PUBLIC HEALTH STATEMENT
Aluminum
CAS#: 7429-90-5

Division of Toxicology and Environmental Medicine **September 2006**

This Public Health Statement is the summary chapter from the Toxicological Profile for Aluminum. It is one in a series of Public Health Statements about hazardous substances and their health effects. A shorter version, the ToxFAQs™, is also available. This information is important because this substance 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 1-800-232-4636.

This public health statement tells you about aluminum and the effects of exposure to it.

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. Aluminum (in some form, e.g., in compounds with other elements such as oxygen, sulfur, or phosphorus) has been found in at least 606 of the 1,678 current or former NPL sites. Although the total number of NPL sites evaluated for this substance is not known, the possibility exists that the number of sites at which aluminum is found may increase in the future as more sites are evaluated. This information is important because these sites may be sources of exposure and exposure to this substance at high levels 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. However, it should be noted that aluminum is a very abundant and widely distributed element and will be found in most rocks, soils, waters, air, and foods. You will always have some exposure to low levels of aluminum from eating food, drinking water, and breathing air.

If you are exposed to aluminum, 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 it. 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 IS ALUMINUM?

Aluminum is the most abundant metal and the third most abundant element, after oxygen and silicon, in the earth's crust. It is widely distributed and constitutes approximately 8.8% of the earth's crust or approximately 88,000 parts of aluminum per million parts of the earth's crust (88,000 ppm). However, aluminum is a very reactive element and is never found as the free metal in nature. It is found combined with other elements, most commonly with oxygen, silicon, and fluorine. These chemical compounds are commonly found in soil, minerals (e.g., sapphires, rubies, turquoise), rocks (especially igneous rocks), and clays. These are the naturally occurring forms of aluminum. Aluminum as the metal is obtained from aluminum-containing minerals, primarily bauxite. Small amounts of aluminum are even found dissolved as ions in water. (Ions are atoms, collections of atoms,

or molecules containing a positive or negative electric charge.) The most commonly found ionic forms of aluminum are complexes formed with hydroxide (hydrogen attached to oxygen) ions.

Aluminum metal is light in weight and silvery-white in appearance. Familiar uses of aluminum are for beverage cans, pots and pans, airplanes, siding and roofing, and foil. The reason why aluminum metal is so durable is that the aluminum atoms on the surface of the metal quickly combine with oxygen in the air to form a thin, strong, and protective coating of aluminum oxide (alumina). Since pure aluminum is very soft, aluminum is often mixed with small amounts of other metals to form aluminum alloys, which are stronger and harder.

Aluminum compounds are used in many diverse and important industrial applications such as alums (aluminum sulfate) in water-treatment and alumina in abrasives and furnace linings. They are found in consumer products such as antacids, astringents, buffered aspirin, food additives, and antiperspirants. Powdered aluminum metal is often used in explosives and fireworks.

1.2 WHAT HAPPENS TO ALUMINUM WHEN IT ENTERS THE ENVIRONMENT?

Aluminum occurs naturally in soil, water, and air. It is redistributed or moved by natural and human activities. High levels in the environment can be caused by the mining and processing of its ores and by the production of aluminum metal, alloys, and compounds. Small amounts of aluminum are released into the environment from coal-fired power plants and incinerators. Virtually all food, water, and air contain some aluminum.

Aluminum cannot be destroyed in the environment. It can only change its form or become attached or separated from particles. Aluminum particles released from power plants and other combustion processes are usually attached to very small particles. Aluminum contained in wind-borne soil is generally found in larger particles. These particles settle to the ground or are washed out of the air by rain. Aluminum that is attached to very small particles may stay in the air for many days. Most aluminum will ultimately end up in the soil or sediment.

Aluminum is not accumulated to a significant extent in most plants or animals. There are some exceptions, such as tea plants, which may be consumed by people, as well as some mosses, ferns, and subtropical evergreen shrubs and trees. Aluminum does not appear to accumulate to any significant degree in cow's milk or beef tissue and is not expected to undergo biomagnification, a progressive increase in the concentration of a chemical that is accumulated in the tissues of organisms, as that chemical is passed from the bottom to the top of the food web. Because of the toxicity of dissolved aluminum to many aquatic organisms, including fish, these animals would die before the amount of aluminum in the animal became very high. Therefore, vegetables, fruits, fish, and meat that you consume will generally not contain high amounts of aluminum.

Most aluminum-containing compounds do not dissolve to a large extent in water unless the water is acidic or very alkaline. However, when acid rain

falls, aluminum compounds in the soil may dissolve and enter lakes and streams. Since the affected bodies of water are often acidic themselves from the acid rain, the dissolved aluminum does not combine with other elements in the water and settle out as it would under normal (i.e., non-acidic) conditions. In this situation, abnormally high concentrations of aluminum may occur.

1.3 HOW MIGHT I BE EXPOSED TO ALUMINUM?

Aluminum is found naturally in the environment. Aluminum is never found as the free element in nature and exists in compounds with other elements, such as oxygen, chloride, or sulfur. You are always exposed to some aluminum compounds by eating food, drinking water, ingesting medicinal products like certain antacids and buffered aspirin that contain aluminum, or breathing air. You may also be exposed by skin contact with soil, water, aluminum metal, antiperspirants, or other substances that contain aluminum or aluminum compounds. Many of the analytical methods used by scientists to determine the levels of aluminum in the environment generally do not determine the specific form of aluminum present and only determine the total amount of aluminum present in the sample. Therefore, we do not always know the form of aluminum to which a person may be exposed from a test of an environmental sample. If a particular method were able to determine the specific form of aluminum present, it would be reported as such. Similarly, we may not know what forms of aluminum are present at hazardous waste sites. Some forms of aluminum may be insoluble or so tightly attached to particles or embedded in minerals that they are not taken up well by plants and animals, while other forms, such as those found in acidic lakes, may be taken up well by plants and animals.

Levels of aluminum in the air generally range from 0.005 to 0.18 micrograms (1 microgram, µg, equals a millionth of a gram, 1 gram equals 0.0022 pound) of aluminum per cubic meter of air (0.005–0.18 $\mu g/m^3$), depending on location, weather conditions, and level of industrial activity in the area. Most of the aluminum in the air is in the form of small suspended particles of soil (dust). Aluminum levels in urban and industrial areas may be higher and can range from 0.4 to 8.0 $\mu g/m^3$. The amount of aluminum you breathe in a day is much less than you consume in food. You may breathe in higher levels of aluminum in dust if you live in areas where the air is dusty, where aluminum is mined or processed into aluminum metal, or near certain hazardous waste sites.

The concentration of aluminum in natural waters (e.g., ponds, lakes, streams) is generally below 0.1 milligrams/liter (mg/L) (1 milligram, mg, equals one thousandth of a gram) unless the water is very acidic. People generally consume very little aluminum from drinking water. Water is sometimes treated with aluminum salts while it is processed to become drinking water, but even then, aluminum levels generally do not exceed 0.1 mg/L, although several cities have concentrations of 0.4–1 mg/L of aluminum in their drinking water. Unprocessed foods like fresh fruits, vegetables, and meat contain very little aluminum. However, aluminum compounds may be added to foods (e.g., baking powder, coloring agents, and anticaking agents) during processing. Foods such as processed cheese and cakes may contain moderate amounts of

aluminum as a result of its addition during processing. An average adult in the United States eats about 7–9 mg of aluminum per day in their food. People are exposed to aluminum in some cosmetics, such as deodorants, and in pharmaceuticals such as antacids, buffered aspirin, and intravenous fluids. Antacids have 300–600 mg aluminum hydroxide (approximately 104–208 mg of aluminum) per tablet/capsule/5 milliliters. Buffered aspirin may contain 10–20 mg of aluminum per tablet. Vaccines may contain small amounts of aluminum compounds, such as aluminum hydroxide, aluminum phosphate, or aluminum sulfate (alum). The U.S. Food and Drug Administration limits the amount of aluminum in vaccines to no greater than 0.85 mg/dose. Children and adults may be exposed to aluminum from vaccinations.

Soy-based infant formulas contain higher concentrations of aluminum, as compared to milk-based infant formulas or breast milk. Average aluminum concentrations of 0.46–0.93 mg/L have been reported for soy-based infant formulas. Average aluminum concentration of 0.058–0.15 mg/L have been reported for milk-based formulas. Typical aluminum concentrations in human breast milk range from 0.0092 to 0.049 mg/L.

1.4 HOW CAN ALUMINUM ENTER AND LEAVE MY BODY?

When you eat aluminum in your food or drink it in liquids, very little goes from your stomach into your bloodstream. Most aluminum leaves your body quickly in the feces. The small amount of aluminum that does enter the bloodstream leaves in the urine. You breathe in very little aluminum from the air, and very little can enter your body through the skin.

1.5 HOW CAN ALUMINUM 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.

Exposure to aluminum is usually not harmful. Aluminum occurs naturally in many foods. Factory workers who breathe large amounts of aluminum dusts can have lung problems, such as coughing or changes that show up in chest X-rays. The use of breathing masks and controls on the levels of dust in factories have largely eliminated this problem. Some workers who breathe aluminum dusts or aluminum fumes have decreased performance in some tests that measure functions of the nervous system. Some people who have kidney disease

store a lot of aluminum in their bodies. The kidney disease causes less aluminum to be removed from the body in the urine. Sometimes, these people developed bone or brain diseases that doctors think were caused by the excess aluminum. Some studies show that people exposed to high levels of aluminum may develop Alzheimer's disease, but other studies have not found this to be true. We do not know for certain whether aluminum causes Alzheimer's disease. People may get skin rashes from the aluminum compounds in some underarm antiperspirants.

Rats and hamsters showed signs of lung damage after breathing very large amounts of aluminum as chlorohydrate or pure metal dust. Studies in rats and mice showed that the nervous system is a sensitive target of aluminum toxicity. Obvious signs of damage were not seen in animals ingesting smaller doses of aluminum. However, the animals did not perform as well in tests that measured the strength of their grip or how much they moved around.

We do not know if aluminum will affect reproduction in people. Aluminum does not appear to affect fertility in animals. Aluminum has not been shown to cause cancer in animals.

1.6 HOW CAN ALUMINUM AFFECT CHILDREN?

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

Brain and bone disease caused by high levels of aluminum in the body have been seen in children with kidney disease. Bone disease has also been seen in children taking some medicines containing aluminum. In these children, the bone damage is caused by aluminum in the stomach preventing the absorption of phosphate; phosphate is required for healthy bones.

We do not know if aluminum will cause birth defects in people. Birth defects have not been seen in animals. However, very young animals appeared weaker and less active in their cages and some movements appeared less coordinated when their mothers were exposed to aluminum during pregnancy and while nursing. In addition, aluminum also affected the animal's memory. These effects are similar to those seen in adults. It does not appear that children are more sensitive than adults.

There does not appear to be any difference between children and adults in terms of how much aluminum will enter the body, where aluminum can be found in the body, and how fast aluminum will leave the body. Aluminum from the mother can enter her unborn baby through the placenta. Aluminum is found in breast milk, but only a small amount of this aluminum will enter the infant's body through breastfeeding.

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

If your doctor finds that you have been exposed to substantial amounts of aluminum, ask whether your children might also have been exposed. Your

doctor might need to ask your state health department to investigate.

The most important way families can lower exposures to aluminum is to know about the sources of aluminum that may affect their health and lessen their exposure to these sources. It is important to point out that since aluminum is so common and widespread in the environment, we cannot avoid exposure to aluminum. In addition, exposure to the levels of aluminum that are naturally present in food and water and the forms of aluminum that are present in dirt and aluminum pots and pans is generally not harmful. Eating large amounts, for example on a daily basis, of processed food containing aluminum additives or frequently cooking acidic foods in aluminum pots may expose a person to higher levels of aluminum than a person who generally consumes unprocessed foods and uses pots made of other materials (e.g., stainless steel or glass). However, aluminum levels found in processed foods and foods cooked in aluminum pots are generally safe. Individuals with the highest exposures to aluminum would be those who routinely, for example daily or several times a week, take aluminum-containing drugs, such as antacids. Limiting your intake of large quantities of aluminum-containing antacids and buffered aspirin and taking these medications as directed may be the best way to reduce exposure to aluminum. As a precaution, products should have child-proof caps or should be kept out of reach of children so that children will not accidentally eat them. Families should also be aware that soy-based infant formula may contain higher levels of aluminum as compared to milk-based infant formulas and breast milk, and may want to consult with their physician on the choice of formula for their infant. However, aluminum levels found in infant formulas, both soy- and milk-based formulas, are generally safe for healthy infants.

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

All people have small amounts of aluminum in their bodies. It can be measured in the blood, bones, feces, or urine. Urine and blood aluminum measurements can tell you whether you have been exposed to larger-than-normal amounts of aluminum. Measuring bone aluminum can also indicate exposure to high levels of aluminum, but this requires a bone biopsy. Tests to measure aluminum levels in the body are not usually available at a doctor's office because they require special equipment.

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.

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; they 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 aluminum include the following:

EPA has recommended a Secondary Maximum Contaminant Level (SMCL) of 0.05–0.2 milligrams per liter (mg/L) for aluminum in drinking water. The SMCL is not based on levels that will affect humans or animals. It is based on taste, smell, or color. OSHA has determined that the amount of aluminum in dusts that workers breathe should not be more than 15 milligrams per cubic meter (mg/m^3) of air. FDA has determined that aluminum cooking utensils, aluminum foil, antiperspirants, antacids, and other aluminum products are generally safe.

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, 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 that result 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 toll-free information and technical assistance number at 1-800-CDCINFO (1-800-232-4636), by e-mailing cdcinfo@cdc.gov, or by writing to

Agency for Toxic Substances and Disease Registry
Division of Toxicology and Environmental Medicine
1600 Clifton Road NE
Mailstop F-32
Atlanta, GA 30333
Fax: 1-770-488-4178

Organizations for-profit may request copies of final Toxicological Profiles from

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/