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NIOSH 2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN EXPOSURE MATRIX

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Abstract
In the 1980's the National Institute for Occupational Safety and Health (NIOSH) constructed a 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) Registry of 5,172 workers from 12 U.S. plants with exposure to TCDD. In 1991, NIOSH investigators published a cohort mortality study of these workers which used duration in TCDD-contaminated processes as a surrogate for TCDD exposure. The NIOSH TCDD Exposure Matrix was constructed to permit additional analyses using estimated TCDD exposure levels. The matrix was constructed for the years 1942-1984 for a sub-cohort of 3,661 workers at 9 plants with sufficient data to characterize level of exposure. A TCDD exposure score was estimated for each job title for each day which a worker was assigned to a TCDD contaminated process. The daily TCDD exposure score was the product of 1) the concentration of TCDD (μg/g) present in process materials, 2) the fraction of the work day exposed to TCDD contamination, and 3) a qualitative factor to account for the extent of worker contact with TCDD. The sum of the daily exposure scores constituted an individual's cumulative occupational exposure score. These exposure scores have no direct interpretation such as micrograms per gram-days. Rather, the cumulative TCDD exposure scores permit the relative ranking of workers in the cohort by intensity of exposure. The daily TCDD exposure scores ranged from 0.001 to 1,250.

Introduction

To evaluate the relationship between TCDD exposure and health outcomes, a method is needed to estimate the amount of TCDD to which workers were exposed during their working lifetimes. Direct measurements of cumulative exposures are not available, so a surrogate must be used. One of the most commonly used surrogates is duration of exposure. The mortality experience of this TCDD cohort has been studied using duration of exposure to TCDD contaminated products as a surrogate of cumulative exposure, and the results have been published.[1]

The use of duration as a surrogate for cumulative exposure assumes that there is no systematic variation in the cohort in the average intensity of exposures over time and among workers, jobs, and plants. However, based on a review by NIOSH staff of the operations at these plants, there were inter-plant, inter-job and era-dependent differences in the intensity of TCDD exposure. Consequently, the use of duration of exposure could have led to some misclassification of the relative exposure levels of cohort members in the published mortality analysis. In order to reduce this misclassification an exposure matrix was developed for a sub-cohort of the TCDD exposed workers for whom adequate information exists to permit an estimation of intensity.

Experimental Methods

The sub-cohort used to construct the job exposure matrix was restricted to those workers at plants with sufficient data to characterize level of exposure. Plants 5, 6 and 12 of the TCDD Registry were excluded because, although work records were sufficient to document exposure to TCDD, they did

not permit determination of the intensity of exposure. Furthermore, to avoid potential confounding in the epidemiologic study by PCP or the higher chlorinated dioxins and furans formed as byproducts during the production of PCP, workers ever employed in PCP departments at Plants 7 and 9 were also excluded. This led to a sub-cohort of 3,661 workers from 9 plants (Table 1) for whom cumulative TCDD exposure scores have been estimated using the NIOSH TCDD Exposure Matrix.

The TCDD Exposure Matrix is based on identification of jobs associated with TCDD-contaminated processes and the evaluation of exposures associated with each job. A TCDD exposure score was estimated for each job title on a work record showing assignment to a TCDD contaminated process, for each day of exposure. The TCDD exposure score is based on 1) the concentration of TCDD in micrograms per gram (μg/g) present in process materials, 2) the duration of exposure to TCDD contamination, expressed as a fraction of a work day and 3) a qualitative contact factor (0.1-1.5) to account for the extent of worker contact with the TCDD contaminated material. Exposures were estimated based upon the algorithm:

Daily TCDD exposure score =

TCDD Concentration (μg/g) x Time exposed (fraction of a day) x Contact Level (0.1-1.5)

These three factors were multiplied together to yield a daily TCDD exposure score for each job title. These exposure scores have no direct interpretation such as micrograms per gram-days. Rather, the cumulative TCDD exposure scores permit the relative ranking of workers in the cohort by intensity of exposure for use in epidemiologic analyses

The production of TCDD contaminated products at the 9 study plants involved similar raw materials, process steps and job duties. The exposure matrix was based upon the similarity of the tasks which had to be performed to operate a process. Although the basic process steps were similar, differences in operating parameters such as temperature, pressure and reaction time resulted in differences in the concentration of TCDD formed.[2] A total of 12,400 samples of products, process and waste streams were collected with data on TCDD concentrations from 1958-1983. The product, process and waste stream data were used to estimate exposure using the algorithm.

Job titles were grouped into seven broad categories, including production workers, maintenance workers, plant supervisors, working supervisors, engineers, chemists and workers assigned to other processes adjacent to a TCDD process (proximity exposure). The majority of the workers included in the exposure matrix were categorized as production workers. Within job category differences in exposure were thought to be driven primarily by level of TCDD contamination. Standard duration and contact assignments were made for each job category and were used across plants unless plant specific information indicated that a different assignment was appropriate. Direct exposure to process materials occurred during the collection of process/product samples, material transfer and packaging, cleaning equipment and from spills and accidents. Indirect exposure occurred from contact with surfaces contaminated with TCDD that resulted from leaks, drips, and spills in production areas and from worker transfer to valves, handles, stair rails, and clothes.

Duration of exposure was defined as the fraction of a work day with the potential for contacting TCDD contamination. Production workers, whose duties kept them tied to the process, were assigned a full day duration (a value of 1) in the process area with the opportunity for direct contact with TCDD contaminated process materials. Production support personnel, such as working supervisors, engineers, and chemists were assigned a full day exposure, however, their job duties

were not as closely tied to TCDD process materials and only part of their work day involved direct contact with TCDD. Based on work tasks, estimates were made of the amount of time (fraction of a day) with the potential for direct contact and also the amount of time with indirect contact.

The third factor in the algorithm is a subjective "contact" factor. The contact level factor is an estimate of the extent of contact to TCDD contaminated materials for workers while performing their job duties. Based on job tasks, the level of contact with TCDD contamination was assigned one of seven values (0.1, 0.25, 0.5, 0.75, 1.0, 1.25, 1.5) to account for the extent of exposure to TCDD. The lowest values of 0.1 and 0.25 reflect the lowest level of contact due to indirect exposure, while the three middle categories (0.5, 0.75, & 1.0) reflect varying degrees of routine direct contact. The contact value of 1.25 was used for exceptionally high levels of contact such as during early production periods with labor intensive process tasks, and accident clean-up operations. The contact value of 1.5 was used for operations with the potential for exposure to TCDD contaminated dust due to the potential for increased dermal contact and inhalation of TCDD contaminated dust.

Substantial worker exposure to TCDD occurred due to accidents at Plants 3, 4, and 8. These accidents resulted from uncontrolled reactions that resulted in explosions and at two of the three sites also resulted in fires. There are no data describing the level of TCDD associated with any of these accidents; however, TCDD concentrations were estimated to be one to two orders of magnitude greater than during routine operations. In addition to higher TCDD concentration, a greater level of contact level was estimated due to increased surface contamination. A contact value of 1.25 was used for accident clean-up.

Results

Daily TCDD exposure scores were computed for each worker in the cohort in this manner for all time periods the worker was assigned to TCDD contaminated processes. The sum of the daily exposure scores constituted an individuals cumulative exposure score. Figure 1 shows the distribution of cumulative TCDD exposure score days by plant. For illustrative purposes, the distribution is plotted as the 0.1 TCDD exposure score days. These exposure scores have no direct interpretation such as micrograms per gram-days. Rather, the cumulative TCDD exposure scores permit the relative ranking of workers in the cohort by intensity of exposure for use in epidemiologic analyses.

Conclusion

A TCDD exposure score algorithm was used to account for differences in exposure for groups of workers due to the range of TCDD contamination of process materials, duration in exposed jobs and differences in contact with TCDD contaminated materials due to job tasks. There is a wide distribution of cumulative TCDD exposure scores by plant as shown in Figure 1. The TCDD cumulative exposure score, which incorporates both duration and level of exposure, provides a means for ranking workers in the matrix for evaluating the relationship between TCDD exposure and mortality in a retrospective cohort study analysis.

References

1. Fingerhut M.; Halperin W.; Marlow D.; Piacitelli L.; Honchar P.; Sweeney M.H.; Greife A.; Dill P.; Steenland K.; and Suruda A. *Cancer Mortality in Workers Exposed 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD).* N Engl J Med 324:212-218 (January 24), 1991

2. Esposito MP.; Tiernan TO. *Dioxins.* U. S. Environmental Protection Agency (EPA), Cincinnati, OH. EPA-600/2-80-197, November 1980.

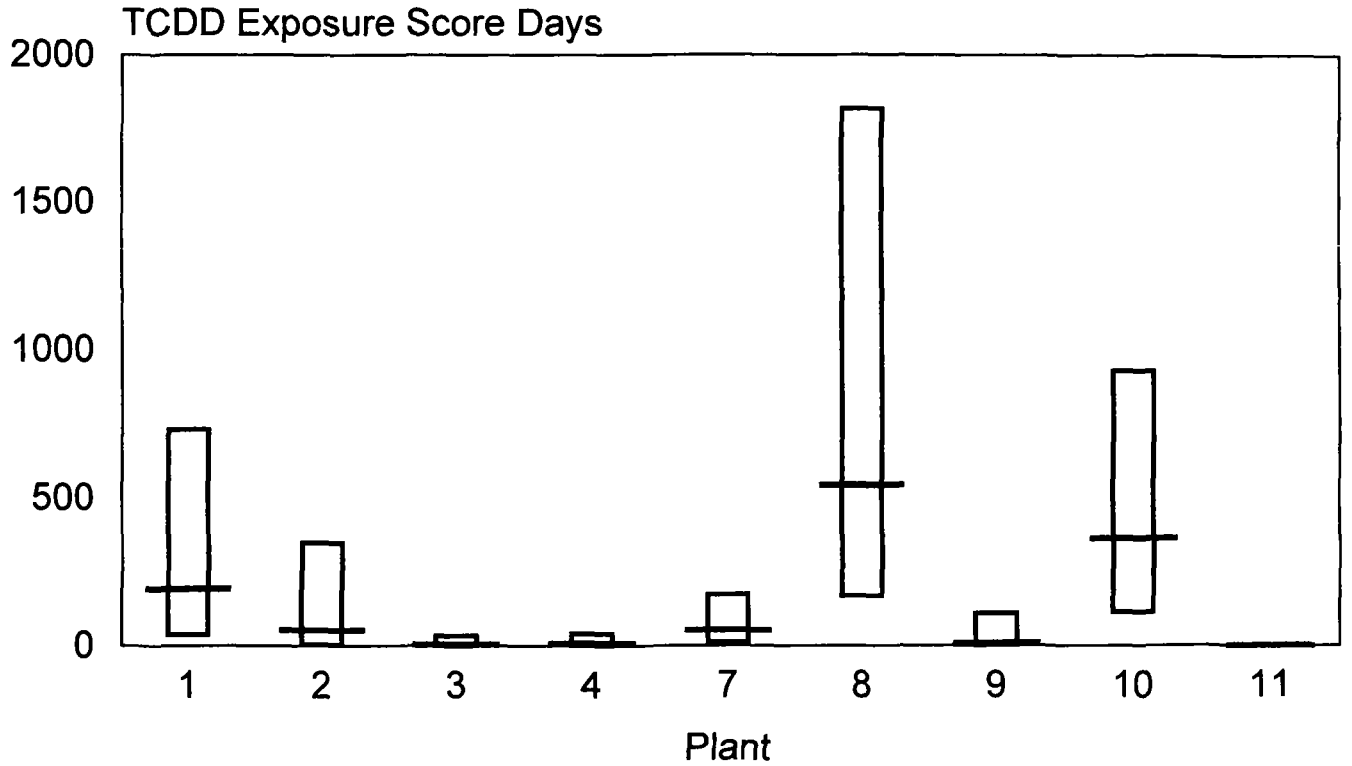
Table 1
NIOSH Dioxin Registry Plants included in the TCDD Exposure Matrix

TCDD Registry Plant Designation	Number Workers in TCDD Exposure Matrix Cohort	TCDD Processes Dates of Operation
1	439	February 1951 to August 1969
2	96	May 1968 to January 1972
3	692	October 1957 to April 1979
4	355	January 1957 to October 1978
7†	54	August 1960 to December 1969
8	202	April 1948 to December 1969
9	1408	March 1942 to February 1979
10	262	January 1949 to June 1972
11	153	January 1945 to May 1984

† Registry Plants 5, 6 and 12 were excluded from the TCDD Exposure Matrix

Figure 1
Cumulative TCDD Exposure Score Days by Plant*

median and inter-quartile range



*0.1 TCDD Exposure Score Days