Screening-level Ecological Risk Assessment of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Sediments and Aquatic Biota from the Venice Lagoon, Italy

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Introduction

The presence of polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) and other organochlorines in bottom sediments and aquatic biota in the Venice Lagoon, Italy is a growing concern to local residents and the new national environmental authority (1). Venice Lagoon is a shallow, poorly mixed estuary located adjacent to a heavily industrialized and populated region on the northeastern coast of the Adriatic Sea. The Venice Lagoon receives freshwater from several tributaries and exchanges marine waters through three channels: Port of Lido, Malamocco and Chioggia, which divide the Venice Lagoon into three homogenous hydraulic basins. The historic city of Venice rises in the Lido basin. The Malamocco basin is the most affected by industrial discharges originating from the industrial zone of Porto Marghera. The Chioggia basin supports one of the Lagoon's largest fisheries (1).

The results of recent sediment and biota monitoring studies indicate that portions of the Venice Lagoon ecosystem are seriously degraded, primarily due to eutrophication and chemical pollution. Sources of the contamination may be attributable to decades of discharges from the rapidly expanding industrial district at Porto Marghera; centuries of untreated domestic sewage from the historical city of Venice; and increased motorboat traffic (1,2,3,4,5,6). The results of a health risk assessment conducted by the Italian national health authority in 1995-96 suggested that consumption of foodstuffs from the Lagoon does not appear to pose a public health risk (1).

This paper presents the results of a screening-level ecological risk assessment (ERA) to evaluate the risks to wildlife posed by 2,3,7,8-substituted PCDD/Fs in sediments, fish and shellfish in the Venice Lagoon. The purpose of this study was two-fold: (a) provide a preliminary indication of the risks, if any, to representative aquatic biota and wildlife receptors at different trophic levels; and, (b) identify data gaps for future investigation and ecological assessment. A comparison of the results with those from other estuarine environments is included to evaluate the relative significance of the contamination.

Methods

Environmental Data. PCDD/F data from sediment, fish and shellfish collected from the Venice Lagoon were compiled from the results of several different investigations [1,4,5,7]. For non-detect concentrations, one-half the detection limit was assumed for the ERA; for PCA, 1×10^{-10} was assumed. Toxic equivalency quotients (TEQs) were calculated using toxic equivalency factors (TEFs) proposed by the World Health Organization [8]. A summary of the available environmental data is presented in Table 1.

Source Identification. Principal components analysis (PCA) was used to compare and contrast the relative distributions of 2,3,7,8-substituted congeners in sediments and aquatic biota. PCA modeling was conducted using Pirouette (version 1.4, InfoMetrix, Seattle, WA). Congener patterns in sediment and aquatic biota were compared to those associated with different anthropogenic sources [9,10]. Sampling results in fish were compared to predicted whole body concentrations calculated using biota-sediment-accumulation-factors [11].

Ecological Risk Assessment. The screening-level ERA was conducted in a manner consistent with U.S. Environmental Protection Agency (USEPA) ERA guidance [12,13]. Two species of birds were selected as receptors of interest (ROIs), including the belted kingfisher (*Ceryle alcyon*) and the spotted sandpiper (*Actitis macularia*) as representative piscivores and invertivores, respectively. In view of the large ecotoxicological database available on the mink (*Mustela vison*), it was selected as representative of both piscivores and invertivores species. Wildlife ROI exposures to PCDD/Fs were estimated by calculating an average daily dose (ADD, mg of chemical per kg body weight). Wildlife ADDs were calculated based on incidental ingestion of sediment and consumption of prey. The effects assessment and risk characterization for wildlife were conducted using measured or predicted whole body tissue concentrations expressed as TEQs and compared to appropriate no-observed-adverse-effect-level (NOAEL) and lowest-observed-adverse-effect-level (LOAEL) wildlife toxicological reference values (TRVs) [11,14]. For fish and aquatic invertebrates, body burdens were compared to the range of acute and chronic lowest-observed-effect-concentrations (LOEC).

Results and Discussion

PCDD/F Patterns in Sediment and Biota. The results of PCA modeling are presented in Figure 1. The PCA results indicate that the composition of PCDD/Fs in sediments is generally different from those in fish and shellfish (blue crab, vongole and mussel). The results are similar to those conducted elsewhere [15,16], and are likely due to differential bioaccumulation and uptake associated with different environmental sources. The congener patterns in sediments appear to correlate with known or suspected sources, particularly Porto Marghera and the city of Venice.

Preliminary ERA Results. Predicted wildlife ADDs are summarized in Table 1. When expressed as total PCDD/F on a TEQ basis, ADDs exceed NOAEL TRVs by as much as 2.5-fold for piscivorous birds and mammals and invertivorous mammals. Predicted ADDs do not exceed wildlife LOAEL TRVs, suggesting that adverse effects to wildlife are possible but highly uncertain. The concentrations of 2,3,7,8-TCDD in lagoon sediments (ranging from ND – 6 ppt, dw) are well below the 25 ppb no-effect concentration identified in recent estuarine sediment toxicity testing [17].

Future Study. Although the results of this study indicate a limited potential for adverse effects on birds and mammals at higher trophic levels in the food web, the results are subject to some uncertainties. For example, few data are available on concentrations of "dioxin-like" compounds in sediment and aquatic biota, particularly coplanar PCBs and other potential endocrine disrupters. At present, total TEQ body burdens in fish and shellfish at different lifestages and trophic levels are unknown. The derivation of no-effect and effect thresholds for different organochlorines using site-specific sediment toxicity tests would improve the assessment of risks to benthic invertebrates. Addressing these and other data gaps in the context of a comprehensive ERA is recommended as the basis for future monitoring and management activities.

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Table 1. 95% Upper Confidence Limit PCDD/F concentrations in sediment, fish, and shellfish (blue crab, vongole, and mussel) and predicted ADDs for representative wildlife receptors in a simplified food web for the Venice Lagoon, Italy

PCDD/F	Sediment (ng/kg dw) N=32	Fish (ng/kg ww) N=6	Shellfish (ng/kg ww) N=13	Total Average Daily Dose (ADD; ng/kg-day)[1] Piscivorous Bird	Piscivorous Mammal	Invertivorous Bird	Invertivorous Mammal
2,3,7,8-TCDD	1.0	0.6	0.5	0.31	0.09	0.51	0.07
1,2,3,7,8-PeCDD	3.8	0.6	0.9	0.31	0.09	1.0	0.15
1,2,3,4,7,8-HxCDD	26	0.2	0.7	0.10	0.03	1.7	0.18
1,2,3,6,7,8-HxCDD	13	0.4	0.3	0.20	0.06	0.79	0.09
1,2,3,7,8,9-HxCDD	20	0.2	0.3	0.10	0.03	1.0	0.10
1,2,3,4,6,7,8-HpCDD	1285	2.1	0.7	1.05	0.32	49	4.0
OCDD	1942	11	2.6	5.50	1.7	75	6.2
2,3,7,8-TCDF	137	11	7.9	5.40	1.6	13	1.6
1,2,3,7,8-PeCDF	159	3.1	2.9	1.55	0.47	8.9	0.92
2,3,4,7,8-PeCDF	206	13	2.4	6.40	1.9	10	0.98
1,2,3,4,7,8-HxCDF	1378	2.6	6.6	1.30	0.39	58	5.1
1,2,3,6,7,8-HxCDF	300	1.1	3.1	0.54	0.16	14	1.4
1,2,3,7,8,9-HxCDF	216	0.8	2.0	0.40	0.12	10	0.95
2,3,4,6,7,8-HxCDF	107	0.1	2.2	0.04	0.01	6.2	0.66
1,2,3,4,6,7,8-HpCDF	950	3.8	7.8	1.90	0.57	43	4.0
1,2,3,4,7,8,9-HpCDF	1833	0.5	1.2	0.25	0.08	70	5.7
OCDF	6500	15	14	7.50	2.3	258	22
Total PCDD/Fs[2]	15076	66	56	33	9.9	621	54
Total TEQ[3]	366	8.9	5	13	1.4	36	1.9

1. A screening-level ADD was calculated based on assumption that exposure is due to incidental ingestion of sediment and diet comprised entirely of aquatic invertebrates (invertivores) or a diet comprised entirely of fish (piscivores).
2. Sum of all congeners.
3. TEQs calculated using proposed WHO (1997) TEFs.

Figure 1. PCA scores plot of 2,3,7,8-substituted PCDD/Fs in sediment (sed1-32), fish (scardole1-6), blue crabs (crab1-5), and shellfish (vongole1-7, mussel) from Venice Lagoon. PC1 and PC2 explain 65% of the variance in the data set.