Validating Dermal Exposure Assessment Techniques for Dioxin Using Body Burden Data and Pharmacokinetic Modeling

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1. Abstract

An approach for calculating the overall and dermal exposure-related TCDD body burden in three different worker scenarios is presented to evaluate the important factors and potential implications of dermal uptake in selected occupations. Reasonable exposure factors and published dermal TCDD uptake rates are used to estimate absorbed dose over time, then a simple pharmacokinetic model is used to examine the relative contribution to body burden due to dietary and occupational exposure. The modeled results for the scenarios seem to correlate well with recently reported studies of TCDD body burden in relevant occupational settings. These findings support the view that dermal uptake to TCDD is probably the primary route of exposure in the workplace.

2. Introduction

The available literature suggests that dermal uptake of dioxin in the workplace may be the primary source of occupational exposure. This is due to the relatively low vapor pressure and high lipid solubility of TCDD. Accordingly, workplace air concentrations of TCDD are generally relatively low, with the exception of work conditions involving extreme heating or aerosolization of the product. For example, most occupational exposures involving the use of primarily diluted 2,4,5-trichlorophenoxy herbicides provide only incidental and/or brief inhalation exposures to aerosolized TCDD. As oral uptake in the workplace is also limited, it seems most plausible that the substantial body burdens recorded in the occupational literature concerning TCDD are best related to the magnitude and frequency of dermal contact with TCDD in products and on work surfaces.

Recently published body burden estimates for TCDD in various worker populations provide an opportunity to examine the validity of numerical exposure assessment techniques. The objective of this study is to examine the potential contribution of dermal exposure for three different occupational exposure scenarios using 1) a conceptual model of workplace exposure, 2) dermal bioavailability/uptake calculations, and 3) fairly simple pharmacokinetic modeling techniques.

3. Methods

Five important questions were evaluated in attempting to provide an accurate model for dermal uptake of TCDD, all of which may significantly affect the ultimate estimate of body burden over time:

1. What is the matrix for worker exposure to TCDD? (e.g., concentrated phenoxy herbicide or chlorophenol mixture versus a dilute aqueous mixture or an organic solvent mixture)
2. What is the frequency, duration before washing, and time of dermal contact with concentrated TCDD-containing products, if any?
3. What is the actual or expected TCDD concentration in the media to which the worker has greatest exposure?
4. What is the expected surface area for skin contact with the product given the type of work activities and the specific workplace conditions?
5. What is the effective thickness of skin that can be considered as a relevant source of absorption of the TCDD dose?

We assigned answers to each of these questions for three different worker exposure scenarios:

Scenario 1: Trichlorophenoxy herbicide manufacturing worker (20-year exposure)
Scenario 2: Contract maintenance mechanic exposed by repairing a trichlorophenol reactor after an explosion incident (6-week exposure) and
Scenario 3: Trichlorophenoxy applicator handling only diluted trichlorophenoxy herbicides (seasonal exposure for 20 years)

The dermal TCDD uptake rates estimated for rat skin by Banks and Birnbaum et al.[1] and for human cadaver skin by Weber et al.[2-3] were incorporated into the exposure calculations separately. This allowed a comparison of results obtained when using a gross indicator of dermal TCDD uptake (in percent of applied dose absorbed per hour) and using a more refined dosimetric rate (in mass absorbed unit area of skin per hour). Absorbed dose estimates from these calculations were inserted into a simple, steady-state pharmacokinetic model which calculated the adipose tissue TCDD concentrations over each worker's lifetime. The contribution of background uptake of TCDD from dietary sources in the United States was accounted for in the estimates of the steady-state adipose concentrations.

4. Results and Discussion

We developed an approach to examine occupational body burdens of dioxin from dermal exposure based on a set of procedures and assumptions about dermal contact, rate of uptake, and pharmacokinetic distribution in the human body. The findings and implications for each of the three worker exposure scenarios are discussed below.

Trichlorophenoxy Herbicide Manufacturing Worker, 20-Year Exposure
The results of our exposure model for a long-term manufacturing worker indicate that regular dermal contact with trichlorophenoxy herbicides containing TCDD may result in an increase in body burden that is consistent with the range of reported concentrations for these workers in the United States and Europe[4-7]. We examined the accumulation of TCDD and the gradual reduction in TCDD body burden over time. It appears that appreciable occupational uptake can occur, and usually can be distinguished from background exposures when body burden is measured within a 10-year period following discontinuation of exposure.

Contract Maintenance Mechanic Following Reactor Explosion, 6-Week Exposure
The results of our exposure model for a short-term maintenance mechanic indicate that even a seemingly brief and nominal rate of contact with highly concentrated TCDD residues may result in a substantial increase in body burden that may equal or exceed those of long-term manufacturing workers not similarly exposed. Our estimates appear to be consistent with the findings of studies examining the workers in plants affected by trichlorophenol reactor explosions, including such maintenance workers.[4,6,8,9] It should be noted that assumptions as to actual residual TCDD concentrations and the hygienic procedures followed by an individual could alter the absorbed dermal dose estimate by one to three orders of magnitude. This result may support the contention that, in the selection of epidemiological groupings, careful job histories are critical. In other words, industrial hygiene information may be more important than the duration of exposure for the purpose of discerning important differences in health risks.

Trichlorophenoxy Herbicide Applicator, Seasonal Contact/Dilute Spray, 20-Year Exposure
The results of our exposure model for a long-term phenoxy herbicide sprayer indicate that seasonal occupational contact with dilute TCDD residues may result in little or no change in TCDD body burden. Our range of body burden estimates appears to be consistent with the findings of studies examining field applicators and Viet Nam veterans.[10-11] It should be noted that the our example worker was not assumed to be involved with the mixing/loading operations, which may increase body burdens somewhat depending on the hygiene procedures used and the TCDD content of the herbicide product.[12-17]

5. Conclusions

The results of our assessment indicate that dermal exposure to TCDD under selected work conditions can result in a wide range of potential body burden estimates. When reasonable assumptions about worker exposure scenarios are compiled with the published literature on sources of TCDD bioavailability, the predicted body burden vs. time estimates appear to be relatively consistent with findings in the epidemiology literature. In short, this work indicates that carefully conducted exposure assessments are capable of retrospectively predicting the likely uptake of persons exposed ten to thirty years since last exposure to TCDD.

6. References

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