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Benefits and risks associated with consumption of Great Lakes fish containing omega-3 fatty acids and polychlorinated biphenyls (PCBs)

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Introduction

Assessment of environmental health effects arising from exposure to multiple substances is often very challenging. This is particularly true when humans are exposed to a mixture that contains both beneficial and harmful substances. A good example relates to the risk and benefits of fish consumption. Fish contain a variety of essential nutrients, such as omega-3 fatty acids and proteins, which are beneficial to human health. Fish may also contain trace amounts of environmental contaminants, such as polychlorinated biphenyls (PCBs), which can disrupt endocrine function. How would environmental health studies confront the challenges of assessing the adverse and beneficial effects from food consumption? A recent study (Haslam et al., 2015) published in the *Journal of Environmental Sciences* demonstrates an example of an approach based on environmental epidemiology to tackle this complex problem. Focusing on a group of sport fishermen in New York, Haslam et al. (2015) examined the effects of estimated consumption of omega-3 fatty acids and PCBs on the risk of thyroid cancer over a 17-year span from 1991 to 2008. The study concluded that consumption of Great Lakes fish, with the concomitant PCBs, did not increase the risk of thyroid cancer in New York fishermen. The study results also suggest that long-term consumption of omega-3 fatty acids may protect against the development of thyroid cancer.

1. Sources and occurrence of PCBs

PCBs are a group of organic compounds consisting of 209 possible congeners. These congeners vary by the number and position of chlorine atoms on the biphenyl rings (Fig. 1). For their stability and low flammability, PCBs were used widely in many industrial processes, such as the manufacturing of electrical equipment, heat exchanges, and hydraulic systems (Erickson and Kaley, 2011). Because of a variety of industrial incidents and food contamination events, the production and use of PCBs were banned by the United States in 1979 and by the Stockholm Convention on Persistent Organic Pollutants in 2001 (Porta and Zumeta, 2002).

Because of their stability, slow biotransformation, and significant bioaccumulation in lipids, PCBs persist in the environment for long periods of time (Li et al., 2009; Xu et al., 2013; Wang et al., 2012; Malisch and Kotz, 2014). The persistence and bioaccumulation of PCBs in organisms results in their biomagnification along the food chain, with increasing concentrations of PCBs in the organisms as the trophic level increases.

The Great Lakes are in close proximity to many industrial plants and factories where PCBs were heavily used in the past.

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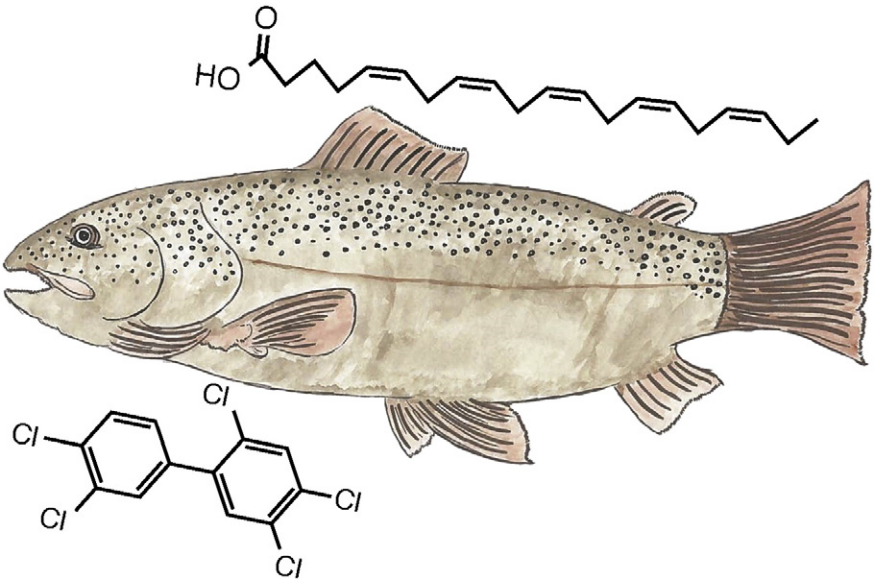

Fig. 1 – Fish from Great Lakes contain both beneficial omega-3 fatty acids (structure above the picture of the fish) and potentially harmful polychlorinated biphenyls (structure below the picture of the fish). The picture of the fish was drawn by Ms. Yi Li, University of Alberta.

The PCB contamination of the Great Lakes has resulted in higher concentrations found in water, sediment, and aquatic life. Though PCBs have been banned in the United States for more than 35 years and their concentrations in the Great Lakes have declined steadily, their concentrations are still above wildlife protection values of 0.16 ppm (US EPA, 2012). Bioaccumulation of PCBs in fish is of particular concern, as fish is a common food for many who live in the area. PCBs have also been detected far away from manufacturing and production, such as regions north of the Arctic Circle and in the Tibetan Plateau (Tian et al., 2014), indicating their ability for long-range transport. New sources of PCBs that are of concern also originate from electronic waste processing (Li et al., 2015).

2. Toxicity of PCBs

The toxicity of PCBs varies considerably among congeners: coplanar PCBs tend to have dioxin-like properties and generally are the most toxic (Hutzinger et al., 1974). The common toxic effects of PCBs include hormonal interference, reproductive disorders, neurological disorders, and cancer (Louis et al., 2005; Meeker and Hauser, 2010; Schantz et al., 2003; Wolff et al., 1993; Høyer et al., 1998). In 2013, the International Agency for Research on Cancer classified PCBs as human carcinogens (IARC, 2015).

The carcinogenicity of PCBs has been studied in animal models, in which high concentrations of PCBs were found to induce tumors in the liver, lung, and oral mucosa in rats (Strauss and Heiger-Bernays, 2012). An epidemiological study by Pavuk et al. (2004) found a higher incidence of thyroid cancer in women living in a site with contamination from previous PCB production. PCBs act as endocrine disrupters, which is of particular concern because of their ability to promote development of thyroid cancer (Boas et al., 2012; Fein et al., 1984). Additionally, Zani et al. (2013) have shown an association between elevated blood levels of PCBs and non-Hodgkin lymphoma. However, studies on health outcomes of human exposure to PCBs are not all consistent. For example, epidemiological studies of people in Kyushu, Japan and Yu-Cheng, Taiwan who were exposed to high doses of PCBs through contaminated rice oil did not show significant adverse health effects (Tsai et al., 2007; Li et al., 2012; Onozuka et al., 2009; Yoshimura, 2012). Although there was increased PCB consumption in these populations, the data showed no definite increase in total cancer mortality and no association with any specific cancers.

3. Benefits of Omega-3 fatty acids

Fish consumption is beneficial as fish contain essential nutrients, such as iodine, selenium, vitamins, and proteins (Larsen et al., 2011). Additionally, fish contain high levels of omega-3 fatty acids that cannot be synthesized by the human body but are essential for normal metabolism. Omega-3 fatty acids have been shown to protect against inflammatory conditions and even cancer, because of their antioxidant activity (Tavani et al., 2003). Antioxidants act as scavenging molecules, removing free radicals that are formed in the body during many cellular processes. Otherwise, elevated levels of free radicals can damage major cell components, such as DNA, proteins, and cell membranes. Damage caused by these free radicals, specifically to DNA, plays a role in the development of cancer (Diplock et al., 1998; Valko et al.,