EPA's Reassessment of Exposure to Dioxin-Like Compounds

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The purpose of this paper is to describe the exposure portion of EPA's dioxin reassessment in terms of both the development process and interim findings. The goal of this effort is to assess current levels of exposures to the dioxin-like compounds and provide procedures for estimating these exposures on a site-specific basis. This document serves as the final version of the draft, EPA published in 1988 called "Estimating Exposure to 2378-TCDD".

The development schedule closely parallels the one for the health document:

- Initial chapter development started last year and resulted in a very preliminary 1st draft this January. This draft was circulated to our 5 lead reviewers.
- A second draft was issued in early June for a second round of invited reviews.
- A third draft will be issued in July for pubic review. Also it was the focus of a Workshop review held this Fall.
- Based on these reviews we'll prepare a fourth draft and submit it to the SAB in late 1992.
- On the basis of the SAB review we'll make the final changes and issue the document final next spring.

A large team of people have been assembled to develop this document representing government, academia and the private sector. In each major area we have a set of primary authors, lead reviewers and an EPA manager.

The principal findings and conclusions of this assessment are summarized below:

1. The dioxin-like compounds are commonly found in soils, sediments and biota throughout the world. Concentrations in nonindustrial rural areas are generally lower than in urban or industrial areas. The higher chlorinated hepta- and octa- dioxin and furan congeners were generally more frequently found and at higher concentrations than the tetra- through hexa- congeners in environmental and exposure media. Selected literature references containing occurrence information on dioxin-like compounds were reviewed in an attempt to

estimate background concentrations of these compounds in exposure media. The estimated background exposure (assuming all pathways are equally additive) to all dioxin-like compounds was estimated by multiplying the average media levels by typical contact rates. This analysis suggests a background exposure level in the range of 80-200 pg of TEq/day using data for world-wide sources. This estimate is highly qualified considering factors such as: sparseness of world-wide data, judgements as to whether data used represents "background" exposures, the assumption that all exposures considered to derive this estimate occur simultaneously contrasting the fact that several exposures, particularly ingestion of meat products other than beef, were not considered, and so on. Data on tissue levels suggest that body burden levels among industrialized nations are reasonably similar.

2. Typical exposure levels were also estimated by applying pharmacokinetic models to body burden data. Using this approach, exposure levels to 2,3,7,8-TCDD are estimated to be about 20 to 40 pg/day. This is consistent with the analysis for exposure to total dioxin-like compounds as described above.

3. Procedures to estimate individual exposures to four categories of dioxin-like contamination sources were described and demonstrated in this assessment. These categories include: 1) on-site soils - the soil contamination and the exposure occur at the same site, 2) off-site soil - the contaminated soil is located distant from the site of exposure, 3) incinerator stack emissions - individuals near incinerator stacks are directly exposed via inhalation of impacted air and indirectly exposed as a result of deposition of contaminated particulates onto soil and vegetation, and 4) ash landfill - similar to the off-site soil category except that source material is incinerator ash rather than soil.

4. In contrast to a few years ago, consensus is emerging as to causes and extent of vegetative contamination by the dioxin-like compounds. It now appears that vegetation is impacted as a result of three processes: sorption to outer portions of below ground parts, "air-to-leaf" transfers of vapor-phase contaminants to outer above ground plant surfaces, and deposition and sorption of air-borne particulate-phase contaminants onto outer portions of above ground vegetation. Translocation from outer to inner portions appears to be minimal, and translocation from root to shoot appears to be essentially nonexistent. This document presents unique approaches for estimating vegetative impacts from these routes. Also, estimates of fruit and vegetable ingestion exposures considered below vs. above ground and protected vs. unprotected fruits.

5. With some modifications, procedures in this assessment to estimate beef and milk concentrations are similar to procedures developed during the 1980s. One principal difference was that most earlier assessments did not include air-to-leaf transfers in their estimates of pasture grass and cattle fodder concentrations. The other principal difference was that earlier assessments did not consider soil ingestion by cattle to the extent considered in this assessment. Analysis showed that critical components of the beef and milk models include the assumptions of soil ingestion by cattle, and estimates of pasture grass and cattle fodder concentrations of the dioxin-like compounds.

6. There are two basic approaches for estimating concentrations in fish. One is based on water concentrations (soluble phase or total concentrations) and one is based on sediment concentrations. Estimates of fish concentrations have classically been made based on water concentrations and a "bioconcentration factor", and this approach has been used in assessment of exposures to 2,3,7,8-TCDD. Bioconcentration factors are typically developed in laboratory flow through experiments where the principle route of fish exposure is through the gills. However, a growing consensus is that fish exposure to strongly hydrophobic contaminants such as the dioxin-like compounds is not via passive movement through the gills but rather through the food chain. Assuming lower trophic aquatic organisms reside in and near the bottom sediments of surface water bodies and that their body concentrations reach equilibrium with such sediments (and there is evidence to this effect), then higher trophic aquatic organism impact might be more appropriately a function of bottom sediment rather than water column concentrations. There are other arguments supporting a sediment-based rather than a water-based approach for estimating fish tissue concentrations. Water concentrations of hydrophobic contaminants are very low so as to preclude analytical measurement, whereas sediment concentrations are within measurable range and there is a large amount of sediment data available for analysis and interpretation. It should be recognized, however, that within a system where true equilibrium between all compartments is established or assumed to exist (which is typically assumed for essentially all such modeling exercises), water column, sediment, and fish concentrations are interrelated and theoretically, water column or sediment concentrations can be used with equal validity to estimate fish concentrations. This assessment presents and demonstrates a procedure for estimating fish tissue concentrations based on a "Bioavailability Index", or BI, which is defined as the ratio of contaminant concentrations in the lipid of fish to the organic-carbon based concentrations in bottom sediments. In sensitivity analyses exercises, approaches based on water column concentrations were also described and demonstrated. These include a lipid-based bioconcentration factor (BCF_{lipid})/total water column concentration approach, and a lipid-based bioaccumulation factor (BAF_{lipid})/soluble phase water column concentration approach. Modeled sediment and water column concentrations, and assignments to the BI, BCF_{lipid}, and BAF_{lipid} for the example dioxin and PCB congener, were used in an exercise which compared the three approaches. General conclusions cannot be made from this exercise due to the uncertainties in the input parameters, the uncertainties in the modeling of sediment and water concentrations, and so on. However, the exercise showed the three approaches to arrive at fairly similar fish tissue concentrations, with the BI approach generally predicting higher than the water column approaches, either within or exceeding an order of magnitude, depending on parameter assignments tested.

Further research is recommended in the following areas. These are not listed in any specific priority order.

1. Collection of more data on the congener-specific properties of these compounds is a high priority for further research.

2. The use of pharmacokinetics in body burden analysis has shown great potential for estimating exposure levels. In order to reduce the uncertainty in these procedures, increased collection of biological samples and improvements in PK model structure and input parameters are recommended. In addition, further research should be conducted on the application of these procedures to estimating target organ dose, absorbed dose, lactational/placental transfers, and effects on offspring.

3. More development is needed for procedures to evaluate pipe discharges. This includes further development of the BI approach for estimating fish tissue concentrations, if, in fact, a consensus can be reached that estimating fish concentrations based on sediment concentrations is more appropriate than based on water column concentrations. A key issue that has been identified is whether BIs that have been developed for one species and water body are transportable with respect to the same species (or other species) and another water body.

4. Considering that beef and dairy exposures are identified as critical exposures in this assessment, more information is needed on several of the components of the model to estimate beef and milk concentrations. Such information includes: cattle soil ingestion rates, pasture grass concentrations and mechanisms of transfer from the air/soil to pasture grass, inventories of cattle production practices (such as fattening prior to slaughter) and the impact of these practices to cattle food product concentrations, and models and data to further develop the bioconcentration factor (termed F in this assessment and translates concentrations on cattle dry matter intake to concentrations in beef and milk fat).

5. This assessment did not evaluate all possible exposure pathways. Other potential pathways include ingestion of other farm products such as eggs, chicken, and pork. The occurrence of these compounds in ground water is expected to be minimal based on strong sorption to soils. However, they have been found in ground water below and near sites of industrial contamination. Co-occurrence with other organic compounds, co-occurrence with solvents, and transport associated with oils have been cited as causes of enhanced mobility in these settings. Exposures through mother's milk or placental transfers (as noted above) need to be evaluated and compared with other exposure pathways. Exposure resulting from bleached paper products, such as occurrences of 2,3,7,8-TCDD leached from milk containers, has also been cited as a route of exposure. Further evaluation of these pathways is recommended.

6. Recent assessments of exposure to dioxin-like compounds have concluded that an inventory of currently identified sources of contamination falls well short of explaining environmental concentrations that have been measured. Researchers have claimed that key sources of dioxin-like compounds in the environment have yet to be identified. This issue wasn't explored in this assessment, but is certainly worthy of careful consideration. Complete source identification and comparative contributions by different sources should be explored in future assessments.