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Environmental Effects of Dredging Technical Notes

Residue Effects Data Base on the Relationship Between Dioxin and Biological Effects in Aquatic Animals

Purpose

The purpose of this note is to present residue-effects data involving dioxins that are presented in the scientific literature. The information will be useful in developing regulatory guidance applicable to dioxin contamination.

Background

Work Unit 31771, "Environmental Interpretation of Consequences from Bioaccumulation," of the Long-Term Effects of Dredging Operations (LEDO) Program is designed to provide interpretive guidance for evaluating data generated by Corps field offices for their permit applicants. This guidance results from identifying residue-effects relationships through laboratory experiments and literature reviews. Previous literature reviews conducted under this work unit have concentrated on heavy metals and chlorinated contaminants (Dillon 1984, Dillon and Gibson 1985). The present effort examines residue-effects relationships with dioxins as reported in the published literature.

Polychlorinated dibenzo-*para*-dioxins (PCDDs) are present as trace impurities in some manufactured chemicals and industrial wastes. Generally, the source for high levels of PCDDs is attributable to industrial discharge, hazardous waste dumps, or the application of PCDD-contaminated herbicide (Miller, Norris, and Hawkes 1973, Helder 1980, 1981). PCDDs are formed as a result of photochemical and thermal reactions in fly ash and other incineration products, as well as in high-temperature chlorination reactions. There are 75 PCDD isomers. The most toxic and most extensively studied is 2,3,7,8-tetrachlorodibenzo-*para*-dioxin (2,3,7,8-TCDD). In general 2,3,7,8-TCDD is the congener referred to by the term dioxin and is the congener discussed in this note.

Additional Information

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Approach

To conduct this review, 15 technical journals and 8 data base literature search services (for example, Tox-Line, Pollution Abstracts, and National Technical Information Service) were used. Additionally, the Dioxin Information Data Base under development by the US Army Engineer Waterways Experiment Station as part of the LEDO Program Work Unit 31772 "Toxic Substances Bioaccumulation in Aquatic Organisms" was searched. All pertinent publications were individually reviewed for the following information: test species, contaminant, exposure conditions, tissue concentration, and corresponding biological effect.

Summary

An intensive review of the technical literature for both residue data and biological effects information showed that studies relating the two were, for the most part, nonexistent. Most of the papers reviewed contained biological effects information related to nominal (not measured) dosage, but with no associated body burden data. Only studies with both tissue residue levels and biological effects information relating to 2,3,7,8-TCDD are discussed in this note.

The majority of scientific studies focusing on dioxins in the aquatic ecosystem dealt with bioaccumulation. In addition, studies conducted to observe the biological effects of dioxins generally concentrated on species other than aquatic organisms (that is, birds and mammals, especially laboratory animals).

The lack of information on dioxin in the aquatic ecosystem is cause for general concern (Miller, Norris, and Hawkes 1973). Information is scarce or lacking on the biological properties of PCDD congeners (Walker and others 1991). No data are available on lethal and sublethal effects of any PCDD congener to aquatic organisms, except 2,3,7,8-TCDD (Eisler 1986).

Only two studies reported on residue-effects data. One was the exposure of carp to fly ash contaminated with 2,3,7,8-TCDD (Kuehl and others 1985). This is a relatively old reference with regard to dioxin research, and the chemical methodology employed by the authors has changed appreciably in the interim. The lowest tissue residue level measured was 1.2 parts per trillion (10^{-12} or pptr) and was associated with some gill tissue damage. A tissue residue of nearly 1,000 pptr, however, only resulted in fin discoloration, fin necrosis, and erosion. These data are presented in Table 1.

Table 1
Dioxin Residues Associated with Known Biological Effects

Organism	Tissue Concentration, pptr	Exposure	Effect
2, 3, 7, 8-TCDD			
Carp* (1)**	1.8, 1.2	1 g fly ash (2,000 pptr) 15 day static	gill tissue damage
Carp* (2)	2.0, 2.2	5 g fly ash (2,000 pptr) 30 day static	gill tissue damage
Carp* (3)	200	1 g fly ash (2,000 pptr) 25 day static	fin discoloration, necrosis, and erosion
Carp* (4)	1,000	5 g fly ash (2,000 pptr) 38 day static	fin discoloration, necrosis, and erosion
Carp* (5)	6.1, 11	250 mg fly ash (2,000 pptr) 95 day flow through	gill tissue damage
Carp* (6)	20, 28, 32	1, 5, 10 g fly ash (160 pptr) 30 day static	gill tissue damage
Carp* (7)	20, 33	5 g fly ash (160 pptr) 10, 30 day flow-through	bioavailability not affected by semi-static conditions
Trout†	0-121	0-40 pptr eggs (static) 48 hr	no effect on hatching
Trout†	226-302	62-100 pptr eggs (static) 48 hr	significant reduction in hatching

* Kuehl (1985).
** Individual groups of carp were measured separately; the number in parentheses is the number of each separate group of carp studied.
† Walker (1991).

In the second study lake trout eggs containing 2,3,7,8-TCDD in concentrations from 0 to 100 pptr were observed through the fry stage (Walker and others 1991). The resultant tissue concentrations in the fry ranged from 0 to 302 pptr. The only adverse effect on hatching was in the two highest treatments (Table 1).

The results summarized in Table 1 were drawn from a very limited number of studies that made only a few measurements associated with biological effects. It should be noted that tissue residues of organisms exposed to 2,3,7,8-TCDD environmental contamination and caught in the wild have been found to have much higher tissue levels of 2,3,7,8-TCDD than the levels reported in Table 1 without any apparent adverse effects. Crabs taken from Newark Bay have been shown to have 3,670.4 and 6,238.2 pptr associated with their hepatopancreas (Rappe and others 1991). In the same study lobsters were found to have 1,611 pptr and striped bass flesh was found to have accumulated 733.9 pptr in the New York Bight (Rappe and others 1991). In another example the liver of a burbot from Sweden was found to have 469 pptr of 2,3,7,8-TCDD (de Wit and others 1990).

On the basis of this literature review, there are not enough published data on 2,3,7,8-TCDD tissue residues and associated biological effects to make definitive recommendations regarding the handling of sediments contaminated with 2,3,7,8-TCDD. There is a clear need for research in the area of 2,3,7,8-TCDD toxicity and additional information concerning residue levels and associated effects before any definitive guidance regarding 2,3,7,8-TCDD can be given.

This review also points out the clear lack of any information regarding tissue residue levels and concomitant biological effects for any of the other dioxin congeners. This information must be generated in a timely manner, as certain states and the US Environmental Protection Agency propose to regulate dioxins by measuring the concentrations of other dioxin congeners in addition to the 2,3,7,8-TCDD congener. The proposed methodology involves measuring all 2,3,7,8-substituted congeners, assessing their toxicity relative to 2,3,7,8-TCDD, and summing the results to achieve a Toxic Equivalency Quotient (TEQ). The TEQ methodology and guidance regarding its use are the subject of another publication (McFarland, Reilly, and Ferguson, in preparation). Without specific information regarding the toxic effects of 2, 3, 7, 8-TCDD and the relative toxicities of other dioxin congeners, providing meaningful guidance on dioxin regulation in the aquatic environment or in dredging and disposal activities will be impossible.

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