

U. S. EPA DIOXIN-IN-PAPER PROJECT: RISK ASSESSMENTS
FOR AQUATIC AND TERRESTRIAL ENVIRONMENTS

William S. Rabert, Robert E. Morcock, and Maurice G. Zeeman*
U.S. Environmental Protection Agency
Washington, D.C. 20460, U.S.A.

ABSTRACT

TCDD/TCDF risk assessments predict localized effects to 1) aquatic organisms from pulp mill effluents, 2) mammals and birds from eating contaminated fish, and 3) terrestrial mammals and birds from land application of pulp sludge.

INTRODUCTION

In response to a legal consent order, the U.S. Environmental Protection Agency conducted a review of risks posed by TCDD and TCDF produced by pulp and paper mills. Monitoring data from five mills indicted that chlorinated bleaching processes produced chlorinated dioxins and furans. Monitoring data from 104 pulp mills indicated the levels of TCDD/TCDF present in effluent, pulp and sludge. Risks to aquatic organisms, birds and mammals were evaluated for effluents and forest applications of pulp sludge.

Chlorinated dioxins and furans are very highly toxic to fish, birds, and mammals (Table 1). The most toxic congener of dioxin appears to be 2,3,7,8-TCDD. TCDD has low water solubility (about 200 ng/L) and a high log P value (about 6.8). TCDD bioaccumulates in food webs from soil, food, water and sediments. Calculated bioconcentration factors (BCF) for TCDD range from about 5,000 to 159,000 times the water concentration (Table 2). BCF tests have not been conducted for an adequate duration to reach steady-state

in fish. Bioaccumulation levels range from 1 to 10 times for food, soils and sediments. TCDD is persistent; the half-life in humans is 7 to 10 years, 10 to 15 years in soil, and even longer in sediments, because compounds adsorbed to the sediments are less subject to degradation.

Fish appear to be the most sensitive species tested against TCDD. Chronic toxicity of TCDD to fish has not yet been determined. Mortality is normally delayed several days depending on the test level and the duration of exposure. A 56-day rainbow trout BCF test produced 45 percent mortality at the lowest test concentration (38 ppq, estimated LC50: 40 ppq); most mortality at the lowest concentration occurred during the depuration phase, after a 28-day exposure. Lethality in fish from short TCDD exposures suggests that migratory fish may be at risk during passage through contaminated parts of rivers and lakes.

METHODS

The aquatic and terrestrial exposure estimates for TCDD and TCDF were based primarily on monitoring data from the "104 pulp and paper mill study" and the EPA National Bioaccumulation Study. Data collected from the mill study included TCDD/TCDF levels in effluent, pulp sludge and pulp. Dilution models and water flow data were used to extrapolate from measured effluent levels to in-stream concentrations for the aquatic risk assessment. Risks to fish-eating birds and mammals were estimated from TCDD levels measured in whole fish in the National Bioaccumulation Study.

Exposures to terrestrial wildlife were estimated from the measured TCDD/TCDF levels in pulp sludge using local application methods. Soil levels were estimated for seven states where land application of pulp sludge has been permitted. Models were used to estimate dietary uptake and risks to wildlife.

RESULTS AND DISCUSSION

The aquatic risk assessments predicted lethal and sublethal effects for local populations of sensitive aquatic organisms and wildlife for most pulp mill scenarios. When additive toxicity for TCDD/TCDF was considered, predicted in-stream concentrations exceeded the 28-day LC50 value for 16 percent of the pulp mills located on streams and rivers. The estimated chronic toxicity level (0.038 pg/l) was exceeded by 90 percent of the effluents. TCDD measured in 66 percent of whole fish samples collected near pulp mills exceeded chronic effect levels for fish-eating birds and mammals. TCDD levels in fish at some locations were high enough to pose unacceptable risks to piscivores taking only a small fraction of their diets from that area. Levels in fish near 10 mill sites were 10X or higher than estimated chronic effect levels.

The terrestrial risk assessments predicted some toxic effects in six out of seven scenarios for land application of sludges. The terrestrial models used reasonable methods and realistic assumptions with moderate parameters. Modeled estimates of exposure compared favorably with measured values reported in a Wisconsin field study. Subsequent reports indicate thinning of robin eggshells in some areas where pulp sludges were applied.

CONCLUSIONS

TCDD/TCDF formed at paper mills pose a risk to local fish and wildlife populations. Effluents from about 90 percent of the mills exceed the estimated TCDD chronic toxicity value for aquatic organisms. Sediment toxicity data were not available, but risk to some benthic organisms might be expected. Uptake by benthic organisms is a potentially important route for TCDD entry into food webs. Contaminated sediments act as a long-term source of TCDD for aquatic systems. Residues in 66% of fish sampled near pulp mills exceeded estimated chronic dietary levels for wildlife.

Land application of TCDD/TCDF-contaminated sludge from pulp and paper mills may pose a risk to terrestrial wildlife. Risks to wildlife are predicted for six out of seven states which have allowed land application. Field data strengthen the modeled estimates of exposure and risk posed by TCDD.

Toxicity tests are needed to determine chronic effect levels for fish, birds, and benthic organisms. Reproduction tests are needed in both fish and birds to identify NOECs for deposition of TCDD in eggs and embryonic effects. Data are needed on TCDD volatilization rates from drying pulp, sludge, soil and effluents and levels entering sensitive lakes by atmospheric transport.

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Table 1. Select environmental toxicity values reported for TCDD

Species	Exposure Duration	Endpoint Type	Toxicity Values	
Mammals ^a				
Guinea pig	1 dose	LD50	0.6 - 2.5	ug/kg
Rats	1 dose	LD50	22 - 45	ug/kg
Rhesus monkey	1 dose	LD50	< 70	ug/kg
Mouse	1 dose	LD50	114 - 284	ug/kg
Rabbit	1 dose	LD50	155	ug/kg
Hamster	1 dose	LD50	1,157 - 5,051	ug/kg
Rat	Reprod.	LOAEL	10	ng/kg
Rhesus monkey	Reprod.	LOAEL	1.7	ng/kg
Birds ^{a,b}				
Bobwhite quail	1 dose	LD50	15	ug/kg
Domestic chicken	1 dose	LD50	25 - 50	ug/kg
Mallard duck	1 dose	LD50	>> 108 ^c	ug/kg
Ringed turtle-dove	1 dose	LD50	> 810 ^d	ug/kg
Leghorn chicken	21 days	NOEL	100	ng/kg
Bluebird (eggs)	Reprod.	LOAEL	65	pptr
Fish ^e				
Rainbow trout	28 days	LC50	40	pg/L

^a Cited in Eisler (1986).

^b Cited in Abt report (unpublished).

^c Acute toxicity value may be lower than indicated because regurgitation was reported in these tests.

^d Ringed turtledoves showed toxic effects, but not enough to compute an LD50. Deaths occurred 13 to 37 days after treatment.

^e Reported by Mehrle *et al.* (1988).

Table 2. TCDD and TCDF bioconcentration factors estimated for various durations of exposure.

Species	Exposure	Measured BCF	Estimated BCF
TCDD:			
Rainbow trout	6 hours ^a	24 X	9,270 X
Rainbow trout	28 days ^b	26,707 X	37,000 - 86,000 X
Fathead minnow	28 days ^c	5,840 X	7,900 X
Fathead minnow	71 days ^d	ND ^e	97,000 - 159,000 X
Carp	71 days ^d	ND	66,000 X
TCDF:			
Rainbow trout	28 days ^b	2,450 - 6,050 X	

^a Branson et al. (1985).

^b Mehrle et al. (1988).

^c Adams et al. (1986).

^d Cook (Unpublished).

^e ND: no data were available.