GE/Housatonic River Site MA/CT

U.S. EPA | HAZARDOUS WASTE PROGRAM AT EPA NEW ENGLAND

THE SUPERFUND PROGRAM *protects human health and the environment by investigating and cleaning up often-abandoned hazardous waste sites and engaging communities throughout the process. Many of these sites are complex and need long-term cleanup actions. Those responsible for contamination are held liable for cleanup costs. EPA strives to return previously contaminated land and groundwater to productive use.*

SITE DESCRIPTION:

PCBs (polychlorinated biphenyls) released from the General Electric facility in Pittsfield, Massachusetts since the 1930's are widespread throughout the Housatonic River and its floodplain, and are found in water, sediment, river banks, floodplain soil, and in both aquatic and terrestrial animals.

INTRODUCTION:

This Fact Sheet summarizes some of the important properties of PCBs as they relate to fate and transport in the Rest of River and shows how the Housatonic River Model Framework is being used to evaluate remedial alternatives. It also provides a concise summary of the effects of PCBs on human health and ecological receptors as demonstrated by the peer-reviewed Human Health and Ecological Risk Assessments. General Electric recently submitted their Revised Corrective Measures Study (RCMS) Report for the Housatonic River Rest of River site. EPA will use the information provided in the CMS, along with other information, including citizen and other stakeholder comments, to develop EPA's preferred approach to addressing PCB contamination in the river and floodplain. EPA welcomes and encourages input from stakeholders and believes that providing this information in a concise fact sheet format will be of use in their review of GE's Revised CMS and EPA's subsequent proposal.

- PCBs are classified as probable human carcinogens.
- PCBs are associated with numerous non-cancer health effects, including neurological, immune, endocrine and reproductive issues.
- PCBs are known to cause adverse effects on numerous Housatonic River ecological receptors, including fish-eating mammals, some birds, fish, amphibians, and benthic invertebrates.
- PCBs are present in large quantities in river sediment and floodplain soil; estimates range from between 100,000 to nearly 600,000 pounds of PCBs.
- The rate of natural degradation of the type of PCBs in the Housatonic River is very slow – on the scale of hundreds of years.
- Currently, more than 50% of the PCBs that enter Woods Pond go over the dam and continue downstream, even into Connecticut.

EPA will be proposing an approach to clean up the PCBs in the Rest of River to protect human health and the environment after the public provides their comments to EPA on GE's Revised Corrective Measures Study. This Fact Sheet reviews what PCBs are and how they move through the environment, and summarizes what EPA knows about the PCBs in the Housatonic River system and their effects.

WHAT ARE PCBs?

PCBs are a group of man-made organic chemicals consisting of carbon, hydrogen, and chlorine atoms. The

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number of chlorine atoms and their location in a PCB molecule determine many of its physical and chemical properties. PCBs have no known taste or smell, and range in consistency from an oil to a waxy solid.

PCBs were manufactured in the US from 1929 until their manufacture was banned in 1979. Due to their non-flammability, chemical stability, high boiling point, and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications including electrical, heat transfer, and hydraulic equipment; as plasticizers in paints, plastics, and rubber products; in pigments, dyes, and carbonless copy paper; and many other industrial applications.

PCBs are a mixture of molecules that contain 12 carbon atoms and a varying number of hydrogen and chlorine atoms. The different combinations of these atoms result in 209 possible PCB molecules, which are called congeners. Some of these congeners have toxicological properties that are similar to those of dioxin.

Aroclor is the trade name used by the Monsanto Company for most of the commercial PCB mixtures created in the United States. Aroclors are mixtures of PCB congeners that were created to have different physical properties, which in turn are largely determined by the amount of chlorine in the overall mixture. These were sold in the US under the name Aroclor followed by a 4-digit number. The first two digits represent the number of carbon atoms (12); the second two digits indicate the percentage of chlorine by mass in the mixture. For example, Aroclor 1260 contains 60% chlorine by mass. Aroclors with lower numbers are "light" oily liquids, while at the higher end they have a "heavier," more waxy form.

The differences between Aroclors can be pronounced; for example, the lighter Aroclor 1242 is made up of 60% of the lighter and less harmful congeners, while the heavier Aroclors 1254 and 1260 (the types of PCBs found in the Housatonic River) have only traces (2% or less) of these more soluble and volatile congeners.

HOW DO PCBs ENTER AND MOVE IN THE ENVIRONMENT?

PCBs entered the air, water, and soil during their manufacture, use, and disposal; from spills and leaks during their transport; and from leaks in products containing PCBs.

WHAT HAPPENS TO PCBs IN THE RIVER DURING STORMS?

Periodic storms, or floods, are a major factor controlling the fate and transport of sediment and bank soil and the associated PCBs in the Housatonic River.

The river rises very quickly in response to storms in the watershed, and river flow can increase dramatically in a matter of a few hours. These events mobilize contaminated sediment from the bottom of the river, erode PCB-contaminated river banks, and transport the sediment, soil, and associated PCBs downstream.

In addition, "out of bank" events, where the amount of water exceeds the amount that can be contained in the river channel, force water and associated sediment/soil and PCBs to flow out onto the floodplain. This is how the PCBs have been, and continue to be distributed throughout the river's 10-year floodplain (i.e., the extent of flooding that is anticipated to occur, on average, once in ten years). Once the water (with the suspended solids and associated PCBs) gets out on the floodplain, the solids and associated PCBs are trapped by the vegetation and settle out as the floodwaters recede, resulting in significant accumulation of PCBs in floodplain soil.

These out-of-bank events have occurred often enough to result in PCB concentrations in floodplain soil that pose risks to humans and to ecological receptors in the floodplain.

Once in the environment, most PCBs do not readily break down and may remain for very long periods of time. PCBs can travel long distances in the air and via suspended solids in water and be deposited in areas far from where they were originally released.

In water, a small amount of PCBs may be dissolved, but most stick to organic particles and soil/sediment. That is because soil and sediment consist not just of mineral particles, but also include organic carbon.

Each congener/PCB mixture has a different potential for degradation. In general, "lighter" PCBs have a higher degradation potential. The heavier PCBs, such as the ones in the Housatonic watershed (Aroclors 1254 and 1260), are more persistent in the environment because they are more resistant to volatilization, weathering, biodegradation and other mechanisms of degradation.

Many different types of natural degradation have been documented in PCB-contaminated sediment and soil; however, although some PCB congeners eventually degrade, the rate of degradation of the type of PCBs found in the Housatonic watershed is very slow, on the scale of hundreds of years.

UPTAKE OF PCBs BY BIOTA

PCBs in the environment are taken up by many animals and a few plants in a process known as bioaccumulation. Bioaccumulation can occur in wild populations and animals that are raised for food in both commercial and backyard operations. The rate of bioaccumulation and the concentration of PCBs in an organism depend on many factors, one of the most important being the amount of fat (lipid) in body. In general, organisms with high amounts of body fat will accumulate higher concentrations of PCBs than those with less fat. The vast majority of PCBs in any living organism will be found in the fat cells. Other factors controlling organism-specific bioaccumulation include life history and diet.

Studies show that while PCBs accumulate rapidly in most animals, they are slow to leave the body. Once they have entered the body, PCBs are moved to fat reservoirs where they tend to remain for long periods of time, typically for the life of the animal, reaching concentrations that may be many thousands of times higher than in water, sediment, or soil, a process known as biomagnification.

PCBs have been measured at very high concentrations in biota in the Housatonic River watershed, leading to consumption advisories for fish, frogs, turtles and waterfowl in MA, and fish in CT.

In contrast, most plants do not bioaccumulate PCBs from contaminated soil due to the presence of a waxy layer, or cuticle, which binds the PCBs and prevents them from being absorbed into the plant. Some plants in the squash family appear to be able to accumulate PCBs from soil via their roots. Studies of tomatoes grown downwind from a PCB-contaminated sediment site demonstrated that lighter, more volatile, congeners released into the atmosphere can be taken up by the leaves and transported into edible portions of the plant. Generally, however, most of the PCBs remain on the surface of fruits and vegetables, often as part of the soil deposited by wind or rainwater splash clinging to the plant.

HOUSATONIC RIVER FATE & TRANSPORT MODEL

Mathematical models, run on computers using equations that simulate the important processes in the system being evaluated, are often used by scientists and engineers to evaluate the behavior of natural and engineered systems.

In the Housatonic River, EPA developed a model of sediment/PCB fate, transport, and bioaccumulation in the river that allows for relatively rapid and cost-effective evaluation of how the PCBs in the river behave in response to no action or various remedial alternatives for the river. EPA's model underwent rigorous testing through calibration and validation to ensure an independent check on model performance. The model also was subject to three Peer Reviews at various stages of development by independent scientific and engineering experts.

MODEL APPLICATION

The Housatonic River model is being used by GE and EPA to gain important insights into current and future conditions in the river and floodplain and in biota. By varying the model setup, any number of remedial scenarios can be simulated.

For example, Figure 1 shows the predicted concentration of PCBs in fish in Woods Pond over more than 50 years in the case of no action (SED1). In contrast, Figure 2 shows the reduction of PCB concentrations in fish with the cleanup of river sediment under SED 4. Figure 3 shows the reduction of PCB concentrations in fish with the cleanup of river sediment under SED 10. The model allows creation of similar output for the

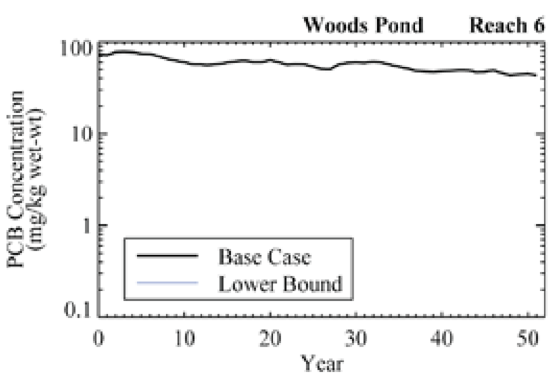

Figure 1: Average PCB concentration in largemouth bass (whole body) in Woods Pond under SED 1/SED 2.
Note: excerpted from Figure K-1.3-1 in GE's Revised Corrective Measures Study Report, October 2010.

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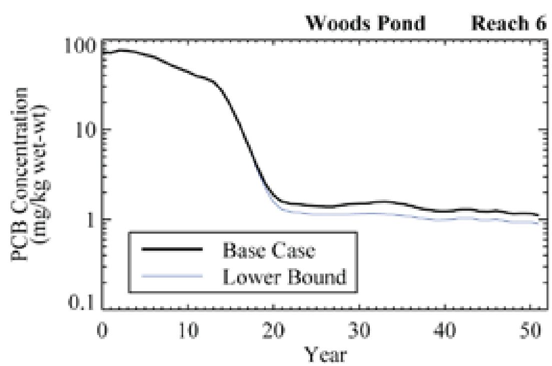

Figure 2: Average PCB concentration in largemouth bass (whole body) in Woods Pond under SED 4.
Note: excerpted from Figure K-1.3-3 in GE's Revised Corrective Measures Study Report, October 2010.

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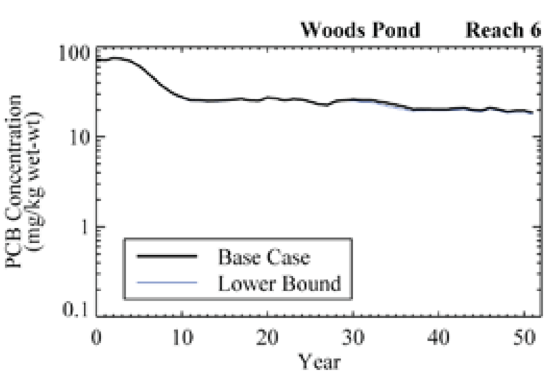

Figure 3: Average PCB concentration in largemouth bass (whole body) in Woods Pond under SED 10.
Note: excerpted from Figure K-1.3-9 in GE's Revised Corrective Measures Study Report, October 2010.

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Please see GE's revised CMS Report for detailed descriptions and evaluations of the ten sediment alternatives. Three example alternatives are described below.

SED 1 No action in all reaches. SED 2 is monitored natural recovery (MNR) with institutional controls (i.e., consumption advisories), periodic fish sampling, water column monitoring, and sediment sampling.

SED 4 Sediment removal in Reach 5A; combination of sediment removal, engineered capping, and/or thin-layer capping in Reaches 5B and 5C and Woods Pond; thin-layer capping in portions of the Reach 5 backwaters. SED 4 includes stabilization of all riverbanks in Reaches 5A and 5B, with removal of bank soil as appropriate. In Reach 6 (Woods Pond) removal areas, an average of 1.5 feet of sediment would be removed, followed by placement of an engineered cap. The remainder of Reach 6 would have a thin-layer cap installed. Monitored natural recovery would be selected for remaining areas in the Reach 5 backwaters and in Reaches 7 through 16.

SED 10 would involve on average a 2-foot sediment removal followed by engineered capping in selected portions of Reach 5A. For Reaches 5A and 5B, selected riverbanks would be stabilized. In Woods Pond, selected areas of sediment with elevated PCB concentrations will be removed to an average depth of 2.5 feet. No caps or backfill material will be placed after sediment removal in Woods Pond. Monitored natural recovery would be selected for the remainder of the Rest of River.

THE ROLE OF IMPOUNDMENTS

The role of impoundments in a river system is important in the fate and transport of PCBs. Because the more highly chlorinated PCBs are not easily dissolved in water, they are primarily transported while attached to particles of suspended solids rather than dissolved in the water itself. These suspended particles fall out of the water at a constant rate whether the water is moving or relatively still in an impoundment behind a dam.

However, because the water remains in an impoundment longer than in the fast-running reaches, relatively more suspended sediment can settle to the bottom, resulting in some accumulation of PCBs in impoundments.

The Housatonic River fate and transport model clearly shows this trapping behavior of the impoundments on the river, but also shows that the trapping is far less than 100% effective. For example, less than one-half of the PCBs entering Woods Pond are trapped in the Pond, leaving the remaining PCBs to pass over Woods Pond Dam and be carried downstream.

various remedial options currently under consideration, showing the relative effectiveness of the various options in reducing PCBs in the system.

HEALTH EFFECTS FROM PCBs

PCBs have been demonstrated to cause a wide variety of adverse health effects. PCBs have been shown to cause cancer in animals. PCBs have also been shown to cause a number of serious non-cancer health effects in animals, including effects on the immune system, reproductive system, nervous system, endocrine system and other organs. Studies in humans provide supportive evidence for potential carcinogenic and non-carcinogenic effects of PCBs. The different health effects of PCBs may be interrelated, as alterations in one system may have significant implications for the other systems of the body. Some PCB congeners exhibit dioxin-like effects.

Cancer

Studies definitively show that PCBs cause cancer in animals. The data strongly suggest that PCBs are probable human carcinogens, and EPA and the International Agency for Research on Cancer have classified them as such.

Immune Effects

Studies in animals have revealed serious effects on the immune system following exposures to PCBs, including a significant decrease in size of the thymus gland, reductions in the response of the immune system following a challenge with sheep red blood cells (a test of the antibody response and protective immunity), and decreased resistance to Epstein-Barr virus and other infections. Immune effects were also noted in humans who experienced exposure to rice oil contaminated with PCBs, dibenzofurans and dioxins.

Reproductive Effects

Reproductive effects of PCBs have been studied in animal species. Potentially serious effects on the reproductive system were seen following exposures to PCB mixtures. Most significantly, PCB exposures were found to reduce the birth weight, conception rates, and live birth rates of monkeys and other species, and PCB exposure reduced sperm counts in rats. Effects in monkeys were long-lasting and were observed long after the dosing with PCBs occurred. Studies of reproductive effects have also been carried out in human populations exposed to PCBs. Children born to women who worked with PCBs in factories, and studies in fishing populations, showed decreased birth weight and a significant decrease in gestational age with increasing exposures to PCBs.

Neurological Effects

Effects of PCBs on nervous system development have been studied in animal species. Newborn monkeys exposed to PCBs showed persistent and significant deficits in neurological development, including visual recognition, short-term memory and learning. Studies in humans have suggested effects similar to those observed in monkeys exposed to PCBs, including learning deficits and changes in activity associated with exposures to PCBs.

Endocrine Effects

PCBs have been demonstrated to exert effects on thyroid hormone levels in animals and humans.

Other Non-cancer Effects

A variety of other non-cancer effects of PCBs have been reported in animals and humans, including skin and eye effects and liver toxicity. Elevations in blood pressure, serum triglyceride, and serum cholesterol have also been reported with increasing serum levels of PCBs in humans.

IN-PLACE (IN SITU) DEGRADATION

Considerable research, some of it conducted in and/or with sediment from Woods Pond, and soil from the watershed, has been done in an attempt to find ways to enhance natural degradation of PCBs, but to date no effective in situ methodology has been developed. In addition, many degradation pathways produce chemicals that are more toxic than the original PCB congeners. While enhanced natural degradation of PCBs remains an attractive potential treatment for PCBs in the environment, it is a potential that has yet to be realized for PCBs like those in the Housatonic River.

Effects to Ecological Receptors

PCBs in the environment affect ecological receptors to varying degrees and in a variety of ways; these differences in the nature and extent of PCB effects depend in part on the specific PCB congeners present, as well as natural differences in basic physiological processes, diet, and life history among animal species. With the type of PCBs and concentrations measured in the Housatonic River and its floodplain, effects are considered likely. In a number of cases, significant adverse effects were documented in site-specific field and/or laboratory studies for the representative animal species evaluated in the Housatonic River Ecological Risk Assessment.

The known toxic effects of PCBs on aquatic species and wildlife include mortality, compromises in immune system function, and various adverse effects on reproduction, development, and endocrine function, in addition to a number of equally serious effects on other body systems. PCB exposure leads to a loss of liver function and death of liver tissue, and similar effects to the tissues and organs of the digestive system. The nervous systems of animals are also affected, with resultant depression of motor activity and decreased perception. Other effects include behavioral abnormalities, impaired reproduction, and developmental toxicity. PCBs have been demonstrated in laboratory studies to promote cancer in a number of animal species. In sufficient doses, PCB exposure can lead to acute mortality in aquatic and wildlife species, and chronic exposure to lower doses can also result in mortality, leading to changes in community and ecosystem structure and function.

Benthic Invertebrates

PCBs in sufficient concentrations, which are exceeded in sediment in some areas of Housatonic River, are acutely toxic to aquatic organisms, particularly benthic invertebrates at the base of the aquatic food chain. These effects are commonly expressed by the absence of species of known sensitivity to PCBs, and as alterations in the structure of the benthic community when the more-sensitive species are replaced by more pollution-tolerant organisms. Non-lethal effects of PCBs on benthic organisms include reduction in growth and number of offspring. All of these types of effects were clearly demonstrated in the site-specific studies conducted using Housatonic River sediment and well-established sediment toxicity testing organisms. In addition, benthic community impairment also corresponded to PCB sediment concentration.

Normal Leopard Frog Egg Mass

Egg Mass From Contaminated Vernal Pool

WHAT'S NEXT?

GE submitted its Revised Corrective Measures Study (RCMS) on October 12, 2010. The report includes GE's recommendations on which alternatives the company believes best meet the objectives and criteria specified for the Rest of River project. These recommendations do not necessarily reflect EPA's views on the alternative that best meets the criteria in the permit. The alternatives are to be evaluated using the nine criteria specified in the Revised RCRA Permit. The public currently has an opportunity to provide input to EPA on GE's RCMS. EPA is currently reviewing GE's RCMS, as well as GE's previous CMS submitted in March of 2008, and input from the public. After conducting its review and analyses, EPA will propose a cleanup plan for the Rest of River for public comment.

Fish

Fish from the Housatonic River that were captured and bred in captivity were shown to produce larvae with increased incidence of a wide variety of deformities, many of which are reported in the scientific literature to be related to PCB exposure. However, because of the large number of eggs fish produce and high natural mortality of the young, the effects of PCBs on the local fish populations do not appear to be significant.

Amphibians

Harmful effects can include damage to the reproductive organs of adults as well as decreased viability of offspring and life-threatening deformities in larvae. A number of reproductive effects such as deformed gonads (see pictures on page 5), impaired development, altered sex ratio, and larval deformities were observed in frogs and frog larvae exposed to PCBs from the Housatonic River floodplain vernal pools and backwaters.

Birds

PCB exposure has been demonstrated in species such as chickens and pheasants to cause decreased egg production and fertility with relatively low PCB exposure, and mortality with higher exposures. In contrast to the animal groups discussed above, however, some bird species such as hawks and finches appear to be less sensitive to the harmful effects of PCBs. Site-specific studies conducted on tree swallows, kingfishers, and robins in the Housatonic River study area did not identify severe effects as a result of PCB exposure. However, although no field study was conducted on wood ducks, measured exposures suggest that harm is likely for that species from dioxin-like PCBs. In addition, very high concentrations of PCBs were present in the migratory waterfowl sampled by EPA. Estimated exposure derived from their fish diet indicates the high probability of risk to fish eating birds such as osprey and bald eagles.

Piscivorous Mammals

Piscivorous (fish-eating) mammals such as mink and otter receive elevated exposure to PCBs with their diet of contaminated fish, due to bioaccumulation. In addition, certain piscivorous mammals, particularly mink, have been shown in the scientific literature to have unusually high sensitivity to the effects of PCBs.

In a carefully controlled dietary study conducted at the University of Michigan, the young (kits) of female mink fed a diet containing fish

Estimated Amount of PCBs in the Housatonic River and Floodplain

Housatonic River Sediment

	PCB Mass (lbs)
Channel - Confluence to Woods Pond	13,000 – 51,000
Backwaters	2,000 – 18,000
Woods Pond	3,000 – 29,000
Woods Pond Dam to Rising Pond Dam	3,900 – 14,000
Rising Pond Dam to CT Border	60 – 110
CT Border to Long Island Sound	120 – 5,000
Total	22,000 – 118,000

Housatonic River Floodplain Soil

	PCB Mass (lbs)
Confluence to Woods Pond	80,000 – 436,000
Woods Pond	350 – 4,800
Woods Pond Dam to Rising Pond	5,300 – 15,000
Rising Pond	30 - 90
Rising Pond Dam to CT Border	2,400 – 2,800
Total	89,000 – 460,000

collected from the Housatonic River were shown to suffer from increased significant increased mortality and developed jaw lesions that would lead to death in the wild due to inability to consume a normal diet.

This study was corroborated by the result of field investigations indicating the absence of resident reproducing mink and otter, despite the highly suitable habitat present in the river and floodplain.

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Housatonic Valley Association
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Important update