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Production and Recycling of Aluminium

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Even though aluminium is the most common metal on the planet, pure aluminium does not occur naturally. Aluminium atoms easily bind with other metals, forming compounds. At the same time it's impossible to isolate aluminium by simply melting down the compounds in a furnace, as is the case with iron, for example. The aluminium production process is much more complex and requires huge amounts of electricity. For this reason, aluminium smelters are always built in the vicinity of power energy sources, usually hydroelectric power plants that don't contaminate the environment [1].

The aluminium production process can be broken down into three stages; first bauxites, which contain aluminium, are extracted from the ground. Second, bauxites are processed into alumina or aluminium oxide, and finally in stage three, pure aluminium is produced using electrolytic reduction. About 4-5 tons of bauxites get processed into 2 tons of alumina from which about 1 ton of aluminium can be made.

There are several minerals available in the world from which aluminium can be obtained, but the most common raw material is bauxite. Bauxite is a mineral made up primarily of aluminium oxide mixed with some other minerals. Bauxite is regarded as high quality if it contains more than 50% of aluminium oxide.

There is a lot of variation in bauxites. Structurally they can be solid and dense or crumbly. The usual color is brick red, flaming red or brown because of iron oxide. If iron content is low, bauxite can be grey or white. But yellow, dark green and even multi-colored bauxites with bluish, purple, red and black strains occur too.

About 90% of global bauxite supplies are found in tropical and subtropical areas, with 73% found in just five countries: Guinea (having the largest supply), Brazil, Jamaica, Australia and India.

The most common way to mine for bauxites is by using open pit mines. Special equipment is used to cut one layer after another off the surface, with the rock then being transported elsewhere for further processing. However, there are places where aluminium ore has to be mined from deep underground which require underground mines to be built to get at it.

Pure aluminium oxide, called alumina, is extracted from bauxite via a process called refining, composed of two steps: a digestion process, using caustic soda, which allows the separation of aluminium hydroxide from the so-called *bauxite residue*, followed by a calcination step which removes the water content in the hydroxide. Both the aluminium hydroxide and the aluminium oxide have further applications outside of the metal industry [2].

In 1886, two 22-year-old scientists on opposite sides of the Atlantic, Charles Hall of the USA and Paul L.T. Heroult of France, made the same discovery – molten cryolite (a sodium aluminum fluoride mineral) could be used to dissolve alumina and the resulting chemical reaction would produce metallic aluminum. The Hall-Heroult process remains in use today. The Hall-Heroult process takes place in a large carbon or graphite lined steel container called a reduction pot. In most plants, the pots are lined up in long rows called potlines. The key to the chemical reaction necessary to convert the alumina to metallic aluminum is the running of an electrical current through the cryolite/alumina mixture.

The process requires the use of direct current (DC) – not the alternating current (AC) used in homes. The electrical voltage used in a typical reduction pot is only 5.25 volts, but the amperage is very high – generally in the range of 100,000 to 150,000 amperes or more. The current flows between a carbon anode (positively charged), made of petroleum coke and pitch, and a cathode (negatively charged), formed by the thick carbon or graphite lining of the pot. When the electric current passes through the mixture, the carbon of the anode combines with the oxygen in the alumina. The chemical reaction produces metallic aluminum and carbon dioxide. The molten aluminum settles to the bottom of the pot where it is periodically syphoned off into crucibles while the carbon dioxide – a gas – escapes. Very little cryolite is lost in the process, and the alumina is constantly replenished from storage containers above the reduction pots [3].

The metal is now ready to be forged, turned into alloys, or extruded into the shapes and forms necessary to make appliances, electronics, automobiles, airplanes, cans and hundreds of other familiar, useful items. Aluminum is formed at about 900°C, but once formed has a melting point of only 660°C. In some smelters this spare heat is used to melt recycled metal, which is then blended with the new metal.

The smelting process required to produce aluminum from the alumina is continuous, the potline is usually kept in production 24 hours a day year-round. A smelter cannot easily be stopped and restarted. If production is interrupted by a power supply failure of more than four hours, the metal in the pots will solidify, often requiring an expensive rebuilding process. The cost of building a typical, modern smelter is about $1.6 billion [3].

Globally, the aluminum industry annually emits millions of tons of greenhouse gases such as carbon dioxide, which contributes to global warming. Although aluminum cans represent only 1.4 percent of a ton of garbage by weight, according to the Container Recycling Institute, they account for 14.1 percent of the greenhouse gas impacts associated with replacing an average ton of garbage with new products made from virgin materials [4]. Aluminum smelting also produces sulfur oxide and nitrogen oxide, two toxic gases that are key elements in smog and acid rain. In addition, every ton of new aluminum cans that must be produced to replace cans that were not recycled requires five tons of bauxite ore, which must be strip-mined, crushed, washed and refined into alumina before it is smelted. That process creates about five tons of caustic mud that can contaminate both surface water and groundwater and, in turn, damage the health of people and animals.

There is no limit to how many times aluminum can be recycled. That's why recycling aluminum is such a boon for the environment. Aluminum is considered a sustainable metal, which means it can be recycled again and again with no loss of material. Aluminum recycling provides many environmental, economic and community benefits; it saves energy, time, money and precious natural resources; and it generates jobs and helps to pay for community services that make life better for millions of people.

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