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## Aluminum and Human Health

### Introduction

Aluminum, the most abundant metal on Earth, is found in soil, in water and in air. Its chemical and physical properties make it ideal for a wide variety of uses. For example, aluminum and its compounds are often used in food as additives, in drugs (e.g., antacids), in consumer products (e.g., cooking utensils and aluminum foil) and in the treatment of drinking water (e.g., coagulants).

Because aluminum is so pervasive in the environment, to the point of being unavoidable, researchers have long been studying its effects on humans. This research has revealed a link between aluminum intake and neurological dementia in kidney dialysis patients (dialysis encephalopathy). In recent years, the public and the media have become concerned about other possible adverse effects of aluminum on human health, including its role in Alzheimer's disease, Parkinson's disease and amyotrophic lateral sclerosis (Lou Gehrig's disease). In addition, questions have been raised about the potential risks to infants who drink baby formula containing aluminum.

This information bulletin looks at the ways in which we are exposed to aluminum every day, the health risks associated with this exposure, and special issues related to aluminum's presence in food and drinking water. The final section outlines what Health Canada is doing to further our understanding of aluminum and its impact on our lives.

### How am I exposed to aluminum?

Because aluminum is present throughout the environment and is used in a variety of products and processes, it is almost impossible to avoid exposure to aluminum on a daily basis.

#### Food

Aluminum occurs naturally in many foods, but usually only in low concentrations. The tea plant is an exception, as it accumulates large amounts of aluminum, which can then leach from the tea leaves into brewed tea. Aluminum can also leach into food from cookware, utensils and wrappings, but studies to date have shown that the amount of aluminum leached from these sources is generally negligible. Certain foods, such as dairy products, grains and grain products, desserts and beverages, may contain levels of aluminum that are higher than naturally-occurring background levels owing to the use of aluminum compounds (e.g., sodium aluminum phosphate) as food additives. Food additive use is controlled to prevent the use of higher than necessary levels of additives.

The intake of aluminum from food for an adult amounts to about 8 milligrams per day, although higher daily intakes have also been estimated. In general, approximately 95% of the normal daily intake of aluminum for an adult comes

from food. For infants, daily intakes of aluminum are usually less than 1 milligram per day.

### **Pharmaceuticals**

The daily intake of aluminum can be greatly increased for individuals consuming maximum recommended doses of aluminum-based over-the-counter drugs such as antacids and buffered acetylsalicylic acid (ASA). The World Health Organization has estimated that individuals who regularly ingest these aluminum-containing pharmaceuticals may have intakes as high as 5 grams per day.

### **Drinking water**

Most surface water treatment plants in Canada use aluminum in the form of alum (aluminum sulphate) to help remove harmful waterborne microorganisms and other particles by causing them to clump together (coagulate) into larger particles that are then easily removed by sedimentation and filtration. This process also removes naturally-occurring organic matter present in water, reducing the formation of disinfection by-products. Disinfection by-products result from the reaction between chemicals used for disinfection (e.g., chlorine) and naturally occurring organic matter, and they may cause cancer.

Since the alum added into the treatment process is largely removed at a later stage, the average aluminum content in treated water is only slightly higher than in untreated water. Thus, the intake of aluminum in drinking water generally amounts to less than 5% of the total daily intake for an adult. Actual intake may vary widely across the country depending on the general quality of the source water (including the natural presence of aluminum in the water), the treatment processes employed and the operating efficiency of the treatment plant.

### **Air**

Intake of aluminum from unpolluted air is generally quite low, below 4 micrograms per day. In industrial areas, where aluminum levels in air may be much higher, intakes can exceed 100 micrograms per day. Occupationally exposed workers may inhale between 3.5 and 7 milligrams per day.

### **Does it matter how I am exposed to aluminum?**

Yes. While it is true that most of our daily intake of aluminum comes from food, only a very small percentage - usually less than 1% - is actually absorbed by the body. Absorption depends on a variety of factors, including the type of aluminum compound, the composition of the food eaten, and the age and the health of the person consuming the food.

Aluminum in drinking water is better absorbed by the body (i.e., is more "bioavailable") than aluminum in food, even though it is responsible for only a small fraction of the total daily intake. This means that drinking water could be a more significant source of aluminum than food. The reason for the difference in the absorption rates is unknown; much more research needs to be done before definitive conclusions can be drawn.

### **What are the health risks associated with aluminum?**

Historically, aluminum has been considered relatively non-toxic; healthy individuals can tolerate oral doses as high as 7 grams per day without experiencing harmful effects. However, abundant evidence now shows that aluminum may adversely affect the nervous system in humans and animals.

### **Dialysis encephalopathy**

Patients with kidney disease who undergo dialysis regularly and who consequently may be exposed to high levels of aluminum in dialysis fluids and medications can develop dialysis encephalopathy, a progressive form of dementia characterized by tremors, convulsions, psychosis and other changes in speech and behaviour. Most experts agree that high levels of aluminum in dialysis fluids and medications are responsible for the dementia, and that controlling the levels of aluminum significantly reduces the incidence of this disease.

### **Alzheimer's disease**

Alzheimer's disease is the most common primary degenerative brain disease in Canada and is a leading cause of death. The first recognizable symptoms of Alzheimer's disease, which mark the start of progressive mental deterioration, include memory lapses, disorientation, confusion, and depression.

Scientists are investigating possible theories to determine the causes of Alzheimer's disease. These theories take into account the roles of genetic factors, abnormal proteins, infectious agents, environmental agents including aluminum, other metals or solvents, and metabolic changes. Growing evidence suggests that complex interactions exist between genetic predisposition and aging, for example, and the series of events leading to the onset of the disease.

Aluminum exposure was suggested as a possible cause of Alzheimer's disease because the brain cells of Alzheimer's patients can contain from 10 to 30 times the normal concentrations of aluminum. However, it is not clear whether the accumulation of aluminum is a cause or a result of the disease.

Several studies on humans have shown a slightly increased risk of Alzheimer's disease or related dementia in communities where the drinking water contains high concentrations of aluminum. On the other hand, a number of other studies have shown no relationship between aluminum in drinking water and the onset of dementia. In addition, scientists have been unable to induce Alzheimer's disease-type changes in the brains of laboratory animals exposed to aluminum, or to explain the absence of Alzheimer's disease-type changes in brains of patients suffering from dialysis encephalopathy. Some studies have also shown little or no accumulation of aluminum in the brain tissues of Alzheimer's patients.

After weighing all the evidence, experts have concluded that even though a true association between dementia (including Alzheimer's disease) and high concentrations of aluminum in drinking water has not yet been proven, the possibility cannot be ruled out, especially for the most elderly.

### **Lou Gehrig's and Parkinson's diseases**

Aluminum has also been associated with other severe diseases of the nervous system, such as Lou Gehrig's and Parkinson's diseases. As with Alzheimer's disease, the significance, if any, of the association is unknown.

An unusually high incidence of Lou Gehrig's and Parkinson's diseases in indigenous populations in Guam and New Guinea suggests a possible correlation between the diseases and local environmental conditions, including high levels of aluminum and low levels of calcium and magnesium in soil and food. As with Alzheimer's, humans with these disorders tend to have high levels of aluminum in some areas of their brains, although it has not been demonstrated that the presence of aluminum in the brain initiates the onset of the diseases. Other possible contributing factors that need to be examined more closely include the diet of the Guam population - in particular, the seeds

of the false sago palm, which contain a toxic amino acid that causes a condition similar to Lou Gehrig's disease in monkeys - as well as the possibility that the dementia is caused by genetic rather than environmental factors.

### **Other health effects**

The intake of large amounts of aluminum can also cause anaemia, osteomalacia (brittle or soft bones), glucose intolerance, and cardiac arrest in humans.

### **Special food issues and drug issues**

*Should I stop using aluminum cookware and aluminum foil?*

No. Studies have shown that the amount of aluminum that leaches from aluminum cookware and aluminum foil into food is generally negligible.

*Why don't manufacturers stop using food additives that contain aluminum?*

Manufacturers may not be able to find suitable alternatives to these aluminum-containing additives that would provide the same technical effect. As with all food additives, the use of aluminum-containing additives by manufacturers is optional under the Food and Drug Regulations. If these substances are used in foods, however, they must be used according to the provisions of the Regulations and must be declared in the ingredient lists of foods containing them.

*Should I be concerned about aluminum in my baby's formula?*

No. Although a Health Canada survey of infant formulas available in Canada found that aluminum levels in formula were higher than levels in human or cow's milk, consumption of aluminum at this level is not considered to pose a health risk based on current information.

*Should I be concerned about using aluminum-containing pharmaceuticals?*

No. To date, no studies have shown that consumption of aluminum-based pharmaceuticals is associated with harmful effects.

### **Special drinking water issues**

*What are the alternatives to aluminum-based coagulants, and why aren't they used?*

Several chemical coagulants - such as iron compounds and organic polymers - can be used instead of aluminum-based coagulants. The choice of a coagulant is based on a number of interrelated factors. Water chemistry (e.g., pH or acidity level, temperature) is the main factor that determines which type of coagulant will perform most effectively. Each alternative has advantages and disadvantages, including potential health risks and environmental and occupational concerns. The most important reason aluminum-based coagulants are chosen is that the alternatives do not always remove pathogens and particles as well. If a treatment plant was specifically designed to use alum with a certain type of water, it is not always possible to use an alternative without adversely affecting water quality. In addition, alternative coagulants are generally more costly, require additional facilities for transport, handling or storage and may be more hazardous to work with.

*Is there any way I can remove aluminum from my tap water?*

There is no easy or inexpensive way to remove aluminum from tap water in the home. Steam distillation and a process called reverse osmosis are effective, but both processes require the purchase of expensive equipment and frequent maintenance.

*Should I be concerned about high levels of aluminum in my well water or in my tap water if my municipal treatment plant doesn't use alum?*

Natural aluminum found in untreated water is generally thought to be in a form that is not easily taken up by the body, and it is therefore of little concern in terms of health effects. It is only during the alum treatment process that aluminum appears to be changed to a form that may be more readily absorbed.

*Does bottled water contain less aluminum than tap water?*

Like tap water, bottled waters vary in their aluminum content. Aluminum may be found in some bottled waters because it occurs naturally at the source. Also, some bottled water manufacturers use tap water with or without additional treatment; if aluminum is in the tap water, it may also be in the bottled water.

*Is municipal drinking water safe?*

The water provided by municipal water suppliers is safe. First, the water usually meets all provincial guidelines for purity. Guidelines are very stringent and are designed to protect human health. Second, municipal water suppliers monitor their water on a regular basis to ensure that the guidelines are met; in most municipalities, this includes an attempt to keep aluminum levels low, despite the lack of a specific guideline for aluminum. Finally, water treatment processes are carefully monitored and controlled to ensure that any process failure is immediately detected and corrected.

### **What is Health Canada doing to ensure the safety of our drinking water?**

The main responsibility for ensuring that drinking water is safe lies with the provinces. A consistent approach to improving drinking water quality is provided by Health Canada's *Guidelines for Canadian Drinking Water Quality* (soon to include a revised statement on aluminum), which are designed to ensure that Canadians have access to wholesome and safe drinking water. In the federal domain, Treasury Board uses these guidelines as standards for federal lands.

At present, there is no health-based guideline recommending a safe level of aluminum in drinking water in Canada. Health Canada has evaluated the literature on the adverse effects of aluminum on humans and animals. The Department, through the Federal-Provincial Subcommittee on Drinking Water (Subcommittee), has determined that there are insufficient data at present, to support setting a health-based guideline for aluminum.

However, in recognition of advancing research into the health effects of aluminum and in an exercise of the "precautionary principle," the Subcommittee has recommended that water treatment plants using aluminum-based coagulants should optimize their operations to reduce aluminum levels in treated water as much as possible. For these plants, operational guidance values of less than 100 micrograms per litre total aluminum (for conventional treatment plants) and less than 200 micrograms per litre total aluminum (for other types of treatment systems) have been recommended. Water meeting these operational guidance values should not contain jelly-like aluminum-containing material, which can decrease the flow rate in the distribution system and can surround and protect microorganisms, interfering with the disinfection process.

The Subcommittee emphasized that the benefits of using aluminum in treating water are more significant than its potential adverse health effects. In other words, since treatment plants use aluminum to get rid of microorganisms and organic matter found in surface waters, they should not compromise the microbiological or chemical quality of drinking water in an attempt to minimize the amount of aluminum left in the treated water. This could happen if treatment plants significantly reduced the amount of alum used in the treatment processes.

If future investigations carried out at Health Canada or elsewhere support the establishment of a health-based guideline for aluminum, the Subcommittee will revisit the issue and set a guideline value.

In addition, Health Canada has introduced the *Drinking Water Materials Safety Act* into Parliament. Once granted Royal Assent, this Act will require drinking water materials - treatment devices (e.g., pitcher-type filters), treatment additives (e.g., alum, chlorine) and system components (e.g., pipes, faucets and storage tanks) - to be certified as meeting prescribed health-based performance standards by accredited third-party organizations before being sold in or imported into Canada.

### **What is Health Canada doing to further our understanding of the aluminum issue?**

Health Canada has launched several separate initiatives designed to contribute to a better understanding of aluminum as a potential health issue. The first of these, the consideration of a Canadian drinking water guideline for aluminum, has already been mentioned. The others include:

- the design of future animal and human studies to determine aluminum health hazards;
- a review of data from animal studies related to aluminum compounds;
- a feasibility study to conduct health-related surveys in areas where drinking water may be contaminated by aluminum as a result of the effects of acid rain; and
- further analysis of the results of a research program on Alzheimer's disease that considered aluminum as one of the possible risk factors.

In addition, the levels of aluminum in foods (including foods for infants) are analysed to estimate how much aluminum people consume on a daily basis and to determine whether more regulations are needed in this area.

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