DIOXINS IN SHEEP AND GOAT LIVER TISSUES FROM TARANTO, ITALY: CONGENER PATTERN

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Introduction

The Italian government decided to build an integrated iron and steel factory in Taranto, Italy, in the early 1960s, and the factory began production of iron and steel in 1964. The choice of the Taranto area was driven by the presence of a port and by the idea to bring heavy metal industry to the South of Italy to enhance the economy of the area. The facility is located northwest of the city of Taranto. The adjacent areas have remained essentially agriculture and sheep and goat pastures. The government privatized this industry in 1995, selling the complex to an Italian steel company.

In 2010 the Judge of the Preliminary Investigation of the Court of Taranto requested that a group of experts address questions regarding the emissions of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/Fs) from the iron and steel factory, including assessing whether the PCDD/F found in the liver tissue of slaughtered goat and sheep coming from the area surrounding the iron and steel factory were attributable to this facility. The experts conducted several investigations that are presented in their final report[1]. Numerous statements regarding the profiles of congener concentrations of PCDDs, PCDFs, and dioxin-like polychlorinated biphenyls (dl-PCBs) in samples of sheep and goat liver tissues were included in the report. It cites the relatively elevated levels of PCDF compounds compared to PCDDs in sheep and goat liver samples and states that this profile reflects the "fingerprint" of PCDD/F emissions from the iron and steel plant. However, no comparison to the common congener profiles from sheep liver samples elsewhere was conducted.

The issue of accumulation of PCDD/F and dioxin-like compounds in sheep liver has been identified as a concern throughout Europe, even in rural areas where there are no identifiable contamination sources. Data collected from member states throughout Europe were recently evaluated and summarized by the European Food Safety Authority (EFSA)[2]. Recently the United Kingdom Food Standards Agency (UK FSA) presented additional data on this issue, and noted the predominance of furan congeners:

> "The dominance of the furans, which are significant contributors to the TEQ, is very apparent and appears to be characteristic of all sheep liver and probably liver in other species."[3]

We present here data sets on sheep liver dioxin content from several sources around Europe, including many of the datasets recently evaluated and summarized by EFSA[2]. The congener contributions to total TEQ (defined below) in sheep liver in these data sets are calculated and presented in this report. The pattern and concentration ranges in Taranto-area samples are compared to the patterns and levels in these other European data sets.

Materials and methods

Taranto-area. Tissue sampling was conducted in 2008, 2009, and 2010 by the local environmental agency, ASL – Taranto (Azienda Sanitaria Locale - Taranto) and was obtained from this organization by request. No information was provided by ASL-Taranto on the rationale for selection of specific farms or locations for the collected samples; nor was information provided on whether these data represent the full set of data collected during these sampling efforts. Thus, neither the spatial representativeness nor selection criteria of these data can be ascertained.

For each sample, the percent contribution of each PCDD/F and dl-PCB congener to the total TEQ was calculated, and the average and standard deviation of the TEQ concentration for each congener in the full dataset was also calculated. The TEQ concentrations were calculated using the 1998 World Health Organization Toxicity Equivalency Factors (TEFs)[4], consistent with EU regulations for evaluation of food products at the time of sample collections. This also allows comparison with important published data sets, e.g., EFSA (2011), discussed below.

Other European sheep liver sampling data. EFSA was petitioned by the European Commission to evaluate the occurrence and levels of PCDD/F and dl-PCB congeners in sheep and deer liver in Europe due to repeated reports of liver tissue concentrations in excess of the EU limits and concerns regarding reporting of results on a fat weight basis rather than a fresh weight basis[2]. As a part of this evaluation, EFSA collected pre-existing liver tissue sampling data sets from member countries and combined these for evaluation. This data collection included data from Taranto. In a report issued in 2011, EFSA reported that typical sheep liver concentrations were in excess of the existing EU limits. In its evaluation, EFSA concluded that "the frequent consumption of sheep liver, particularly by women of child-bearing age and children, may be a potential health concern"[2].

The pattern of congener contribution to TEQ was extracted from the graphical presentation based on 148 sheep liver samples in EFSA (2011) report. We also retrieved several sets of the raw data included in the EFSA compilation from the literature, from public reports, and from researchers or government officials in EU member states. These datasets in many cases contained individual sample analytical results and allowed calculation of not only average contribution by congener to total TEQ levels, but also allowed characterization of the variability in the contribution by congener.

Results and discussion

Figures 1A and 1B present the congener TEQ contribution profile from the EFSA (2011) compilation and from each of the specific European datasets that we were able to retrieve (all of which were included in the EFSA compilation). Also included in these figures is the profile of congener concentrations calculated from the Taranto-area liver samples from 2008, which were collected closest in time to many of the other datasets and which were the basis of the Sanna et al. report conclusions.

The average profile of dioxin, furan, and PCB congener contribution to TEQ in the Taranto-area samples is essentially indistinguishable from the profile in the overall EFSA compilation and the individual data sets. In particular, the substantial contributions to TEQ from furan congeners, which was cited in the Sanna Report as reflecting the "fingerprint" of emissions from the iron and steel plant, is seen in every dataset, regardless of the pattern of congeners in the various exposure sources. This pattern is entirely determined by congener differences in the biology of PCDD/F absorption, distribution, and metabolism in sheep and liver-specific affinity of selected PCDD/F and PCB congeners[5]. In particular, the degree to which sheep livers accumulate 2,3,4,7,8-pentachlorodibenzofuran is extreme in all datasets.

This affinity is due to the presence of the cytochrome P450 1A2 protein (CYP1A2) in liver tissue. This protein binds selected dioxin-like compounds preferentially, and this protein is induced in liver in response to even trace exposure levels of these compounds[6,7]. As a result, accumulation of dioxin-like compounds in liver tissue, with varying degrees of accumulation by congener, is observed in every species examined, even at background exposure levels[8], leading to concern regarding exposures to dioxin-like compounds following consumption of liver[2]. These biological factors overwhelm variations in congener profile in exposure sources, and the resulting pattern of congener concentrations in sheep liver tissue is largely independent of the pattern of congeners in the exposure source.

Because the pattern of congeners in the Taranto-area samples is similar to that observed in sheep liver samples from all over Europe, this pattern cannot be used to "fingerprint" or identify a particular source of exposure. The congener pattern in the Taranto-area samples simply reflects the relative accumulation affinity of sheep liver for the various PCDD, PCDF, and PCB congeners present at trace levels in the environment from all sources. In particular, the predominance of furan congeners, which is cited in the Sanna Report as resembling the "fingerprint" of emissions from the iron and steel plant, is instead, as noted by Mortimer (2012) the characteristic "fingerprint" of sheep liver in general, regardless of the source of exposure.

These comparisons also show that the ranges of dioxin and furan TEQ concentrations in sheep and goat liver tissue samples from the Taranto area are within the range of dioxin and furan concentrations reported elsewhere in Europe (Figure 2). Concentrations of dioxin-like PCB compounds, which have not been associated with the iron and steel factory emissions, appear to be elevated in some Taranto area samples compared to other European datasets. As noted above, the EFSA collection of data included data from Taranto, and the highest PCB TEQ concentration in the EFSA data collection appears to have come from the Taranto data.

References

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Figure 1A: Comparison of dioxin/furan TEQ (WHO 1998 TEFs; non-detected results set to ½ detection limit) profile in Taranto goat and sheep liver samples from 2008 to that from other European datasets.

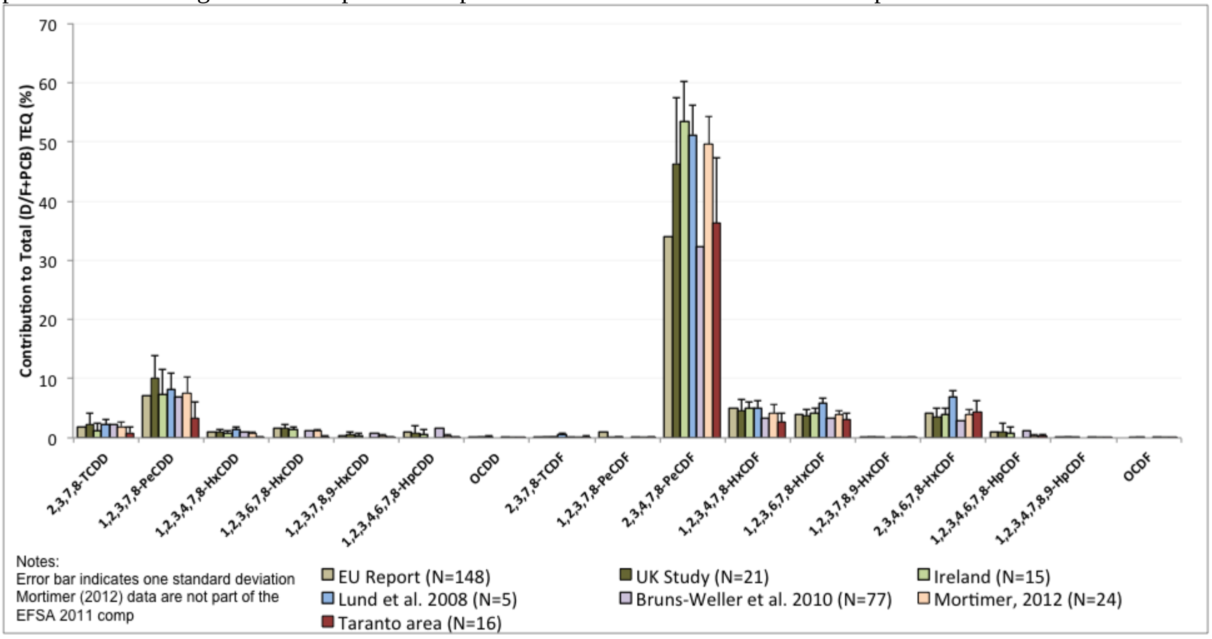

Figure 1B: Comparison of PCB TEQ (WHO 1998 TEFs) profile in Taranto goat and sheep liver samples from 2008 to that from other European datasets.

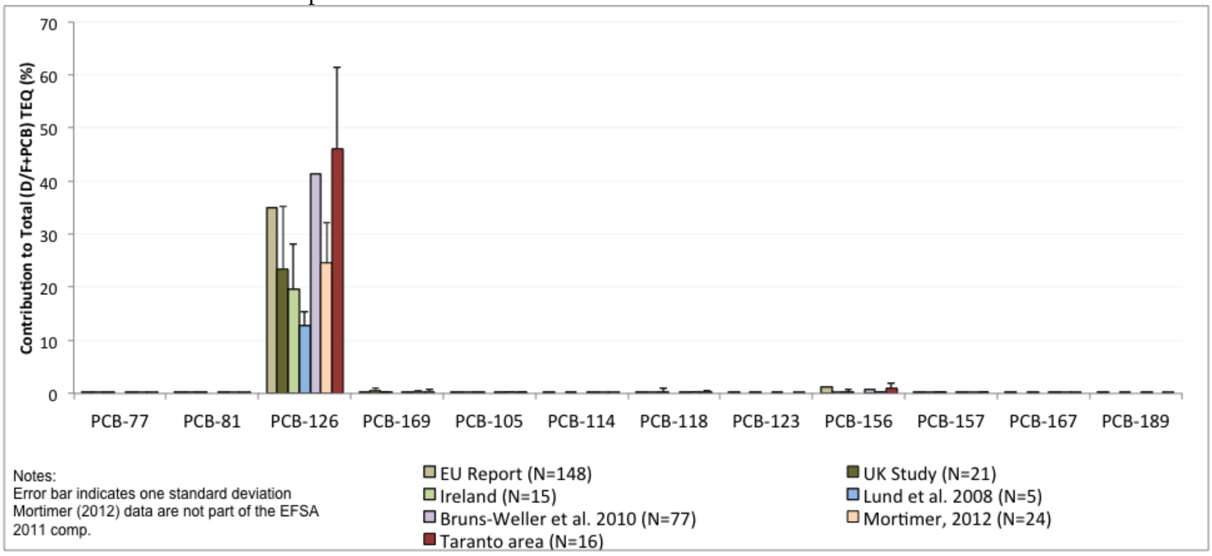

Figure 2: Levels of PCDD/F, PCB, and total TEQ (WHO 1998 TEFs) in sheep and goat liver samples collected from the Taranto area in 2008, 2009, and 2010, in comparison with the distribution of sheep and goat liver sample concentrations reported in the EFSA (2011) report. As noted above, the 2008 Taranto samples were included in the EFSA data collection.