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This Statement was prepared to give you information about chlorinated dibenzofurans (CDFs) and to emphasize the human health effects that may result from exposure to them. The Environmental Protection Agency (EPA) has identified 1,350 hazardous waste sites as the most serious in the nation. These sites comprise the "National Priorities List" (NPL): Those sites which are targeted for long-term federal cleanup activities. CDFs have been found in at least 57 of the sites on the NPL. However, the number of NPL sites evaluated for CDFs is not known. As EPA evaluates more sites, the number of sites at which CDFs is found may increase. This information is important because exposure to CDFs may cause harmful health effects and because these sites are potential or actual sources of human exposure to CDFs.

When a substance is released from a large area, such as an industrial plant, or from a container, such as a drum or bottle, it enters the environment. This 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 substances containing the substance or by skin contact with it.

If you are exposed to substances such as CDFs, many factors will determine whether harmful health effects will occur and what the type and severity of those health effects will be. These factors include the dose (how much), the duration (how long), the route or pathway by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics such as age, gender, nutritional status, family traits, life-style, and state of health.

1.1 WHAT ARE CDFs?

CDFs are a family of chemicals known as chlorinated dibenzofurans. These chemicals contain one to eight chlorine atoms attached to the carbon atoms of the parent chemical, dibenzofuran. The CDF family contains 135 individual compounds (known as congeners) with varying harmful health and environmental effects. Of these 135 compounds, those that

contain chlorine atoms at the 2,3,7,8-positions of the parent dibenzofuran molecule (see Section 3.1) are especially harmful. Other than for laboratory use of small amounts of CDFs for research and development purposes, these chemicals are not deliberately produced by industry. Most CDFs are produced in very small amounts as unwanted impurities of certain products and processes utilizing chlorinated compounds. Only a few of the 135 CDF compounds have been produced in large enough quantities so that their properties, such as color, smell, taste, and toxicity could be studied. The few CDF compounds that have been produced in those quantities are colorless solids. They do not dissolve in water very easily. There is no known use for these chemicals. You will find further information on the physical properties of these compounds in Chapter 3 of this profile. CDFs are often found in association with dibenzo-p-dioxins (CDDs), which cause similar toxic effects.

1.2 WHAT HAPPENS TO CDFs WHEN THEY ENTER THE ENVIRONMENT?

Small amounts of CDFs can enter the environment from a number of sources. Accidental fires or breakdowns involving capacitors, transformers, and other electrical equipment (e.g., fluorescent light fixtures) that contain polychlorinated biphenyls (PCBs) are known to release high levels of CDFs formed by thermal degradation. A fire involving a transformer containing PCBs contaminated the State Office Building in Binghamton, New York, with CDFs. Accidents of a different kind involving heated PCBs occurred in Japan (Yusho incident) and Taiwan (Yu-Cheng incident). These incidents involved exposure to CDFs-contaminated PCBs that were used as a heat exchanger fluid for processing rice oil and which accidentally leaked into the oil. CDFs are also produced as unwanted compounds during the manufacture of several chlorinated chemicals and consumer products, such as wood treatment chemicals, some metals, and paper products. When the waste water, sludge, or solids from these processes are released into waterways or soil in dumpsites, they become contaminated with CDFs. CDFs also enter into the environment from burning municipal and industrial waste in incinerators. The exhaust from cars that use leaded gasoline, which contains chlorine, releases small amounts of CDFs in the environment. Small amounts of CDFs may also enter into the environment from burning of coal, wood, or oil for home heating and

production of electricity. Many of these chemicals or processes that produce CDFs in the environment are either being slowly phased out or strictly controlled.

CDFs in air are present mostly as solid particles and to a much lesser extent as vapor. Some of the CDFs present in air return to the land and water by settling, snow, and rainwater. An amount of CDFs in the vapor phase is destroyed by reacting with certain chemical agents (called hydroxyl radicals) naturally present in the atmosphere. CDFs may remain in air for an average of more than 10 days depending on the CDF compound. Once in the air, CDFs can be carried long distances. They have been found in air and waters and at the bottom of lakes and rivers in areas far away from where they were released into the environment. CDFs tend to stick to suspended particles and settled particles in lakes and rivers and can remain at the bottom of lakes and rivers for several years. Sediment acts as a medium where CDFs that are present in air or water eventually settle. CDFs can build up in fish, and the amount of CDFs in fish can be tens of thousands times higher than the levels in water. The CDFs in water can get into birds or other animals and humans that eat fish containing CDFs. CDFs bind strongly to soil and are not likely to move from the surface soil into groundwater. In some instances, CDFs from some waste landfills may reach underground water. CDFs are more likely to move from soil to water or other soils by soil erosion and flooding. The breakdown or loss of CDFs in soil occurs over years, so CDFs remain in soil for years. Most CDFs found in plants are probably deposited by air. Cattle that eat plants on which CDFs have been deposited will build up some of the CDFs in their bodies. Some of the CDFs will enter the milk and meat of cattle. You will find more information about the fate and movement of CDFs in the environment in Chapter 5.

1.3 HOW MIGHT I BE EXPOSED TO CDFs?

CDFs are found at very low levels in the environment of industrial countries and at even lower levels in nonindustrial countries. People are exposed to very small levels of CDFs by breathing air, drinking water, and eating food, but most human exposure comes from food containing CDFs. The levels of CDFs in air are usually higher in city and suburb areas than in rural areas. The concentration of CDFs in city and suburb areas ranges from less than one

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femtogram (fg) (one quadrillionth of a gram, that is 1/100,000,000,000th of a gram) to a few picograms (pg) in a cubic meter (m^3) of air. The levels in rural air are usually so low that measurements are not possible. The levels of CDFs in most drinking waters are also below the level that can be measured. CDFs were found in drinking water of one of the 20 water supplies in New York State at a concentration of 3.4 parts of CDF in a quadrillion part of water. CDFs are not found in soils that have not been polluted. CDFs have been detected in the stack emissions and ash from certain industries and processes that are sources of these compounds in air at levels that are thousands of times higher than the levels in the air that we usually breathe. Once emitted in the air from stacks, CDFs are dispersed by the cleaner air and the level of CDFs drops substantially. Similarly, the levels of CDFs in waste waters from certain industries and in soil at dumpsites can be thousands to millions times higher than the levels found in clean water and soil.

Some products you use, such as paper towels, coffee filters, tampons, and milk cartons, can contain extremely low levels of CDFs. The intake of CDFs from these sources is very low. Since CDFs tend to concentrate in the fat, and milk contains fat, mother's milk can be a source of CDFs for babies. But considering the small amounts of CDFs in milk and the other beneficial effects of human milk to a baby and the length of time a baby uses mother's milk, scientists believe that mother's milk, on balance, is still beneficial to babies. Cow's milk and formula usually contain lower amounts of CDFs than human milk. Children playing in dumpsites may come in contact with CDFs through their skin and by eating dirt. It has been estimated that over 90% of the total daily intake of CDFs (on the order of a few pg per day) for the general adult population occurs from eating food containing them. The rest comes from air, consumer products, and drinking water. Meat and meat products, fish and fish products, and milk and milk products contribute equally to intake of CDFs from food, while intake from vegetable products contributes much less. Eating large amounts of fatty fish from water containing CDFs may increase your daily intake of CDFs from food.

People in certain occupations may be exposed to higher levels of CDFs than the general population. Exposure in the workplace occurs mostly by breathing air and touching substances that contain CDFs. Workers involved with cleaning up after transformer fires,

workers in the pulp and papermill industry, workers in municipal incinerators, and workers in sawmills may be exposed to higher levels of CDFs than the general population. Contact with CDFs at hazardous waste sites can happen when workers breathe air or touch soil containing CDFs. You will find more information about CDF exposure in Chapter 5 of this profile.

1.4 HOW CAN CDFs ENTER AND LEAVE MY BODY?

If you breathe air that contains CDFs, they can enter your body through your lungs and pass into the bloodstream, but we do not know how fast this occurs or how much of the CDFs will pass into the bloodstream. If you swallow food, water, or soil contaminated with CDFs, most of the CDFs will probably enter your body and pass from the stomach into the bloodstream, but we do not know how fast this occurs. If you touch soil containing CDFs, which might occur at a hazardous waste site, some of the CDFs will pass through your skin into the bloodstream, but we do not know how fast this occurs. Most commonly, CDFs enter your body when you eat food contaminated with CDFs, in particular fish and fish products, meat and meat products, and milk and milk products containing CDFs. Exposure from drinking water is less than that from food. For people living around waste sites and for people who work with or around other chemicals that produce CDFs when heated, skin contact with contaminated soil or breathing CDF vapors are the most likely ways CDFs will enter the body. Once CDFs are in your body, some may change into breakdown products called metabolites. We do not know whether these metabolites are harmful. Some metabolites and some unchanged CDFs may leave your body mainly in the feces and in very small amounts in the urine in a few days, but other unchanged CDFs may stay in your body and be stored for years in your body fat. CDFs build up in milk fat and can enter the bodies of infants through breast feeding. CDFs can also enter the bodies of unborn babies through the placenta. For more information on how CDFs can enter and leave your body, see Chapter 2.

1.5 HOW CAN CDFs AFFECT MY HEALTH?

Much of what we know about the health effects of CDFs comes from studies of accidental poisonings in Japan and Taiwan in the 1960s and 1970s where many people ate food cooked

in contaminated rice oil for several months. In both of these incidents, the rice oil was contaminated with PCBs that contained CDFs. The amounts of CDFs that these people accidentally ate were much higher than those normally found in your diet. Skin and eye irritations, especially severe acne, darkened skin color, and swollen eyelids with discharge, were the most obvious health effects of the CDF poisoning. However, these effects did not develop in some people until weeks or months after exposure and might not have occurred at all in other people. CDFs also caused vomiting and diarrhea, anemia (a blood disease), more frequent lung infections, numbness and other effects on the nervous system, and mild changes in the liver, but there were no permanent liver changes or definite liver damage in the people who accidentally ate the CDFs. The children born to the poisoned mothers also had acne and other skin irritations. Young children of these mothers also had some trouble learning, but we do not know if this effect was permanent. It is unknown whether these health effects were caused by CDFs alone or CDFs and PCBs in combination. We know nothing about the health of people who are exposed to low levels of CDFs by breathing, skin contact, or for long periods of time.

Many of the same health effects that occurred in the people accidentally exposed also occurred in experimental or laboratory animals that ate CDFs. Animals fed CDFs also had severe body weight loss, and their stomachs, livers, kidneys, and immune systems were seriously injured. Some fed high doses died. CDFs also caused birth defects and testicular damage in animals, but we do not know if CDFs make males or females infertile. Most of the effects in animals occurred after they ate large amounts of CDFs for short periods or smaller amounts of CDFs for several weeks or months. Nothing is known about the possible health effects in animals from eating CDFs over a lifetime. Only one study tested animals exposed to CDFs by skin contact. The health effects were similar to those that occurred in animals that ate CDFs. We do not know the possible health effects in animals of breathing in CDFs. The amounts of CDFs that caused health effects in animals were far greater than the levels normally found in the environment.

We do not definitely know if CDFs caused cancer in any of the accidentally poisoned people. There are no cancer studies in animals that ate or breathed CDFs. One study found that

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CDFs alone did not cause skin cancer in animals when they were applied to the skin for several months. However, when researchers applied another carcinogen to the animals' skin before applying CDFs, skin cancer developed. Although skin cancer developed in these animals, the Department of Health and Human Services, the International Agency for Research on Cancer, and the Environmental Protection Agency have not classified the carcinogenicity of CDFs.

1.6 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO CDFs?

There are tests to find out if CDFs are in blood, body fat, and breast milk; however, these are not routinely done. High levels of CDFs in these body fluids and in fat will show that you have been exposed to high levels of CDFs. However, these measurements cannot show the exact amount or type of CDFs you were exposed to or for how long you were exposed. These tests do not predict whether you will experience harmful health effects. Blood tests can detect recent exposures to CDFs, but are not always the easiest, safest, or best method. Fat biopsies (small amounts of fat taken with a needle and syringe) may be less traumatic to a small child or very sick person and more diagnostic than blood tests. Nearly everyone in the United States and other industrial countries has been exposed to CDFs because they are found throughout the environment, and nearly all people are likely to have some CDFs in their blood, fat, and breast milk. For more information on tests to determine whether you have been exposed to CDFs, please refer to Chapters 2 and 6.

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

There are no federal guidelines or recommendations for protecting human health from exposure to CDFs. CDFs are, however, listed as hazardous waste components by the EPA.

1.8 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 or:

Agency for Toxic Substances and Disease Registry
Division of Toxicology
1600 Clifton Road NE, E-29
Atlanta, Georgia 30333
(404) 639-6000

This agency can also provide you with information on the location of occupational and environmental health clinics. These clinics specialize in the recognition, evaluation, and treatment of illness resulting from exposure to hazardous substances.