

CHAPTER 8

EXPOSURE INDEX

This chapter describes the development of the exposure index of the AFHS. Portions of this chapter are paraphrased from the Baseline Morbidity Report, 24 February 1984.

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 Ranch Hand cohort of the AFHS. However, due to a variety of biomedical mechanisms, there can be exceptions to the hypothesis of a consistently increasing dose-response relationship.

An index of potential exposure to any of four 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 cannot be made. 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 provides some degree of useful inference for groups of similarly exposed individuals. In summary, the exposure index in the AFHS is a surrogate indicator of TCDD exposure.

The exposure index developed for the Baseline study and used in this report is defined in Table 8-1.

The exposure index for the i th subject, denoted E_i , is defined as the product of the TCDD weighting factor, the gallons of TCDD-containing herbicide sprayed in the Republic of Vietnam theater during the tour of the i th subject, and the inverse of the number of men sharing the subject's duties during the tour of the i th 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 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

TABLE 8-1.

Algorithm for Exposure Index

$$E_i = \left\{ \begin{array}{l} \text{TCDD} \\ \text{Weighting} \\ \text{Factor} \end{array} \right\} \times \left\{ \begin{array}{l} \text{Gallons of TCDD-} \\ \text{Containing Herbicide} \\ \text{Sprayed in the RVN} \\ \text{Theater During the} \\ \text{Tour of the } i\text{th Subject} \end{array} \right\} \times \left\{ \frac{1}{\begin{array}{l} \text{Number of Men with Subject's} \\ \text{Duties in the RVN Theater During} \\ \text{the Tour of the } i\text{th Subject} \end{array}} \right\}$$

where E_i = Exposure Index for the i th Subject

$$\text{TCDD Weighting Factor} = \begin{cases} 24.0 & \text{if before 1 July 1965} \\ 1.0 & \text{if on or after 1 July 1965} \end{cases}$$

Since prior to 1 July 1965 a combination of Herbicides Green, Pink, and Purple with a mean concentration of 48.0 ppm was sprayed, and after 1 July 1965 only Herbicide Orange with a mean concentration of 2 ppm was sprayed, the ratio is then 48:2 or 24:1.

$$\left\{ \begin{array}{l} \text{Gallons of TCDD-Containing} \\ \text{Herbicide Sprayed in the} \\ \text{RVN Theater During the} \\ \text{Tour of the } i\text{th Subject} \end{array} \right\} = \left\{ \begin{array}{l} \text{Number of Gallons of Herbicides Orange,} \\ \text{Green, Pink, and Purple Expressed in} \\ \text{Herbicide Orange Equivalent Gallons} \\ \text{Based on Mean Concentration of TCDD} \end{array} \right.$$

Using the following:

<u>Herbicide</u>	<u>Mean Concentration (ppm)</u> <u>of TCDD</u>
Green	66
Orange	2
Pink	66
Purple	33

$$\left\{ \begin{array}{l} \text{Number of Men with Subject's} \\ \text{Duties in the RVN Theater During} \\ \text{the Tour of the } i\text{th Subject} \end{array} \right\} = \left\{ \begin{array}{l} \text{Number of Personnel} \\ \text{in the Same} \\ \text{Occupational Category} \end{array} \right.$$

Source: Baseline Morbidity Report, 24 February 1984.

Pink, and Herbicide Purple was sprayed between January 1962 and 1965. The estimated mean concentration of TCDD for this time was 48.0 ppm, using available data on the number of gallons procured and sprayed.

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 (CHECO) 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 F-1 of Appendix F.

The dates and occupational category of each Ranch Hand's tour(s) in the Republic of Vietnam 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. This information is also presented in Table F-1 of Appendix F.

A numeric exposure index reflecting the effective number of gallons of Herbicide Orange to which each individual was potentially exposed was computed. For the purpose of analysis, 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 8-2), 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 8-2, along with the frequencies of Ranch Hand participants by occupation and exposure level.

The current exposure index is not specific to job 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.

Because of the acknowledged imprecision of the exposure index, Air Force efforts are under way to develop new perspectives of exposure. One effort is the construction of a new questionnaire for the 459 enlisted groundcrew personnel that may permit more accurate exposure analyses within this category. Another approach is the measurement of serum dioxin levels.

TABLE 8-2.

Exposure Index Categorization of
1,016 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	127
	Medium	35,000-70,000	130
	High	>70,000	123
Enlisted Flyer	Low	<50,000	55
	Medium	50,000-85,000	65
	High	>85,000	57
Enlisted Groundcrew	Low	<20,000	154
	Medium	20,000-27,000	163
	High	>27,000	142
Total			1,016

The Air Force currently is conducting a pilot study in conjunction with the laboratories of the Centers for Disease Control, Atlanta, Georgia, to determine levels of TCDD in serum and to establish the validity of exposure differential within the Ranch Hand and Comparison groups. This study is in accordance with the Study Protocol commitment to estimate dosage of TCDD as accurately as current technology permits. If successful, use of time-adjusted TCDD levels would permit more accurate exposure analyses within the Ranch Hand group. Perhaps of most importance, accurate TCDD levels within the Ranch Hand group could standardize exposure to a comparable baseline for all participants. Thus, the use of adjusted TCDD levels will place the exposure concepts on a firm scientific basis, and if herbicide effects exist, they can be discerned more accurately.

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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.