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Toxins in Lake Erie

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Background

For many centuries, Lake Erie has been important to the inhabitants that surrounded the fresh body of water. Known to Native Americans as the "Sweetwater Seas"[1], Lake Erie was the habitat for prized fish like the blue walleye, northern pike, and the smallmouth bass. The lake was a source of food, water, and transportation for the Native Americans. By the turn of the 18th century, cities blossomed along its basin. Lake Erie witnessed an explosion in European settlement following the American Revolutionary war, the War of 1812, the building of the Erie Canal, and most importantly the Industrial Revolution (1760-1850).[2] For example, as the number of steel, textile, coal, and oil industries increased, the availability of jobs attracted people to move people to move to the cities along the basin in the 20th century. According to the United State's 1900 and 1960 census, the population in Cleveland increased from 381,768 people in 1900 to a whopping 876,050 just 60 years later.[3] With both sides of Lake Erie being an eye-catching location for industries, agriculture, and settlement, the once fresh body of water was becoming dangerously toxic at an alarming rate. In fact, by June of 1969, Lake Erie was so polluted that water in the Cuyahoga River that was en route to Lake Erie caught on fire. Moreover, in the late 1960s Time Magazine headlines declared the lake dead.[4]

Due to increasing human activity, there have been several pathways in which toxins entered the waters of Lake Erie. The main pathways are eutrophication, the introduction of non-native invasive species, and acidification. The first process that has elevated the concentrations of toxins in the lake is eutrophication. Eutrophication is a natural process in a pond or a lake in which increasing plant nutrients cause algal blooms. This usually occurs in aging lakes or ponds. Although eutrophication is a natural process, human activity (urban, industrial, and agricultural run-offs) has greatly increased the aging process of Lake Erie. This accelerated version of eutrophication is known as cultural eutrophication. Before cultural eutrophication, Lake Erie was primarily an oligotrophic lake, where low productivity, cool waters, and great visibility allowed for a plethora of fish to thrive. Unfortunately, cultural eutrophication poses harm to organisms living in Lake Erie. For instance, cultural eutrophication recently increased the growth rate of algal blooms in the western and central basins. With increased production of algae on the epilimnion (the top most layer), sunlight is not able to get to the hypolimnion (most bottom layer) of the Lake. As a result, plant productivity is diminished at the bottom of the lake. Moreover, eutrophic conditions also deplete the oxygen levels in the bottom of the lake. Lack of dissolved oxygen prevents organisms and bottom feeders to receive this important element. Furthermore, the increasing algal blooms can releases toxins called Harmful Algae Blooms (HAB). In 2000, it was found that the algae growing in the western basin contained *Microcystis*

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[1] Jeanneret, Doug. "Lake Erie Water Quality: Past, Present and Future." *Ohio Sea Grant College Program*. National Sea Grant College Program, 1989. Web. 28 Apr 2010. <http://www.ohioseagrant.osu.edu/_documents/publications/FS/FS-046%20Lake%20Erie%20water%20quality%20past%20present%20future.pdf>.

[2] Langmyer, Tom. "Lake Erie: History and Views." *Lake Erie History*. Blue Water Group, 2009. Web. 28 Apr 2010. <http://www.lakeeriehistory.com/about_book.htm>.

[3] "Population of the 20 Largest U.S. Cities, 1900–2005." *InfoPlease*. Pearson Education, 2007. Web. 28 Apr 2010. <http://www.infoplease.com/ipa/A0922422.html>.

[4] "Environment: Comeback for the Great Lakes." *Time Inc.* 03 Dec 1979: 1-3. Web. 28 Apr 2010. <http://www.time.com/time/magazine/article/0,9171,948661-1,00.html>.

which contained high concentrations of the toxin microcystin. As a result, the foul-smelling, rotting, algal mats, washed upon shorelines. Beaches and recreational boating areas were rendered unusable and sport fishing was adversely affected.[5]

Another consequence of anthropogenic activity was the introduction of invasive species. Since the 1800s, more than 25 invasive species have entered Lake Erie. One of the most dangerous invasive species was the Dresseind Mussel (also known as the zebra mussel). Zebra mussels were introduced to Lake Erie in the late 1980s in the ballast water of a transatlantic freighter. These organisms soon colonized Lake St. Clair. Within 10 years, zebra mussels had inhabited all the Great Lakes. Zebra mussels are a major concern in Lake Erie because its ecological impact is tremendous. For example, "Since zebra mussels became established in Lake Erie, water clarity has increased from 6 inches to 30 feet in some areas. Unfortunately, the material removed from the water consists of other live animals and algae that supply food for larval fish and other invertebrates. In response to this changing food supply, populations of some animals have begun to decline."[6] Hence, zebra mussels have had a huge impact on the now near-extinct blue walleye community in Lake Erie.[7]

Lastly, human activity has increased the process of acidification in Lake Erie. Acidification is the process in which rain has a high concentration of acid. The most common form of acidification is aid rain. Acid rain results from pollution (most likely from "smokestack" industries along the basin) that has been transferred into the air and then into the Lake. Unfortunately, one of the consequences of acid rain is that it lowers the pH of Lake Erie. Lower pH levels in Lake Erie make it difficult to support fish and animal life.

Toxicology and Environmental Risk Assessment

By the 1800s, Lake Erie had been exposed to a wide array of toxic chemicals. Under the unfortunate assumption that water dilutes any substance, Lake Erie became a dumping ground for wastes. As a result, close to 5,000 toxic chemicals entered the Lake Erie waters. Some of the toxins included: PCBs, mercury, dioxins, and DDTs. These toxins entered Lake Erie mainly through point source pollution or nonpoint source pollution. Point source pollution is when pollutants enter Lake Erie at a specific entry point. For example, industrial water discharges and sewage treatment plants are the main culprits of this type of pollution. In nonpoint source pollution, pollution comes from many different sources. The most common examples of nonpoint source pollutants include run-offs, salt from the highways, fertilizers, and pesticides from agriculture. Another example of nonpoint source pollution in Lake Erie is atmospheric pollution. The most common form of atmospheric pollution is acid rain.

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[5] "Detroit River-Western Lake Erie Basin Indicator Project." *Large Lakes and Rivers Forecasting Research Branch*. U.S. Environmental Protection Agency, 26 Aug 2009. Web. 28 Apr 2010. <http://www.epa.gov/med/grosseile_site/indicators/algae-blooms.html>.

[6] "Zebra Mussels." *USGS Science Changing the World*. USGS, 31 Jan 2008. Web. 28 Apr 2010. <http://www.glsc.usgs.gov/main.php?content=research_invasive_zebramussel&title=Invasive%20Invertebrates0&menu=research_invasive_invertebrates>.

[7] "Zebra Mussels." *USGS Science Changing the World*. USGS, 31 Jan 2008. Web. 28 Apr 2010. <http://www.glsc.usgs.gov/main.php?content=research_invasive_zebramussel&title=Invasive%20Invertebrates0&menu=research_invasive_invertebrates>.

With the potential of either being inhaled, ingested, or absorbed into the bodies of many organisms, these toxins have affected numerous systems and organs. Due to the hazardous health affects these toxic chemicals pose humans and wildlife, by the 1970s many toxins were banned in industries and in agriculture. Toxins enter the human bodies primarily through the consumption of sport fish in Lake Erie. The native fish that accidently feed on the contaminated bottom feeders and sedimentation in the benthic zone of the lake, accumulate and absorb PCBs, DDT, Dixions, and Methylmercury and other toxins in their tissues. Toxins, at a lesser extent, can also enter the human body through the drinking contaminated water.

Polychlorinated Biphenyls

The first major toxin in Lake Erie is polychlorinated biphenyls (PCBs). PCBs are a group of man-made organic chlorinated hydrocarbons produced from 1929 until 1979 when it was banned from commercial use. The physical characteristics of PCBs can range "from thin, light-colored liquids to yellow or black waxy solids."[8] Polychlorinated biphenyls were primarily used in commercial products due to its high boiling point, anti-flammability, and its electrical insulating properties. Although the chemical was banned more than 30 years ago, PCBs are still present in many commercial products. For example, polychlorinated biphenyl's is found in plastics, oil-based paint, fluorescent light ballasts, cable insulation, tapes and adhesives, carbonless copy paper, dyes, pigments, motor oil and as well as oil used in hydraulic systems. The major route of exposure in humans is through the consumption of fish. The waters of Lake Erie today is usually contaminated with PCBs through illegal dumping of wastes, the burning of products that contain PCB, and even leaks and releases from electrical transformers.

Polychlorinated biphenyls have caused many hazardous effects in human health. Although the toxicity levels vary depends on the congener, the Food and Drug Administration determined that fish eating more than 2 parts per million of PCB poses as a health threat.[9] According to the World Health Organization in 1993, the average intake of PCBs in industrialized countries was less than 200 ng for drinking water, 5-15 Fg for daily intake through food consumption, and about 15-55 Fg in infants (almost 3 times more than the concentration in adults).[10]

There are many health risks that PCBs cause in the humans. One health threat is the ability to cause cancer. EPA's cancer reassessment of "PCBs: Cancer Dose-Response Assessment and Application to Environmental Mixtures" was an article peer reviewed by 15 experts on PCBs. The peer reviewers agreed with EPA's conclusion that PCBs are probable human carcinogens.[11] PCBs have found to also affect the nervous system, the reproductive

[8] "PCBs: Cancer Dose-Response Assessment." *Environmental Protection Agency*. Environmental Protection Agency, Sept. 1996. Web. 28 Apr 2010. <http://www.epa.gov/osw/hazard/tsd/pcbs/pubs/pcb.pdf>.

[9] Jeanneret, Doug. "Lake Erie Water Quality: Past, Present and Future." *Ohio Sea Grant College Program*. National Sea Grant College Program, 1989. Web. 28 Apr 2010. <http://www.ohioseagrant.osu.edu/_documents/publications/FS/FS-046%20Lake%20Erie%20water%20quality%20past%20present%20future.pdf>.

[10] "Basic Information Polycholinated Biphenyls." *U.S. Environmental Protection Agency*. The United States Environmental Protection Agency, 24 Mar 2009. Web. 28 Apr 2010. <http://www.epa.gov/osw/hazard/tsd/pcbs/pubs/about.htm>.

[11] "Basic Information Polycholinated Biphenyls." *U.S. Environmental Protection Agency*. The United States Environmental Protection Agency, 24 Mar 2009. Web. 28 Apr 2010. <http://www.epa.gov/osw/hazard/tsd/pcbs/pubs/about.htm>.

system, immune system and the endocrine system. In the nervous system, PCBs can affect learning in adolescents. For example, in a Michigan infant cohort study, researchers wanted to see the health effects of contaminated fish on pregnant women and their new born infants. In the experiment, there were 242 pregnant women who ate moderate to high amounts of contaminated fish from Lake Michigan and 71 pregnant mothers that did not eat the contaminated fish from Lake Michigan. The results showed that pregnant mothers who ate the contaminated fish 6 years prior to giving birth and during their pregnancy had developmental disorders and cognitive deficits in their children. Furthermore, the study observed, "Developmental effects including statistically significant decreases in gestational age (4.9 days), birth weight (160–190 g), and head circumference (0.6 cm) in which developmental effects were still evident 5 to 7 months after the infants' births. Neurobehavioral deficits observed included depressed responsiveness, impaired visual recognition, and poor short-term memory at 7 months of age."[12] Moreover, PCBs was shown to affect the visual recognition as well as short term memory. In the immune system, PCBs suppressed the immune system. As a result, patients exposed to PCBs have demonstrated a risk factor to non-Hodgkin's lymphoma. Lastly, PCBs have also affected the hormone levels in the endocrine system. PCBs affected the thyroid gland which changed the normal levels of hormones for growth and development.

Risk estimates for PCBs are based on either human or animal studies. According to the EPA, "Estimates derived from human studies reflect an observed association between human exposure and cancer; however, it is difficult to reconstruct reliable estimates of past exposure and separate the effect of confounding exposures to other carcinogens. Estimates derived from animal studies benefit from controlled exposures and absence of confounding factors; however, there is uncertainty in extrapolating dose and response rates across species. EPA's cancer guidelines (U.S. EPA, 1986a, 1996a) favor basing dose-response assessments on human studies." When there is not enough human information, animal studies are usually done.

When doing a dose-response assessment for PCBs, new assessments have used dose-response slopes. This is because environmental factors play a role in level of toxicity in PCB congeners. Hence, the environmental processes allow researchers to choose the most appropriate slope. Unfortunately, there are no cancer studies of PCB mixtures that are found in the environment. The only studies that are currently available are some commercial studies. Other methods that have been used include: "a tiered approach that can use site-specific congener information when available, but can be adapted if information is limited to total PCBs encountered through each exposure pathway."[13] Furthermore another innovative technique that has been used was "A range of upper-bound potency estimates for PCB mixtures, plus a range of central estimates, with guidance for choosing estimates from these ranges to reflect the effect of

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[12] Johnson, Barry L., Heraline E. Hicks, Williams Cibulas, Obaid Faroon, and Annette E. Ashizawa. "PUBLIC HEALTH IMPLICATIONS OF EXPOSURE TO POLYCHLORINATED BIPHENYLS (PCBs) ." *Agency for Toxic Substances and Disease Registry*. U.S. Department of Health and Human Services , 24 Mar 2009. Web. 28 Apr 2010. <http://www.atsdr.cdc.gov/DT/pcb007.html>.

[13] "PCBs: Cancer Dose-Response Assessment." *Environmental Protection Agency*. Environmental Protection Agency, Sept. 1996. Web. 28 Apr 2010. <http://www.epa.gov/osw/hazard/tsd/pcbs/pubs/pcb.pdf>.

environmental processes on a mixture's toxicity."[14] As of 1996, biologically based models have been developed for 2,4,2',5'- and 3,4,3',4'-tetrachlorobiphenyl. Lower dose extrapolation uses both linear and nonlinear approaches.

Mercury

Another toxin in Lake Erie worth mentioning is mercury. Mercury is usually manufactured for chemical and pharmaceutical uses. Even though mercury is naturally occurs in the environment, the burning of coal in industries and in commercial products constitutes for than 40% of domestic human-caused emission in the United States. [15] Mercury is released into the environment through the "burning of hazardous wastes, the production of chlorine, breaking mercury products, the spilling mercury, as well as the improper treatment and disposal of products or wastes containing mercury."[16] Found in the air, soil, and water, mercury can enter the human body through inhalation, ingestion of contaminated water or food. It can also be transmitted through dental and medical treatments. Humans are exposed to mercury mainly through fish and shellfish. Mercury settles to the bottom of the lake where microorganisms change the element to methylmercury. The levels of methylmercury (the more toxic form of mercury) in fish and shellfish depend on several of factors. For example, concentration levels of mercury depend on the type of prey, lifespan, and how high they are in the food chain.[17] The Food and Drug Administration states that the mercury limit in fish is 1 part per million in fish.

Like PCBs, high levels of mercury can affect the health. The toxicity levels of methlymercury in humans are dependent on the following: the duration of exposure, the age of the person exposed, the health of the person exposed, the dose, and the chemical exposure. The Center for Disease Control found that typically humans have below "a level (5.8 µg/L of whole blood) associated with possible health effects."[18] For example, one of the major systems in the body mercury affects is the nervous system. The long term affects of methylmercury is brain damage. Furthermore, high exposures of mercury can result irritability, shyness, tremors, changes in vision or hearing, and memory problems. "U.S. EPA's 2001 Reference Dose (RfD) for methylmercury was calculated to protect the developing nervous system. Currently, U.S. EPA uses a RfD of 0.1 µg/kg body weight/day as an exposure without recognized adverse effects."[19] Short term affects of mercury includes: lung damage, nausea, vomiting, diarrhea,

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[14] "PCBs: Cancer Dose-Response Assessment." *Environmental Protection Agency*. Environmental Protection Agency, Sept. 1996. Web. 28 Apr 2010. <http://www.epa.gov/osw/hazard/tsd/pcbs/pubs/pcb.pdf>.

[15] "Basic Information: Mercury ." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, 19 Oct. 2009. Web. 28 Apr 2010. <http://www.epa.gov/epafiles/usenotice.htm>.

[16] "Basic Information: Mercury ." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, 19 Oct. 2009. Web. 28 Apr 2010. <http://www.epa.gov/epafiles/usenotice.htm>.

[17] "Basic Information: Mercury ." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, 19 Oct. 2009. Web. 28 Apr 2010. <http://www.epa.gov/epafiles/usenotice.htm>.

[18] "Human Exposure ." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, 07 Oct. 2009. Web. 28 Apr 2010. <http://www.epa.gov/mercury/exposure.htm>.

[19] "Human Exposure ." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, 07 Oct. 2009. Web. 28 Apr 2010. <http://www.epa.gov/mercury/exposure.htm>.

increases in blood pressure or heart rate, skin rashes, and eye irritation. Although it is uncertain if mercury causes cancer in humans, the EPA has determined that mercuric chloride and methylmercury are possible human carcinogens.[20]

The EPA says that most people are not at harm when consuming fish that are contaminated with methylmercury. The population that is most at risk *in utero* children. One appropriate model that could be used to assess the health risk of methylmercury is through calculating the "chronic daily intake (for an individual at a specified consumption level and a specified fish tissue MeHg concentration level), and dividing the chronic daily intake by the RfD for a specified health endpoint to get a hazard quotient, where a value greater than one represents incremental exposure greater than the RfD"[21] In a algebraic equation the EPA condensed this model to the following:

$$\frac{\text{(consumption rate * fish tissue MeHg concentrtn* correction factor for cooking)/ (body weight)}}{\text{RfD}}$$

Risk assessments are usually done for women at childbearing age (16-49) with special concentration to those who consume a lot of fish. One study did a review of human exposure to Hg and resulting concentrations in hair or blood (which are the best indicators for methylmercury). The median Hg level in hair is much less than 1 ppm in the average individual in the United States. Studies showed that there is a positive correlation of increased fish consumption with the increased concentration of mercury in the body. Dose-response factors were determined through epidemiologic studies in populations where fish consumption was high.

Dioxins

Another group of toxins in Lake Erie are Dioxins. Dioxins are chemicals found in places like pulp, paper mills, the burning of municipal solid waste and medical waste, forest fires, cement kilns, and even in backyard burning of household waste. The most toxic compound of dioxin is 2,3,7,8 TCDD. Dioxins can be found in the air, soil, food, and in the sediment. Dioxins settle into the environment through the combustion of products in the air and enter the lake and storm water runoffs from urban areas. The major route of exposure in humans is through the ingestion of food especially via contaminated fish. According to the EPA, it is estimated "that most dioxin exposure occurs through the diet, with over 95% of dioxin intake for a typical person coming through dietary intake of animal fats."[22] According to the United States Environmental Protection Agency, dioxin causes hazardous health effects in fish when concentration levels reach 1 part per trillion in fish.

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[20] "Mercury Study Report to Congress." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, Dec. 1997. Web. 28 Apr 2010. <http://www.epa.gov/ttn/oarpg/t3/reports/volume5.pdf>.

[21] "Human Health Risk Assessment of Methymercury Contaminated Fish." *Virginia Commonwealth University*. Virginia Commonwealth University, Dec. 1997. Web. 28 Apr 2010. <http://www.deq.state.va.us/air/vamercury/Mercury_Scope.pdf

[22] " Dioxin Reassessment. National Academy of Sciences (NAS) Review Draft 2004 ." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, 26 April 2010. Web. 28 Apr 2010. <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=87843>.

The health risk assessment is dependent on both human exposures (some controversial) and animal studies. Animal studies are usually preferred than human studies. TCDD is the best studied dioxin and is also used as reference to its congeners. There are many biological effects of TCDD in high concentrations. Biochemical, cellular, and organ-level endpoints have been shown to be affected by the toxin in experiments. In humans, dioxin primarily affects early development and hormone levels. It has shown that with increasing concentrations, dioxins also can also cause chloracne, a type of skin disease.

The EPA and several organizations have determined dioxins to be a human carcinogen. According to the Minnesota Department of Health (MDH), "The consistent, suggestive evidence from epidemiology studies combined with the unequivocal evidence in animal studies and inferences drawn from mechanistic data support the characterization of complex mixtures of dioxin and related compounds as "likely" cancer hazards."[23] The EPA utilized two upper bound slope factors for estimating human cancer risk from exposure to dioxins. 1×10^{-3} (pg TCDD TEQ/ kg body weight/day)$^{-1}$ based on an evaluation of the human epidemiology data and 1.4×10^{-3} (pg TCDD TEQ/kg body weight/day) $^{-1}$ based on a re-evaluation of the animal data (liver cancer in female rats).

DDT

The last major toxin in Lake Erie is DDT. DDT is a term used for a family of toxins that have similar chemical structure and mechanism. DDT was the most common pesticide used in the United States before it was banned in 1972.[24] Although concentrations of DDT have declined since the early 1970s, current concentration levels in the environment are still a major concern. Furthermore, DDT is still legally produced in the United States and sold to and used by foreign countries.[25] According to the Environmental Protection Agency, it can take up to 15 years for DDT to break down in the environment. DDT is found in many areas. For example, it has been found in the soil, in the water, the atmosphere, and in the sediment. One of the routes of exposure for DDT is through the consumption of plants and earthworms. The main route of exposures in humans is through contaminated fish and shellfish. "The U.S. Environmental Protection Agency estimates that current lifetime human exposures to dioxin average approximately 1 pg/kg/day (99% percentile: 3 pg/kg/day). Although it appears unlikely that current exposures through foods would reach either 7 pg/kg/day or the ED01"[26]

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[23] "Methods for Estimating the Carcinogenic Health Risks from Dioxin-Like Compounds." *Minnesota Department of Health*. Minnesota Department of Public Health, Oct. 2006. Web. 28 Apr 2010. <http://citationmachine.net/index2.php?start=&reqstyleid=1&mode=form&reqsrcid=MLAWebDocument&more=&nameCnt=1#>.

[24] "DDT." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, 22 April 2010. Web. 28 Apr 2010. <http://www.epa.gov/pbt/pubs/ddt.htm>.

[25] "National Pesticides Information Center." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, Dec. 1999. Web. 28 Apr 2010. <http://npic.orst.edu/factsheets/ddttech.pdf>.

[26] Crump, Kenny S., Richard Canady, and Manolis Kogevinas. "Meta-analysis of Dioxin Cancer Dose Response for Three Occupational Cohorts." *Environmental Health Perspectives* 111.5 (2005): 681-687. Web. 28 Apr 2010. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1241475/pdf/ehp0111-000681.pdf>.

It is found that DDT is slightly to moderately acutely toxic to humans and other mammals when ingested. For example, A study found that in rats had DDT toxicity concentration levels of 113 to 800 milligrams per kilogram of body weight.[27] The mechanism of action for DDT is that it affects the nervous system by disturbing the nerve impulses. As a result, tremors in the body are observed due to the nerve cells continuously generating an impulse.[28] Moreover DDT partially destroys the nervous system by affecting the central nervous system and increasing neural ATPase activities. Other symptoms associated with DDT toxicity include excitability, convulsions and even death. In animals, increased concentrations of DDT can cause thinning of the eggshell, infertility, and ebroyo-fetotoxicity.

Like PCBs, dioxins, and mercury, DDT has the possibility of causing cancer in humans. Because data on human carcinogenicity was inadequate, animal carcinogenicity data was thus used and proven to be sufficient. "Three studies using Wistar, MRC Porton and Osborne-Mendel rats and doses from 25-40 mg/kg/day produced increased incidence of benign liver tumors (Rossi et al., 1977; Cabral et al., 1982; Fitzhugh and Nelson, 1946)."[29] Furthermore, DDT does not only have toxic effects to the liver, but it also reduces reproductive success by damaging the reproductive system.

Potential Impact on Vulnerable Populations

The toxins in Lake Erie have a huge impact on the health of the people that surround its basins. PCBs, DDT, dioxins, and mercury all uniquely impact the overall health of vulnerable populations. According to the Environmental Protection Agency, it has been found that "humans are the final biological receptors for many toxic substances."[30] The primary mode of human exposure to these toxins in Lake Erie is through the consumption of fish. Although there is still ongoing research to what extent toxins affect the human body, toxins in the lake still are a major concern for high risk populations.

The first vulnerable populations to high concentrations of toxins discussed are newborn infants and fetuses. The mode in which infants are exposed to these toxins from Lake Erie is

[27] "National Pesticides Information Center." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, Dec. 1999. Web. 28 Apr 2010. <http://npic.orst.edu/factsheets/ddttech.pdf>.

[28] "National Pesticides Information Center." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, Dec. 1999. Web. 28 Apr 2010. <http://npic.orst.edu/factsheets/ddttech.pdf>.

[29] "p,p'-Dichlorodiphenyltrichloroethane (DDT) (CASRN 50-29-3)." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, 16 Mar. 2010. Web. 28 Apr 2010. <http://www.epa.gov/iris/subst/0147.htm>.

[30] "The Effects of Great Lakes Contaminants in Human Health." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, Sept. 1995. Web. 28 Apr 2010. <http://nepis.epa.gov/Exe/ZyNET.exe/2000BSHI.txt?ZyActionD=ZyDocument&Client=EPA&Index=1995%20Thru%201999&Docs=&Query=&Time=&EndTime=&SearchMethod=3&TocRestrict=n&Toc=&TocEntry=&QField=pubnumber^%22905R95017%22&QFieldYear=&QFieldMonth=&QFieldDay=&UseQField=pubnumber&IntQFieldOp=1&ExtQFieldOp=1&XmlQuery=&File=D%3A\ZYFILES\INDEX%20DATA\95THRU99\TXT\00000002\2000BSHI.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h|-&MaximumDocuments=10&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p|f&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages>.

primarily through milk when nursing. Even though pregnant mothers (who have high concentrations of methylmercury) may not show any symptoms of nervous damage, their children can have severe damages to the brain and nerves. Likewise, the results in a study that was done on pregnant mothers who had taken more than 11.8 kilograms of contaminated fish with PCBs showed that the children had developmental deficiency in relation to head circumference, birth weight, and gestational age. Low levels of PCBs in consumption in maternal mothers also had a significant impact on the neurological behavior in newborns. Behavioral deficits included: increased inclination to startle, abnormal motor reflexes, and depressed responsiveness. Moreover, fetuses, infants, and subsequently children may be vulnerable to dioxin and DDT exposures because it affects their rapid development and growth. Although breast milk appears to be a significant source of dioxin, DDT, PCBs, and methylmercury exposure for nursing infants, the overwhelming body of evidence supports the health benefits of breastfeeding despite the potential presence of dioxin. Women who are in the childbearing years should also in the vulnerable population because although they might not be pregnant, toxins like methylmercury can accumulate in the bloodstream over the years which can then pose serious harm to a fetus when the woman does become pregnant.

Other vulnerable populations to high levels of toxic chemicals are the ones that may live in close proximity to hazardous wastes sites around the lake and the ones that consume high concentrations of fish. As stated before, fish is a major pathway of exposure in humans. Since many of the toxins can take many years to break down, the toxins accumulate in the fatty tissues of the native and invasive species. It has been found that "people who eat sport-caught fish consumed more than 2 times more fish than the overall U.S. population."[31] Unfortunately, many people who do consume sport-caught fish, live near hazardous wastes where they can be exposed to concentration of PCBs as high as 750 ppm.[32]

Present approaches to resolve problem and protect human health

Lake Erie is important for transportation, recreation, and the economy. Several acts and policies have been initiated in order to clean up the toxins in Lake Erie and to improve the overall quality of health in the residents that surround its basins. One of the most effective policy made to prevent dangerous toxins from mixing with the waters of Lake Erie, was the actual banning of the production of toxins in industries. Although this was the first step to the overall improvement of the Lake and human health, toxins still remained in the soil, air, and lake. In the early 70s the Great Lakes Water Quality Agreement was signed in 1972. The Agreement, which was signed by the Canadian Prime Minister Pierre Trudeau and U.S. President Richard Nixon, established guidelines for reducing point source pollutants by using the best known technology and knowledge at the time. This attempt focused on decreasing phosphorous levels in Lake Erie and was created to reduce the human sewage and improve its treatment.

[31] "Polychlorinated Biphenyls." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, n.d. Web. 28 Apr 2010. <http://www.epa.gov/wastes/hazard/wastemin/minimize/factshts/pcb-fs.pdf>.

[32] "Polychlorinated Biphenyls." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, n.d. Web. 28 Apr 2010. <http://www.epa.gov/wastes/hazard/wastemin/minimize/factshts/pcb-fs.pdf>.

Although by the late 70s the cleanliness of the lake dramatically improved, there were still many nonpoint source toxins that persisted in the lake. The 1978 and 1987 the Great Lakes Water Agreement strived to diminish all toxins in the Great Lakes. In the document it stated, "The philosophy adopted for control inputs of persistent toxic substances shall be zero discharge."[33] This was the beginning point of many agencies initiating research to decrease the prevalence of toxins in Lake Erie. For example the International Joint Commission in the United States and in Canada started to work on methods needed to reduce the toxins that caused the most harm in the environment. Furthermore, in order to reduce the pollution entering Lake Erie, the International Joint Commission targeted 45 areas that had been grossly polluted with toxins and declared as the areas of concern for massive cleanup. Remedial Action Plans were developed to help community members understand the cleanup process that was being done, as well as what they can do to actively participate.

This ended up being a very difficult task because it involved major changes in the industrial technique. Furthermore, eliminating the toxins in Lake Erie will be difficult because according to Dough Jeanneret of the Ohio Sea Grant College Program, "many companies still feel like Lake Erie is there to exploit. Many toxins which are no longer discharged are still creating problems because their insolubility and affinity to remain in the environment."[34]

In order to fully restore Lake Erie and the other Great Lakes, the projected costs would accumulate to about 26 billion dollars. According to the Lake Erie Protection and Restoration plan, "this expenditure would yield over 50 billion in long term economic benefits and between $30 and $50 billion in short term benefits. Studies have also shown this could have a direct benefit of $2.1 to $3.7 billion to the Cleveland area alone."[35] Today, with efforts in the past several decades to reduce water toxicity in Lake Erie, there have been many programs and research projects initiated to reduce the prevalence of DDT, dioxins, PCBs, and methylmercury. For example, with non-point pollution being the primary cause of toxins entering Lake Erie, the Lake Erie Protection and Restoration Plan propose to reduce sediment loading in Lake Erie. According to the National Center for Water Quality Research, "The proposed 33% reduction continues on a linear trend currently being achieved along the basins."[36] Furthermore, to control nonpoint pollution in Lake Erie, The Coastal Nonpoint Pollution Control Program has created a set of measures for states to control polluted runoff then just cleaning already contaminated water. Therefore, the program targets controlling runoffs in urban areas, agriculture, and forestry.

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[33] Jeanneret, Doug. "Lake Erie Water Quality: Past, Present and Future." *Ohio Sea Grant College Program*. National Sea Grant College Program, 1989. Web. 28 Apr 2010. <http://www.ohioseagrant.osu.edu/_documents/publications/FS/FS-046%20Lake%20Erie%20water%20quality%20past%20present%20future.pdf>.

[34] Jeanneret, Doug. "Lake Erie Water Quality: Past, Present and Future." *Ohio Sea Grant College Program*. National Sea Grant College Program, 1989. Web. 28 Apr 2010. <http://www.ohioseagrant.osu.edu/_documents/publications/FS/FS-046%20Lake%20Erie%20water%20quality%20past%20present%20future.pdf>.

[35] "Lake Erie Protection & Restoration Plan 2008." *Ohio Lake Erie Commission*. Ohio Lake Erie Commission, n.d. Web. 28 Apr 2010. <http://lakeerie.ohio.gov/Portals/0/Reports/2008LEPRplan.pdf>.

[36] "Lake Erie Protection & Restoration Plan 2008." *Ohio Lake Erie Commission*. Ohio Lake Erie Commission, n.d. Web. 28 Apr 2010. <http://lakeerie.ohio.gov/Portals/0/Reports/2008LEPRplan.pdf>.

To protect human health through the consumption of contaminated fish, the EPA in conjunction with the FDA listed several fish consumption advisories that specifically targets vulnerable populations (pregnant women, child-bearing women, parents, and infants). For example, the advisories inform these populations the benefits of eating certain fish and shellfish that contain lower concentrations of mercury (like shrimp, salmons, Pollock, and tuna). The EPA recommends eating no more than 12 ounces a week of the fish and shellfish that contain lower concentrations of mercury. The best way to avoid high concentrations of toxins like mercury is to avoid older and bigger fish. Furthermore, it is advised that vulnerable populations stay away from fish that contain a lot of fat (because they can absorb a lot of the toxins). If fatty fish has been bought, there are several methods the FDA and the EPA suggest in reducing the risk of human exposure to the toxins. For example, the FDA and EPA recommend that the fish be thoroughly cleaned and trimmed of any fat (for example the belly, the back and the dark meat along the sides). Furthermore, they suggest puncturing the skin so that when the fish is grilled, broiled, roasted, or steamed, the fat will drain off. The EPA and the FDA make an important advisory about fish that is caught locally by neighbors, family, and friends. They say that if there are no local advisories near the lake, they recommend eating up to 6 ounces of that fish (without the consumption of any other fish) per week.

The EPA has also regulated the concentration levels of PCBs in Lake Erie. To reduce human exposure to PCBs, the EPA regulates the concentration of PCBs in the waters to be no greater than .17 parts of PCBs per trillion (ppt) of water. The FDA has also set limits of PCBs in various foods. For example, the FDA required limits included 0.2 parts of PCBs per million parts (ppm) in infant and junior foods, and 2ppm in the edible portions of fish and shellfish.

Recommendations provide valuable guidelines to protect public health but cannot be enforced by law. Federal organizations that develop recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH).[37]

There are currently several proposals made in the year 2010 for cleaning up Lake Erie through the Great Lakes Restoration Initiative Funding. President Obama has projected about 475 million dollars to tackle the leading causes for drastic ecological changes that have been happening in the Great Lakes. The highest priorities in which the government deemed required urgent action were: Toxic Substances & Areas of Concern (4.2 million for 5 projects), Invasive Species (1.3 million for 5 projects), Nearshore Health and Nonpoint Source Pollution (6.71 million for 14 projects), Habitat and Wildlife Protection and Restoration (8.43 million for 8 projects), and finally Accountability, Monitoring, Evaluating, Communication and Partnerships (2.08 million for 8 projects).[38]

One program called “Toxic Substances in Brownfield Sites” is dedicated to addressing toxic substances in the Great Lakes industrial cities. This project restores trees and native vegetation to reduce storm water run-off and trap toxic substances. Another project that is to receive money from the Obama Administration is the “Enhanced Sate/Tribe Fish Consumption

[37] "Polychlorinated Biphenyls." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, n.d. Web. 28 Apr 2010. <http://www.epa.gov/wastes/hazard/wastemin/minimize/factshts/pcb-fs.pdf>.

[38] "Ohio's Projects for 2010: Great Lakes Initiative Funding." *Ohio Lake Erie Commission*. Ohio Lake Erie Commission, 11 Mar. 2010. Web. 28 Apr 2010. <http://www.lakeerie.ohio.gov/LinkClick.aspx?fileticket=SYBKE8C%2bkfw%3d&tabid=146>.

Advisory Support". With more than 4 million dollars, its goal is to increase the public's knowledge and understanding of the risk and benefits of consuming fish.[39] Furthermore, the project wants to continue to monitor, improve, and enhance current State fish advisory programs. A project that focuses on sedimentation is the Great Lakes Legacy Act. The Environmental Protection Agency is allocating about 75 million dollars to clean up and assess contaminated sediments in the Great Lakes (in the Areas of Concern). The Environmental Protection Agency is also providing money more than 8 million dollars to control, prevent, and eradicate the non-native invasive species in the Great Lakes through the Invasive Species Prevention and Control Grant Program. Lastly, within Ohio, the Ohio Lake Erie Commission (OLEC) has prioritized projects that will "remove barriers to fish spawning areas, restore beneficial uses in Ohio's 4 areas of concern, reduce harmful algal blooms, make beaches safer, reduce contamination from nonpoint sources address emerging contaminants of concern, and track measurable goals through the country's best monitoring programs."[40]

Research Needs

Although toxins in Lake Erie have been reduced dramatically over the past several decades, toxins PCBs, DDT, dioxins, and mercury still persist and pose as potential threat to the human population. There are several research or monitoring needs that need to be addressed. First of all, there needs to be more emphasis on the detection, characterization, and prediction of harmful algal blooms. For example, prediction is necessary to better foresee non-native invasive species like the zebra mussel's dynamics as well as how these invasive species process nutrients in Lake Erie. Zebra mussels are a major contributor to increased algal blooms in the western basin of Lake Erie. If we find how they process these nutrients we can prevent harmful algal blooms that contain toxic microcystins from forming. Likewise, there are future needs for site-specific calibration of the Lake Erie ecosystem model. This will help to determine which organisms in which basins are most susceptible to these algal toxins. In addition it is important to find out what actually triggers Microcystis to produce toxins. This is necessary because Microcystis do not produce these toxins all the time. Furthermore, it is imperative to be able to predict the "upper food web predator-prey interactions, population dynamics and coupling with lower food web".[41] This will help to determine how these toxins travel within the food chain. Moreover, we need better methods to measure light attenuation in Lake Erie. The current method of using Secchi transparency is quite difficult when trying to measure the water clarity of Lake Erie. Furthermore, secchi disks can only be seen at a depth of three meters. One solution that has been proposed was using remote sensing from satellites.[42]

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[39] "Great Lakes Restoration Initiative (GLRI) Program Summary." *Michigan Tech Research Institute*. Michigan Tech Research Institute, 10 Aug. 2009. Web. 28 Apr 2010. <http://www.lakeerie.ohio.gov/LinkClick.aspx?fileticket=SYBKE8C%2bkfw%3d&tabid=146>.

[40] "Ohio's Projects for 2010: Great Lakes Initiative Funding." *Ohio Lake Erie Commission*. Ohio Lake Erie Commission, 11 Mar. 2010. Web. 28 Apr 2010. <http://www.lakeerie.ohio.gov/LinkClick.aspx?fileticket=SYBKE8C%2bkfw%3d&tabid=146>.

[41] "Detroit River-Western Lake Erie Basin Indicator Project." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, 26 Apr. 2009. Web. 28 Apr 2010. <http://www.epa.gov/medatwrk/grosseile_site/indicators/algae-blooms.html>.

[42] "Detroit River-Western Lake Erie Basin Indicator Project." *U.S. Environmental Protection Agency*. U.S. Environmental Protection Agency, 26 Apr. 2009. Web. 28 Apr 2010. <http://www.epa.gov/medatwrk/grosseile_site/indicators/algae-blooms.html>.

Furthermore, there is a need to monitor the populations along the Lake Erie basins in order to predict future growth and population distributions. Human activity is one of major reasons for cultural eutrophication (which ultimately results in algal blooms in Lake Erie) and the increased concentration of pesticides and other toxins in soil run-offs. Furthermore, "more research is needed that integrate population trends with the land use and transportation planning on a regional scale." Therefore future research on the population and land and transportation use is a vital component in ensuring the improved health of the inhabitants around its basins.

Another important research need is to find alternative ways to use the land for development. With current development plans and at the fast rate in which land is changing from a rural setting to an urban setting, the land is becoming more unsuitable. Furthermore, we need to have research needs that will predict how the land will be utilized in the future by using and assessing models that will predict with accuracy. This will help us to control the amount of toxins that do enter into the land, air, and water. Moreover we need to use research to determine how the ecosystem will be affected with different land use practices and change. Research also needs to be done to see how changing land use practices (changing how farmers tend their crops to improve soil quality) will not only benefit the environment, but also the economy and the society.

The last research need is the continual monitoring and research on the prevalence of toxins DDT, PCB, HABs, Dioxins, and Mercury. For example, we should continue to do research on dead embryos of birds or deformities to see if they could have been potentially been impacted by toxic fish in the lake. Although the toxic effects may differ between a bird and a human, it will still be useful to see how the various concentrations in the Lake can affect the environment. By monitoring the concentrations in the air, soil, and water, health environmentalist can determine whether current cleanup methods are actually reducing the toxin levels in the environment.

It is imperative to continually bring awareness to how human activity has greatly impacted the water quality, the organisms, and the people that surround its basins. Lake Erie serves as a habitat, and a means to transportation, food, and recreation. Although we can never bring Lake Erie back to how it was before European settlement, through projects and education, we can certainly make sure that toxins PCBs, Dioxins, DDT, and mercury are kept to a minimum in the environment.