



PUBLIC HEALTH STATEMENT

Polybrominated Diphenyl Ethers

Division of Toxicology

September 2004

This Public Health Statement is the summary chapter from the Toxicological Profile for Polybrominated Biphenyls and Polybrominated Diphenyl Ethers. It is one in a series of Public Health Statements about hazardous substances and their health effects. A shorter version, the ToxFQATM, is also available. This information is important because these substances may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present. For more information, call the ATSDR Information Center at 1-888-422-8737.

This public health statement tells you about polybrominated diphenyl ethers (PBDEs) and the effects of exposure to PBDEs.

The Environmental Protection Agency (EPA) identifies the most serious hazardous waste sites in the nation. These sites are then placed on the National Priorities List (NPL) and are targeted for long-term federal clean-up activities. PBDEs have not been found in the 1,647 current or former NPL sites. Although the total number of NPL sites evaluated for these substances is not known, the possibility exists that PBDEs may be found in the future as more sites are evaluated. This information is important because these sites may be sources of exposure and exposure to these substances may harm you.

When a substance is released either from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. Such a release does not always lead to exposure. You can be exposed to a substance only when you

come in contact with it. You may be exposed by breathing, eating, or drinking the substance, or by skin contact.

If you are exposed to PBDEs, many factors will determine whether you will be harmed. These factors include the dose (how much), the duration (how long), and how you come in contact with PBDEs. You must also consider any other chemicals you are exposed to and your age, sex, diet, family traits, lifestyle, and state of health.

1.1 WHAT ARE PBDEs?

PBDEs are flame-retardant chemicals that are added to a variety of consumer products to make them difficult to burn. Because PBDEs are added rather than reacted to the product, they could leave the product under ideal conditions and enter the environment, but this rarely happens. The first commercial productions of PBDEs began in the 1970s in Germany. Production of PBDEs has continued until the present. There are three commercial PBDE products (i.e., penta-, octa-, and decabromodiphenyl ethers). Deca- and octa-brominated types of PBDEs are also produced outside of the United States (in China and Israel). Decabromodiphenyl ether (decaBDE) makes up 82% of these products manufactured globally. Its main use is for electronic enclosures, such as television cabinets. Octabromodiphenyl ether (octaBDE) product is used in plastics for business equipment. Pentabromodiphenyl ether (pentaBDE) product is used in foam for cushioning in upholstery. PBDEs have not been associated with actual health-related effects. Concerns have increased, however, because some of these

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chemicals (particularly the pentaBDEs) have been found in the environment at varying concentrations. Environmental concentrations of lower brominated PBDEs, which may be leveling off in Europe, appear to be increasing in certain areas of Canada and the United States.

PBDEs are a group of synthetic organic chemicals with no known natural sources in the environment, except for a few marine organisms that produce forms of PBDEs that contain higher levels of oxygen. Commercial decaBDE and octaBDE products are colorless to off-white solids, whereas commercial pentaBDE product is a thick liquid. PBDEs are not expected to evaporate into the air. PBDEs in the air are mostly found with dust rather than as a vapor. PBDEs enter the environment as mixtures containing a variety of individual brominated diphenyl ether (for PBDEs) components, known as congeners. Congeners are distinct members of a class of chemical substances. Some commercial mixtures of PBDEs may be known by their industrial trade names, (i.e., DE-60F Special, DE-61, DE-62, DE-71, DE-79, DE-83R, Saytex® 102E). PBDEs are still produced and widely used in the United States, although the sole manufacturer of penta- and octaPBDE commercial products in the United States is expected to quit making these chemicals by the end of 2004.

1.2 WHAT HAPPENS TO PBDEs WHEN THEY ENTER THE ENVIRONMENT?

PBDEs enter air, water, and soil during their manufacture and use in consumer products. When PBDEs are suspended in air, they can be present as particles. They eventually return to land or water as

the dust settles and are washed out by snow and rainwater. It is not yet possible to say how long PBDEs remain in the air. PBDEs do not dissolve easily in water, and therefore, high levels of PBDEs are not found in water. The very small amounts of PBDEs that do occur in water stick to particles and eventually settle to the bottom. Sediments at the bottom of bodies of water, such as lakes and rivers, generally act as reservoirs for decaBDEs, which can remain there for years. Some lower brominated PBDEs (e.g., tetra- and penta-congeners of PBDE) in water may build up in fish to low concentrations (about 10 billionths of a gram to 1 millionth of a gram of PBDE per gram of fresh fish [or 10×10^{-9} – 1×10^{-6} grams of PBDE per gram of fresh fish]). However, higher brominated PBDEs, such as decaBDE, are not found in fish at measurable concentrations. In general, the breakdown of PBDEs in soil is very slow, so they may remain in soil for several years. PBDEs bind strongly to soil particles. Rainwater is not expected to spread them much below the soil surface; thus, it is unlikely that PBDEs will enter groundwater.

1.3 HOW MIGHT I BE EXPOSED TO PBDEs?

Certain PBDE mixtures, especially decaBDE, are produced in many places in the world. Currently, the United States is the only producer of the pentaBDE mixture for commerce. However, production pentaBDE and octaBDE for commerce soon will begin to be phased out in the United States and elsewhere. Lower brominated PBDEs, such as tetraBDE and pentaBDE congeners, are found throughout the environment and are found at low levels in air, sediments, animals, and food. The

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concentrations of lower brominated PBDEs in blood, breast milk, and body fat indicate that most people are exposed to low levels of these PBDEs. Concentrations of lower brominated PBDEs have been increasing in tissues and body fluids of individuals living in the United States. Currently, levels of lower brominated PBDE congeners in individuals living in the United States are greater than levels reported in other regions of the world. Highly brominated congeners, such as decaBDE, are not commonly found throughout the environment. They may be found at low levels close to places where they are produced or used. In 2001, PBDEs were detected in dust and smoke samples taken near the World Trade Center disaster site. Although no definitive studies in the United States have been conducted to identify the sources of exposure, people appear to be exposed to the lower brominated congeners of PBDEs by eating food that contains these PBDEs. In the United States, the concentration of PBDEs (primarily the tetra- and penta-brominated congeners of PBDEs) in outdoor air ranges from 2 to 77 trillionths of a gram per cubic meter (or $2-77 \times 10^{-12}$ grams/m³), which indicates low levels of exposure of the general population to these PBDEs. Indoor air concentrations of PBDEs in lecture halls, indoor environments with computers, and rooms with computers or other electronic devices, such as television sets, also have low levels of PBDEs in suspended dust. Workers involved in the manufacture and production of PBDE-containing resins are exposed to higher concentrations of PBDEs. Occupational exposure can also occur in confined workplaces where plastic and foam products containing PBDEs are recycled, or where computer monitors containing PBDEs are repaired. People who live near hazardous waste sites may be exposed to PBDEs by breathing air containing

PBDE-contaminated dust. However, PBDE eventually settles or washes out of the air, so this potential exposure route likely to be minimal.

1.4 HOW CAN PBDEs ENTER AND LEAVE MY BODY?

The main source of exposure to PBDEs may be through foods, particularly those with high fat content, such as fatty fish. Some lower brominated PBDEs have been detected in air samples, indicating that people can also be exposed by inhalation. The ways that PBDEs might enter and leave your body depend on the chemical structures of the congener components. The higher brominated PBDEs, particularly decaBDE (the major PBDE in use today), act much differently in the body than do lower brominated PBDEs. If you breathe air that contains PBDEs, or swallow food, water, or soil contaminated with PBDEs, the lower brominated congeners are much more likely than decaBDE to enter your body through your lungs and stomach and pass into the bloodstream. If you touch soil containing PBDEs, which could happen at a hazardous waste site, it is highly unlikely that either lower or higher brominated PBDEs would pass through your skin into the bloodstream. Once PBDEs are in your body, the congeners might partially change into breakdown products called metabolites. DecaBDE might leave your body unchanged or as metabolites, mainly in the feces and in very small amounts in the urine, within a few days. Lower brominated PBDEs, generally tetra-, penta-, and hexaBDE congeners, might stay in your body for many years, stored mainly in body fat. The lower brominated PBDEs also tend to concentrate in breast milk fat, and can enter the

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bodies of children through breast feeding. PBDEs also can enter the bodies of unborn babies through the placenta.

1.5 HOW CAN PBDEs AFFECT MY HEALTH?

Scientists use many tests to protect the public from harmful effects of toxic chemicals and to find ways for treating persons who have been harmed.

One way to learn whether a chemical will harm people is to determine how the body absorbs, uses, and releases the chemical. For some chemicals, animal testing may be necessary. Animal testing may also help identify health effects such as cancer or birth defects. Without laboratory animals, scientists would lose a basic method for getting information needed to make wise decisions that protect public health. Scientists have the responsibility to treat research animals with care and compassion. Scientists must comply with strict animal care guidelines because laws today protect the welfare of research animals.

Nothing definite is known about the health effects of PBDEs in people. Practically all of the available information is from studies of laboratory animals. Animal studies indicate that commercial decaBDE mixtures are generally much less toxic than the products containing lower brominated PBDEs. Because of its very different toxicity, decaBDE is expected to have relatively little effect on the health of humans. Rats and mice that ate food containing moderate amounts of lower brominated PBDEs for short periods of time had mainly thyroid effects. Rats and mice that ate smaller amounts over several

weeks or months developed effects in the liver and in the thyroid. It is speculated that many of the thyroid effects of PBDEs are specific to the species of test animals, suggesting that they are less likely to occur in humans. Subtle behavioral changes have been observed in animals exposed to PBDEs as infants. One possible explanation for the behavioral effects might be related to changes in the thyroid, because development of the nervous system is dependent on thyroid hormones. PBDEs have not caused other kinds of birth defects in animals, but more studies are needed to determine if PBDEs can impair reproduction. Preliminary findings from short-term animal studies suggest that some PBDEs might impair the immune system. Animals exposed to PBDEs by skin contact showed signs of skin irritation only if they had been scratched.

We don't know if PBDEs can cause cancer in people, although liver tumors developed in rats and mice that ate extremely large amounts of decaBDE throughout their lifetime. On the basis of evidence for cancer in animals, decaBDE is classified as a possible human carcinogen by EPA. Lower brominated PBDEs have not yet been tested for cancer. Neither the U.S. Department of Health and Human Services (DHHS) nor the International Agency for Research on Cancer (IARC) have classified the carcinogenicity of any PBDEs.

We don't know whether the effects found in animals exposed to PBDEs would also occur in people exposed in the same way. The amounts of PBDEs that caused health effects in animals are much greater than levels of PBDEs normally found in the environment. Long-term exposure to PBDEs has a greater potential to cause health effects than does short-term exposure to low levels because of their tendency to build up in your body over many

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years. Additionally, the lower brominated commercial pentaBDE and octaBDE products are much more likely to cause health effects than is decaBDE.

1.6 HOW CAN PBDEs AFFECT CHILDREN?

This section discusses potential health effects in humans from exposures during the period from conception to maturity at 18 years of age.

Children are exposed to PBDEs in generally the same way as are adults, probably mainly by eating contaminated food. Because of their smaller weight, children's intake of PBDEs per kilogram (or pound) of body weight may be greater than that of adults. The most likely way that infants might be exposed to PBDEs is from breast milk containing lower brominated congeners, although fetuses in the womb could also be exposed. DecaBDE is poorly absorbed in the body and, therefore, is unlikely to be found in breast milk or the fetus to any significant extent. Children who live near hazardous waste sites might accidentally eat some PBDEs by putting dirty hands or other soil/dirt covered objects in their mouths, or through eating without washing their hands. Some children also eat dirt on purpose. It is also possible that children could be exposed to PBDEs following transport of the chemical on clothing from the parent's workplace to the home.

As indicated above, children can be exposed to PBDEs—mainly the lower brominated congeners—both before birth and from breast milk. The lower brominated PBDEs are much more likely than

decaBDE to be stored in the mother's body and released during pregnancy, cross the placenta, and entering fetal tissues. Because lower brominated PBDEs dissolve readily in fat, they can accumulate in breast milk fat and be transferred to babies and young children. Lower brominated PBDEs have been found in breast milk. In most cases, however, the benefits of breast-feeding outweigh any risks from exposure in mother's milk. You should consult your health care provider if you have any concerns about PBDEs and breast feeding. The nervous system and thyroid are still developing in the fetus and child. That means the effects of lower brominated PBDEs on these systems might be more significant if exposure occurs during the periods before and soon after birth. That suggests that fetuses and children are more susceptible to PBDEs than adults.

1.7 HOW CAN FAMILIES REDUCE THE RISK OF EXPOSURE TO PBDEs?

If your doctor finds that you have been exposed to substantial amounts of PBDEs, ask whether your children might also have been exposed. Your doctor might need to ask your state health department to investigate.

PBDEs are currently in widespread production and use. However, production of commercial pentaBDE and octaBDE products will soon begin to be phased out in the United States and elsewhere. You and your children may be exposed to lower brominated PBDEs by eating fish or wildlife from contaminated locations. Children who live near hazardous waste sites should be discouraged from playing in the dirt near these sites because they

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could contain PBDEs. Children should also be discouraged from eating dirt, and careful handwashing practices should be followed.

As mentioned in Section 2.3, workplace exposure to PBDEs can occur during the production of commercial PBDE mixtures and of PBDE-containing plastic products. Workers involved in recycling plastic products, or who repair computers in confined workplaces can also be exposed to PBDEs. If you are exposed to PBDEs while at work, you may carry them home on your clothes or body. Your occupational health and safety officer at work can tell you whether the products you work with may contain PBDEs and whether those are likely to be carried home. If this is the case, you should shower and change clothing before leaving work. Your work clothes should be kept separate from other clothes and laundered separately.

1.8 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO PBDEs?

Special tests can determine whether PBDEs are in the blood, body fat, and breast milk. These are not regular or routine clinical tests, but could be ordered by a doctor to detect PBDEs in people exposed to them in the environment and at work. If your PBDE levels are higher than the normal levels, this will show that you have been exposed to high levels of the chemicals. However, these measurements cannot determine the exact amount or type of PBDEs that you have been exposed to, or how long you have been exposed. Blood tests cannot distinguish between recent or past exposures to PBDEs because these chemicals remain in the body

a long time. Although tests can indicate whether you have been exposed to PBDEs to a greater extent than the general population, they do not predict whether you will be harmed. Blood tests are the easiest, safest, and probably the best method for detecting recent exposures to large amounts of PBDEs. Results of such tests should be reviewed and carefully interpreted by physicians with a background in environmental and occupational medicine. Nearly everyone has been exposed to pentaBDE commercial mixtures because they are found throughout the environment. That means people are more likely to have detectable amounts of the lower brominated PBDEs in their blood, fat, and breast milk. Recent studies have shown that levels of lower brominated PBDEs in the general population of the United States continue to rise. The U.S. levels are 10–100 times higher than levels in individuals living in Europe.

1.9 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?

The federal government develops regulations and recommendations to protect public health. Regulations *can* be enforced by law. The EPA, the Occupational Safety and Health Administration (OSHA), and the Food and Drug Administration (FDA) are some federal agencies that develop regulations for toxic substances. Recommendations provide valuable guidelines to protect public health, but *cannot* be enforced by law. The Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH) are two federal organizations that develop recommendations for toxic substances.

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Regulations and recommendations can be expressed as “not-to-exceed” levels, that is, levels of a toxic substance in air, water, soil, or food that do not exceed a critical value that is usually based on levels that affect animals. Those levels are then adjusted to levels that will help protect humans. Sometimes these not-to-exceed levels differ among federal organizations because they used different exposure times (an 8-hour workday or a 24-hour day), different animal studies, or other factors.

Recommendations and regulations are also updated periodically as more information becomes available. For the most current information, check with the federal agency or organization that provides it. Some regulations and recommendations for PBDEs include the following:

EPA requires that companies that transport, store, or dispose of *p*-bromodiphenyl ether (a particular PBDE compound not found in any commercial PBDE product) follow the rules and regulations of the federal hazardous waste management program. EPA also limits the amount of *p*-bromodiphenyl ether put into publicly owned waste water treatment plants. To minimize exposure of people to *p*-bromodiphenyl ether, EPA requires that industry tell the National Response Center each time 100 pounds or more of *p*-bromodiphenyl ether have been released to the environment.

1.10 WHERE CAN I GET MORE INFORMATION?

If you have any more questions or concerns, please contact your community or state health or environmental quality department, your regional

Nuclear Regulatory Commission office, or contact ATSDR at the address and phone number below.

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

Toxicological profiles are also available on-line at www.atsdr.cdc.gov and on CD-ROM. You may request a copy of the ATSDR ToxProfiles™ CD-ROM by calling the information and technical assistance toll-free number at 1-888-42ATSDR (1-888-422-8737), by email at atsdric@cdc.gov, or by writing to:

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1600 Clifton Road NE
Mailstop F-32
Atlanta, GA 30333
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For-profit organizations may request a copy of final profiles from the following:

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161
Phone: 1-800-553-6847 or 1-703-605-6000
Web site: <http://www.ntis.gov/>

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