Evaluating Terrestrial Food Chain Impacts Near Sources of Dioxin Release in EPA Risk Assessments

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Introduction

Prior to the mid 1980s, assessments of health impacts from dioxin-like compounds released into the air only evaluated the inhalation exposure pathway. In the latter 1980s it was demonstrated that consumption of animal food products is the principal source of exposure to dioxin-like compounds. When evaluating the environmental and human health impacts of dioxin-like releases from a given source, the United States Environmental Protection Agency (EPA) currently focuses on the impacts to soils and plants on nearby farms where terrestrial food animals are raised. Exposure is evaluated for consumption of these vegetable/fruit and terrestrial animal farm products by the farming family. Also, dioxins can affect surficial water bodies and fish. However, this paper only evaluates terrestrial farming exposure scenarios in representative EPA dioxin risk assessments. Assessments summarized here were conducted as a part of either national rule-making activities or of site-specific regulatory decision-making processes. The results of the review are arrayed in a table showing similarities and differences in these assessments.

Description of Tabular Entries

Table 1 provides data only on the "high end" exposure scenario in 9 risk assessments, namely, the "subsistence farming family scenario", and specifically focuses on the adult beef and milk ingestion pathway. In most cases this scenario yielded the highest cancer risks. The table shows the regulatory context, amount of dioxin introduced into the environment from the source, receptor identification, exposure factors, results of the risk assessment, and regulatory outcomes. Most of these risk assessments had corresponding "central tendency" scenarios in which exposure may have also occurred by consumption of home produced foods, but to a lesser extent than in the "high end" scenarios. Finally, the 9 risk assessments only evaluated excess cancer risks due to the 17 dioxin-like dioxin and furan congeners; they did not evaluate risks from exposure to dioxin-like PCBs. Toxic Equivalent (TEQ) concentrations cited here are based on the International scheme.

This analysis does not cover several important areas: 1) all fate and transport modeling from source to receptor, 2) receptors other than adults (children, breast-fed infants, e.g.), 3) all other contaminants considered (dioxin may have been critical, but was not the only contaminant in most of these assessments), 4) approaches to assessing variability, and 5) dioxin non-cancer evaluations.

Observations

1) Six of the risk assessments were performed in support of national rulemaking activities; 3 dealt with dioxin risks from land application of solids, and 3 addressed sources emitting dioxins into the atmosphere. The remaining 3 were site-specific risk assessments of stack emissions of waste combustors. The assessments were performed under 4 statutes administered by EPA: Resource Conservation and Recovery Act (RCRA), Clean Air Act (CAA),Clean Water Act (CWA), and Comprehensive Environmental Response Compensation and Liability Act

(CERCLA). All have undergone or are currently undergoing independent peer review. The risk assessments were only one of a number of factors considered in regulatory decisions described in Table 1.

2) All assessments utilized realistic source strength terms, relying on incinerator stack measurements and surveys of the solid material concentrations for the farmland application of cement kiln ash and sewage sludge. The "high end" scenarios most often utilized the higher values of stack emission measurements and of surveyed concentrations in the solids materials.

3) There is a lack of consistency across risk assessments with respect to treatment of exposure factors and other exposure assumptions. The biggest variation is in the most important exposure factor - the consumption rates of beef and milk. Beef ingestion rates varied by about six-fold, from 58 to 323 g/day, while milk ingestion varied from 523 to 2100 g/day. There was also significant variation in the assumed proportion of total consumption which was home produced, with contact fractions ranging from 0.03 to the maximum of 1.00.

4) Most assessments, 6 of 9, assessed impacts at hypothetical farm locations (sited at areas of predicted maximum impacts based on air dispersion/deposition modeling) rather than at actual farm locations. The assessment of the Columbus Municipal Solid Waste Incinerator, which emitted nearly 1 kg TEQ/yr, evaluated actual farm locations that were the farthest from the source, between 8 and 17 km away; all other incinerator assessments located farms within 3 km.

5) Predictions of beef and milk concentrations were close to or lower than average US background concentrations in 8 of 9 assessments. Based on national surveys, the average concentrations of these products are 0.20 pg TEQ/g for whole beef and 0.03 pg TEQ/g for whole milk. Only the assessment of the Columbus Municipal Solid Waste Incinerator had significantly higher predictions, at 4.71 and 0.64 pg/g whole weight for beef and milk, respectively.

6) All 9 risk assessments evaluated excess cancer risks from dioxin exposures from the modeled sources; background cancer risks were not considered. For the 4 assessments resulting in excess cancer risks from dioxins in the 10^{-6} and 10^{-7} range, no additional regulatory actions were taken to limit exposures from the sources. Regulatory activities were undertaken in the 4 cases in which excess cancer risks were in the 10^{-4} and 10^{-5} range. For kilns burning hazardous waste, where excess cancer risk was assessed at $2*10^{-5}$, no action beyond planned Maximum Achievable Control Technologies was planned.

Comment

Even though the subsistence farm scenario is rare in the United States, it is still useful to consider this scenario for decision-making purposes. It is a way for the EPA to quantify impacts to the "highly exposed individual". Given continuing concerns about cancer risks and non-cancer health effects from exposure to dioxin-like compounds, it is important to continue to evaluate local impacts from specific sources and to work towards harmonization of a "subsistence farm scenario" in such assessments. This still leaves open the question of evaluating regional and global impacts. Substantial progress has been made in the last 20 years in evaluating dioxin risks to local populations from multiple exposure pathways. It is time to develop an approach to analyzing risks to populations on a regional and global level.

For a complete list of references and further detail on this effort, please contact Matt Lorber (lorber.matthew@epa.gov).

Table 1. Summaries of the subsistence farm scenario in EPA risk assessments (all concentration in TEQ; beef and milk in whole wt; see Table legend below table for description of tabular entries).

Title and Context	Source to Receptor	Farming Scenario	Results and Outcomes
I. Land application of solids			
Title: "Draft Risk Assessment for Cement Kiln Dust Used as an Agricultural Soil Amendment" Context: cement kiln dust (CKD) agricultural use standards are part of larger proposal to regulate cement kiln dust (RCRA).	Source & Receptor: hypothetical farm located near existing cement kilns; "high end" rate of 11.2 mt/ha biannually at TEQ concentration of 197 ppt (95% in CKD survey) for 100 years. Steady-state soil concentrations calculated to be 40 ppt.	Duration: 58 years Rates: 110 g/day beef; 726 g/day dairy Description: median rate for both foods for "consumers only" from "households who farm" Contact Fractions: 0.32 (beef); 0.25 (dairy) Other Pathways: veg/fruit, and soil ingestion.	Concentrations: NA Cancer Risk: $1^* 10^{-4}$ Outcome: Proposal to prohibit agricultural applications CKD with concentrations > 40 ppt.
Title: "Risk Analysis for the Round Two Biosolids Pollutants" Context: EPA regulations dealing with disposal of sewage sludge, including application to agricultural land (CWA).	Source & Receptor: hypothetical farm; maximum allowable rate of 10 dry mt/ha-yr at concentration of 300 ppt (95% in sewage sludge survey) biannually for 100 years. Steady state soil concentration calculated to be 40 ppt.	Duration: 58 years Rates: 58 g/day beef, 1729 g/day dairy Description: mean "per capita" for beef, 95% "per capita non-metropolitan" for dairy Contact Fractions: 0.10 (beef); 0.03 (dairy) Other Pathways: ingestion of beef liver, lamb and game.	Concentrations: NA Cancer Risk: $1.7^* 10^{-5}$. Outcome: Proposal to prohibit land application for sludge with concentrations >300 ppt.
Title: "Risk Assessment Technical Background Document for the Chlorinated Aliphatics Listing Determination" Context: Hazardous waste listing determination for wastewater treatment sludges (RCRA).	Source: Volatilization plus runoff/erosion from land treatment unit to nearby farm to result in soil and air concentrations of 61 ppt and 0.018 pg/m^3, respectively. Receptor: hypothetical farm 300 m away.	Duration: 48 years Rates: 98 g/day beef, 730 g /day diary Description: 50% for both foods for "consumers only" from "households who farm" Contact Fractions: 0.49 (beef); 0.25 (dairy) Other Pathways: inhalation, ingestion of soil and veg/fruit.	Concentrations: 1.4 ppt (beef); 0.32 ppt (milk) Cancer Risk: 2^*10^{-4} Outcome: proposal to list sludges as hazardous unless managed in federal/state permitted landfills.

Table legend: **Column #1 Title and Context**: title of assessment; regulatory context in which developed; **Column #2 Source to Receptor**: source strength information: annual emissions from incinerators or solids concentration that is to be applied to the land; receptor information: hypothetical or actual farming site.

Table 1 (cont'd).

Title and Context	Source to Receptor	Farming Scenario	Results and Outcomes
II. Incinerator and Other Air Sources			
Title: "Sewage Sludge Incinerators' Dioxin-like Compound Risk Analysis" Context: EPA regulations dealing with disposal of sewage sludge, including incineration as a disposal option (CWA).	Source: based on 6 of 100 actual facilities which had highest measured emission rates of dioxin; 0.3 g TEQ emitted/yr Receptor: used US Census data for locations of farms within 20 km of facilities.	Duration: 17.3 years Rates: 148 g beef/d; 532 g dairy/d Description: mean rates for "consumers only" for adults ages 20-39 Contact Fraction: 1.00 for both Other Pathways: inhalation, ingestion of veg, fruit, soil, water, and fish.	Concentrations: 0.06 ppt (beef); 0.02 ppt (milk) Cancer risk: $8*10^{-7}$ Outcome: no additional standards proposed for incinerated sewage sludge.
Title: "Risk Assessment Technical Background Document for the Chlorinated Aliphatics Listing Determination" Context: Hazardous waste listing determination for wastewaters (RCRA).	Source: Volatilization from aerated on-site, biological treatment tanks, emission rate estimated at 0.003 g TEQ/yr Receptor: hypothetical farm 300 m away.	Duration: 48 years Rates: 98 g beef/day, 730 g dairy/day Description: 50% from "households who farm", (subset of "consumers only") Contact Fractions: 0.49 (beef); 0.25 (dairy) Other Pathways: inhalation, ingestion of soil, exposed/root vegetables, and fruit	Concentrations: 0.12 ppt (beef); 0.03 ppt (milk) Cancer Risk: $2*10^{-5}$ Outcome: proposal to list wastewaters and require covers on tanks when influent wastewater concentrations >= 1 ng/L;
Title: "Risk Assessment for the Waste Technologies Industries (WTI) Hazardous Waste Incineration Facility (East Liverpool, Ohio)" Context: Permitting decision for commercial hazardous waste incinerator assumed to operate for 30 years (RCRA)	Source: 0.04 g TEQ/yr based upon 26 separate runs over one year period during actual operation. Receptor: Hypothetical farm location, based on maximum predicted vapor phase air concentration; located 1 km east of WTI	Duration: 40 years Rates: 203 g/day beef, 552 g/day milk Description: median rates for "per capita" consumption, adjusted upward by factors of 2.5 (beef) and 3.0 (milk) for median to 90 th %; e.g., beef = 81 g/d (median) * 2.5 = 203 Contact Fraction: 0.75 for beef/milk Other Pathways: inhalation, soil ing/dermal contact, surface water ing/dermal, homegrown vegetables	Concentrations: 0.034 ppt (beef); 0.003 ppt (milk) Cancer Risk: $1*10^{-6}$ Outcome: Incinerator operating under RCRA permit

Column #3 Farming Scenario: exposure factors, including exposure duration: length of time the individual is exposed to the source in question; ingestion rate: rate of ingestion of whole beef or milk; description: how beef and milk ingestion rates were derived from different US national dietary surveys - "per capita" refers to the rate derived from all participants in the survey regardless of whether they consumed the product or not, and so on; contact fraction: fraction of total consumption produced on farm site (1.00 = all beef/milk consumed is home produced); other pathways: listing of other exposure pathways considered in the "subsistence farming scenario"

Table 1 (cont'd).

Title and Context	Source to Receptor	Farming Scenario	Results and Outcomes
Title: "Human Health and Ecological Risk Assessment Support to the Development of Technical Standards for Emissions from Combustion Units Burning Hazardous Wastes" Context: Emission standards for hazardous waste combustors including incinerators ("inc") and kilns ("k") (CAA and RCRA)	Source: random national sample of actual facilities (140+ inc. and 20+ k) with top emission rates of 1.8 (inc) and 4.0 (k) g TEQ/yr at baseline (no further pollution control) and 0.3 (inc) and 2.0 (k) g TEQ/yr under MACT (Maximum Achievable Control Technology) Receptor: hypothetical farm in 16 sectors out to 20 km (closest sector corresponds to an areal average distance of 1.4 km)	Exposure Duration: 17.3 years Rates: 79 g beef/day; 510 g dairy/day Description: mean rates for "consumers only" of home-produced foods for adults ages 20 years and older, adjusted for preparation and cooking losses (meats) and fraction of dairy that is milk Contact Fraction: 1.00 for both Other Pathways: inhalation, ingestion of soil, water, veg, fruits, farm-raised hogs, poultry, eggs, and fish	Concentrations: 0.7 and 0.2 (inc); 0.2 and 0.07 (k) ppt for beef/milk at baseline Cancer Risk: $1*10^{-4}$ (inc) and $3*10^{-5}$ (k) at baseline; $4*10^{-6}$ (inc) and $2*10^{-5}$ (k) under MACT Outcome: no additional RCRA regulation beyond technology-based MACT standards.
Title: "A Screening Level Risk Assessment of the Indirect Impacts From the Columbus Waste-to-Energy Facility in Columbus, OH" Context: EPA evaluated risks to determine whether additional pollution control technologies needed (CAA).	Source: 1992 stack test showed dioxin emissions to equal 984 g TEQ/yr. Receptor: Average concentrations predicted to occur for 9 actual farm sites located between 8 and 19 km away in all directions	Duration: 70 years including 45 years of operation (15 yrs of high emissions + 30 years of MACT)/25 years of post-operation impacts from soil. Rates: 100 g beef/day; 300 g milk/day Description: mean for "per capita" Contact Fraction: 1.00 Other Pathways: soil ingestion/dermal contact, and vegetable ingestion.	Concentrations: 4.71ppt (beef); 0.64 ppt (milk) during period of high emissions; 0.92 and 0.12 pg/g for 70 year average. Cancer Risk: $2.8*10^{-4}$ Outcome: Additional pollution controls required.
Title: "Final Multimedia Level Risk Assessment for the Thermal Treatment Unit; Crab Orchard National Wildlife Refuge" Context: Evaluation of thermal treatment of 118,000 tons of contaminated soil for a 128-day burn (CERCLA).	Source: 0.108 g TEQ (0.31 g/yr) during the limited operation. Receptor: hypothetical farm located at point of maximum deposition in area of actual residences - about 3.75 km north of site.	Duration: 40 years including 1 year of operation/39 years of post-operation impacts from residual dioxins in soil. Rates: 57 g beef/day; no dairy considered Description: mean rates for "per capita" consumption Contact Fraction: 1.00 Other Pathways: inhalation, soil ing/dermal contact, water , veg ingestion.	Concentrations: 0.027 ppt for beef during burn period; 0.00004 ppt over 40 year exp. duration. Cancer Risk: $9.2*10^{-7}$ Outcome: Incremental exposures to dioxin over background judged to be insignificant.

Column #4: results including predicted whole beef and milk concentrations, overall estimated cancer risk, and outcome of the effort for which the risk assessment was done.