)	0 / 0.2	—
Cancer of Skin	5 / 3.8	130 (42-303)	3 / 2.0	144 (30-421)	4 / 1.9	210 (57-538)	0 / 0.4	—
Cancer of Brain and Nervous System	2 / 5.1	39 (5-140)	2 / 3.7	53 (6-192)	4 / 2.5	156 (42-398)	0 / 0.7	—
Lymphosarcoma	2 / 2.1	92 (11-331)	1 / 1.5	65 (2-364)	0 / 1.0	—	0 / 0.2	—
Leukemia & Aleukemia	4 / 6.3	63 (17-162)	4 / 4.3	93 (25-238)	5 / 3.1	166 (54-387)	0 / 0.8	—
Other Lymphatic & Hematopoietic Tissue	5 / 5.7	87 (28-202)	5 / 4.7	105 (34-245)	4 / 3.0	131 (36-336)	0 / 0.8	—

DSW 189742

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Cause of Death	HOURLY				SALARY			
	Males Obs/Exp	SMR (95% C.I.)	Females Obs/Exp	SMR (95% C.I.)	Males Obs/Exp	SMR (95% C.I.)	Females Obs/Exp	SMR (95% C.I.)
Diabetes	4 / 10.5	38* (10-97)	9 / 10.3	87 (40-165)	5 / 5.1	97 (32-226)	0 / 1.8	—
Ischemic Heart Disease	182 / 205	89 (76-103)	71 / 87	81 (64-103)	44 / 97.5	45** (33-61)	8 / 14.3	56 (24-110)
Cerebrovascular Disease	26 / 34.9	74 (49-109)	27 / 30	89 (59-130)	3 / 15.2	20** (4-58)	6 / 5	120 (44-260)
Diseases of Arteries, Veins, Pulmonary Circulation	19 / 17.0	112 (67-174)	10 / 11	95 (46-175)	4 / 8.0	50 (14-128)	1 / 1.8	56 (1-310)
Emphysema	7 / 7.3	96 (39-198)	3 / 3.1	97 (20-283)	1 / 3.3	30 (0.8-168)	0 / 0.5	—
Pneumoconioses & other Respiratory Diseases	18 / 19.6	92 (54-145)	10 / 11.9	84 (40-154)	3 / 10.2	29* (6-86)	0 / 2.1	—
Cirrhosis of the Liver	13 / 17.9	72 (39-124)	6 / 9.2	65 (24-142)	3 / 9.1	33* (7-96)	1 / 1.7	57 (1-318)
Transportation Accidents	29 / 34.7	84 (56-120)	14 / 9.1	153 (84-257)	3 / 12.6	24** (5-69)	3 / 1.9	156 (32-455)
Other Accidents	10 / 14.4	69 (33-127)	5 / 3.1	158 (51-369)	3 / 5.9	51 (11-148)	1 / 0.6	169 (4-886)
Suicide	14 / 21.3	66 (36-110)	3 / 2	44 (9-128)	2 / 6.6	23* (3-84)	2 / 1.4	140 (17-507)
Homicide	3 / 8.4	36 (7-104)	2 / 2	96 (12-345)	0 / 3.0	—	0 / 0.4	—

* Significant at $p < 0.05$; ** significant at $P < 0.01$

Expected numbers based on age-sex-race and time specific United States rates coded according to the rules of the International Classification of Diseases coding in force at the time of death.

85-99: 1 person-years of observation

75-84: 4 person-years of observation

55-74: 16 person-years of observation

15-54: 358 person-years of observation

TABLE 9

Observed and Expected¹ Deaths for Selected Causes Using Regional Comparison Data in 2544 Hourly Female (75,674 Person-Years) and 2984 Hourly Male Workers (86,056 Person-Years)

Cause of Death ²	Males		Females	
	Observed/Expected	SMR(95% CI) ³	Observed/Expected	SMR (95% CI)
All Causes	586 / 713	82.2** (76-89)	380 / 449	84.6* (76-94)
All Cancers	128 / 170	75.2** (62-89)	150 / 152	99 (84-116)
Cancer of Buccal Cavity & Pharynx	7 / 4.2	164 (66-337)	6 / 2.2	268 (98-583)
Cancer of Digestive Organs and Peritoneum	32 / 45.1	71 (49-100)	40 / 35.6	112 (80-153)
Cancer of Esophagus	5 / 4.1	120 (39-280)	1 / 1.5	65 (2-360)
Cancer of Stomach	4 / 5.1	77 (21-199)	4 / 3.2	124 (33-318)
Cancer of Large Intestine	7 / 17.0	41.1* (17-85)	20 / 16.6	120 (74-186)
Cancer of Rectum	3 / 5.0	60 (13-174)	4 / 3.0	131 (36-335)
Cancer of Biliary Passages & Liver	3 / 3.2	93 (19-273)	3 / 2.6	113 (23-330)
Cancer of Pancreas	9 / 8.6	104 (48-198)	7 / 7.2	97 (39-200)
Cancer of All Other Digestive Organs	1 / 1.8	54 (1-300)	1 / 1.3	73 (2-408)
Cancer of Respiratory System	46 / 64.0	72* (53-96)	34 / 29.0	117 (81-164)
Cancer of Larynx	3 / 2.6	114 (23-332)	1 / 0.8	121 (3-672)
Cancer of Trachea, Bronchus & Lung	42 / 60.7	69* (50-93)	32 / 27.8	115 (79-162)
Cancer of Other Respiratory Sites	1 / 0.5	185 (5-1033)	1 / 0.3	273 (7-1519)
Cancer of Breast	—	—	25 / 31.3	80 (52-118)
All Uterine Cancers	—	—	11 / 11.3	97 (48-173)
Cancer of Cervix Uteri	—	—	6 / 7.6	78 (29-170)
Cancer of Other Genital Organs	—	—	9 / 11.7	77 (35-146)
Cancer of Prostate	12 / 11.3	105 (55-184)	—	—

DSW 189744

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TABLE 9 (Cont.)

Cause of Death	Males		Females	
	Observed/Expected	SMR (95% CI)	Observed/Expected	SMR (95% CI)
Cancer of Testes and Other Male Genital Organs	—	—	—	—
Cancer of Kidney	3 / 4.9	61 (13-179)	2 / 2.9	68 (8-245)
Cancer of Bladder & Other Urinary Tract	3 / 5.1	58 (12-170)	2 / 1.8	111 (13-401)
Malignant Melanoma	5 / 2.5	196 (64-458)	2 / 1.5	130 (16-468)
Cancer of Eye	—	—	—	—
Cancer of Central Nervous System	2 / 4.3	46 (5-164)	2 / 2.8	69 (8-251)
Cancer of Thyroid & Other Endocrine Glands	—	—	1 / 0.4	206 (5-1145)
Cancer of Bone	1 / 0.5	186 (4-1035)	—	—
Cancer of All Lymphatic and Hematopoietic Tumors	11 / 16.3	67 (34-120)	10 / 11.8	84 (40-155)
Lymphosarcoma & Reticulosarcoma	2 / 2.7	74 (9-268)	2 / 1.8	107 (12-385)
Hodgkin's Disease	—	—	—	—
Leukemia & Aleukemia	4 / 6.1	65 (18-167)	4 / 4.6	86 (23-220)
Other Lymphatic & Hematopoietic Tumors	5 / 5.5	91 (30-212)	5 / 4.1	121 (39-282)
All Other Malignant Neoplasms	6 / 9.7	62 (23-135)	5 / 8.3	60 (19-139)
All Heart Disease	229 / 286	80** (70-91)	94 / 144	65** (53-80)
Non-malignant Respiratory Disease	41 / 55.3	74 (53-101)	27 / 31.4	86 (57-125)
Motor Vehicle Accidents	27 / 29.8	90 (60-131)	14 / 8.3	167 (91-280)
All other Accidents	20 / 25.1	80 (49-123)	9 / 7.4	121 (55-230)

* Significant at p < 0.05; ** significant at p < 0.01

¹ Expected numbers based on age-sex-race and time-specific New York County rates provided by OCMAP (Franklin, Essex, Warren, Saratoga, Washington, Hamilton, Clinton, Herkimer)

² Deaths coded according to the rules of the International Classification of Diseases coding in force at the time of death for causes of death with counts greater than one.

³ SMR equals deaths observed divided by deaths expected based on New York County rates and multiplied by 100. CI=Confidence Interval.

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CONCLUSION

In conclusion, this is the largest cohort of workers directly exposed to PCBs that was assembled specifically for the examination of the association between exposure and increased cancer mortality. ... Neither overall cancer mortality nor numbers of any of the a priori cancers of interest previously reported as being elevated were elevated in this cohort. ...

...[T]he best way to evaluate the validity of a reported association is to replicate the study in similarly exposed populations. To date none of the reported elevations in cancer mortality have been successfully replicated ... [T]he lack of consistent findings with respect to occupational PCB exposure and mortality in studies conducted to date would suggest a lack of an association.

Kimbrough, R. D., et al., JOEM, 1999, 41(3), p170.

**IEHR Advisory Committee on the Mortality Study of
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PCBs and Cancer: A Summary of the Literature

Author	Yr	Nature of Exposure	Persons	Person years	All Cancer		
					Obs	Exp	SMR
1. Zack	79	PCB mfg.	89	1800	8	4.5	1.79
2. Gustavsson	86	Equipment mfg.	142	(1846)	7	5.4	1.30
3. Bertazzi	87	Equipment mfg.	2100	41010	26	13.2	1.97
4. Brown	87	Equipment mfg.	2588	55545	62	79.7	0.78
5. Nicholson	87	Equipment mfg.	769	NA	44	55.4	0.79
6. Taylor	88	Equipment mfg.	6292	122783	136	144.4	0.94
7. Liss	89	Equipment mfg.	502	NA	32	22.6	1.42
8. Sinks	92	Equipment mfg.	3588	72180	54	63.7	0.85
Totals			16070	293318	369	388.9	0.95