Elements and Substances of Concern in WEEE

Note: The following section uses definitions created by the Ad-hoc Working Group on Defining Critical Materials, a subgroup of the Raw Materials Supply Group of the European Commission's Enterprise and Industry Directorate General. The working group classifies materials based on economic importance and supply risk. If a material is of high economic importance, and the supply is at risk due to any one of a number of factors, that material will be considered critical. Some of the factors that will see the supply of a material declared as "at risk" are low substitutability, low recycling rates, or production concentrated in countries with risky political-economic stability, which means that its supply could be suddenly shut off by some political or economic problem in the country that dominates production.

Antimony is found in small quantities in the printed circuit boards of most electronic devices and display devices, especially CRT displays and televisions sets. It is used as a flame retardant.

Breathing high levels of antimony for a long time can irritate the eyes and lungs and can cause problems with the lungs, heart, and stomach. Tests on animals have shown that breathing high levels of antimony can cause damage to the lungs, heart, liver and kidneys. Fertility issues were also noted in animals exposed to high levels over a longer period.

Although some studies have shown lung cancer in rats exposed to antimony, there are no studies that show conclusively that antimony is carcinogenic to humans.

The Ad-hoc Working Group on Defining Critical Materials defines antimony as a "critical raw material." There are no effective substitutes, supply is dominated by China, and there is a low recycling rate.

Arsenic is found in very small quantities in the transistors of some computers and technological equipment. Arsenic in the environment can combine with oxygen, chlorine, or sulfur to form inorganic arsenic compounds.

Ingesting or breathing low to medium levels of inorganic arsenic can cause warts, sore throat, irritated lungs, or other problems, and ingesting high amounts of arsenic can result in death.

The International Agency for Research on Cancer (IARC) and the US Environmental Protection Agency (EPA) have both determined that inorganic arsenic is carcinogenic to humans.

Barium, found in CRT screens, can accumulate in water and aquatic organisms. Humans exposed to barium, usually through contaminated drinking water, can suffer gastrointestinal disturbances and muscle weakness. High levels of ingestion over a long period of time may lead to kidney damage.

The IARC has not classified barium as to its carcinogenicity.

Beryllium, used in trace quantities for the circuit boards of information technology electronics, can be quite harmful if high levels of it are airborne. About 1–15% of all people occupationally exposed to beryllium in the air become sensitive to it and may develop chronic beryllium disease (CBD), an irreversible and sometimes fatal scarring of the lungs.

Ingesting beryllium by swallowing has not been shown to cause negative effects in humans, but tests on animals have resulted in ulcers that may have been caused by beryllium exposure.

The IARC and the US EPA have both determined that beryllium is a human carcinogen.

EC's working group rates beryllium as a "critical raw material" because 99% of world production is in the United States and China, there is a low recycling rate, and it is difficult to find a substitute for the material.

Cadmium is found in printed circuit boards, semi-conductors, copy machines, batteries, and possibly older CRT screens. Lungs can be severely damaged by breathing in high levels of cadmium. Eating or drinking cadmium can irritate the stomach. Long-term exposure can cause a build-up of cadmium in the kidneys, potentially resulting in kidney disease.

The IARC has determined that cadmium and cadmium compounds are human carcinogens. The EPA has listed cadmium as a possible human carcinogen.

Chromium is found in trace amounts in nearly all WEEE. The greatest concentrations are in CRT display devices. Chromium is found in different compounds, the most harmful of which is chromium VI, more commonly known as hexavalent chromium.

Ingestion of chromium VI is linked to irritation of the nose and other breathing issues. In laboratory tests, animals exposed to chromium VI have shown damage to their reproductive systems and sperm.

The IARC and the EPA have both determined that chromium VI is a human carcinogen.

Cobalt is in some batteries and the hard drives of consumer equipment. It is naturally occurring and can be beneficial to humans at low levels. High levels of exposure to cobalt can cause negative effects to the heart, lungs, skin, liver, and kidneys.

Tests on laboratory animals have shown that cobalt may be linked to cancer. The IARC has determined that cobalt and cobalt compounds are possible human carcinogens.

Cobalt is defined as a "critical raw material" by the EC's working group. Production is concentrated in the Democratic Republic of Congo, and there are limited options for substitution.

Copper is used as conductive cabling in nearly all electronic devices. Humans are regularly exposed to low levels of copper. High levels of exposure, however, can cause irritation of the nose, mouth, and eyes, as well as vomiting, diarrhoea, stomach cramps, nausea, and even death.

The EPA has determined that copper is not classifiable as to its human carcinogenicity.

Because of its high value, most copper is recovered from WEEE and recycled.

Lead is considered to be one of the greatest potential sources of toxicity in WEEE. It has been nearly eliminated from new products because of directives or agreements such as the RoHS Directive and California's WEEE provisions, but there are still tremendous quantities of lead in existing electronic devices, particularly in CRT screens, and this lead will eventually enter the waste stream. The EPA estimates that over 1 billion CRT PC's and television sets were sold in the United States between 1980 and 2010, many of which are still in use or in storage and yet to enter the waste stream. And all of these will contain lead.

The EU's *2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment: Final Report* suggests that a typical 26 kg CRT television set has over 1 kg of lead oxide in the tube itself and an additional 24 grams of lead in the rest of the set.

Exacerbating the problem with leaded CRT displays is that, right now, the market value for leaded glass is so low that recyclers are stockpiling it rather than selling it to be repurposed. An article in *The New York Times* from March 18, 2013, estimates that, at present, there is roughly 660 million pounds of it stored in warehouses across the United States. [10]

In humans, lead toxicity affects the nervous system, primarily, but it can affect nearly every organ in the body.

Exposure to high levels of lead, either through breathing or swallowing, can damage the brain and kidneys. In pregnant women, it can cause miscarriage.

In children, lead can cause blood anaemia and brain damage. If unborn children are exposed to lead through their mothers, the results can include premature birth and decreased mental and learning abilities.

Though tests have proved inconclusive, both the IARC and the EPA have determined that lead is "probably" carcinogenic to humans.

Lithium, found in many rechargeable batteries, can cause symptoms such as nausea and vomiting if humans are exposed to mild doses, but, in high doses, exposure can lead to seizures and kidney failure.

There is no evidence that lithium exposure can lead to any form of cancer.

Manganese, also common in batteries, is an essential nutrient for humans. Exposure to high levels of manganese, for example in industrial settings such as factories, can lead to consequences for the nervous system, lung irritation, and reproductive system effects.

The EPA has concluded that there is not enough scientific information to determine if manganese is a human carcinogen.

Mercury, found in trace amounts in many electronics, particularly in LCD screens, can affect the nervous system and damage the brain, the kidneys, and a developing fetus. It has the ability to build up in the environment, for example, in fish, and be consumed by humans or other organisms eating fish with high levels of mercury.

The EPA has determined that mercuric chloride and methylmercury are possible human carcinogens. Laboratory tests on animals have shown that mercury increases incidents of tumours in rats and mice.

Nickel, which is present in most electronics and in some batteries, is an abundant natural element. Approximately 10–20% of the population is "sensitive" to nickel. The most common reaction to nickel for those allergic is a skin rash.

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[10] Ian Urbina, "Unwanted Electronic Gear Rising in Toxic Piles," The New York Times, March 18, 2013, http://www.nytimes.com/2013/03/19/us/disposal-of-older-monitors-leaves-a-hazardous-trail.html.

People exposed to large amounts of nickel in industrial settings have reported bronchitis, reduced lung function, and adverse effects to blood and kidneys.

Tests have shown lung and sinus cancers in workers in refineries or processing plants who have been exposed to air containing high levels of nickel compounds. The EPA has determined that nickel refinery dust and nickel subsulfide are human carcinogens.

PBBs/PDBEs (polybrominated biphenyls and polybrominated diphenyl ethers) were commonly used to make the plastic housing for electronics flame retardant. Their use has been reduced greatly because of the RHoS Directive and California's WEEE provisions, but there are still many items containing PBB's entering the waste stream.

The IARC has determined that PBB's are possibly carcinogenic to humans.

Palladium, found in trace amounts in most electronic items, is widely used in multilayer ceramic capacitors for its resistance to corrosion.

Palladium on its own is regarded as having low toxicity, but palladium compounds, such as palladium chloride, are highly toxic and could cause bone marrow, liver, and kidney damage in humans. It has shown these results in laboratory tests on animals.

As part of the "platinum group" of metals, palladium is considered by the EC's working group to be a "critical raw material." The palladium that is used by EU countries comes mainly form two sources, South Africa and Russia.

PVC is a flame retardant plastic commonly used for cabling and housing in electronic products. The manufacture of PVC often creates toxic chemical pollutants such as dioxin, hydrochloric acid, and vinyl chloride.

People who work with vinyl chloride have been known to develop problems with their immune systems, nerve changes, and liver damage.

The US Department of Health and Human Services (DHHS) has determined that vinyl chloride is a known carcinogen.

Ruthenium is used as a corrosion-resistant hardener in electrical contacts and chip resistors. Ruthenium is one of the most rare metals on earth. Ruthenium has not been found to cause cancer, but its compounds should be regarded as toxic and potentially carcinogenic to humans.

Selenium can be found in some circuit boards and in the photosensitive drums of equipment such as photocopiers. Humans need small amounts of selenium to maintain proper health. High levels of exposure, though, can lead to neurological abnormalities such as numbness. Breathing selenium in the air can cause respiratory tract infection.

There is no evidence that selenium exposure increases the risk of cancer in humans.

Silver is found in small amounts in most electronic products. Because of the relatively high value of silver, it is usually extracted from WEEE and repurposed.

Exposure to air containing high concentrations of silver has been known to result in breathing problems and irritation to the lungs and throat. Some people have allergic reactions, such as a rash, when silver contacts their skin.

The EPA has determined that silver is not classifiable as to its human carcinogenicity.

Tantalum is a soft, corrosion-resistant metal used in some electronics as capacitors. Tantalum may cause eye and skin irritation or issues in mucous membranes and upper respiratory tracts if ingested, inhaled, or absorbed through skin.

The EC's working group defines tantalum as a "critical raw material." There are no substitutes that perform as well as tantalum, supply is dominated by the Democratic Republic of Congo, and there is a low recycling rate.

Thallium is used in some batteries and semiconductors. Exposure to high levels of thallium has been reported to cause nervous system effects and problems with the heart, lungs, and kidneys.

No study into the possible carcinogenic effects of thallium is available.

Tin, found in the lead-free solder used in many electronic devices made today, can combine with other chemicals to make compounds. When tin is released into the environment, metallic tin will quickly form inorganic tin compounds that cannot be destroyed naturally. Exposure to large amounts of inorganic tin compounds can lead to anaemia and liver or kidney problems.

There is no evidence that tin or tin compounds can cause cancer in humans.

Zinc is found in most electronic products, especially in monitors and televisions. Inhalation of large amounts of zinc as dust or fumes is known to cause a short-term disease called "metal-fume fever," but zinc is not classified as to its carcinogenicity.