ALUMINIUM

in the Building
and
Construction Industry

Ecological and Sustainable

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Foreword

Man has been influencing his environment since the beginning of civilisation. However, until during the 19th century man's influence was at most of local or regional significance. Increased economic activity and population growth have meant that environmental protection and conservation of resources are now among the fundamental challenges of our time. This also includes the need to adopt a responsible approach towards natural resources.

Acting responsibly means acting rationally, free from ideological influences. On the contrary, it is important to present ecological facts transparently in the context of the life cycle of a product. One can only make significant statements about the environmental impact of a product if one has a precise knowledge of the raw materials required, and the emissions produced, and if details of the waste produced during all phases of the life cycle are available and systematically documented. The use phase has to be assigned equal importance in this respect.

At an international level the discussion about the ecological assessment of products is now of a high technical standard. Ecological considerations of products should aim at achieving the same level as these discussions.

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1 Introduction

The demand for aluminium in Germany cannot be met by the country's own production. Aluminium therefore has to be imported. Bauxite, which is the most important raw material for the extraction of aluminium, is mined mainly on other continents, such as Australia, South America and Africa. Aluminium products "Made in Germany", on the other hand, are sold all over the world. Discussions of economic and ecological aspects must therefore take the global network of production, sale and provision of the necessary raw materials into account.

The ecological component depends on several aspects and therefore cannot be used as the sole basis for any decision. If, for example, a draughtsman, a designer or an architect is able to choose between several materials for a building, he will not base his decision merely on ecological criteria. A balanced judgement can only be made based on an overall assessment of economical, technical, environmental and socio-political considerations. This requires objective information on the previous history of the material to be used and the efforts required during the useful life of a component, such as the need for replacement because of a short product life or inadequate maintenance. Even aspects associated with dismantling and the ecological and economic value after use must also be included in the big picture.

The acceptance of a product therefore depends on lots of factors. The most important ones are that it fulfils its function, is easy to handle, is economical and long-lasting, offers plenty of scope for design, has a pleasant appearance, and of course is environmentally compatible.

It is important that ecological considerations include the complete life cycle of a product. Lifecycle Analysis can be a useful tool in this respect.

2. The phases in the life cycle of an aluminium product and its ecological relevance

Below, consideration is given to the environmental impact of aluminium building products during the different phases of the life cycle and to changes that have been made in recent years.

2.1 Bauxite mining

After oxygen and silicon, aluminium is the third most abundant element in the earth's crust. It occurs in a strongly concentrated form in bauxite, an ore that is made up of different chemical components containing varying amounts of aluminium and which is found in various places around the world. The main deposits are in Australia, West Africa and South America where bauxite is obtained mainly by open-cast mining. One requires about four tonnes of bauxite to produce a tonne of primary aluminium. In contrast to many other metals, the metal content of the bauxite ore does not have to be enriched using complex processing techniques.

The known reserves of mineable ore are now put at 23 000 million tonnes. There is no scarcity of resources, especially when one considers the increased recycling of used aluminium products.

2.1.1 Ecological aspects

As far as bauxite mining is concerned, the topics raised in the ecological debate include the following:

- the Third World problem
- damage to the landscape as a result of earth movements in the bauxite mines
- destruction of rain forests.

The "Third World problem" is often raised as a general criticism but usually nothing concrete is mentioned. It is a term that the public often associates with exploitation, child labour and political suppression. This is not a problem that occurs in connection with bauxite mining. In developing countries, the income from the mining and export of bauxite make an important contribution towards tackling poverty and under-development.

Bauxite is usually open-cast mined. This results in major earth movements. The layers of soil that have to be removed to get to the bauxite are stored separately. After use, the mining area is then covered over with the same soil and reforested. The world’s production of bauxite in 1996 was 122 million tonnes. By comparison, 213 million tonnes of gravel were extracted in 1994 in Germany alone, together with the associated earth movements.

Worldwide, of the area used for bauxite mining, about 2.4 square kilometres are in rain forests. The total area of the rain forests used annually for bauxite mining is 0.00002 percent. Even a large part of this is re-cultivated. The major cause of damage to the rain forests occurs as a result of normadic farming and agricultural use by native races and the poorest classes of the population, for whom this is the only way to earn a living because of the absence of industrial development.

2.1.2 Measures taken by the industry

The industry undertakes considerable efforts to keep any disruptions of nature to a minimum and to re-cultivate the mined area after completion of the mining activities. In 1990 the Aluminum Company of America (Alcoa) was awarded the "Global 500" United Nations’ environmental prize for exemplary re-cultivation of its bauxite mines in Australia.

In Brazil, Hydro Aluminium is working together with rain forest conservationists. Hydro Aluminium is undertaking comprehensive measures aimed at keeping detrimental effects on the rain forest as small as possible. Worked out bauxite mines have been successfully reforested.

In Guinea, bauxite mining carried out by the Compagnie des Bauxits de Guinee (CBG) is subjected to the use of new environmental monitoring technologies. In addition to evaluating the environmental compatibility of all large projects, these technologies include the management of soil, water and waste. After completion of the mining activities, extensive re-cultivation is carried out.

2.2 Alumina production

Aluminium compounds are first removed chemically using caustic soda. Alumina (aluminium oxide) is produced from the bauxite as an intermediate product. This also requires the addition of limestone.

Years ago, alumina plants were operated in those countries in which the aluminium was consumed. Nowadays, alumina production is being carried out in the bauxite-producing countries, possibly with direct access to the sea to facilitate sea-borne transport. One important reason for this shift to the bauxite-producing countries is the desire of many developing countries to upgrade their raw materials themselves and hereby to achieve further economic development by creating jobs in their own countries. This makes a significant contribution along the path towards sustainable development in these countries.

2.2.1 Ecological aspects

As far as the production of alumina is concerned, a topic raised in the ecological debate is:

- problems with waste tips and the disposal of red mud.

Red mud is the concentrate that is left over after aluminium has been extracted from the bauxite. The red colour is attributable to the high, natural iron content of the ore. Red mud comprises essentially of a mixture of minerals containing aluminium, iron, titanium and silica. It is slightly alkaline as a result of the chemical treatment with caustic soda. At one time, this red mud was simply dumped untreated into lakes, rivers or the sea.

Nowadays, one removes as much caustic soda as possible from the red mud before the mud is dried and sent to waste. There is still a small residual amount of alkali in the red mud at this stage. However, over a period of time, this reacts with carbon dioxide from the atmosphere to produce sodium bicarbonate. There are no environmental impacts of any significance. The concentrations of the components that can be washed out are well below the severe criteria demanded by the German *"TA Abfall"* (German Federal Government regulations relating to waste) for the disposal of waste above-ground.

2.2.2 Measures taken by the industry

Waste disposal sites operated today have a basic seal and a processing plant for all excess rain-water that does not evaporate. Checks are carried out regularly on the ground water in inspection wells to ensure that the seal is functioning properly. The method of disposal used means that even if the levels of alkalis and naturally-occurring secondary components in the red mud are higher than those occurring naturally in the soil they do not escape to the surroundings. There is thus no environmental impact.

Red mud is used in building materials, as a colouring pigment or as a filler material in the plastics industry, and to extract the iron. This use is, however, very limited at the moment.

In the only German alumina plant in Stade, the technology has been developed to such an extent that the red mud is pumped via a piping system to a controlled dumping site, where it is stored in an environmentally neutral manner. The caustic soda that remains behind after the sedimentation process is returned to the production process. This, too, is sustainable development.

2.3 Primary aluminium production

The most widely used process for extracting aluminium from alumina is based on fused electrolysis. One requires 1.9 tonnes of alumina to produce a tonne of primary aluminium. During the electrolysis process, the alumina is broken down into aluminium and oxygen. The molten aluminium is drawn off from the electrolysis cells and is cast to extrusion billets, rolling slabs or ingots before being processed further.

Aluminium electrolysis requires the use of electrical energy. For ecological as well as economical reasons, there is an increasing tendency for primary aluminium production to be carried out in those countries where energy, usually hydroelectric power, is readily available but cannot be used for other purposes.

Primary aluminium production in Germany is decreasing. The growth of German primary aluminium production has been as follows:

1985: 745 351 tonnes
1997: 571 941 tonnes.

2.3.1 Ecological aspects

As far as the production of primary aluminium is concerned, topics raised in the ecological debate include:

- energy use
- emissions.

The use of electrical energy in the electrolysis process is unavoidable. The environmental relevance will vary with the type of energy carrier used and the energy source. In particular, fossil-fuel energy carriers and the associated emissions lead to criticism. On top of this there is the question of resources of fossil fuels. Nuclear energy is to a large extent free from emissions but has problems with public acceptance. The use of renewable energy carriers, such as hydroelectric power, is usually acceptable.

Fluorides, sulphur dioxide, organic compounds and dust are produced during electrolysis and during the production of the anodes. Without the appropriate plant and equipment for environmental protection, impurities would escape to the atmosphere or pollute water and the soil, with corresponding consequences for mankind and the environment.

Investigations have failed to find any relationship between primary aluminium production and damage to health. A Norwegian study carried out between 1990 and 1994 did not find any irreversible damage in flora and fauna and people. Modern filter technology removes 99 % of gaseous and solid fluoride emissions.

2.3.2 Measures taken by the industry

In the past, furnace technology has been further developed, not least to improve electrical efficiency and reduce the energy required for electrolysis. The cost of electricity is an important cost factor in the production of primary aluminium so aluminium producers are particularly keen to reduce these costs. Here, economical and ecological improvements go hand in hand with sustainability.

Energy costs are an important factor when analysing plant locations. New primary aluminium smelters are usually built in countries with abundant supplies of energy. A smelter that went into production in Nigeria in 1997 uses so-called associated gas to produce energy. This is a by-product obtained during oil production. In the absence of other possible applications this gas would otherwise be burnt off. In Norway, Iceland, Brazil, Venezuela and Canada, primary aluminium is produced exclusively using hydroelectric power. Often there is no alternative use for the excess energy. Worldwide, about sixty percent of the primary aluminium produced today is already being produced with the help of hydroelectric power.

In Europe, the average amount of energy required to produce one kilogram of primary aluminium has been reduced from 17 kWh to 15 kWh since 1980. This alone has led to a 12 % reduction in specific emissions. Increased energy efficiency in the electrolysis cells has also led to a reduction in the amount of energy used and thus to the quantities of CO_2 emitted.

Emissions in primary aluminium smelters have been markedly reduced by improved filter technologies. Sulphur dioxide emissions are treated with salt and caustic solutions. The anode effect, which is responsible for specific organic emissions, has been drastically reduced by the use of computer-controlled monitoring, improved furnace technologies and better training of personnel.

The German aluminium industry has not only continually introduced technical improvements to reduce emissions but is also willing to commit itself to achieving further improvements in the future too. Through a declaration made by its parent organisation, Wirtschaftsvereinigung Metalle e. V, together with other associations and presented to the Federal Government on 10. March 1995, it committed itself to:

- reducing CO_2 emissions and energy consumption by use of products containing light and high strength non-ferrous metallic materials

- reducing CO_2 emissions and energy consumption by processes and techniques in which the process is optimised, secondary aluminium production is increased and recycling is encouraged

- presenting biannual reports to enable reduction targets to be checked.

Besides this, the German aluminium industry has issued a commitment to the Federal Ministry for the Environment that it will reduce emissions of perfluorinated hydrocarbons (PFCs) by a half by the year 2005, based on 1990 levels.

2.3.3 The ecological significance of energy consumption

Energy in its different forms is the basis for life and is often at the centre of ecological considerations of a product. During the life cycle, the energy supply processes are an aspect of eco-balance considerations, as are useful life, manufacturing and transport processes and recycling. As with any other process, energy can only be supplied by disrupting the eco-system. These disruptions will differ depending on the energy carrier used and the different methods of use. Ecologically, there are major differences between energy supplied from renewable energy sources and non-renewable energy sources. Thus, for example, the supply of electrical energy from fossil fuels leads to larger quantities of emissions, which are not produced if the energy is supplied by hydroelectric power.

Statements concerning energy can only be interpreted from an ecological point of view if one has a knowledge of the nature and quantity of primary energy carriers being consumed and the emissions associated with the conversion process.

2.4 Product manufacture

In terms of quantity, the building and construction industry is the second most important application for aluminium after transport.

The main uses are windows, doors and facades, followed by uses for roofs and walls. Other applications include, for example, fittings for windows, handles for doors and windows, aerials and lightening conductors, and support structures for solar panels and photovoltaic units. A favourable combination of properties is the prerequisite for this wide range of applications of aluminium in the building and construction industry.

The high material strength provides the basis for intricate and stable support structures. In addition, it ensures that even thin frames do not warp. The low density enables lightweight support structures to be constructed, which fulfil the requirements of complex building physics and design. In addition, it permits a high degree of prefinishing of components in the factory, and these can then often be handled at the building site without the need for lifting gear. The corrosion resistance is a particularly important factor with components that cannot be accessed once installation is complete and thus cannot be checked to ensure they are still functional.

Different shaping processes have to be used depending on the part in question. Thus, profiles, rods and bars, wire or tubes are made from round billets in extrusion plants. In the building sector these are used mainly for windows, doors, facades and items that afford protection against the sun. Thanks to aluminium’s good shaping properties, it is possible to produce extruded profiles with complex cross sections, which can be used to provide system solutions. Such profile systems are used mainly in building construction for the ends of roofs and walls, railings, hanging ceilings, window frames, window walls and doors.

Slabs are processed to sheet and strip in rolling mills. A large proportion of these rolled products is further processed for roofing and external applications. Aluminium foil is also rolled. It is used, for example, as a backing material, with a thickness of less than 0.2 mm. In foundries, ingots are processed to produce shaped castings. These are used for handles for doors or windows or for radiators.

Aluminium products can be specially finished by use of different surface treatments. These lead to improved corrosion resistance and surface finish and optical effects.

2.4.1 Ecological aspects

Arguments against the aluminium industry are not usually raised in the debate about the ecological relevance of product manufacture. The most important reason for this is the fact that traditionally these processes have been well below the requirements demanded by the legislators.

However, as far as products are concerned, one topic raised in the ecological debate is:

- smaller fraction of secondary aluminium.

The demands for aluminium products made exclusively from recycled aluminium or with a high recycled-aluminium content does not make sense either ecologically or economically. In addition, the fact that aluminium is tied up in products with a long life coupled with the fact that the demand for aluminium products will continue to increase in the foreseeable future (even with 100 % recycling) means that demand cannot be met by secondary aluminium alone. The additional use of primary aluminium is necessary.

Moreover, for technical reasons, some aluminium products are only produced from primary aluminium, whereas others are made completely from secondary aluminium.

Because primary and secondary aluminium have the same technical properties, billets, slabs and ingots can be made from primary or secondary aluminium. Different alloys are tailor-made to for a specific application. If one takes an aluminium billet at random one cannot analyse it to say from what starting material, primary or secondary aluminium it originated. The material streams flow into one another.

2.4.2 Measures taken by the industry

The industry is continually developing its products further. This ensures that in many cases today less material is used for a given application than in the past, but without any limitations to the functionality (downgauging). Besides conserving resources and reducing emissions, this has also increased the competitiveness of the products.

Further ecological optimisation is achieved by the recycling of other materials used in the plant. Thus, for example, used rolling mill lubricants are treated and recycled. This, too, is a contribution to conservation of resources and sustainability.

2.5 Use phase

The use phase is the longest phase in the life of a building product. It often determines the ecological relevance of a building component. The use phase of aluminium building products is often dictated by the life of the building in which the aluminium product is used. The San Gioacchino Church in Rome exemplifies the long use phase of aluminium products. The aluminium dome has withstood the elements for more than 100 years.

Besides this, the fact that the products are long-lasting means that one can avoid having to replace a building component for a good many years, and thus avoid the inevitable consumption of resources that would otherwise occur.

At the end of the use phase of many building components one is faced with deciding whether to dismantle the building component, dispose of it as waste or to recycle it. The dumping of a used aluminium building component can be ruled out because of the high intrinsic material value and good recycling properties.

2.5.1 Ecological aspects

As far as the use phase of aluminium products in the building and construction industry is concerned, the topics raised in the ecological debate are mainly positive:

- long-lasting
- little need for maintenance during use
- little repair effort required.

These properties have contributed significantly to aluminium products being able to establish themselves in the building and construction industry.

2.5.2 Measures taken by the industry

The natural properties of aluminium manifest themselves fully during the use phase. Even so, the industry is undertaking further developments in the field of surface technology in order to increase the life of building components, even under extreme environmental conditions, while still maintaining the same functionality.

2.6 Recycling of aluminium products

When it comes to recycling, there are two main reasons why aluminium is such a valuable material. The first is the small quantity of energy required to recycle the metal. The other is the fact that the metallurgical properties of aluminium enable scrap to be melted down and used to make the same products again and again without any loss in quality. Thus, scrap windows can easily be made into new windows, or even some other high quality product. Aluminium products that have reached the end of their useful life are an important raw material. In addition to the ecological benefits associated with recycling there are also economical benefits.

Because of the benefits associated with aluminium recycling in terms of savings in energy and raw materials, an ever-larger fraction is being recycled. In the building and construction industry, 85 % of the aluminium used is already recycled. With certain products almost 100 % of the products are fed back into the material loop.

Depending on the surface condition, the aluminium scrap collected is either melted down in rotary drum furnaces under a molten salt slag or as a low-salt process in hearth furnaces or special recycling furnace.

2.6.1 Ecological aspect

As far as the production of secondary aluminium is concerned, a topic raised in the ecological debate is:

- problems associated with the treatment and disposal of salt slags.

Salt slags are mainly used in rotary drum furnaces for melting down scrap, which would otherwise be susceptible to considerable metal losses, by oxidation. The salt slag is also capable of removing metallurgically-undesirable impurities. During the process, what starts out as a pure mixture of salts gradually turns into a slag consisting mainly of sodium or potassium chloride and alumina. The mixture contains about 70 % metallic aluminium. Salt slag was also dumped as waste up to the end of the eighties.

2.6.2 Measures taken by the industry

The waste gases from the melting furnaces are treated in a central waste gas cleaning plant. The complex cleaning systems, which remove dust and emissions from the waste gases, fulfil the most-demanding waste gas purification requirements. German secondary aluminium smelters keep within the limits imposed by "TA Luft" (German Federal Government regulations relating to air emissions) or are considerably lower than these values. The equipment available for dealing with lacquered scrap has been continually improved. The efficiency of the furnaces has been improved by installing waste heat recovery units.

The salt slag produced is subjected to special treatment. In a process consisting of dissolution and recrystallisation, both the aluminium in the protective flux and the salts themselves are recovered, the latter being then used again. The total capacity of salt slag treatment plants in Germany is now higher than the amount of slag produced in Germany. In 1997 the capacity of the reconditioning plants was about 300,000 tonnes per annum, with about 200,000 tonnes of salt slag accruing annually. The industry’s attempts to reduce the amount of salt used, and thus the amount of salt slag produced, are showing clear signs of success.

3. Recycling in the building industry: the A/U/F initiative

The environmental debate is increasingly demanding closed material loops. Aluminium products satisfy this demand, not least because of the low energy requirement for recycling and the high economic value of secondary aluminium.

In 1994 building-system suppliers and aluminium companies set up the A/U/F initiative (Aluminium and Environment in the Manufacture of Windows and Façades). The aim of this initiative is to establish a complete material loop for building products. In particular, one wants to ensure that dismantled components and processing waste are returned to a closed material loop.

The following will ensure that materials are recycled:

- The system profile manufacturer or supplier of profiles delivers product to the window or façade manufacturer.
- The system supplier reaches an eco-agreement with the window or façade manufacturer, who commits himself to returning used aluminium building products to the material loop.
- The window or façade manufacturer reaches an agreement with a collection organisation to transport dismantled, used elements and any processing waste to a reprocessing plant.
- Here all the aluminium scrap supplied, whether it be simple aluminium sections or old windows that have been dismantled and still have some glass, seals and fittings attached, will be processed in a purely mechanical manner.

- The processed, clean aluminium scrap will then be supplied to a secondary aluminium smelter. Here it will be cast into new extrusion billets or rolling ingots, which will be used to produce new aluminium products.

4. Conclusion

This table summarises the improvements that have been achieved in recent years:

Bauxite mining - consideration of ethnic factors - reforestation / re-cultivation - environmental monitoring (soil, water and waste management) - improved working conditions - job creation / training
Alumina production - use as colour pigment or filler material - research programmes - controlled waste disposal - internal closed loop recycling of caustic soda
Primary aluminium production - increased use of hydroelectric power - reductions in energy requirement and emissions by use of modern technologies - hooding of pots - research into inert electrodes - improved monitoring - improved qualification of staff - voluntary self-commitment of the German aluminium industry to CO_2 emissions - voluntary self-commitment of the German aluminium industry to reducing emissions of perfluorinated hydrocarbon emissions - use of modern filter technologies **Product manufacture** - recycling of materials used in the plant and production scrap - reduced use of materials
Use phase - long life - little need for maintenance during use - little repair effort required
Recycling - improved process technologies - twin-chamber melting furnace technology - improved cleaning plant and filter technologies - high recycling rates - system for guaranteeing to take back used products (A/U/F)

An additional effect of improving environmentally relevant data is the gradual replacement of out of date technologies out of economic, technical or environmental necessity.

The use of aluminium building products is ecologically sustainable and economical. It benefits mankind and the environment.