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Significance of toxaphene in Great Lakes fish consumption advisories

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ABSTRACT

Fish consumption advisories have been issued for the Great Lakes generally based on the most restrictive contaminant. For the Canadian waters of the Great Lakes, toxaphene causes minor restrictions only in Lake Superior, i.e., 3% of the total (restrictive + unrestrictive) advisories issued. However, the significance of the hazard posed by toxaphene in fish is not clear since more restrictive advisories due to other priority contaminants may be masking the less restrictive advisories. We simulated fish consumption advisories for the Toxaphene-only scenario by neglecting the presence of contaminants other than toxaphene, and compared with the issued advisories as well as with the published simulated Mercury-only scenario. Restrictive advisories under the Toxaphene-only scenario compared to the issued toxaphene related advisories would increase from 3% to 14%, <1% to 4%, and 0% to 2% for Lakes Superior, Huron and Ontario, respectively, and remain at 0% for Lake Erie. For Lake Superior, most of the restrictive Toxaphene-only advisories would be for fatty fish. Overall, the Toxaphene-only advisories would be significantly less restrictive compared to the issued advisories, and also generally less restrictive compared to the Mercury-only scenario. These results suggest that toxaphene is less of a concern than PCBs (including dioxin-like PCBs), dioxins–furans and mercury from the perspective of health risk to humans consuming Great Lakes fish; elevated toxaphene is mainly a concern for human consumers of Lake Superior fatty fish. Our results suggest that the routine monitoring of toxaphene in other Canadian waters of the Great Lakes and Lake Superior lean/pan fish could be discontinued.
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Introduction

Toxaphene was used as an insecticide in the southern and midwest U.S. agricultural areas (Muir et al., 2006; Murphy et al., 2012). Toxaphene use began in the late 1940s, peaked in the early 1970s, and was banned in Canada and the United States in the mid-1980s (Muir et al., 2006; Murphy et al., 2012). Long-range atmospheric transport of toxaphene applied in these areas resulted in the detection of toxaphene in various matrices including fish of the Great Lakes (Muir et al., 2006; Murphy et al., 2012). Toxaphene is a probable human carcinogen, and can damage the immune system, liver and kidneys (ATSDR, 2010). The major route for human exposure to toxaphene is through fish consumption (ATSDR, 2010).

For most Canadian waters of the Great Lakes, fish consumption advisories are issued by the Province of Ontario based on benchmarks developed using Health Canada's health protection guidelines, which are applied to a series of priority contaminants measured in individual fish species, fish size classes and water bodies. For a given sample set of fish species, size classes and water body, the contaminant which produces the most restrictive advice (i.e., lowest number of recommended meals per month) is used and identified as the contributing contaminant in the Guide to Eating Ontario Sport Fish (OMOE, 2009). For the Canadian waters of the Great Lakes, PCBs and dioxins/furans currently generate most (84–99%) of the restrictive advisories. In contrast, toxaphene contributes 8% to restrictive advisories for Lake Superior fish only and is not listed as a contributor to the restrictive advisories for Lakes Huron, Erie or Ontario fish (OMOE, 2009). However, if PCBs and dioxins–furans decreased below their fish consumption advisory benchmarks, it is not clear whether current fish toxaphene levels would replace some, most or all current PCB- and dioxin-driven fish consumption restrictions with similar or less restrictive advice. This research question is supported by the fact that the contribution of toxaphene to restrictive fish consumption advisories for the Canadian waters of the Great Lakes dropped significantly between 2003 and 2005: from 71% to 6% in Superior, 10% to <1% in Huron, and 2% to 0% in Ontario (Environmental Defence, 2009; OMOE, 2003, 2005). This drop was largely due to adoption of more stringent fish consumption benchmarks for PCBs and dioxins/furans (OMOE, 2003, 2005).

The reduction in the contribution of toxaphene to restrictive fish consumption advisories gives a false impression that the toxaphene levels significantly declined below its benchmark levels for fish consumption advisories. A recent study has reported declines in the fish toxaphene levels between the mid-1990s and 2010 (Xia et al., 2012).

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However, it is currently unclear how these declines would be reflected in risk to human fish consumers.

The goal of this study was to examine the significance of current toxaphene levels in fish consumption advisories for the Canadian waters of the Great Lakes. Fish consumption advisories were simulated for a Toxaphene-only scenario by neglecting the presence of contaminants other than toxaphene. This approach isolated the true impact of toxaphene levels in fish on consumption advisories because advisory information under the Toxaphene-only scenario would not be superseded by more restrictive advice information generated by other contaminants present within fish samples. These simulated Toxaphene-only advisories were then compared with the corresponding published fish consumption advisories, which are issued by the government authority based on the most restrictive contaminant out of all contaminants measured. In general, published restrictive advisories for the Great Lakes are largely due to elevated levels of PCBs (including dioxin-like PCBs) and dioxins/furans. The Toxaphene-only advisories were then compared with the previously published advisories for the Mercury-only scenario (Bhavsar et al., 2011) in which the presence of all contaminants except mercury was neglected.

Methods

Dataset

The Great Lakes are shared by the U.S. and Canada. For the Canadian waters of the Great Lakes, fish consumption advisories have been consistent because for the most part only one government agency, Ontario Ministry of the Environment (OMOE), is responsible for collecting comprehensive contaminant monitoring data for edible portion of fish and then issuing consumption advisories. On the U.S. side, eight state agencies along with tribal agencies have monitored contaminants in edible portion of fish and issued advisories. For this study we used the data collected by OMOE considering consistency of monitoring data and the fish consumption advisory benchmarks used.

The OMOE, in partnership with Ontario Ministry of Natural Resources, monitors contaminants in sport fish collected from the Canadian waters of Lakes Superior, Huron (including North Channel and Georgian Bay), Erie and Ontario (OMOE, 2013). The samples are analyzed for a variety of contaminants including toxaphene, mercury, polychlorinated biphenyls or PCBs, dioxins/furans, and other organochlorine pesticides as well as contaminants of emerging concern such as polybrominated diphenyls (PBDEs) and perfluorinated alkyl substances (PFASs) (OMOE, 2013). The monitoring results are used to advise the public on safe consumption of sport fish.

Advisory calculations

The Great Lakes cover a wide geographical area (244,100 km^2) and contaminant levels in fish can vary from one location to another. To capture spatial variability, the Canadian waters of the Great Lakes have been divided by OMOE into 60 smaller areas (called blocks) for consumption advisory purposes (Fig. 1). The OMOE fish consumption advisory benchmarks are generally based on the tolerable daily intake (TDI) values developed by the Food Directorate of Health Canada. Separate benchmarks are used for the general population (GP) and the sensitive population (SP) of children and women of child-bearing age. The benchmarks used for the 2009–2010 edition of the Guide to Eating Ontario Sport Fish have been presented by Bhavsar et al. (2011). Toxaphene related 2009–2010 OMOE advisory benchmarks have been listed in Table 1. Due to limitations of the current state of the science on toxicity of chemical mixtures, the advisories are issued based on the most restrictive contaminant. The dioxin and dioxin-like chemicals such as furans and dioxin-like PCBs are considered as a group and assessed using a 2,3,7,8-TCDD Toxic Equivalent (TEQ) concentration concept, which allows converting concentrations of various chemicals in a group into one value that is equivalent to concentration of the most toxic chemical in the group (van den Berg et al., 2006).

It is well established that levels of major contaminants of concern for the Great Lakes generally increase with fish size and vary by fish species (Gewurtz et al., 2011a; Gewurtz et al., 2011b). To incorporate such variability in the advisory calculations, the OMOE calculates levels of each contaminant for each 5-cm length interval of every fish species with available data using power regressions of fish length versus contaminant concentration. These values are then compared with the advisory benchmarks, and population- (i.e., GP or SP), location-, species- and size-specific advisories are issued in terms of recommended meals per month (8 = unrestricted, 4, 2, 1, 0 = do not eat). Because not all fish species are found at various locations in the Great Lakes, the availability of advisories for fish species also varies (Bhavsar et al., 2011).

When historical advisories for fish lengths outside of a size range for the latest advisories exist, these older measurements are considered to expand the size range in the new advisories (Bhavsar et al., 2011). The decision to include older data/advisories depends on various factors including the size range in question (larger or smaller fish size), how the older advisories compare with the new advisories, as well as the general temporal trends of the contaminant that are causing the restrictive advisories. An example of the advisory tables listed in the 2009–2010 Guide to Eating Ontario Sport Fish (Guide) has been included in the Electronic Supplementary Information (SI) Table S1.

Toxaphene-only advisories

For the Toxaphene-only advisory scenario, we neglected the presence of all other chemicals in the Great Lakes fish. The advisories were calculated using the same OMOE approach as described above. In addition to the fish species for which OMOE issues fish consumption advisories (OMOE, 2013), we also considered alewife, American eel, humper (banker) lake trout, lake chub, mooneye, shorthead redhorse, and other species of the sucker family to better understand the toxaphene significance even though the OMOE no longer issue advisories for these species mainly because of their low populations or it is illegal to keep them.

Using 21,800 fish toxaphene measurements for the main basins of the Great Lakes, 4716 advisories were simulated for 446 species–location combinations at each 5 cm fish length interval. For statistical comparison purpose, each advisory was classified into one of the three categories: (1) no restriction (i.e., “unrestricted” = 8 meals/month), (2) partial restriction (1, 2 and 4 meals/month), and (3) complete restriction (0 meal/month or “do not eat”). The total restrictions are the sum of the partial and complete restrictions. The statistics are then presented as a percentage of simulated advisories in the abovementioned three categories on a lake-wide basis for all species combined as well as individual species, and block-specific basis for all species combined. The advisories statistics for the Toxaphene-only scenario are also compared with the published advisories (OMOE, 2009) as well as the Mercury-only scenario presented by Bhavsar et al. (2011). Because currently there are no restrictions for consuming fish from the connecting rivers of the Great Lakes due to elevated toxaphene levels as advised by OMOE, measurements collected from these locations were analyzed separately. Toxaphene measurements for 2480 fish samples collected recently (2000–2012; SI Table S2) were assessed against the OMOE fish consumption advisory benchmarks to investigate potential risk to human consumers of these fish.

Results

Basin-wide advisories

The Toxaphene-only advisories were substantially less restrictive compared to the overall published 2009–2010 advisories (Figs. 2 and 3). A comparison of percentage of the simulated advisories that

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