Dioxins in the Food Chain: Background

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Summary

Dioxin and related chemical compounds are toxic industrial pollutants which are ubiquitous and persistent in the environment, and which accumulate in the fat tissue of animals and humans. Foods of animal origin are the primary source of human exposure to dioxins. In June 2000, the Environmental Protection Agency (EPA) completed a ten-year effort to reassess the science base associated with dioxin and closely related compounds and their associated risk to human health. The draft dioxin reassessment concludes that dioxin is a human carcinogen and that the lifetime cancer risk associated with the average person's body burden of dioxin is between 1 in 1000 and 1 in 100. This estimate of risk is ten times higher than EPA's previous estimate and represents a very significant public health concern.

Terrestrial food animals are thought to accumulate background levels of dioxin primarily through ingestion of contaminated vegetation and soil. Several incidents of contamination of food animals with dioxin concentrations significantly above background levels have occurred during the past five years: (1) in the U.S. due to the use of contaminated ball clay, an anti-caking agent, in animal feed; (2) in Europe due to contaminated citrus pulp from Brazil used as an ingredient in animal feed; (3) and in Belgium due to contamination of recycled fats added to animal feed.

Routine monitoring of dioxin levels in foods or animal feed has not been conducted by either the Food and Drug Administration (FDA), the Environmental Protection Agency (EPA), or the Food Safety Inspection Service (FSIS) in the past, although targeted surveys were done by all three agencies. Beginning in 1999, dioxin levels in foods are being tested on an annual basis in the FDA's Total Diet Study. The FDA also conducts testing for dioxins in imported animal feed products and human food products in certain situations, such as following the dioxin contamination incident in Belgium. FDA and

FSIS do plan to increase their efforts in monitoring for dioxins. Research into sources of dioxin exposure in food animals has been conducted by the Agricultural Research Service (ARS).

Background dioxin levels do not appear to be a trade issue at present. The occurrence of a serious incident of contamination significantly above background levels in the U.S. would likely lead to trade restrictions on affected U.S. exports, based on Belgium's experience in 1999.

Introduction

In June 2000, the Environmental Protection Agency (EPA) completed a ten-year effort to reassess the science base associated with the environmental contaminant dioxin and closely related compounds, and their associated risk to human health. This draft report will now be submitted to an independent scientific peer review process, stakeholder comment (e.g., the public, regulated community, advocacy groups), and then a final review by the EPA's Science Advisory Board, with an anticipated final EPA dioxin reassessment document for public release by the end of calendar year 2000. The draft dioxin reassessment concludes that dioxin is a human carcinogen and that the lifetime cancer risk associated with the average person's body burden of dioxin is between 1 in 1000 and 1 in 100. This estimate of risk is ten times higher than EPA's previous estimate and represents a very significant public health concern.

Dioxin and related compounds, i.e. polychlorinated dibenzo-p-dioxin (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs), are halogenated aromatic compounds which are industrial pollutants that persist in the environment. In addition to cancer, dioxins have been linked to adverse human health effects such as developmental, immunologic, and endocrine toxicity. The major environmental sources of dioxin and dioxin-like compounds (referred to below simply as "dioxins") are emissions from combustion, incineration, any industrial processes using chlorine, paper mills, fireplaces, grass fires, etc. The aerial transport of these emissions is the primary pathway dioxins enter the terrestrial environment and food chain.

Another source of dioxins in the environment is chlorophenol-based products, such as pentachlorophenol (PCP), which was widely used as a wood preservative in the past until its use was restricted in 1980.

Levels of dioxins in the environment have steadily decreased since the early seventies, due to reduced emissions from the major industrial sources. Human daily intake of dioxin and dioxin-like compounds, of which over 90% occurs through foods of animal origin, has also been reduced since the 1970s. However, the EPA's draft reassessment of dioxin exposure concludes that adverse human health effects may be occurring due to current levels of human intake of these compounds. Therefore, in order to safeguard public health, efforts to reduce dioxin in the environment and in the food supply must continue.

What are the major sources of dioxin and related compounds in the human diet?

Dioxins are lipophilic compounds which accumulate in the fat of animals. The types of foods which tend to have the highest dioxin concentrations are dairy products, meat and poultry, eggs, fish, and animal fats (Eduljee and Gair, 1996). Green vegetables, fruits and grains are the types of foods with the lowest dioxin concentrations. Schecter et al. (1997) measured dioxins in pooled food samples that were collected in 1995 at supermarkets across the U.S. The pooled sample of fresh water fish had the highest level of dioxins (1.43 TEQ[1]), followed by butter (1.07 TEQ), hotdog/bologna (0.54 TEQ), ocean fish (0.47 TEQ), cheese (0.40 TEQ), beef (0.38 TEQ), eggs (0.34 TEQ), ice cream (0.33 TEQ), chicken (0.32 TEQ), pork (0.32 TEQ), milk (0.12 TEQ), and vegetables, fruits, grains and legumes (0.07 TEQ). A person's intake of dioxins through the diet therefore, depends on the relative intake of foods with high or low levels of contamination and the quantity consumed. For example, Patandin et al. (1999) investigated the dietary intake of a group of preschool children in The Netherlands and found that dairy products contributed about 50% of their intake of dioxins and related compounds, while meat/meat products and processed foods contributed about 20% and 25%, respectively (Patandin et al. 1999).

How do food animals become contaminated with dioxin and related compounds?

Deposition of airborne dioxins onto plant and soil surfaces, and subsequent ingestion of this contaminated vegetation and soil by food animals, is considered the primary pathway by which dioxins enter the food chain (Fries, 1995). The levels produced in this way are considered background levels. Fish become contaminated due to airborne dioxin deposition into the water and also from contaminated soil or industrial waste washed into rivers and lakes, leading to high sediment concentrations. Inhalation and water pathways are not considered significant sources of exposure for terrestrial animals. Contamination above background levels can occur if food animals are fed products which are adulterated, either by natural or unnatural means, with high concentrations of dioxins (see section on contamination incidents below).

For terrestrial animals, the intake of vegetation or roughages is considered the most important dioxin exposure factor (Fries 1995a). Feeds derived from seeds contain lower concentrations of dioxins, since the seed is not directly exposed to the air. Ruminants therefore are more vulnerable to dioxin exposure than poultry and swine, as their feed source is predominantly roughage based. Travis and Hattemer-Frey (1991) predicted that ingestion of contaminated grains and forage should account for 70% and 79% of the total daily intake of dioxins in beef and dairy cattle, respectively. Lorber et al. (1994) also modeled concentrations of dioxins in beef and found that the consumption of grass/hay/silage/grain explained over 90% of dioxin concentrations in their model. Finishing cattle in feedlots is thought to significantly reduce concentrations of dioxins in beef. This is hypothesized to be due to the feeding of a predominantly grain based diet for several months before slaughter (Lorber, et al. 1994).

Soil ingestion by livestock is also a significant source of exposure to dioxins (Fries, 1995b). The use of pasture for ruminants is a factor in the soil pathway, since animals on pasture ingest contaminated soil along with the vegetation. The amount of soil ingested is related inversely to the availability of forage when pasture is the sole source of feed. Soil ingestion is reduced when animals on pasture are given supplemental feed. Cattle confined to dirt lots also consume small amounts of soil that can lead to meat residues. Travis and Hattemer-Frey (1991) predicted that ingestion of contaminated soil should account for 29% and 20% of the total daily intake of dioxins in beef and dairy cattle, respectively. In another model of dioxin concentrations in beef, Lorber et al. (1994) found that soil ingestion by beef cattle only explained about 10% of final dioxin concentrations in beef. Soil ingestion is also a possible pathway for contamination in free range poultry and swine raised on pasture or dirt lots.

Livestock may also be exposed to dioxins from pentachlorophenol (PCP) treated wood on production facilities. PCP treated wood was used extensively in animal housing and confinement facilities until its use was restricted by the EPA in 1980 (Fries et al. 1996). A 1977-79 survey of usage patterns of chemically treated wood on Michigan dairy farms indicated that about half of Michigan dairy farms exercised proper usage of treated wood, however about a third had used it improperly on areas such as feed structures, calf pens and rafters (Shull et al. 1981). Fries et al. (1996) and others (Feil and Larsen, 1999) found that the dioxin congener (chemical variations) patterns in beef fat samples were similar, after adjusting for differential congener absorption by animals, to the congener patterns identified in PCP treated wood samples from the facilities housing the animals. Fries et al. (1996) concluded that the "frequent use of PCP treated wood, the propensity of animals to lick or chew wood, and the compatibility of congener profiles" suggest that "PCP treated wood may be an important source of residues in animal products in the U.S."

How can dioxin contamination in food animals be decreased?

Numerous factors may influence the concentration of dioxins in food animals such as the source of the dioxins (e.g. new emissions vs. recycling in the environment), aerial transport, degree of plant uptake, fate in the soil (half-life), animal uptake via feed and soil ingestion, bioavailability to the animal, and pharmacokinetics. Since ingestion of dioxins in contaminated vegetation and soil is considered the major pathway of exposure for food animals, different feeding practices such as confinement feeding, grazing, and percentage grain fed should have significant effects on actual concentrations of dioxins in animals. While these factors have been theoretically researched and modeled (as described in the previous section), little epidemiological or controlled research has been done to validate these hypotheses (Feil and Ellis, 1998).

Concentrations of dioxins in adipose tissue of cattle at slaughter were investigated in two small surveys, one conducted jointly by the USDA Food Safety Inspection Service (FSIS) and the EPA, and the other conducted by the USDA Agricultural Research Service (ARS) (Feil and Ellis, 1998). In general, the results from both surveys indicated that dioxin concentrations varied considerably among animals. In both surveys, bulls had higher dioxin concentrations than other slaughter animals. Results from the ARS survey suggest that certain geographical areas may generate animals with higher dioxin concentrations. More research is needed to identify potential risk factors associated with varying dioxin concentrations in cattle, other livestock, and poultry.

Locating livestock and poultry operations and cultivating crops used for animal feed away from sources of dioxin emissions may be important in controlling dioxin concentrations in food animals. Lovett et al. (1998) conducted a survey of dioxins in eggs and poultry meat from a site close to a chemical waste incinerator, and several other urban and rural sites in the United Kingdom. Dioxin concentrations in poultry produced from the site closest to the incinerator were higher than concentrations in poultry produced from other sites. There were also variations in the chemical composition of the dioxins associated with their geographic origin. Ramos et al. (1997) compared dioxin concentrations in milk samples from dairy farms in Spain located in rural areas without specific dioxin sources (control farms), to milk from farms in the vicinity of potential dioxin emission sources (case farms), and to pasteurized milk from retail outlets. The milk samples from control farms had only slightly lower concentrations of dioxins than the milk produced near emissions sources. However, the highest concentrations of dioxins were found in samples produced near a waste incinerator and a chemical plant. The lowest levels were found in pasteurized milk samples purchased from retail outlets in Spain and in milk from one of the control farms.

Another potential source of dioxin contamination of the vegetation and soil consumed by animals is the application of sewage sludge to pasture or crops intended for animal consumption. Sewage sludge is contaminated with a complex mixture of organic compounds, including dioxins (Engwall and Hjelm, 2000). In a study of the impact of using sewage sludge to restore degraded land, Molina et al. (2000) found that sewage sludge increased the dioxin concentration in the soils and that the contamination persisted through the one year study period. Engwall and Hjelm, (2000) found carrots grown in soil that had sewage sludge applied to it had higher concentrations of dioxins compared to controls; however, concentrations in the parts of the plant which grow above ground were generally low. No studies were found which investigated dioxin levels in soils to which animal manure had been applied.

Little information is available on the bioavailability and absorption of dioxins in food animals. The bioavailability of dioxins may vary according to the source of the dioxin, such as vegetation or soil. Fifty percent of the dioxin in lactating dairy cow feed is absorbed, with the remainder being excreted primarily in the feces (Fries and Paustenbach, 1990). Absorption of dioxins in the diet is enhanced when accompanied by oil (Fries, 1995b). A better understanding of the bioavailability and absorption of dioxins in food animals may lead to potential ways to interfere with uptake from animal feed and other sources, or ways to enhance elimination of dioxin from the animal, thereby decreasing dioxin concentrations.

Recent studies have linked the presence of PCP treated wood on food animal production facilities to concentrations of dioxins in the animals. Therefore, the elimination of the PCP treated wood from areas where animals could have direct contact, or ingest the contaminated wood, may result in decreased animal concentrations of dioxins.

Have there been any serious incidents of contamination of food products with dioxins above background levels recently?

Contamination of ball clay, an anti-caking agent, used in animal feed in the U.S.

During a nationwide survey for dioxins in food products that was conducted in 1997 by the EPA and the FSIS, samples of poultry meat were found to have elevated levels of dioxins. This finding led to a multi-agency investigation which implicated animal feed as the likely source of the dioxin contamination. Further investigation traced the source to ball clay, an anti-caking agent used in the production of animal feed. The joint industry and government response was to eliminate the use of ball clay in animal feeds to prevent further contamination. Since the incident in 1997, the Food and Drug Administration (FDA) now offers general advice to the feed industry regarding monitoring of anti-caking agents.

In 1998, the FDA and the EPA collected samples of clay and non-clay anti-caking products, testing them for the presence of dioxins. From this testing, 9 of 15 samples contained detectable dioxins at varying levels. Conclusions from the study were: (1) dioxins can be present in non-clay as well as clay anti-caking products; (2) there are several types of dioxin that can be present, not just one; and (3) the significance to human health of the relatively low levels of dioxins found in these products is unknown. (FDA, 2000) Other projects that stemmed from the ball clay incident include: (1) an industry driven examination of data regarding dioxin that are relevant to the animal feed industry; (2) the testing of mined feed ingredients to see if other types of mined products contain dioxins; and (3) the continued sampling of clay and non-clay anti-caking products for dioxins.

Contaminated citrus pulp fed to animals in Europe

In Germany, a comprehensive monitoring program of dioxins in food documented a gradual decline of food contamination from 1993 to 1997. Beginning in September 1997, a gradual increase in concentration of specific types of dioxins was noted in milk, butter and meat (beef and veal) samples. After an intensive investigation, the source of contamination was found to be use of dioxin contaminated citrus pulp from Brazil as feed material for ruminants. Feed containing the contaminated citrus pulp contained 20-100 times more dioxins than background levels. After elimination of the contaminated feed, the dioxin level in milk in Germany decreased. Other European countries also import citrus pulp from Brazil, and in response to the findings of the German investigation, the European Community in 1998 set a tolerance limit for dioxins in citrus pulp of 500 pg I-TEQ/kg. The source of the contamination of the citrus pulp was contaminated lime, which is added to the wet peel for neutralization and constitutes about 2% of the dried citrus pulp. Brazil no longer uses this contaminated lime for citrus pulp production. Conclusions from the investigation highlight the importance of analyzing high numbers of food samples throughout the year for dioxins in order to detect shifts in trends, including seasonal changes. (Malisch, 2000)

Contamination of animal feed in Belgium

In March 1999, Belgian farmers began noticing clinical signs of dioxin toxicity in their chickens, and in late April 1999, dioxin contamination of the feed was identified as the cause (Anonymous, 1999). A stock of recycled fat that had been delivered to a manufacturer of animal feed, was determined to be the source of the problem (Bernard et al., 1999). Almost 3,000 Belgian poultry, beef, and pig farms may have used the contaminated feed, along with some farms in France, the Netherlands, and Spain. Belgium implemented a large-scale food monitoring program to determine the extent of contamination, and found that poultry and poultry products were affected to a greater extent than swine (Bernard et al., 1999). Bovine livestock were free of contamination. Affected farms were quarantined and contaminated products were destroyed. More than 30 countries, including the U.S., temporarily banned Belgian food imports ranging from pork, poultry, eggs, and milk to chocolate. The estimated cost to the Belgian economy was more than $750 million (Ekperigin, 2000).

What activities involving dioxins are U.S. governmental agencies currently doing?

APHIS

APHIS does not currently have any activities or programs that involve dioxins.

EPA

The EPA is responsible for setting and enforcing acceptable levels of pesticides and other environmental contaminants in foods (except for meat and poultry). As a part of this, the EPA collects and uses data on the incidence and levels of pesticides and contaminants in foods. While the EPA has not been conducting routine monitoring of food products for the presence of dioxins, they have completed various studies over time, as well as having some ongoing research projects.

In the mid-90's, the EPA and the FSIS conducted a joint survey which measured dioxin levels in commercial beef, pork, and poultry, as well as other food products. It was from this survey that the high levels of dioxin were discovered in poultry meat that eventually traced back to the ball clay anti-caking agent used in the production of animal feed.

The EPA's Dioxin Exposure Initiative is modeling the human intake of dioxins. This initiative also includes the following ongoing research projects that involve animals. The National Study on Animal Feeds is characterizing the components of feed for cattle, poultry, and swine and determining which components of the feed contribute the greatest amount of dioxins to livestock. A sideline of this work will be to determine if the air-to-leaf-to-animal route of exposure does indeed account for all or most of animal dioxin levels as is currently believed, or if there are other significant routes of exposure that need to be explored. The Mass Balance on Lactating Cows study will verify if feed is the source of dioxin exposure to lactating cows. And finally, the National Milk Study on PBTs (persistent and bioaccumulative toxics) is a follow-up study to a previous milk study which determined levels of dioxins in milk samples.

FDA

While the FDA does not routinely survey imported animal feed products, they do conduct testing for dioxin if a need arises. The Center for Food Safety and Applied Nutrition has procedures developed for sampling shipments (FDA Investigations Operations manual) and for dioxin testing procedures (FDA Laboratory Information Bulletin 4084). The Center for Drug Evaluation and Research developed industry guidelines in response to dioxin related events in Belgium, focusing on certification of the safety of product imported from Belgium and testing of end products which were produced with potentially contaminated ingredients. In 1999, dioxins were added to the Total Diet Study, an annual study to determine levels of various pesticide residues, contaminants, and nutrients in foods. As a part of this study, approximately 200 food items are tested for dioxins on an annual basis, including fish, meats, eggs, and dairy products.

In collaboration with the EPA, the FDA is beginning a study which will test animal feeds for dioxins, targeting common feed ingredients that contain animal fats (beef fat; pork fat; fat from mixed animal species or other sources; meat and bone meal; poultry byproduct meal; fish meal) or that are considered to be a possible dioxin source (deodorizer distillates that are byproducts of the commercial refining of vegetable oils and likely contain PCBs; molasses which might be contaminated by air deposition, soil contamination on beets, or by fire during cane harvesting). Sample collection is scheduled to be completed by mid-August of this year, with approximately 16 types of feeds being sampled.

The FDA's FY 2001 budget request includes moneys to continue to work on the issue of animal feed contamination with dioxins via ball clay. Activities are targeted to include complete dioxin analysis of clays that are used in animal feeds, testing at mines beyond the Mississippi area involved in the 1997 incident, and in-depth testing throughout the affected mines in the Mississippi area.

FSIS

As previously mentioned, FSIS collaborated with EPA in a one time survey of meat and poultry products in the mid-90's. While FSIS currently has no programs or projects that routinely involve testing for dioxin, discussions regarding new surveys are ongoing.

Other Agencies

The ARS and the National Institutes of Health’s National Institute of Environmental Health Sciences conduct research on dioxins, but neither conduct monitoring or ongoing testing. The Center for Disease Control and Prevention (CDC) occasionally tests for dioxins during site investigations of spills and superfund sites.

Where can dioxin testing be done and what is the cost?

The EPA and the FDA have laboratories which conduct dioxin testing and there are a number of private laboratories that conduct dioxin testing. In order to look at 17+ congeners and to detect very low levels of dioxin, costs can run as much as $1000 per sample utilizing the gas chromatography/mass spectrometry (GCMS) technique which is specific to types of dioxin. For testing which does not identify specific congeners nor detect very low levels, the cost can be as low as several hundred dollars per sample. The FDA has developed an ion trap testing method which has the specificity of the GCMS method, but is much less costly. This new method has not been verified in controlled studies; however, FDA personnel believe the test performs satisfactorily. (personal communication, FDA)

If you seek more information or wish to comment on this report, please contact Judy Akkina at (970) 490-7852 or Vicki Bridges at (970) 490-7822.

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[1]Toxicity Equivalent Quantity (TEQ) or parts per trillion (ppt) of toxicity equivalents, is the sum of the quantity of individual congeners (chemical variations) of the dioxin family of compounds, multiplied by the respective toxicity equivalency factor (TEF) for that congener.

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