

Risk Assessment and Risk Management 1

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D32-084 From soil contamination to food safety management: physiologically based toxicokinetic modelling to predict PCDD/F transfer in beef production systems

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Introduction

Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) are persistent organic pollutants that accumulate in animal tissues and pose a risk to food safety (EFSA, 2018). In grass-based ruminant systems, soil ingestion may represent a major pathway of animal exposure to PCDD/Fs (Weber et al., 2018). However, interactions between soil and feed PCDD/F contamination, transfer to animals, and final concentrations in animal products remain insufficiently characterized. This study proposes an integrated framework combining limited on-farm measurements and physiologically based toxicokinetic (PBTk) modelling to predict PCDD/F concentrations in beef meat from a soil-contaminated environment and support risk assessment and management strategies.

Materials and Methods

A study was conducted on a suckler beef farm in the Lausanne area (Switzerland), where topsoil PCDD/F concentrations ranged from 5 to 20 ng TEQ/kg DM (Vernez et al., 2023). For PCDD/F analyses, soil, feed, and blood samples from five multiparous cows and their offspring were collected over one production cycle, as well as adipose tissue, muscle and liver at slaughter from five post-weaning fattening bulls. Hay, silage and pasture grass contamination levels were estimated from the proportion of soil inorganic impurities measured in forages and paired soil PCDD/F levels, and compared to measured forage PCDD/F concentrations. Two PBTk models were then applied to reproduce first the on-farm study, and further prospective scenarios: the RuMoPOP model for lactating cows (Lerch et al., 2025), and the BeefPOP model for growing cattle (Tiercin et al., 2026). These models describe the absorption, distribution, metabolism and excretion of lipophilic contaminants across body compartments, allowing simulation of accumulation and depuration kinetics in adipose tissues, muscles and milk. Prospective exposure scenarios ranged from background feed contamination (0.1 ng TEQ/kg DM) to regulatory feed action and maximum levels (0.57 and 0.85 ng TEQ/kg DM, respectively; Regulation EU No 277/2012), and a worst-case scenario (1.0 ng TEQ/kg DM).

Results

A linear relationship was observed between measured PCDD/F concentrations in forages and those estimated from soil inorganic impurities ($R^2 = 0.91$). The BeefPOP model closely reproduced on-farm measurements, with predictions within 1.1- and 1.4-fold of observations for adipose tissue and muscle of fattening bulls. Under constant exposure with feed contamination at the action level (0.57 ng TEQ/kg DM), PCDD/F concentrations in cow and growing cattle adipose tissues could exceed the maximum level for meat (2.5 pg TEQ/g lipids; Regulation EU No 2023/915). With soil ingestion of 1% of DM intake, a soil PCDD/F concentration above 30 ng TEQ/kg DM would lead to non-compliant meat.

Discussion and Conclusion

The strong agreement between measured and soil inorganic impurities-estimated PCDD/F concentrations in forages suggests that feed soiling is the dominant source of PCDD/F and that concomitant soil ingestion drives PCDD/F exposure in this beef production case-study. Accordingly, analysis of soil inorganic impurities in forages combined with mapping of soil PCDD/F contamination could allow estimating cattle exposure risks without systematically performing costly PCDD/F analyses. Integrating PBTk modelling further allows predictions of PCDD/F concentrations in meat and offal products. Prospective model simulations also suggest that current feed regulatory maximum and action levels may not always ensure compliance of beef meat under constant exposure conditions. Overall, PBTk models prove to be valuable tools for risk assessment and food safety management in livestock systems exposed to PCDD/Fs.

Acknowledgment

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References

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