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The influence of soil contamination on the concentrations of PCBs in milk in Siberia

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Abstract

Although atmospheric deposition is generally the dominant pathway of PCBs into agricultural food chains, soil ingestion by livestock can be important in some cases. The relationship between PCB levels in cow's milk and in pasture soil was studied in the Irkutsk region in Siberia where an historical atmospheric source(s) of PCBs has led to widespread contamination of soil. Milk samples were collected in spring and again in autumn from 18 different farms and analyzed for PCBs. Pasture soil samples were also collected and analyzed. The PCB concentrations in both milk and soil ranged over more than an order of magnitude between the farms. A good correlation was obtained between PCB levels in autumn milk and in soil. This together with a range of other evidence suggested that ingestion of pasture soil was the dominant source of the PCB contamination in the milk. The average soil ingestion rate was estimated to be 1700 g/d, which is at the upper end of values reported in the literature. This may be due to the arid summer climate or the animal husbandry practices in Siberia.

Keywords: PCB; Cow's milk; Pasture; Soil ingestion

1. Introduction

In Europe, cow's milk and dairy products are a major source of human exposure to persistent, lipophilic compounds. They contribute 30–45% of human exposure to polychlorinated dibenzo-*p*-dioxins (PCDD/F) (Furst et al., 1990; Theelen et al., 1993) and 27% of the exposure to polychlorinated biphenyls (PCBs) (Duarte-Davidson and Jones, 1994). Dairy cattle take up these chemicals via feed, primarily grass (McLachlan et al., 1990; McLachlan, 1993). Atmospheric deposition is usually the primary vector of lipophilic chemicals into grass (Welsch-Pausch et al., 1995; Thomas et al., 1998). One reason is that plants as a rule cannot take up these chemicals from the soil and translocate them to the aerial plant parts to a significant extent (Hülster and Marschner, 1993). However, cattle do ingest soil (Fries, 1996), and it is conceivable that if the soil contamination is high compared to atmospheric levels that soil can be a significant source of chemicals like PCBs in cow's milk, and thereby an important vector of human exposure.

The Irkutsk region, located to the west of the southern end of Lake Baikal in Siberia, has extensive soil contamination with PCBs and PCDD/Fs. Our work indicates that this is the consequence of historical accumulation from atmospheric source(s) located close to the city of Usol'e-Sibirskoe in this heavily industrialized area. The dramatic decrease in industrial activity in the last 15 years makes it unlikely that the atmospheric sources are still strong. Otherwise the area has very low background levels of these chemicals in the atmosphere.

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The local population has elevated tissue levels of these chemicals. PCB levels are particularly high. The sum of the indicator PCBs in breast milk from 32 women from Usol'e-Sibirskoe averaged 182 ng/g lipid (Mamontova et al., 2005). This is comparable to levels in western European countries, a region with high PCB contamination (Malisch and van Leeuwen, 2003), which is surprising given the remote location of Lake Baikal. Locally produced dairy products are estimated to contribute 65% and 24% of the daily intake of PCDD/Fs and PCBs, respectively (Mamontova et al., 2000). The PCB and PCDD/F levels measured in milk samples collected from three dairies in the region were positively correlated with the levels in soil in the district served by the dairies, which suggested that soil might be an important vector of these contaminants into the milk and thereby to the local population.

The goal of this study was to establish whether there was a relationship between PCB levels in milk and in soil in the Irkutsk region. Milk samples and soil samples were collected from 18 farms located throughout the area and analyzed for PCBs.

2. Methods and materials

2.1. Sampling

Samples were collected from 15 farms located around the suspected atmospheric PCB source and from one farm located 200 km away (see Fig. 1). Each farm had at least 97 cows, mostly black-piebald, but in some cases simmental (see Table 1). The cows were kept under similar conditions in cowsheds with the exception of two farms (P-4(2) and P-4(3)), which had more modern, cleaner cowsheds. During the summer (May–September) cows in this region graze on pastures and receive small quantities of supplementary feed, while in the winter (October–May) they are mainly fed hay, corn silage, sunflower, and lucerne. In contrast to the others farms, the cows at P-4(1) did not graze during the summer but were fed freshly cut grass instead. In addition, in two cases where there were no farms in an area of interest, samples were taken from private households with several cows and pooled (a total of 5–8 cows per pool).

Cow's milk was sampled twice in 2003, during spring (April–May) and autumn (September). The time of sampling was chosen so that the milk would reflect the summer and winter feeding regimes of the cows. The milk was taken from the central milk container which contained the milk of all cows on the farm. It was collected in glass bottles, frozen, and stored at −30 °C until analysis.

Soil was sampled in the autumn of 2003 from summer pastures belonging to the sampled farms. All farms had their own summer pastures except P-4(1), P-20 and P-21. The cows from private households in P-20 and P-21 grazed freely in and outside of the villages, so the soil was collected from preferred pasturing sites. The top 5 cm layer of soil was sampled with a hand corer at five points on each pasture, wrapped in aluminum foil, and stored at −30 °C until analysis in the laboratory of the Institute of Geochemistry in Irkutsk.

2.2. Sample preparation and extraction

The milk samples (~50–200 ml) were thawed and a surrogate standard containing two PCB congeners (21.5 ng PCB 14 and 8.3 ng PCB 65) was added. The milk was freeze-dried, the residue was taken up in 200–300 ml *n*-hexane:acetone (1:1), transferred to a pre-weighed flask, the solvent was evaporated, and the lipid weight was determined gravimetrically.

The soil samples (~50–100 g) were dried at room temperature to constant weight. They were then sieved and the fraction <2 mm was extracted in a Soxhlet extractor for 12 h. Surrogate standards (21.5 ng PCB 14 and

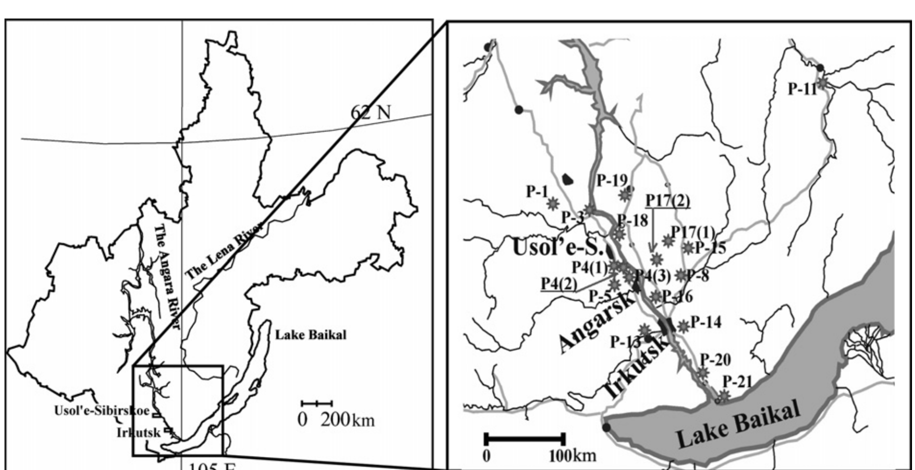

Fig. 1. Location of the sampling sites in the southern part of the Irkutsk region.