

**DIOXINS/FURANS FROM THE BLEACHED PULP AND PAPER INDUSTRY  
INTEGRATED RISK ASSESSMENT: HAZARD ASSESSMENT AND RISK  
CHARACTERIZATION**

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**ABSTRACT**

The interagency integrated risk assessment combined eight major risk analyses that addressed toxicities to humans, aquatic organisms, and avian and terrestrial wildlife. A primary focus of the integrated assessment involved human carcinogenic effects. Wildlife risks were also assessed, as percentages of low-effect or calculated no-effect CDD/F concentrations. These risk analyses were characterized as to assumptions used, uncertainties involved, and further work identified.

**I. HUMAN HEALTH HAZARDS**

EPA classifies the 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) congener as a probable human carcinogen, based on sufficient evidence in animals (and inadequate evidence in humans). Upper-bound cancer potency estimates for 2,3,7,8 TCDD published by EPA as well as other U.S. agencies, some state agencies, foreign governments, and individual investigators range across three orders of magnitude. (This large range indicates the lack of consensus regarding current approaches to estimating potential cancer risks.) The resulting slope factors for 2,3,7,8-TCDD calculated by EPA, FDA, and CPSC for their risk assessments (CPSC using  $q_1$ ) vary by up to a factor of 10; all three agencies employed linear-at-low-dose extrapolations to estimate cancer risk, but used different animal test data and extrapolation techniques. Consequently, differences among the risk assessments developed by various agencies were generally due to such differences in scientific judgment, as well as in methods used to estimate risks.

The integrated assessment also addressed non-cancer endpoints (e.g., reproductive toxicity), and considered both effects from long-term, low-level CDD/F exposures and effects from brief, high-level exposures. Based on studies of effects on rat reproduction from chronic exposures to 2,3,7,8-TCDD, as well as studies in other animals such as monkeys, EPA derived a reference dose (RFD) of 1 pg/kg/day ( $1 \times 10^{-9}$  mg/kg/day), representing the lifetime daily human exposure level associated with minimal risk of adverse health effects. However, exposure to 2,3,7,8-TCDD levels greater than the RFD can presumably initiate non-cancer toxic effects in humans, and the duration of exposure required for expression of the effects can be much shorter than a lifetime exposure. The Agency has therefore established one- and ten-day health advisories for liver and developmental toxicity effects.

## II. HAZARDS TO WILDLIFE

The integrated assessment also evaluates CDD/F toxicities to aquatic, avian, and terrestrial wildlife, in terms of effect-level concentrations. Available data indicate that a no-effect concentration (NOEC) for CDDs/Fs in water has not yet been determined; however, the integrated assessment includes a "functional" standard for protection of aquatic species, derived by applying a factor of 1,000 (based on scientific judgment) to the lowest concentrations recorded for 2,3,7,8-TCDD and 2,3,7,8-TCDF in recent mortality tests. Applying this factor results in a toxicity concern level of .038pg/l (ppq) (i.e.,  $3.8 \times 10^{-11}$  mg/l or ppm) for aquatic species.

The toxic effects to aquatic species from 2,3,7,8-TCDD are numerous. It is important to note that a subacute test in trout demonstrated extraordinary toxicity of 2,3,7,8-TCDD in fish. It also demonstrated that the onset of sublethal and lethal effects induced by 2,3,7,8-TCDD are delayed several days, depending upon the duration and level of exposure. Further, very short periods of exposure to 2,3,7,8 TCDD can produce delayed toxic effects; higher test concentrations cause earlier onset of toxic effects and mortality; and longer periods of exposure hasten the onset of post-exposure mortality in aquatic species.

Although methods for accurately assessing effects on terrestrial

populations in the wild are still under development, laboratory tests on animal reproduction serve as useful indicators to those effects. Such tests have determined "no observed adverse effect levels" (NOAELs) to be 10 ng/kg/day ( $1 \times 10^{-5}$  mg/kg/day) for leghorn chickens and 1 ng/kg/day ( $1 \times 10^{-6}$  mg/kg/day) for rats; no NOAEL was determined for bird eggs, although a "lowest observed adverse effect level" (LOAEL) of 65 ppt was determined for chicken embryos.

### III. RISK CHARACTERIZATION

The integrated assessment identified credible health risks to humans and wildlife from exposure to three CDD/F-contaminated process streams: effluent, sludge, and pulp.

The integrated assessment contains uncertainties connected with the establishment of the health hazards and with the development of exposure evaluations. For example, it is recognized that there are legitimate differences of opinion within the international scientific community regarding the quantification of the cancer risk to humans from dioxins/furans.

There is a particular need for more research and development of additional data for some of the potential exposures. Most noticeable of these is the need for actual sampling data on stack emissions of CDD/F from the incineration of pulp and paper mill sludge. Only one actual measured stack gas level of CDD/F was available for use in the incineration exposure estimate. The risk assessment is also not a complete assessment of the health risks due to chemical contamination from the bleached pulp and paper industry. Chlorination of wood pulp produces numerous toxic compounds. Although the only requirement of the 1989 Consent Decree between EPA and two environmental groups (which initiated the integrated risk assessment) was to investigate CDDs/Fs, EPA is aware that the kinds of total chlorinated organic compounds (TCOCl) produced during pulp bleaching and processing operations are many. Even though other compounds may be present at relatively low concentrations in pulp and paper mill effluents, sludges, and pulps, the cumulative effect of CDDs/Fs and TCOCl on exposed populations could be significant.

It is reasonable to suppose that certain individuals or segments of the population may be exposed to CDD/F's from more than one source originating from the pulp and paper industry. In these situations the derived risks would be additive, and those individuals or segments of the population would be at higher risk than others. There are no empirical data yet available to definitively answer the question of aggregate risk.

Summarizing risks of concern, there are important health risks to aquatic species from contaminated effluent. 2,3,7,8-TCDD has been shown to be extraordinarily toxic to fish and to produce delayed effects after short term exposures. (Therefore, the actual toxicity to fish may be greater than the number used in the assessment). Levels of 2,3,7,8-TCDD/TCDF downstream from most of the mills were estimated to be well above the toxicity concern level for fish. These health risks are especially important because they are geographically widespread, affecting aquatic wildlife living in the vicinity of all the 104 bleached pulp and paper mills. This study looked only at toxic effects on fish, and did not investigate effects on other aquatic organisms, the food web, or contamination of the sediments.

There are important health risks to humans for cancer, reproductive toxicity, developmental toxicity, and liver toxicity from eating fish contaminated with 2,3,7,8-TCDD/TCDF from pulp and paper mill effluent. The risk for cancer is based on the assumption that people will be eating contaminated fish over a lifetime of exposure. Risks for non-cancer effects are based on much shorter exposure periods.

Although site specific data were used to calculate risks to humans eating contaminated fish caught downstream from each of the paper mills, there was no readily available source of information on actual numbers of persons fishing and eating these fish. Information from EPA regional and state environmental personnel do, however, indicate the presence of people fishing downstream from many of the mills, but on a population basis we do not know the extent of the risk from eating fish contaminated with bleached pulp and paper mill effluent. However, it is presumed that certain subpopulations are at greater risk for cancer and non-cancer health effects. They are: (a) subsistence fishers who obtain a large quantity of their diet from

contaminated fish; (b) sports or recreational fishers who eat a large quantity of contaminated fish in their diet; (c) persons eating heavily contaminated fish, who are at risk of developmental and liver toxicities (i.e., non-cancer effects).

There appear to be risks to terrestrial and avian species living and feeding in areas where contaminated pulp and paper sludge is applied. The case is not as strong as the one for aquatic organisms, since measured levels of CDD/F in the terrestrial animals and actual sightings of the specific species in land application areas were unavailable. However, the species considered were common to each state, and generally presumed abundant. A major data gap in the assessment is lack of information on possible adverse effects to the ecosystem as a whole, which can directly influence effects to wildlife.

There may be cancer risks to persons consuming food from paper food packaging and food-contact articles contaminated with CDD/F. Evaluation of the CDD/F exposures and risks for individuals consuming either average amounts of food from all paper food-contact articles or 90th percentile amounts of foods from individual articles identified health risks for both the average consumers of all foods as well as high-level consumers of certain foods. Although these estimated risks are much lower than risks for ingestion of contaminated fish, they are of particular concern because they can affect a much larger number of people throughout the country.

The risks assessed by the interagency workgroup include some estimates of considerable risk, but are based on assessments with associated levels of uncertainty. However, as the data needs identified in the various assessments are met, a more precise determination and description of risk will be possible, and necessary actions more clearly identified.

#### REFERENCES

- U.S. Environmental Protection Agency, 1990. Integrated Assessment of Risks from Exposure of Humans, Terrestrial and Avian Wildlife, and Aquatic Life to Dioxins and Furans Formed During Chlorine Bleaching at Kraft and Sulfite Pulp Mills, Draft Report, April.

