# TOXICOLOGY AND HUMAN RISK CHARACTERIZATION

## An Evaluation of Hazards and Risks from Exposure to Dioxin/Furan Contaminants in Pentachlorophenol-treated Wood

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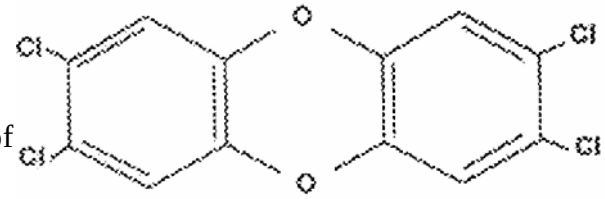
## 1.0 BACKGROUND

The purpose of the risk characterization is to quantify the potential health risks to the potential receptors associated with exposure to the chemicals of concern. As part of the pentachlorophenol (PCP) Reregistration Eligibility Decision (RED) Document prepared by the US EPA, presented herein is the risk characterization risk characterization of Occupational and Residential Exposure to the Dioxin/Furan microcontaminants (CDDs/CDFs) contained in Pentachlorophenol (PCP).

## 2.0 PHYSICAL/CHEMICAL PROPERTIES CHARACTERIZATION



2,3,7,8-TETRACHLORODIXENZO-P-DOXIN

Polychlorinated dibenzo-*p*-dioxins (CDDs) and polychlorinated dibenzofurans (CDFs) are members of a family of polychlorinated isomers of "dioxin-like" compounds. CDD congeners may contain from 1 to 8 chlorine atoms at various sites on the aromatic rings of the molecule. Physical and chemical properties and toxicity vary with the degree of chlorination. The most toxic congener of the family is 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). The toxicity of other CDD/CDF isomers as well as coplanar polychlorinated biphenyls (PCBs) have been characterized in relation to 2,3,7,8-TCDD (WHO, 1998).

The U.S. EPA Office of Research and Development, beginning in 1991, undertook a comprehensive scientific assessment of the health risks from exposure to 2,3,7,8 TCDD and chemically similar compounds in collaboration with scientists from inside and outside the Federal government. The most recent draft of this document is posted at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=55264. It should be noted that this document is a draft for review purposes only and does not constitute U.S. Environmental Protection Agency policy. While this draft assessment contains a comprehensive review of the hazards and exposures associated with dioxin and dioxin-like family of compounds from all sources of exposure, the present assessment from the Antimicrobials Division covers only those exposures and risks associated with exposure to the dioxin and furan contaminants of pentachlorophenol as a wood preservative chemical.

## 2.1 **Potential Sources of CDDs/CDFs**

CDDs/ CDFs are not intentionally manufactured but are formed as impurities from a variety of processes. Sources include combustion (including waste incineration, burning of various fuels, forest fires, and open burning of wastes), chemical manufacturing (as by-products from manufacture of chlorine bleached wood pulp, chlorinated phenols, and phenoxy herbicides), biochemical and photochemical processes (composting), and reservoir sources (such as soils, sediment, and water ,where previously formed CDDs/ CDFs or dioxin-like PCBs have the potential for redistribution and circulation into the environment). Environmental release of CDDs/CDFs occur from all of these sources, but of all sources, air release from combustion is the dominant source. It has been stated that quantifiable emissions of dioxins from combustion sources are more than an order of magnitude greater than quantifiable emissions from all other categories combined (USEPA, 2000). (ATSDR 1989; NATO 1988a and 1988b; USEPA 1980).

Air emissions of CDDs/CDFs from combustion processes may result in transport of these compounds over long distances before deposition on land or in water. During transport, the compounds are either adsorbed to particulate matter or present in the vapor phase and can, during the course of time, undergo association with aerosols as they are transported (Broman et al. 1991). In the case of the accidental release of TCDD at Seveso, Italy, it has been estimated that dispersion of this compound from air to soil followed an exponential decay pattern along the downwind direction.

## 2.2 **Physical Property of CDDs/CDFs**

CDDs/CDFs are generally expected to be relatively immobile in the soil/groundwater system due to strong sorption properties; surface-applied contamination is expected to be confined to the uppermost 6-12 inches of soil. However, releases of CDD and CDF contaminants from soil via erosion and runoff may be significant (USEPA, 2000). Vapor phase diffusion and subsequent volatilization from surface soils may be significant in the absence of other transport processes; translocation of adsorbed CDDs/CDFs with soil particles may also be important. In general, persistence studies indicate that levels of CDDs/CDFs in soil diminish sharply within the first 6-15 months, followed by negligible changes; the initial decrease is attributed to photodecomposition and heat-promoted volatilization at the surface. Several studies have reported that photolysis is the major route of TCDD disappearance. In laboratory experiments, photodegradation of polychlorinated dibenzo-*p*-dioxins occurred by preferential dechlorination at the 2,3,7,8-positions;

continued irradiation resulted in some decomposition of the dibenzo-*p*-dioxin structure. Polychlorinated dibenzo-*p*-dioxins exhibit relatively strong resistance to microbial degradation in soils. The primary pathway of concern in soil/groundwater systems is the migration to groundwater drinking water supplies via colloidal transport. In surface waters, CDD/CDFs are expected to remain strongly adsorbed and persist in the suspended sediment or bottom sediment. The entrance of dioxins into water via erosion and/or runoff of contaminated soil leads to bioaccumulation in fish through contact with water, sediment, and ingestion of aquatic organisms.

## 3.0 HAZARD CHARACTERIZATION

In mammals, CDD/CDFs are readily absorbed through the gastrointestinal tract. Absorption through intact skin has also been reported but is considered limited. Absorption may decrease dramatically if CDD/CDFs are adsorbed to particulate matter such as activated carbon or soil. After absorption, CDD/CDFs are distributed to tissues high in lipid content and to liver where they are slowly metabolized by the cytochrome P-450 monooxygenase system. The high lipophilicity of the CDDs/CDFs can result in significant half-lives of elimination. Metabolites of CDDs/CDFs may be excreted in the urine and feces. Unmetabolized CDDs/CDFs can be eliminated in the feces and in milk. There is ample experimental evidence that the toxic response to the CDDs/CDFs is mediated through cytosolic Ah-receptor site binding. Differences in the magnitude of the toxic response may be related to the affinity of binding and/or magnitude of the biochemical response following binding (USEPA 1986).

The primary routes of human dietary exposure to CDDs/CDFs have been determined to be through ingestion of animal products which have ingested plant material concentrated with dioxins through atmospheric deposition to soil, and through ingestion of aquatic organisms that have bioaccumulated dioxins through runoff from soil in to water. Elevated levels of dioxin have also been observed in cattle that have come into contact with pentachlorophenol-treated wood (USEPA, 2000). As a result of such exposures, the average tissue level of CDD/CDF/PCBs in the adult human population has been estimated at 25 parts per trillion lipid (USEPA, 2000).

If 2,3,7,8-TCDD is ingested in drinking water, fatty or oily foods, other foods, paper, dust, sludge, or soil, >50% of the oral dose is expected to be bioavailable. It may be assumed that, due to their high lipophilicity, there would be 100% absorption of TCDD or TCDF vapors entering

the respiratory tract. Following dermal exposure to 2,3,7,8-TCDD in soil, approximately 1% of the TCDD was found in the liver. When TCDDs or TCDFs were applied to the skin in an organic solvent (acetone), up to 40% of the TCDDs and 48% of the TCDFs were absorbed by 72 hours (USEPA 1990). In contrast, uptake of 2,3,7,8-TCDD by crops from soils is not significant (IRP 1989; USEPA 1990).

### 3.1 Non-Carcinogenic Effects

The major toxic effects produced by CDDs/CDFs include lethality, chloracne, liver damage, cancer, immunosuppression (including thymic involution), developmental toxicity, endocrine disruption, and reproductive toxicity. Chloracne is usually only observed after substantial exposure to 2,3,7,8 TCDD (USEPA, 2000).

Acute effects among experimental animals include general weight loss, liver pathology, skin lesions, liver, thymus, splenic, and pancreatic atrophy and dysfunction, as well as central nervous system abnormalities. The lethal potency of TCDD varies greatly among species and the toxicity of different CDD isomers also varies greatly. Guinea pigs are among the most sensitive species, where TCDD $LD_{50}$ values range from 0.6 to 19μg/kg. Hamsters are among the least sensitive species tested, with $LD_{50}$ values for TCDD ranging from 1,157 to 5,051 μg/kg. (USEPA 1985). Many of the effects of 2,3,7,8-TCDD are associated with relatively high doses, but several significant adverse effects such as effects on the developing immune, nervous, and reproductive systems are observed at maternal body burdens which are close to those present in the background human population (Birnbaum and Tuomisto, 2000). Further, as noted by Steenland et al. (2004), dose-response assessments conducted for TCDD and cancer indicate that TCDD exposure levels close to those in the general population may be carcinogenic as well. Therefore, at doses close to those of background, TCDD has been implicated in both carcinogenic and non - carcinogenic effects.

The limited data for other CDDs indicate that these chemicals produce the same acute effects as TCDD in a given species, but the required doses are higher. Humans have been exposed to herbicides and other chlorinated chemicals containing TCDD as a contaminant. The symptoms of toxicity in many cases are similar to those observed in animals, with exposure leading to altered liver function and lipid metabolism, porphyria cutanea tarda, neurotoxicity, pathologic changes in hematologic parameters, and skin lesions. Although some signs of toxicity such as chloracne are

attributed to the CDDs, other signs may arise, at least in part, from the other chemicals in which CDDs are minor contaminants. Chloracne, which is characterized by comedones (blackheads), keratin cysts, pustules, papules, and abscesses, is a classical sign of high dose 2,3,7,8-TCDD exposure in humans. Chloracne can be caused by ingestion, inhalation, or skin contact with CDDs (USEPA 1980). In 1991, Greenlee et al. (as cited in Schmidt 1992) identified two dioxin-responsive genes in human skin cells that may be involved in dioxin-induced chloracne. Treatment of monkeys or hairless mice with 2,3,7,8-TCDD produced lesions on the face that were similar to chloracne lesions seen in humans (ATSDR 1989).

A full spectrum of developmental toxicity is observed in experimental animals exposed to TCDD, including reduced prenatal and post-natal viability, alterations in development of reproductive organs, delay in onset of puberty in the male rat, and altered sexual differentiation in the female rat (USEPA, 2000). Many of these effects result from only a single low dose exposure at a discrete time point during fetal development.

In adult animals, developmental and reproductive toxicity is also observed, and includes decreased fertility, decreased litter size, and inability to maintain pregnancy in female rats, and decreased testis and accessory sex organ weights, abnormal testicular morphology, decreased spermatogenesis, and reduced fertility in male rats (USEPA, 2000). Studies in rats have indicated that a no-observable-adverse-effect level (NOAEL) for reproductive effects may be as low as 0.001 μg/kg/day. Reproductive effects in rabbits, including increases in abortions and resorptions, have been observed at the 0.25 μg/kg/day level. Spontaneous abortions occurred in two-thirds of monkeys fed 2,3,7,8-TCDD at levels of 0.0015 or 0.01 μg/kg/day for 7 months. In a 3-generation reproductive toxicity study in rats, the lowest dietary dose (0.001 μg/kg/day) produced dilated renal pelvis, decreased fetal weight, and changes in the gestational index (ATSDR 1989). The developmental effects observed in experimental animals are indicative of the potential for developmental and reproductive toxicity in humans, based on the phylogenetic conservation of the Ah receptor among species including humans, and the incorporation of this tenet into the EPA's risk assessment guidelines for developmental toxicity (USEPA, 1991b).

### 3.2 Mutagenicity and Carcinogenicity

Mutagenicity studies with TCDD have shown that the chemical is not a direct acting genotoxic agent (USEPA, 2000). TCDD has been shown to be negative in the Ames Salmonella assay and does not form DNA adducts in vivo or in vitro. The National Toxicology Program (1984) declared TCDD to be a non-mutagen using their standard battery of mutagenicity assays. In human populations exposed accidentally or occupationally to TCDD, there is no consistent evidence for increased frequencies of chromosomal aberrations (USEPA, 2000). Therefore, TCDD is designated as nongenotoxic based upon the negative results from assays measuring potential DNA damage, and the significant tumor promoting but not initiating potential of TCDD.

Although classified as a nonmutagen, TCDD, and by inference other dioxin-like compounds including coplanar PCBs, are described as potential multisite carcinogens in the more highly exposed human populations that have been studied, consisting primarily of adult males. There is adequate evidence that 2,3,7,8-TCDD is a carcinogen in laboratory animals based on long-term bioassays conducted in both sexes of rats and mice. All studies have produced positive results, leading to conclusions that TCDD is a multistage carcinogen increasing the incidence of tumors at sites distant from the site of treatment (USEPA, 2000). While several mechanisms have been proposed to explain the carcinogenic action of TCDD, further research is necessary to elucidate a detailed mechanistic model for any particular carcinogenic response in animals or in humans (USEPA, 2000).

In 1985, EPA classified 2,3,7,8-TCDD and related compounds as "probable" human carcinogens based on the available data. Since that time, the database relating to the carcinogenicity of dioxin and related compounds has grown and strengthened considerably. As noted by the International Agency for Research on Cancer (IARC, 1997), although the epidemiologic data for 2,3,7,8-TCDD was limited with respect to supporting a causal association between exposure to 2,3,7,8-TCDD and cancer, the overall weight of the evidence including human, animal, and mechanistic data was sufficient to characterize 2,3,7,8-TCDD as a "known" human carcinogen. A similar conclusion has also been stated in the addendum to the ninth report on carcinogens issued by the National Toxicology Program (NTP, 2001). Other dioxin-like compounds are characterized as "likely" human carcinogens primarily on the basis of the inference that, based on toxic equivalency, that they would behave in humans as 2,3,7,8-TCDD does.

At this time, the knowledge of the mechanism of action of dioxin, receptor theory, and the

available dose-response data do not firmly establish a scientific basis for replacing a linear procedure for estimating cancer potency. Therefore, for purposes of cancer risk assessment, the Agency is using the currently published slope factor of 1.56 E+5 $(mg/kg/day)^{-1}$ for the 2,3,7,8 congener (USEPA, 1985).

In addition to the 2,3,7,8 TCDD isomer, two hexachloro CDD isomers (1,2,3,6,7,8- and 1,2,3,7,8,9-hexachlorodibenzo-p-dioxin) were tested in Osborne-Mendel rats and B6C3F1 mice by the National Toxicology Program (NTP, 1980). Fifty rats and 50 mice of each sex were administered the HxCDD isomers suspended in a vehicle of 9:1 corn oil-acetate 2 days per week for 104 weeks at doses of 1.25, 2.5, or 5 μg/kg/wk for rats and male mice and 2.5, 5, or 10 μg/kg/wk for female mice. Under the conditions of this bioassay, the HxCDD isomer mixture administered by gavage was carcinogenic, causing increased incidences of hepatocellular carcinomas or neoplastic nodules in female Osborne-Mendel rats and inducing hepatocellular carcinomas and adenomas in male and female B6C3F1 mice. HCDD was not demonstrated to be carcinogenic for male rats. However, when administered by the dermal route to Swiss Webster mice (0.01 μg suspended in 0.1 ml acetone applied to the backs of 30 mice of each sex 3 days per week for 104 weeks) there was no evidence of carcinogenicity (NTP, 1982 a,b). Administration of 1,2,3,4,6,7,8 heptachlorodibenzo-p-dioxin to female rats by gavage was shown to result in increased incidence of lung tumors (Rozman, 2000). A recent study also conducted by NTP (NTP, 2004) examined toxicity and carcinogenicity of 2,3,4,7,8-pentachlorodibenzofuran (PeCDF) in female Sprague-Dawley rats. Groups of 81 rats were administered PeCDF in corn oil: acetone at doses of 6, 20, 44, 92, and 200 ng/kg PeCDF for up to 104 weeks. Up to 10 rats/group were evaluated at 14, 31, and 53 weeks. At 14 and 53 weeks, hepatocyte proliferation indices were significantly higher at the 200 ng/kg dose vs. time-matched controls. Increased incidence of hepatocellular adenoma and cholangiocarcinoma were observed at 2 years at the 200 ng/kg dose, as was increased incidence of gingival squamous cell carcinoma of the oral mucosa.

A study of the health records of 5172 workers exposed to 2,3,7,8-TCDD at a dozen chemical plants indicated that workers were 15% more likely to die of cancer than the general population. Records on 1520 workers whose exposures began at greater than 30 years ago - when plant dioxin levels were typically much higher than today - showed 9 times the normal rate for one particular cancer, soft-tissue sarcoma (Fingerhut et al. 1991, as cited in Schmidt 1992). A similar study in 1583 pesticide workers showed that, compared with the general population, 2,3,7,8-TCDD-exposed workers experienced a 24% higher rate of death from all cancers. Among

workers with more than 20 years' exposure, the cancer death rate increased to 87% above normal (Manz et al. 1991, as cited in Schmidt 1992). Other studies have found inadequate or equivocal evidence for the carcinogenicity of 2,3,7,8-TCDD in humans (NTP 1989; Schmidt 1992).

### 3.3 Toxic Equivalency Factors (TEFs) and Toxic Equivalency (TEQ)

CDDs/CDFs present in PCP present a unique case for purposes of risk characterization that differs from the Office of Pesticide Programs' usual approach. The 17 CDD/CDF congeners are produced as contaminants in the manufacture of technical grade PCP. All of these congeners have chlorine substitution in at least the 2,3,7, and 8 positions, thus imparting these contaminants with "dioxin like" activity. Thus, all must be considered in the risk assessment for the contaminants of PCP.

The concept of toxic equivalency factors (TEFs) has been developed to facilitate risk assessment of exposure to chemical mixtures of CDDs/CDFs. In this procedure, individual TEFs are assigned to the 17 CDDs/CDFs. These values have been published by both the USEPA and the World Health Organization (Van den Berg et al., 1998, 1998; U.S. EPA, 1989) and are based on assigning relative values in relation to the most studied and one of the most toxic congeners,2,3,7,8-TCDD, which is assigned a TEF value of 1.0. Multiplying the exposure concentration of individual congeners by their respective TEFs yields a toxic equivalent TEQ for each congener, which, when summed for all the congeners of the mixture, gives the TEQ concentration for that mixture.

In the case of PCP, the TEQ concentration is defined as the 2,3,7,8-TCDD equivalent concentration of CDDs/CDFs. It is estimated by multiplying the mass concentrations of 2,3,7,8-CDDs/CDFs by the corresponding TEFs established by the World Health Organization (WHO) in 1998 (Van den Berg et al., 1998). A CDD/CDF TEQ value of 0.616 mg TEQ/kg for technical PCP was used in this assessment. This value represents the weighted combined average dioxin and furan concentrations in PCP manufactured from January 2000 to April 2004 for the two industrial facilities in the United States manufacturing technical grade PCP. This TEQ was developed using the WHO-TEF weighting scheme. The development of the TEQ is discussed in-depth in the addendum to the CDD/CDF Product Chemistry Chapter for the PCP RED. The calculate TEQ factor of 0.616 mg/kg was then applied to the PCP absorbed doses to develop CDDs/CDFs exposure doses for the handler and

postapplication cancer risk assessments. This method assumes that CDDs/CDFs in PCP are absorbed at the same rate as PCP.

For CDDs/CDFs, the body burden approach appears to be the most practical dosimetric for expressing the effects of CDDs/CDFs across species (DeVito and Birnbaum, 1995; Birnbaum and Tuomisto, 2000). This approach takes into account the large differences in half-life of these chemicals between animal species and humans. While it is recognized that both carcinogenic and non-carcinogenic effects can occur from exposure to CDDs/CDFs at background levels (Birnbaum and Tuomisto, 2000; Steenland et al., 2004), because of the expression of the carcinogenic potency of CDDs/CDFs as a linear term, this would by default be the risk of most concern from exposure to CDDs/CDFs, still recognizing that non-carcinogenic effects could occur at similar exposure levels.

## 3.4 FQPA Considerations

Under the Food Quality Protection Act (FQPA), P.L. 104-170, which was promulgated in 1996 as an amendment to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Federal Food, Drug and Cosmetic Act (FFDCA), the Agency was directed to "ensure that there is a reasonable certainty that no harm will result to infants and children" from aggregate exposure to a pesticide chemical residue. The law further states that in the case of threshold effects, for purposes of providing this reasonable certainty of no harm, "an additional tenfold margin of safety for the pesticide chemical residue and other sources of exposure shall be applied for infants and children to take into account potential pre- and post-natal toxicity and completeness of the data with respect to exposure and toxicity to infants and children. Notwithstanding such requirement for an additional margin of safety, the Administrator may use a different margin of safety for the pesticide residue only if, on the basis of reliable data, such margin will be safe for infants and children."

It is recognized that infants and children are an important sensitive population in risk assessment because they may be more highly exposed than adults given their lower body weights. That is, for a given level of exposure, children will have a higher exposure on a per kg body weight basis than an adult. However, uses of pentachlorophenol involving potential contact with food or feed were

restricted in the 1980's (USEPA, 1984) such that the chemical was not allowed for such uses subsequent to this restriction. Therefore, dietary exposure to the dioxin/furan contaminants from PCP-treated wood is not expected and FQPA considerations will not apply in this case. However, any issues with respect to sensitivity as applied to the wood preservative uses of PCP will be taken into consideration in estimation of risk.

**TABLE 1**

**TOXICITY EQUIVALENCY FACTORS FOR DIOXIN-LIKE COMPOUNDS** [a]

| CDD congener | TEF | CDF Congener | TEF |
|---|---|---|---|
| 2,3,7,8-TCDD | 1.0 | 2,3,7,8-TCDF | 0.1 |
| 1,2,3,7,8-PeCDD | 1.0 | 1,2,3,7,8-PeCDF | 0.05 |
| 1,2,3,4,7,8-HxCDD | 0.1 | 2,3,4,7,8-PeCDF | 0.5 |
| 1,2,3,6,7,8-HxCDD | 0.1 | 1,2,3,4,7,8-HxCDF | 0.1 |
| 1,2,3,7,8,9 - HxCDD | 0.01 | 1,2,3,6,7,8-HxCDF | 0.1 |
| 1,2,3,4,6,7,8,9-OCDD | 0.0001 | 1,2,3,7,8,9-HxCDF | 0.1 |
| | | 2,3,4,6,7,8-HxCDF | 0.1 |
| | | 1,2,3,4,6,7,8-HpCDF | 0.01 |
| | | 1,2,3,4,7,8,9-HpCDF | 0.01 |
| | | 1,2,3,4,6,7,8,9-OCDF | 0.0001 |

Note:

(a). The TEF values are taken from the World Health Organization's (WHO) revised list for TEFs, published in 1998 (Van den Berg et al., 1998).

## 4.0 EXPOSURE ASSESSMENT

The purpose of the exposure assessment is to estimate the magnitude of potential chemical intake for various receptors. Detailed Exposure to the CDD and CDF contaminants in PCP is addressed in detail in a separate document (Aviado, 2004). Here, only summary information from that document is provided for clarity in the risk assessment.

## 4.1 Identification of Potential Receptor Populations

The exposure scenarios developed for this RED Chapter are representative of potential occupational exposures to the chemicals of concern over a long-term ( > 6 months) exposure duration and is focused primarily on cancer risk. EPA has determined that there are potential exposures to CDDs/CDFs for mixers, loaders, applicators, and other handlers during typical pressure treatment use-patterns associated with the restricted use of PCP by certified applicators in industrial settings. Summary results are presented here.

### 4.1.1 Occupational Handlers

#### *Primary Occupational Handlers*

Handler exposure to PCP wood preservatives, as product concentrates and treatment solutions, results in potential exposure to CDDs/CDFs during handler operations in pressure treatment plants. The following handler scenarios for pressure treatment uses have been identified from the PCP biomonitoring and inhalation study submitted by the Pentachlorophenol Task Force entitled *Inhalation Dosimetry and Biomonitoring Assessment of Worker Exposure to Pentachlorophenol During Pressure-Treatment of Lumber* (PTF, 1999), further detailed in the PCP RED Human Exposure Chapter:

(1a) Applying crystalline technical grade product- Pressure Treatment Operator;
(1b)Applying liquid formulation-Pressure Treatment Operator;
(2a) Applying crystalline technical grade product- Pressure Treatment Assistant; and
(2b)Applying liquid formulation- Pressure Treatment Assistant.

The LADDs for the CDDs/CDFs cancer risk assessment are derived from the absorbed long-term doses for PCP adjusted by the 0.616 mg TEQ/kg factor to yield absorbed long-term doses for CDDs/CDFs which are then amortized over a lifetime. Exposure frequency is assumed to be 250 working days per year (i.e., five days per week, 50 days per year). This is a standard Agency

assumption for days worked per year. Exposure duration was assumed to be 40 years and is a conservative standard value used by OPP to represent a working lifetime. Lifetime is assumed to be 75 years. This is the recommended value for the U.S. population, as cited in EPA's Exposure Factors Handbook (U.S. EPA, 1997) and typically used in OPP assessments as a standard value. Cancer risk was calculated by multiplying the CDDs/CDFs LADD by the cancer slope factor of 1.56E+05 $(mg/kg/day)^{-1}$ A cancer risk greater than E-6 is of concern to be mitigated and risks greater than E-4 are generally considered unacceptable. All of the assessed occupational handler scenarios are in the range of E-4 for the pressure treatment operator handling the crystalline product (1.1E-4) and the liquid formulation (2.3E-4), and the pressure treatment assistant handling the crystalline product (4.2E-4) and the liquid formulation (6.7E-4). The Agency will seek ways to mitigate the risks, to the extent that it is practical and economically feasible, to lower the risks to E-6 or less.

***Occupational Postapplication Exposure***

In the pressure treatment industry, postapplication exposure may result from typical work tasks associated with removing wet treated wood from treatment cylinders, reentry activities in treatment areas including maintenance of treatment equipment and cleanup, handling freshly-treated wood to bore test core samples, stacking/loading wet wood onto drip pads, and handling dry wood for storage or transport. The following postapplication exposure scenarios for pressure treatment uses have been identified from the PCP biomonitoring and inhalation study (PTF, 1999) further detailed in the PCP RED Human Exposure Chapter:

(1) Pressure Treatment Loader Operator;
(2) Pressure Treatment Test Borer; and,
(3) Pressure Treatment General Helpers.

In addition, potential occupational postapplication exposures exist for electrical utility linemen in dermal contact with PCP-treated utility poles during installation and/or while working on in-service poles. Biomonitoring data from a worker exposure study on utility linemen entitled *Occupational Exposure of Electrical Utility Linemen to Pentachlorophenol.* (Thind et al., 1991) were used to characterize chronic or long-term exposure from absorbed doses of CDDs/CDFs in PCP based on measured PCP residue levels in monitored worker urine samples. As noted in this

published study, the work activities of the linemen include frequent climbing of new or in-service PCP-treated poles, which require significant skin contact to PCP-containing oils which run down the surface of the telephone poles. The following postapplication exposure scenario represents electrical utility workers:

(4) Pole Installers (Electrical Utility Linemen).

For both postapplication pressure treatment and electrical utility linemen scenarios, the lifetime average daily doses (LADDs) for the cancer risk assessment are based on the absorbed doses derived from the data on PCP residues in worker urine samples from both biomonitoring studies detailed in the PCP RED Human Exposure Chapter (PTF, 1999 and Thind et al., 1991). The dose and risk calculations for the cancer assessment were conducted as described in the occupational exposure chapter.

None of the assessed occupational postapplication scenarios exceeded the Agency's level of concern (i.e., E-4) for cancer risks. Cancer risks are as follows: the pressure treatment loader operator (9.5E-5), pressure treatment test borer (8.4E-5), general helpers (4.9E-5) and electrical utility linemen (3.4E-5). The Agency will seek ways to mitigate the risks, to the extent that it is practical and economically feasible, to lower the risks to E-6 or less.

### 4.1.2 Residential Receptors

Residential postapplication exposure to CDD/CDF contaminants of PCP is unlikely to occur to adult and child populations as a result of contact with PCP-treated wood products or through child contact with PCP-contaminated soil via the dermal and oral route (i.e., incidental ingestion of CDD/CDF residues through hand-to-mouth contact and direct soil ingestion). The Agency has not conducted an exposure and risk assessment for residential populations due to the following consideration:

- The opportunity for residential consumer contact is limited since PCP-treated wood is not sold to the general public. Rather it is predominantly marketed for commercial installations as utility poles. Where utility poles are installed on home/school or other residential sites, child contact via the dermal or oral routes is not anticipated since play activities with or

around these pole structures would not normally occur and any incidental exposure would therefore be negligible.

## 5.0 RISK CHARACTERIZATION

As noted above, carcinogenic risks have been assessed using the published cancer slope factor for TCDD. As noted above in this document, at doses close to those of background, TCDD has been implicated in both carcinogenic and non -carcinogenic effects. Non-cancer risks have not been separately addressed since the expression of carcinogenic potency of CDDs/CDFs as a linear term would be, by default, the risk of most concern and anticipated to be protective of non-cancer risks.

### Occupational Cancer Risks from Absorbed Doses of CDD/CDF Impurities in PCP

For primary occupational handlers, the assessed exposure scenarios were in the range of E-4 for the pressure treatment operator handling the crystalline product (1.1E-4) and the liquid formulation (2.3E-4), and the pressure treatment assistant handling the crystalline product (4.2E-4) and the liquid formulation (6.7E-4).

None of the assessed occupational postapplication scenarios exceeded the Agency's level of concern (i.e., E-4) for cancer risks. Cancer risks are in the E-5 range for all scenarios: the pressure treatment loader operator (9.5E-5), pressure treatment test borer (8.4E-5), general helpers (4.9E-5) and electrical utility linemen (3.4E-5).

## 6.0 UNCERTAINTY ANALYSIS

When assessing risks from exposure to the dioxins and dioxin-like compounds, "knowing the increment [exposure] relative to background may help to understand the impact of the incremental exposure" (USEPA, 2000). In this sense, then, in order to properly assess risk, one should have an adequate characterization of "background" dioxin exposures, a discussion of the percent

increase over background for the exposure of interest, and a policy statement that describes at what point the increases over background become significant in terms of risk. Risk from exposure to dioxins in pentachlorophenol-treated wood should be considered in the context of all sources to which a person may be exposed to dioxins. According to the most current data, intake levels of dioxin from food sources are estimated at approximately 1 pg TEQ/kg /day, but this is an average value and may not be inclusive of all subpopulations (USEPA, 2000), where additional exposures may occur as a result of contamination incidents or exposures from discrete sources. While the current assessment has estimated occupational exposures to dioxins and dioxin-like contaminants from contact with pentachlorophenol-treated wood, the ORD reassessment only addresses PCP in treated wood as a reservoir source that could contribute to overall background exposures through possible release of CDDs/CDFs from the wood while it is still in service. The ORD reassessment does not explicitly quantify occupational exposures (except in the context of the evaluation of epidemiological studies where significant occupational exposures are known to have occurred in the past), but the results in this assessment suggest that the potential exposures faced by individuals in occupations associated with treating wood and PCP, and then putting this treated wood in service, could face dioxin exposures comparable to background exposures for this important class of compounds (USEPA, 2000).

From the analysis of occupational exposure to the "dioxin like" CDD and CDF contaminants of PCP, it is apparent that the most significant exposures occur within the occupational setting, particularly for those individuals involved in handling treated lumber in the workplace. However, exposures identified in the occupational setting in the present assessment need to be considered within the context of the assumptions made.

The data used to develop the occupational scenarios and estimates of exposure to CDDs/CDFs in PCP were from limited available study data on PCP. The handler/postapplication assessments for pressure treatment plant workers were based on data for PCP in the study entitled *Inhalation Dosimetry and Biomonitoring of Worker Exposure to Pentachlorophenol During Pressure-Treatment of Lumber* (PTF, 1999). The postapplication assessment for pole installers utilized published biomonitoring data in the industrial hygiene study entitled *Occupational Exposure of Electrical Utility Linemen to Pentachlorophenol* (Thind et al., 1991) to estimate potential worker dermal exposure. Specific limitations related to these studies are noted in the PCP RED Human Exposure Chapter.

Occupational postapplication scenarios were developed for workers engaged in post-treatment

handling of wood in a pressure treatment plant, and for electrical utility linemen involved in utility pole installation. Other PCP exposures not addressed in this study include postapplication exposure to workers engaged in construction fabrication of PCP-treated timbers/lumber. Activities involving cutting and sanding of PCP-treated wood may cause dermal, inhalation or oral ingestion exposure concerns for CDDs/CDFs in PCP.

An additional area of uncertainty involves the selection of the TEQ factor of 0.616 mg TEQ/kg for the occupational assessment, as derived from the analyses conducted on EPA industry monitoring data from KMG-Bernuth and Vulcan Chemicals for manufactured technical PCP in production years 2000-2004. The TEQ factor was calculated based on both *measured* and *predicted* values for certain congener concentrations using linear regression analysis. As per the CDDs/CDFs Product Chemistry Chapter addendum (Shamim, 2005) a linear regression analysis of KMG HpCDD on OCDCC and HpCDF on OCDF, to calculate the concentrations of octa congeners of Vulcan resulted in a very poor linear relationship ($R^2$ = 0.22 for dioxins and $R^2$ = 0.46 for the furan congeners) yielding a high degree of uncertainty built into the total TEQ calculations.

The current occupational assessment presents only potential cancer risks. A limitation is that non-cancer exposure risks have not been separately addressed. The expression of carcinogenic potency of CDDs/CDFs as a linear term would be, by default, the risk of most concern and anticipated to be protective of non-cancer risks.

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