

CHAPTER 8

EXPOSURE INDEX

An increased incidence of adverse health effects at higher levels of exposure represents a classic increasing dose-response relationship. The potential relationship of clinical endpoints with herbicide exposure can be tested using an estimate of exposure, hereinafter called an exposure index, for each member of the Air Force Health Study Ranch Hand cohort.

An index of potential exposure to any of four 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)-containing herbicides from fixed-wing spray missions was constructed for each Ranch Hand from the available historical data. The index serves as an estimate only, since the actual concentration of TCDD in the herbicides varied from lot to lot and individual assessments of actual body burden during or just after exposure in Vietnam were not feasible. The four TCDD-containing herbicides used in the development of the index are Herbicide Orange, Herbicide Purple, Herbicide Pink, and Herbicide Green. The exposure index was designed to correlate as closely as possible with exposure and is not an exact measure of actual individual exposures. Although the index contains errors when used to assess the exposure of a specific individual, it was thought to provide some degree of useful inference for groups of similarly exposed individuals.

The exposure index for each subject is defined as the product of the TCDD weighting factor, the gallons of TCDD-containing herbicide sprayed in the Republic of Vietnam (RVN) theater during the tour of the subject, and the inverse of the number of men sharing the subject's duties during the tour of the subject. Each of these factors is described below.

The TCDD weighting factor reflects the estimated relative concentration of TCDD in the herbicides sprayed. The estimated mean concentrations of TCDD in Herbicide Orange, Herbicide Purple, Herbicide Pink, and Herbicide Green are 2 parts per million (ppm), 33 ppm, 66 ppm, and 66 ppm, respectively. Archived samples of Herbicide Purple indicate a mean concentration of approximately 33 ppm, and samples of Herbicide Orange had a mean concentration of about 2 ppm. Since Herbicide Pink and Herbicide Green contained twice as much 2,4,5-T as Herbicide Purple, the estimated mean concentration of TCDD in these two herbicides was approximately 66 ppm. Based on procurement records and dissemination information, a combination of Herbicide Green, Herbicide Pink, and Herbicide Purple was sprayed between January 1962 and 1965. Using available data on the number of gallons procured and sprayed,¹ the estimated mean concentration of TCDD for this time period was 48.0 ppm.

The Herbs Tape and other data sources¹ indicate that only Herbicide Orange was disseminated after 1 July 1965. Normalizing to Herbicide Orange, the weighting factor becomes 24.0 before 1 July 1965 and 1.0 after 1 July 1965.

Using the Herbs Tape, Contemporary Historical Evaluation and Combat Operations Reports, and quarterly operations reports, a table of gallons of TCDD-containing herbicide sprayed for each month of the operation was constructed. Gallons of Herbicides Purple, Pink, and Green were converted to Herbicide Orange equivalent gallons based on the TCDD weighting factor of 24.0. This information is provided in Table E-1 of Appendix E.

The dates and occupational category of each Ranch Hand's tour(s) in the RVN were obtained by a manual review of military records. The study design specified five occupational categories: (1) officer-pilot, (2) officer-navigator, (3) officer-nonflying, (4) enlisted flyer, and (5) enlisted groundcrew. Based on the review of the records, the Ranch Hand manning for each occupational category by month was compiled.

A numeric exposure index reflecting the effective number of gallons of Herbicide Orange to which each individual was potentially exposed was computed. For analysis purposes, the values were categorized as high, medium, or low for each occupational category. Only three occupational categories were used. The three officer categories were combined into one since pilots and navigators were exposed in the same manner and the officer-nonflying category, which included a relatively small number of participants, consisted of administrators whose exposure was considered to be essentially zero. The overall group of "nonexposed" Ranch Hands, estimated at approximately 2 percent of the Ranch Hand group, was analyzed in the low exposure category (see Table 8-1), conceivably leading to dilution of the exposure analyses and group contrasts. The exposure index categorizations developed for the Baseline study and used in this report are provided in Table 8-1, along with the frequencies of Ranch Hand participants by occupation and exposure level. The cutpoints for the categories of the exposure index were the 33rd and 66th percentiles of the exposure index distributions within each of the three occupational strata (officer, enlisted flyer, and enlisted groundcrew). Ranch Hands with administrative duties were assigned an index of zero.

TABLE 8-1.

Exposure Index Categorization of
995 Compliant Ranch Hands

Occupational Group	Exposure Category	Effective Herbicide Orange Gallons Corresponding to Exposure Category	Number of Ranch Hand Participants in Exposure Category
Officer	Low	<35,000	130
	Medium	35,000-70,000	124
	High	>70,000	125
Enlisted Flyer	Low	<50,000	55
	Medium	50,000-85,000	63
	High	>85,000	53
Enlisted Groundcrew	Low	<20,000	147
	Medium	20,000-27,000	158
	High	>27,000	140
Total			995

The calculated exposure index is not specific to individual and, therefore, may underestimate exposure for those individuals whose jobs required routine handling of herbicide. For example, maintenance schedules for the aircraft herbicide spray tank required that an emergency dump valve be periodically greased, requiring entry into the tank. The current exposure index cannot distinguish between men who received such exposure and men who did not. The extent to which individuals are misclassified by the current exposure index is not known, precluding bias calculations at this time.

Every laboratory and physical examination endpoint in this study was assessed for dose-response effects versus the calculated exposure index. Current TCDD assay results did not correlate with the exposure index, with or without adjustment for time since exposure. These exposure index analyses are presented because some members of the Advisory Committee of the Science Panel of the Agent Orange Working Group advised that they be included in this report.

Because of the acknowledged imprecision of the exposure index, Air Force efforts are under way to measure TCDD levels in serum collected from participants in the 1987 followup. Serum was obtained for 1,999 of the 2,294 participants and is currently being analyzed by the Centers for Disease Control. As of September 1989, results of 1,366 serum specimens (888 Ranch Hands and 468 Comparisons) have been reported. These results are summarized in Table 8-2.

TABLE 8-2.
Serum TCDD Results

Stratum	Ranch Hand			Comparison		
	Sample Size	Median*	Range*	Sample Size	Median*	Range*
Officer--Pilot	247	7.3	0.0-42.6	118	4.7	0.0-13.1
Officer--Navigator	63	9.3	1.1-36.0	27	4.9	2.4-7.9
Officer--Nonflying	19	6.7	3.0-24.9	4	4.0	0.0-4.6
Enlisted Flyer	152	17.2	0.0-195.5	76	4.3	0.0-12.8
Enlisted Groundcrew	407	23.6	0.0-617.8	243	4.2	0.0-54.8
All Personnel	888	12.4	0.0-617.8	468	4.4	0.0-54.8

*In parts per trillion.

These results indicate that (1) Comparisons have background levels; (2) Ranch Hands have higher current TCDD levels than Comparisons; and (3) among Ranch Hands, nonflying enlisted personnel have the highest and officers have the lowest TCDD levels.

The relationship between current TCDD body burden and the constructed exposure index will be described in a future report. This report is expected in early 1991.

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REFERENCES

1. Young, A.L., J.A. Calcagni, C.E. Thalken, and J.W. Tremblay. 1978. The toxicology, environmental fate, and human risk of herbicide orange and its associated dioxin. Technical report OEHL-TR-78-92, USAF Occupational and Environmental Health Laboratory, Brooks AFB, Texas. 247 pp.