The Effect of PCB Pollution in the Willamette River on Human Health

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Pollution of the environment can severely alter the ecosystem and impose stress on the survival abilities of organisms in an environment. As if it were a curse, humans do not escape the horrific consequences of the disaster that they create either. In the past, humans have been inconsiderate of the environment in pursuit of civil development. Technological advances have come at a heavy price of contamination of the natural environment. Only in recent history, after experiencing devastating effects, have humans begun to realize the potential harm. Locally, the Willamette River Basin and surrounding area have suffered from severe pollution. Although efforts to clean the river have been successfully implemented, the task to maintain a truly clean river is far from over. Contrary to the misconception that the current condition of the Willamette River basin is once again clean and safe, the river, in reality, still contains many pollutants. Pollution in the river comes in many forms, such as chemical, biological, and heat. One class of chemical pollutant, polychlorinated biphenyls (PCBs), is particularly dangerous. Better understanding of the current pollution conditions in the Willamette watershed along with supplementary studies of this pollutant will shed light on the effects on human health. One can clearly see that future action must be taken to preserve the health of the river and humans.

The Willamette River plays an important role in the daily lives of Oregonians. Stretching across 100 miles in the Willamette Valley, it is the tenth largest river in the United States and the river of life for Oregonians. More than 70% of Oregon residents reside along the winnowing waters and its thirteen tributary rivers (Phillips et al, 21). The river itself is a major economical and recreational natural resource. The health of the river closely reflects human activity, and in turn, not only intimately connects to the overall well-being of the ecological system, but also affects human life.

The pollution history of the Willamette River has been a long story. In the early 20th century, people were ignorant of the potential harm they may do to themselves by neglecting to protect the environment. Raw sewage and industrial waste were dumped into the Willamette River with little regulation and concern. However, Oregonians would soon suffer from their own actions and learn the importance of maintaining a clean river. In just a few decades, Oregonians witnessed the Willamette River turn into one of the most polluted rivers in the United States. It was no longer the river of life, but a river that threatened the lives of creatures residing along the river, including humans. In the 1960s, Oregonians strongly supported Governor Tom McCall to take action and clean the river. Since then, the people of Oregon passed laws to restrict pollution sources, and implemented tremendous efforts to clean the river. (*Willamette River Quality*).

Today, the Willamette River has recovered much of its purity. The water is no longer the color of concentrated industrial waste, and smell is no longer raw sewage, fish once again swim in the river, and humans return to the river for recreation.

Despite the apparent purity of today's Willamette River, the pollution problem is far from over. Rick Bastasch, a local resident and a Willamette River water management expert, points out in his book, *Waters of Oregon*, that today's main problem, unlike the past, is "nonpoint" pollution sources (168). Everyone in the watershed is still unknowingly contributing to the pollution of the river by careless handling of oils on the driveway, pesticides, aged septic tanks, and more. In addition, toxic pollutants remain in the river at alarming concentrations. In particular, chemical pollutants such as polychlorinated biphenyls (PCBs) are a great danger to people because even though they are prevalent in the river, humans are unable to detect them by the naked eye or smell. It is easy to assume that a river that looks clean is indeed clean. However, many independent scientific studies affirm that PCBs have a negative impact on human health and must be treated with seriousness.

PCBs should be a major concern to citizens residing in the Willamette Basin. In a government-funded assessment of the Willamette River by the Willamette Restoration Initiative Board, the researchers of the Oregon Department of Environmental Quality found PCBs at high levels in local fish species. In fact, this alarming finding prompted the US EPA to specify six miles of the Willamette River as Superfund sites, critical regions that requires cleanup (Jerrick et al, 17). In another recent study conducted by Sethajintanin et al, an independent research group, the authors examined the toxin levels in fish in the Willamette River. In the sampled population of fish along the river, the authors found that the average concentration of PCBs in the fish exceeds the human health screening value of 0.02 µg/g set by the US Environmental Protection Agency (Sethajintanin et al, 115). These studies clearly demonstrate the need for cleanup treatment of PCBs in the Willamette River to protect human health.

PCBs are common industrial chemical compounds. they are often found in dielectric fluid, coolant, heat transfer fluids, hydraulic lubricants, flame-retardants, plasticizers, and sealants. Despite the recognition of their capacity to harm, industries did not stop producing PCBs until 1977. Presently, although new PCB-containing products are no longer created, previously made PCB-containing fluids are still being used in industry (National Safety Council). Thus there are many opportunities for PCBs to contaminate the watershed, such as leaking and industrial waste release.

The chemical nature of PCBs offers some explanations of why they are dangerous to humans. PCBs are a family of compounds that have two phenyl groups attached to each other with multiple chloride groups attached to the phenyl groups. Depending on the molecular structure, mass, and other chemical properties of each specific compound, different PCBs have different effects on humans (Machala et al, 340). These compounds share certain chemical properties. For example, the aromaticity (a property of a class of compounds that contain a closed loop of pi electrons that obey the Hückel rule of having 4n+2 electrons and establish resonance) of the benzene rings makes PCBs very stable structures, such that they do not easily degrade. Also, the lipophilicity (a property of compound that can dissolve in lipids) of the benzene rings allows PCBs to accumulate in fat tissues in fish and humans. The combination of these two characteristics results in the bioaccumulation effect (Machala et al, 340), where PCBs are collected in high concentrations and travel up the food web to higher organisms. The human body does not have a mechanism to cope with PCBs, since the lipophilicity of PCBs prohibit them from traveling through the blood stream to be excreted by the kidneys, or getting eliminated by sweat glands.

How exactly do PCBs harm humans? Many sources claim that PCBs have a number of negative impacts on humans, most notably, cancer. Without convincing evidence, critics may easily discount the dangers of PCBs. Driven by a strong interest in understanding how PCBs affect humans, the scientific community has been actively studying PCBs. In the numerous studies, scientists use various methods, including population statistical analyses, cellular studies in model organisms, and molecular studies in human cell cultures. A few studies discount PCBs as cancer-causing agents, while the vast majority of such studies reveal that PCBs are not only carcinogens, but also have a number of negative impacts on humans in various aspects. The following case studies are examples of studies that provide evidence for such claims.

The population statistics studies follow a population exposed to PCBs and collect data on PCB exposure levels and incidences of diseases. By analyzing these data compared to a control population of unaffected humans, one can see whether or not PCBs have a significant effect on a group of humans. The International Agency for Research on Cancer labels PCBs as a class of "possible" and "probable" carcinogens (Stellman et al, 1241). Many researchers in different parts of the world have tested this hypothesis. In some studies, in fact, the researchers have been able to show that PCBs are not correlated to a higher rate of cancer occurrence. In one such study, Ward et al evaluated random samples of breast cancer patients' serum and concluded that PCBs are not linked to higher cancer risks (1357-67). The flaws in the methods of this study, however, should caution the readers to doubt the validity of the results. Ward et al did not study a population that was clearly exposed to PCBs. They randomly selected serum samples from cancer patients and studied the chemical toxin levels in these samples. However, while their intention of using a random sample is to exclude subjective bias, in this case it is a poor choice because without predetermined perimeters, blindly searching for potentially significant factors is inefficient; also, a data set of only 150 samples using this approach is too small a sample population for significant conclusions.

In another population study conducted under more careful guidelines, researchers showed that although PCBs do not directly correlate to higher cancer risk in the general population, they show a trend of causing higher risk for cancer in subsets of populations, depending on ethnicity, exposure levels, and preexisting health conditions (Millikan et al, 1237). Although this finding does not conclusively declare that PCBs are carcinogens, it does suggest that PCBs are potential carcinogens and deserve a closer examination using more accurate methods. Human populations are complex systems that have many unknown factors affecting the subjects at once. For this reason, it is difficult to assess the effect of a single toxin on humans based on studies of the vastly different population of humans. Therefore, organismal, cellular, and molecular studies are often more insightful. These studies allow researchers to set control conditions and better understand the exact mechanism of PCBs' activity in humans.

Some researchers have studied the effect of PCBs on mammals using model organisms. Model organisms are a reliable method of such studies because according to theories of evolution, many traits are retained in related species. Rats, for example, have many of the same cellular phenotypes and molecular mechanisms as humans. Since human testing is unethical, rats are excellent models from which scientists can make educated projections of what would happen in humans.

In a recent study using the rat as a model organism, scientists found evidence of PCBs' carcinogenic activity and proposed a possible model of its molecular role in cell cycle controls. In the study conducted by Lu et al, the authors focused on NF-κB, a transcription factor that normally plays a role in cell division cycle control and apoptosis (programmed cell death). In a healthy cell, a complex system of factors provides cues for the cell to replicate and divide at appropriate times. Cells may age and undergo apoptosis. When this system is disrupted, however, cells divide inappropriately and escape apoptosis. A mass of these mutant cells collectively forms a tumor. When these cells become malignant and spread to other parts of an organism, it becomes cancer. Lu et al found that when rats of the same genetic, nutritional, and environmental backgrounds were subjected to PCB injections, their liver tissues were significantly more likely to undergo abnormal cell proliferation. Furthermore, the authors explained that the addition of PCB-153 induces a cytochrome family, which releases superoxides (reactive oxygen species), hence placing cells under oxidative stress, causing the response of increased NF-κB activity (171-80). Through a series of events, the final effect is the induction of cell proliferation and formation of cancer.

Another plausible model of studies that elucidates specific effects of PCBs on humans is the use of human cell cultures. In these experiments, scientists extracted cells from humans and grew them in a culture mimicking physiological conditions. Although some systemic effects cannot be observed because the cells are not interacting with other cells in their natural environment, nevertheless, these studies provide clear evidence of how single cells within humans respond to PCBs. Rattenborg et al used this method to show that PCBs have a negative effect on human cells by disrupting the normal activities of BRCA1. BRCA1 is a breast cancer gene. Previous studies demonstrate a down-regulation of BRCA1 expression in breast and ovarian cancer patients. Rattenborg et al demonstrated that three industrially used PCBs (PCB130, PCB153, and PCB180) all significantly decreased the level of BRCA1 basal expression (12). Such an alteration is linked to the development of cancer in organism studies. This result strongly suggests the possibility that the presence of PCB in humans, particularly women, directly interferes with the promoter region of cancer-critical genes and causes cancer by altering the expression of such gene products.

In addition to causing cancer, a vast number of studies show that PCBs have negative impacts on several other aspects of human health, including decreasing weight of human infants (Baibergenova et al, 1355), reducing male reproductive capabilities by causing a decrease in testosterone and ventral prostate mass (Sridhar et al, 20), reducing female reproductive capabilities including higher infant death rate by upsetting the endocrine system and causing an increase in abnormal menstrual cycles (Yu et al, 675), interfering with serum thyroid hormone levels, thereby causing developmental damage particularly in fetuses, leading to neurodegenerative diseases (Garuger et al, 520), and the list of harm that PCBs cause goes on.

The above evidence undoubtedly indicates that the harm of PCBs on human health is a serious problem. Oregonians must take action to protect the health of the river and the people that live in the Willamette River watershed. The Willamette Restoration Initiative has several suggestions for maintaining a river that does not damage human health, including supporting the Willamette Basin total maximum daily load (TMDL) to limit the concentration of pollutants released into the river on a daily basis, supporting agricultural water quality management, reducing toxic pollutant levels, providing economic incentives to decrease water pollution, and promoting certification programs for developers (Jerrick et al, 5). These suggestions are excellent for general pollutants; however, PCBs no longer come from point sources and are difficult to measure, and therefore require a unique set of solutions in addition to following present resolutions.

The immediate necessary solution is to supply additional government funding to support PCB testing in local waters, particularly in fish. This information will help formulate further detailed steps of remediation actions. However, this goal is difficult to achieve because current economic conditions do not allow distribution of sufficient funding specifically for PCBs. The allocation of funding should be incorporated into laws that Oregonians should pass regarding PCBs. These laws should allocate funding for PCB studies and treatment, and more importantly, restrict the sources of PCBs by further limiting industries that still use PCB-containing materials.

The wise solution to pollution, however, is not simply dilution. A new active research field in microbiology presents the method of bioremediation, which uses microorganisms to clean up wastewater. Some unique microorganisms can use unusual chemical compounds as nutrient sources. These microorganisms can be placed in sludge tanks of the secondary wastewater treatment plants, where they can survive on the toxins in the tank, and humans benefit from this because they break down the toxins to non-hazardous compounds (Madigan et al, 674). Recently, scientists have isolated three marine bacteria strains that can break down PCBs, including *Cycloclasticus pugetii, Alteromonas nucleodii*, and *Neptunomonas naphthovorans* (Fuse et al, 1123). A long-term solution for the PCB problem should be the incorporation of bioremediation using these bacteria in local sewage treatment plants. This is a responsible solution that benefits not only local residents, but also Oregonian's neighbors and future generations.

The most important remediation strategy is to educate Oregonians. The immediate step must focus on education of local residents, primarily those who are unaware of the presence of PCBs and other toxins in the river and fish in the contaminated river. Education of the presence and dangers of PCBs in the fish in the Willamette will prevent people from ingesting the unsafe fish. Second, education should be provided for citizens in general, especially voters who can influence political decisions that deeply affect cleanup of the river. It is extremely important that voters learn the unbiased scientific facts. The knowledge of the real dangers of PCBs is the most powerful motive for Oregonians to make a change. Furthermore, higher education in the scientific community should continue. The research results thus far have provided valuable information. In the future, scientists should resume studying the effects of PCBs in order to find preventions and treatments for the harms and methods of eliminating PCBs in the environment. In addition, such information should be easily accessible to the general public, so that concerned citizens can further educate themselves. Last but not least, education of the importance of keeping a clean and safe environment should start with children. Current education of this subject is insufficient in schools. As residents and future voters of Oregon, children have the right to learn what their river can do to their bodies and what they can do for their river.

The mission of keeping the Willamette River clean and safe is far from over. PCBs are just some of many pollutants that affect the health of Oregonians. Despite past successes of river cleanup, more must be done in the future to protect human health. The Willamette River belongs to Oregonians, and Oregonians have the privilege and the responsibility of caring for this river of life.

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