Journal of Indigenous Research

Full Circle: Returning Native Research to the People

Volume 10 | Issue 2022 Article 1

April 2022

Review of Environmental Contamination at Akwesasne and Associated Health Outcomes

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American Indian (AI) and Alaska Native (AN) peoples account for less than 2.0% of the population of the United States (US) (Norris et al., 2012), however, they are disproportionally affected by various health issues. One such indigenous community is the Mohawk Nation at Akwesasne. The Mohawk Nation is comprised of approximately 12,000 persons from 2,089 families (Fitzgerald et al., 1996). This small community has historically been exposed to numerous environmental contaminants which has changed their community and health.

The Akwesasne reservation is a 28,000-acre reservation spanning the St. Lawrence River in upstate New York and in the Canadian provinces of Quebec and Ontario. It is located at the confluence of four rivers—St. Regis, Raquette, Grasse, and the St. Lawrence River. Prior to the late 1990s and early 2000s, the community relied heavily on the abundance of local fish from the nearby water bodies, wildlife such as wild birds, and on nutrient rich alluvial soil for farming (Hoover, 2013).

History of environmental contamination

In the 19th and 20th centuries, industrialization began encroaching on the lands near the reservation. Aluminum Company of America began operation in Massena in 1908. Construction of the Robert Moses Dam made electricity easily affordable allowing for easy access to intense heat, essential to aluminum work, making the area ideal for aluminum foundries. In 1945, the St. Lawrence Seaway project began to create canals and lock for vessels heading towards the Atlantic Ocean. By 1959, General Motors (GM), and Reynolds Metals established foundries along the St. Lawrence (Hoover, 2013). These foundries used polychlorinated biphenyls (PCBs) as hydraulic fluids, which leaked and were washing down the drain into the rivers or illegally dumped on their property.

Environmental PCB contamination

The limited operations of these industrial facilities had a lasting impact on the local environment which in turn affected the community as well. In the late 1950s, fluoride contamination from the foundries devastated the agricultural practices of the Akwesasne Indian Reservation, severely affecting the cows, turtles, bees, and vegetation (Krook & Maylin, 1979). The Mount Sinai School of Medicine Health Study revealed that traces of PCBs were found in biospecimen collected from residents of the reservation (Hoover, 2017). Although this was informative, the community felt that the research did not benefit the community. Thus, leading to a research partnership between the Akwesasne Mohawk Nation and scientists at the New York State Department of Health and the University at Albany, initiated to address community and scientific concerns regarding environmental contamination and its health consequences.

In the 1990s, snapping turtle eggs collected near the Great Lakes had high concentrations of PCBs and several persistent organochlorine pesticides (Pagano et al., 1999). In 1978 the Mohawk Council of Akwesasne sampled local fish and found PCBs, mercury, and Mirex. The 4,270 acres of GM land in the area was subsequently declared as a superfund site and remediation plans began to be discussed. In the early 1990s, several risk assessments by epidemiologists found toxic environmental contaminates in fish (Sloan & Jock, 1990), wildlife (Skinner, 1992) and breast milk (Fitzgerald et al., 1992). Further investigation showed that there was a significant relation between consumption of local fish and breast milk levels (Fitzgerald et al., 1992). The relation went away after the consumption advisories had been in place a while.

While pesticides were detected in the serum collected from the residents of Akwesasne they were not significantly higher than the levels measured among the general US population (Schell et al., 2008). Prior to remediation, soil levels of PCBs ranged from 1 ppm to 380 ppm and

after remediation maximum soil level of PCBs was 0.886 ppm (Carpenter et al., 2002). Analysis of PCBs in the local fish showed that bottom feeders like bullheads were heavily contaminated. Mean tap water concentrations of PCBs were 16 ppt. Most vegetables had undetectable levels of PCBs, posing a low health risk. Lightly chlorinated congeners are more volatile but higher chlorinated also volatilize to some degree. The highest levels of PCBs in the air were measured in May, consistent with warmer temperatures and drying of contaminated sediment deposited by the spring floods (Chiarenzelli et al., 1996). The highest measured concentration of PCBs among Akwesasne residents was 31.7 ppb, which is very high relative to the average background PCB levels in the US population at that point in time, which was about 0.9 to 1.5 ppb (ATSDR, 2000).

PCB exposure and growth and development

Biomonitoring studies assessed exposure to PCBs, pesticides, and other environmental toxicants among Akwesasne adolescents and young adults (Gallo et al., 2011; Gallo & Schell, 2005, 2007). Initial anthropometric measurements of Akwesasne Mohawk youth show that they have thicker skinfolds and larger circumferences than youth in the national surveys putting them at a greater risk or chronic, obesity-related diseases (Gallo & Schell, 2007). An epidemiological study of adolescents found that levels of PCBs were highest in individuals who were breastfed as infants, were first born, or had consumed local fish within the past year (Gallo et al., 2011). Additionally, this shows that fish consumption and breast milk are routes of exposure by which a mother reduces her body burden of PCBs by having and breast feeding a child. Significant predictors of exposure to environmental toxicants include sex, body mass index, and being born before or after the fish advisory. Males had a higher body mass index, significantly higher intake of calories, protein, dietary cholesterol, and more alcohol consumption per month than females.

PCB exposure and neurobehavioral outcomes

Several investigations examined the relationships between exposure to PCBs and neurocognitive development, behavior, and other aspects of cognitive function among adolescents and adults in the Akwesasne community. An epidemiological study sought to determine if there was any relationship between current body burden of environmental contaminants among adolescents in Akwesasne and cognitive functioning (Newman et al., 2006). Their most notable results include finding significant negative relationship between PCB levels and decrements in performance on four different cognitive tests, two of which measured of long-term memory. There was also a negative relationship with a measure of comprehension and knowledge.

One study examined the relationship between current body burden of persistent PCBs and attention and impulsivity (Behforooz et al., 2017). The study found a significant positive relationship between PCB levels and omission scores, but only for males. Another study investigated the relationship between the levels of persistent serum PCBs and concurrent measures of their Attention Deficit Disorder (ADHD) -like behavior derived from ratings provided by parents and teachers (Newman et al., 2014). However, the study did not find any association between PCB levels and ADHD-like behavior even after adjusting for socio-economic status and breastfeeding history.

The relationship between PCBs and neuropsychological functioning has been examined through an extensive series of neuropsychological evaluations (Haase et al., 2009). The study a clear reduction in cognitive functioning which was significantly associated with PCB exposure. They observed a clear evidence of a threshold of the effect of PCBs on the variables measured. Only the 37-79-year-old group showed an effect to PCBs whereas the younger adults showed no linear or threshold effect. Furthermore, the investigators observed a significant increment at a

threshold of 2 ppb among the older group of participants. This is important because 2 ppb is near the average background concentrations, indicating that even among the general population exposed to PCBs, we may be able to measure adverse neuropsychological functioning (ATSDR, 2000).

Exposure to environmental toxicants and thyroid functioning

One analysis examined whether levels of PCBs, pesticides, lead, and mercury reflecting past chronic exposure are associated with alterations in levels of thyroid-stimulating hormone (TSH), and thyroid hormones among adolescents (Schell et al., 2008). The study did find that exposure to persistent PCBs was positively associated with TSH but inversely related to free thyroxine (FT_4). Significant associations were also found with exposure to pesticides and these associations were further complicated by history of breastfeeding. These findings suggest that pre-natal exposure to PCBs alters thyroid function in a long-lasting manner, but this does not exclude the possibility that postnatal exposure is also influential.

Exposure to environmental toxicants and reproductive health

Several studies examined the relationships of measured persistent organic pollutants (POPs) and heavy metals to outcomes directly related to thyroid function and sexual maturation (Schell & Gallo, 2010). Participants were first recruited during puberty, around adolescence, and followed-up with as adults. PCB levels were positively related to TSH and negatively to FT_4, indicating hypothyroidism. Earlier age at menarche was associated with higher PCB levels while risk of delay was associated with higher lead levels, reflecting the estrogenic activity of PCBs. Another study found that the testosterone levels among males were significantly and inversely

related to concentrations of certain PCBs and total PCB concentrations (Goncharov et al., 2009; Schell et al., 2014)

Studies examined associations between exposure to PCBs and the ovulatory status and the follicle stimulating hormone: luteinizing hormone ratio of reproductive aged women (Gallo et al., 2016, 2018). Both studies suggest that persistent exposure to airborne, volatile, non-persistent PCBs, may adversely affect menstrual cycles and thus have the capacity to impair reproductive function.

There was some evidence that the timing of exposure produces different effects and the measured level of exposure in the participants, suggesting that exposure during windows of vulnerability require further investigation (Gallo et al., 2018).

Exposure to environmental toxicants and chronic diseases

An epidemiological investigation assessed the relationship between exposure to different POPs and metabolic disorders and determine whether all components of the metabolic syndrome show similar associations with the individual POPs (Aminov & Carpenter, 2020; Goncharov et al., 2008). Diabetes and hypertension were strongly associated with exposure to lower chlorinated and mono-ortho PCBs, but not other PCB groups or pesticides. Obesity was associated with highly chlorinated PCBs and negatively associated with Mirex. High serum lipids were strongly positively associated with higher chlorinated PCBs and PCBs with multiple ortho-substituted chlorines, as well as total pesticides. These findings suggest that while exposure to POPs is associated with increased risk of most of the diseases comprising the metabolic syndrome, the specific contaminants associated with risk of the various components of diseases are not the same.

Several investigations sought to determine which POPs were most associated with the prevalence of diabetes(Aminov et al., 2016; Codru et al., 2007) . A cross-sectional study investigated the potential association between diabetes and serum levels of PCBs and other toxicants among the Mohawk population (Codru et al., 2007). They found that the odds ratio of having diabetes for participants in the highest tertile of total PCB concentration compared with the lowest tertile was 3.9 (95% confidence interval, 1.5–10.6).A later study found that total PCBs and pesticide concentrations were each significantly positively associated with the prevalence of diabetes, however, the associations with diabetes after adjustment for other POPs were strongest with the more volatile, non-dioxin-like, low-chlorinated PCB congeners and hexachlorobenzene. This suggests that low-chlorinated congeners which are more volatile and may result from inhalation of vapor-phase PCBs is an important route of exposure and requires further investigation.

Remediation

The remediation process took over a decade. It began with measuring pollutant levels in the environment prior to remediation to assess the extent of environmental contamination (Chiarenzelli et al., 1996). By 1995, the St. Lawrence River was dredged and capped in areas where cleanup did not meet the standards (Hoover, 2013). Aerobic bacteria can metabolize PCBs, which can reduce overall mass, and sorption onto organic particles can decrease bioavailability, but this is quite limited (Renner et al., 2001). Anaerobic bacteria can partially de-chlorination to reduce toxicity. While de-chlorination does not ever destroy the PCB molecule, it just reduces the number of chlorines (Chiarenzelli et al., 1996). However, both of these processes are not significant enough or fast enough to clean up the river.

Between the years of 2000 to 2004, GM remediated the inactive lagoons at the facility, excavated contaminated sludge and soils, stabilized them, and shipped all of the contaminated solid material to an offsite facility. In 2009, the GM plant was shut down, the site was bulldozed, and the remains were shipped away from the area. The entire cleanup and remediation were deemed completed by 2016 by the Environmental Protection Agency, with the filling lagoons, sludge pits, and other restoration activities. However, the site is still releasing a significant amount of pollutants into the environment as pollutants volatilize into the atmosphere. The highest concentrations of ambient PCBs were measured along the St. Lawrence–Franklin County border, east from the GM site (Hermanson, unpublished). The range of PCBs measured in Akwesasne air is higher than levels measured at Anniston, Alabama indicating more extreme source affecting air and soil in the area, and therefore, the surrounding vegetation, measured using tree bark (Hermanson & Johnson, 2007). Additionally, there is evidence of an unidentified, perhaps airborne, exposure pathway which warrants further attention as it accounted for 50% of total variance within adolescents' serum PCB levels (Ravenscroft & Schell, 2018).

Conclusions

The unique university and community partnership between the University at Albany and Mohawk people of Akwesasne has yielded significant data on health outcomes associated with exposure to several environmental chemical pollutants. Data from the Indian Health Services of the St. Regis Mohawk found that hypothyroidism and diabetes showed higher age-specific prevalence than the general US population (Negoita et al., 2001). Incidence and prevalence trends of diabetes type II and osteoarthritis were stationary, but those for asthma and hypothyroidism showed increases over the study period. These trends along with the findings of numerous epidemiological studies suggest that lifestyle, behavioral, and environmental factors

may be playing a unique and complex role in this community. When this collaborative study began, the assumption was that higher chlorinated, dioxin like PCB congeners were the most harmful for health and exposure was primarily occurring through diet. However, the findings of subsequent investigations suggest that there is significant exposure to lower chlorinated, more volatile PCB congeners and this may be occurring via inhalation of airborne PCBs. Future studies should examine to what extent lower chlorinated and more volatile PCBs are affecting the health of the Akwesasne Mohawk population and what role these PCBs play in the development of diseases.

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