ORGANOCHLORINE RESIDUES IN MEAT: WHAT IS THE SITUATION IN CANADA?

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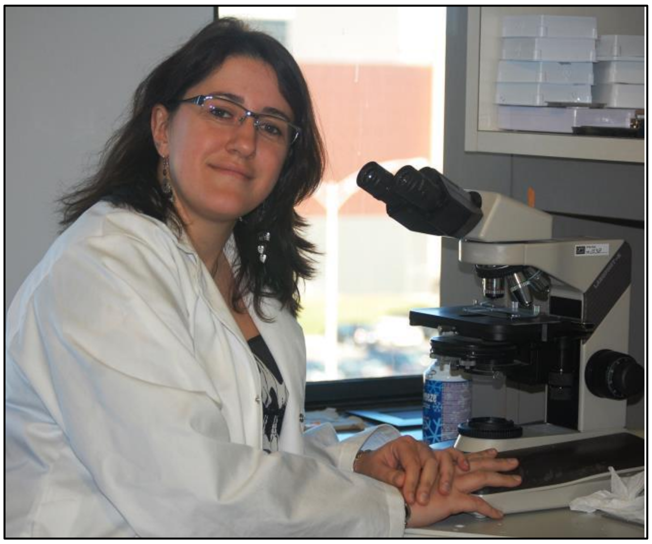

Understanding Organochlorines?
Organochlorines are a large family of organic compounds composed of carbon and hydrogen containing at least one chlorine atom through covalent bonding. Several notorious chemical groups fall into this family, notably industrial by-products, including polychlorinated biphenyls (PCBs), furans and dioxins, and insecticides such as dichlorodiphenyltrichloroethane (DDT). The "dirty dozen" most hazardous persistent organic pollutants (POPs) targeted by the Stockholm Convention are organochlorines. Many organochlorines are thereby considered to be "Legacy Contaminants" because their use has been banned or severely restricted by government agencies for many years. In North America, organochlorines were used or produced in significant quantities mostly between the 1940s and 1980s, after which they were largely restricted. Despite a long-time ban in North America, DDT remains a very popular insecticide to control malaria-carrying mosquitos in many tropical countries due to its efficacy and affordability (Rehwagen, 2006).
The physical and chemical properties of organochlorines, allow them to break down very slowly in air, water and soil. They are thus subject to long trans-boundary air pollution transport, where they carried over long distances via the atmospheric transport and by incineration of municipal and industrial wastes (Alcock, 2003). The exchanges from the atmosphere to the ocean are important for these compounds that are volatile or semi-volatile organic substances with low vapour pressure like PCB's. They are released into the atmosphere in the vapour phase and could be transported on long distances as gases, aerosols or adsorbed to particles. By a condensation phase, organchlorines fall to the ground or in the ocean as a rain (Duce et al, 1983). For this reason, substantial quantities of organochlorines produced over the last century have been transported to the Arctic, where the food chain is now persistently contaminated, affecting especially Inuit populations. Organochlorines are dangerous because they are stable and toxic but also liposoluble, bioaccumulate in fatty tissues and, consequently, biomagnify (Borga *et al.*, 2001). For example, in the environment, it takes 75 to 105 years to completely eliminate *p,p'*DDT. Moreover, this insecticide can remain in the body of mammals for 50 years, sequestering into adipose tissue, from which it partitions to the bloodstream into plasma. It can circulate into the whole body and affect all organs. During pregnancy, organochlorines can cross the placenta, a fatty organ, to expose the foetus (Shen *et al.*, 2007). Also in mothers, organochlorine compounds pass into the serum lipids, to breast milk and contaminate children during their early lactation. Exposure to these persistent chemicals has been associated with health effects including cancer (Recio-Vega *et al.*, 2011), male reproductive defects (Anas *et al.*, 2005; Skakkebaek *et al.*, 2001), behavioural changes (Zala and Penn, 2004) and respiratory tract diseases (Kovesi *et al.*, 2011; Gascon *et al.*, 2012). These effects are related to the ability of organochlorines to disrupt the functions of certain hormones, enzymes, growth factors, and neurotransmitters (Gourounti *et al.*, 2008). For all these reasons, governmental agencies like Health Canada, have elaborated a tolerable daily intake levels to prevent any toxic effects from different organochlorine contaminants (Table). Environmental exposure tends to be to a mixture of organochlorine congeners of the same group, from different groups, or with others chemicals, not to one simple chemical. Ironically, most research has focused on the impact of only one or two compounds. Therefore, the available data on health effects of organochlorine exposure cannot be readily interpreted with respect of environmental relevance. Similarly, most regulatory guidelines are for one contaminant, as opposed to for an environmental mixture. Furthermore, although many organochlorines are not lethal at low exposures, they are responsible for significant health problems in human and wild animals (Feron and Groten, 2002).

Table 1: A tolerable daily intake (ADI) for some organochlorine adopted by Health Canada (Health, 2007) and EPA (U.S. EPA, 2000)

Products	Recommendation levels by Health Canada (µg/kg of body weight/day)	Recommendation levels by EPA (µg/kg of body weight/day)
Aldrin and Dieldrin	0.1	0.05
Chlordane + related isomer/metabolites	0.05	0.5
Dichlorodiphenyltrichloroethane (DDT)	10	0.5
Hexachlorobenzene (HCB)	0.27	0.8
Lindane	0.5	0.3
Mirex	0.07	0.2
Toxaphene	0.2	0.25
Polychlorinated Biphenyls (PCBs)	0.5 but it is under review	0.025

The Arctic and other ecosystems in Canada are contaminated with organochlorines through pollution. For farmed fish, exposure starts with the fish food. The high level of lipids in fish food for farmed salmon, generally comes from concentrated marine fish oil. Presently, the aquaculture industry is trying to reduce contaminant levels by replacing fish oil with polyunsaturated fatty acid-rich plant oils (soy and canola) and other animal products (e.g. poultry fat) (Kelly *et al.*, 2011). A big factor of contamination is rainfall (organochlorines in liquid phase) from the Arctic or via countries that still use organochlorines, contaminate lakes, rivers and, unfortunately, Canadian farms. Kuo *et al.*, 2012 reported that farms (soil, water and crops) can be more contaminate by organochlorines, especially by endosulfan, a pesticide still use in Canada at low doses (CCME, 2010) as a function of the rain and irrigation. The problem is always the same, bioaccumulation in fat tissues and interaction with other organochlorine compounds or contaminants are never considered together to determine "safe" levels.

Meanwhile, it is recommended that consumers of meat and fish select lean meats and cook with processes that favor to release of contaminated fats, thereby minimizing the concentrations of organochlorines (Domingo, 2011).

Organochlorine contamination in fish

It is not surprising that a fatty fish like salmon tends to be contaminated by organochlorines. In 2004, a controversial report by Hites *et al.* stated that PCBs, dioxin, toxaphene and dieldrin are present in higher quantities in farmed salmon than in wild salmon and this salmon is more contaminated in Europe than in North America. However, these levels stay under the EPA tolerance level (Hites *et al.*, 2004). In addition, many authors have published letters against these data because the consumption of fish, especially omega-3, should not be stopped. The benefice of eating fish for the health people mainly people with heart deceases like coronary artery decease is really important (Rembold 2004; Tuomisto *et al.*, 2004; Weaver 2004). Others have shown organochlorine pesticides like DDTs (DDT and its residues), chlordanes and mirex to be found in flesh of farmed and wild salmon from British Columbia in Canada (Kelly *et al.*, 2011). PCBs and theirs metabolites were discovered in wild fish (brown bullhead) in the Wheathley Harbour area in Ontario (Gilroy *et al.*, 2012) showing that the Canadian environment could be a problem with wild but also farmed animals. In these data, the levels of fish contamination, wild and farm, are under the Health Canada tolerate daily intake concentration (Health 2007), so the health risk does not seem as strong as what those authors meant. Most aquaculture productions now take organochlorine contamination very seriously and are attentive to the levels in their fish food and also encourage water circulation to discourage accumulation. As well, eating fish is well-known to benefit human health. Its rich content of omega-3 fatty acids and proteins are beneficial for brain development and protective against cardiovascular diseases, mental disorders and inflammatory conditions. In theory, organochlorine contamination could counterbalance the beneficial effects of fish consumption (Hamilton *et al.*, 2005), although in 2007, Dewailly *et al.*, showed that the contaminants in salmon, especially salmon from Chilean farms sold in Quebec, can be consumed regularly to achieve optimal nutritional benefits from omega-3 fatty acids, without incurring significant organochlorine-related health risks. Nonetheless, one could argue that the detection of low organochlorine levels (below regulatory levels) in consumed fish cannot predict the negative effect on mammal physiology. For example, the combined effects of organochlorine and other contaminants, such as heavy metals due to chronic consumption are poorly established.

Organochlorine contamination in meat

The contaminant problem in the fish industry appears to be the most studied, perhaps due to the longstanding conflict between fish producers and the anti-aquaculture lobby, which is well-established in Canada. However, it is also known that different pesticide residues (some being organochlorines) can be detected on vegetables and fruits (Health Canada, 1997). In 1998, Newsome *et al.* compared the level of PCBs in meats in six Canadian cities including Ottawa, Montréal, Vancouver and Toronto. The level of PCBs were higher in fish, but it was important to note that the level of PCBs in ground beef and pork (fresh and cured) was close or superior to 2000 pg/g wet wt in Toronto, Halifax and Ottawa. The level of PCBs was generally high in organ and cold cuts (Newsome *et al.*, 1998). In another study from the same authors, high levels of a DDT metabolite, dichlorodiphenyldichloroethylene (DDE; 7 ng/g of food) were present in meat-based infant food (Newsome *et al.*, 2000). Like with fish contamination, the levels in meat are lower than the government recommendations. Meat could be considered not toxic for the consumption for each organochlorine. As mentioned previously, organochlorine contamination accumulates throughout life, starting with placental exposure during pregnancy, through breast milk, in such baby foods, then with adult dietary exposures.

The levels of organochlorines in meat did not significantly change from 1986 to 1998 (Newsome *et al.*, 1998). More recent research from Mexico (Pardio *et al.*, 2012) has shown that none of the estimated dietary intakes exceeded its corresponding U.S. EPA (2000) reference doses.

Schecter *et al.* (2010) explained that the levels in meat are not high *per se*, but are problematic given the very high meat consumption by Americans, and can approach 100 ng/day (majority being PCBs and DDT). Therefore, the level of meat consumption per day is an important parameter determining human exposure to organochlorine. However, in reality, it is very rare for individual to be exposed to only one chemical at a time. Meat contained multiple pollutants. Toxicity of mixture of organochlorines and others contaminants is frequently uncharacterized. Toxic interactions between them are still unknown.

Conclusions

Because organochlorine contamination is environmental, it cannot really be eliminated. However, with the increase of diseases that are correlated with exposure to organochlorines, the public should be aware of which foods increase our exposures, and fish appear to be a principal source. Unfortunately there are a limited number of studies linking the contaminant-associated risks to meat consumption by Canadians today so proper assessment to the health impact of a regular exposure to even low levels of different organochlorines consumed over a person's lifetime cannot be established at this time. In addition, toxicity of mixtures must be study. In fact, interactions can occur independently as an additive process, through agonism or antagonism, or through synergy, where the combined effect is greater than the sum of the individuals (Stewart and Carter 2009).

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