

# Aluminium Recycling, Energy Conservation and Environmental Concerns: A Review

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**Abstract:**-Aluminium has more uses and applications than any other metal. This implies that there should be a continuous production of this metal so as to meet the increasing demand. Manufacture of aluminium is one that consumes a significant amount of energy. Studies have shown that less amount of energy is required to recycle existing aluminium items. More than a hundred billion aluminium cans and other aluminium based products are sold in the United States each year. A similar number of aluminium cans in other countries are incinerated or sent to unauthorized landfills or dumpsites or littered all over as a result of poor waste management and absence of refuse disposal laws while less than half are recycled. However, the aluminium industry emits millions of tons of greenhouse gases such as carbon (IV) oxide which contributes to global warming annually. It is against this background that the paper reviewing the recycling of aluminium, conservation of energy and environmental concerns is drawn. The extraction of aluminium, environmental impact, aluminium recycling, energy conservation and the future of aluminium will be fully discussed.

**Keywords:** Aluminium, Extraction, Recycling, Conservation,

## I. INTRODUCTION

Aluminium has emerged as the most environmentally sustainable substance available to planet earth. Its strength, conductivity, ability to be recycled and lightweight makes it preferably suited to the demands of a highly mobile and technologically advanced world. It offers customers a clear advantage through its ability to be repeatedly recycled without loss of quality and with only five per cent of the original process energy use and emissions. The demand for aluminium products is growing steadily because of their positive contribution to modern living. Aluminium finds extensive use in air, road and sea transport; food and medicine; packaging; construction; electronics and electrical power transmission (Salman, 2018)

Aluminium was discovered by a Danish chemist Hans Christian Oersted in 1825 in Denmark (Essays, UK 2018). It is the third most abundant element in the earth's crust comprising. It is found abundantly as trioxosilicates (iv) in rocks and clays with the primary source being the mineral bauxite,  $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ . Other important minerals include kaolin;  $(\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O})$ , cryolite;  $(\text{Na}_3\text{AlF}_6)$ , corundum;  $(\text{Al}_2\text{O}_3)$  and mica;  $(\text{K}_2\text{O}_3 \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2)$  (Ose Yaw, 2013)

In nature, aluminium is found only in chemical compounds with other elements such as sulphur, silicon and oxygen (Shakhashiri, 2008). Aluminium was acknowledged as an

element and isolated as pure metal around mid nineteenth century. The metal stayed uncommon for many years due to the difficulty associated with extracting it from its ore. Half a century after its discovery, aluminium was still as rare and valuable as silver (Ose Yaw, 2013). Pure metallic aluminium can be economically produced from aluminium oxide ore.

## II. ALUMINIUM EXTRACTION

Industrial production of aluminium commenced with the mining of bauxite, an impure form of aluminium oxide which constitutes approximately 16% of the earth's crust (Smith, 2013). Bauxite is made principally out of iron oxides, titanium oxide, silicon oxide and un-dissolved alumina together with an extensive variety of different oxides that varies depending on the country of origin of the bauxite. The high iron content in the bauxite gives the residue its characteristic red colour hence the name 'red mud' or bauxite residue (EA, 2015, Rai, *et al*, 2013). The chemical composition and mineral content is shown in table 1 and 2 respectively

Table 1: Percentage chemical composition

Components	Range %
$\text{Fe}_2\text{O}_3$	20-45
$\text{Al}_2\text{O}_3$	10-22
$\text{TiO}_2$	4-20
$\text{CaO}$	0-14
$\text{SiO}_2$	5-30
$\text{Na}_2\text{O}$	2-8

Source: EA, 2015

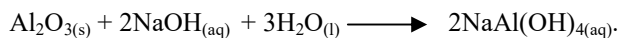
Table 2: Percentage mineralogical composition

Components	Range %
Boehmite( $\text{AlOOH}$ )	0-20
Calcite ( $\text{CaCO}_3$ )	2-20
Calcium aluminate ( $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{H}_2\text{O}$ )	2-20
Cancrinite ( $\text{Na}_6[\text{Al}_6\text{Si}_6\text{O}_{24}] \cdot 2\text{CaCO}_3$ )	0-50
Diaspore( $\text{AlOOH}$ )	0-5
Geothite ( $\text{FeOOH}$ )	10-30
Gibbsite ( $\text{Al}(\text{OH})_3$ )	0-5
Hematite ( $\text{Fe}_2\text{O}_3$ )	10-30

Kaolinite ( $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ )	0-5
Magnetite ( $\text{Fe}_3\text{O}_4$ )	0-8
Muscovite ( $\text{K}_2\text{O} \cdot 3\text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ )	0-15
Perovskite ( $\text{CaTiO}_3$ )	0-12
Silica ( $\text{SiO}_2$ )	3-20
Sodalite ( $3\text{Na}_2\text{O} \cdot 3\text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \cdot \text{Na}_2\text{SO}_4$ )	4-40
Titanium dioxide ( $\text{TiO}_2$ )	2-15

Source: EA, 2015

Due to the high silica content of the ore, aluminium is extracted from bauxite by electrolysis. The extraction involves purification of the crude bauxite to yield pure anhydrous aluminium oxide which in the second stage is electrolyzed. The bauxite is first treated with sodium hydroxide solution under pressure to form sodium aluminate (III).



Iron (iii) oxide and various trioxosilicates (iv) which are impurities in the ore and are inert and insoluble in alkali can then be filtered off as sludge. The filtrate which contains the aluminate (iii) is then seeded with crystals of aluminium hydroxide to induce the precipitation of aluminium hydroxide (Philip, 2003).



The aluminium hydroxide precipitate is then filtered off, washed, dried and heated strongly to yield pure aluminium oxide or alumina ( $\text{Al}_2\text{O}_3$ ), while the sodium hydroxide is concentrated and reused (Philip, 2003). Figure 1 below shows a step-wise process of aluminium extraction from bauxite using the Bayer's process. However, mining alone is not sufficient to meet this demand. Recycling, therefore, comes in to bridge the gap.

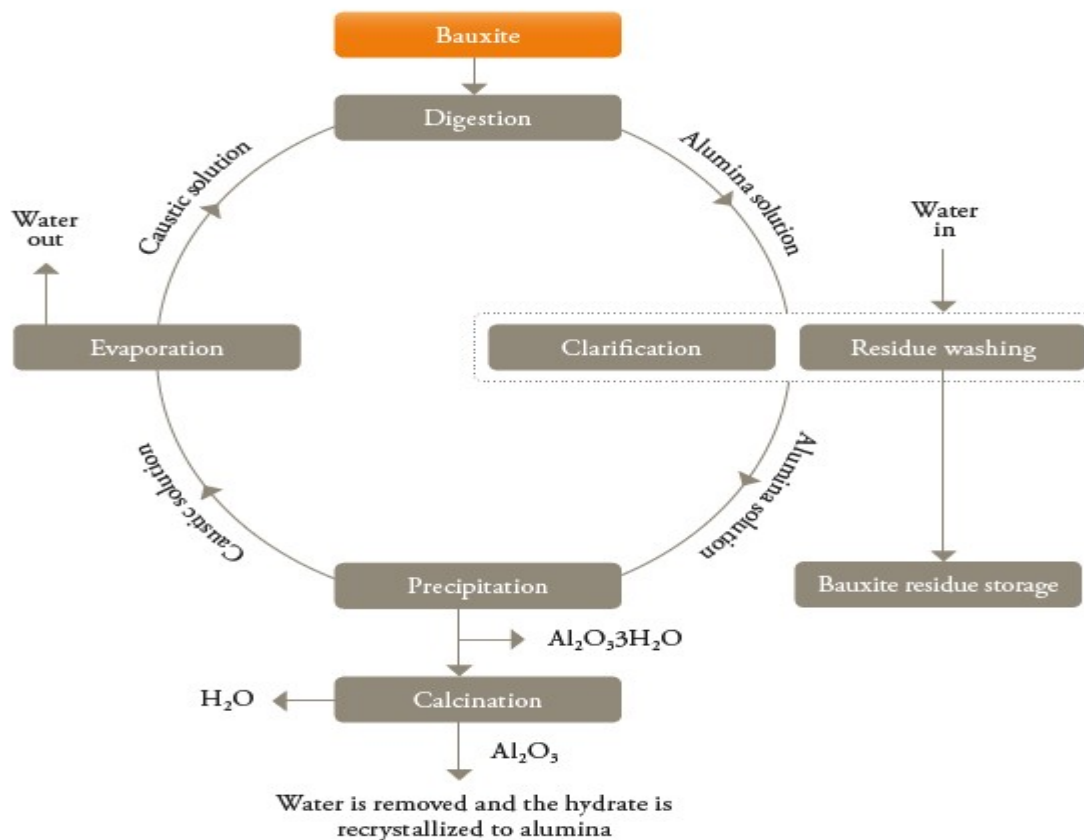


Figure 1: Flow diagram of the Bayer's process

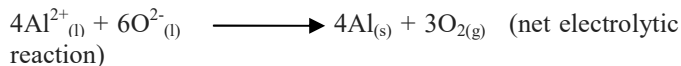
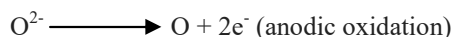
Source: www.hydro.com

### 2.0.1 Electrolysis of Alumina

Alumina ( $\text{Al}_2\text{O}_3$ ), is dissolved in molten synthetic cryolite,  $\text{Na}_3\text{AlF}_6$ , to lower its melting point for easier electrolysis (Totten *et al*, 2003) During the electrolysis of alumina,

oxygen is given off at the anode (oxidation) following the donation of two electrons by oxygen ions which then combine to form gaseous oxygen. This causes the anode to burn away slowly and so must be replaced continuously. At the cathode,

aluminium ions gain electrons (reduction) and become deposited as metallic aluminium. Molten aluminium is collected at the bottom of the cell and tapped off periodically.



### 2.1 Environmental Impact

The biggest environmental problem in various towns and cities around the world is that of solid wastes (Ajiwe *et al.*, 1998). Solid wastes generate horrid open dumps and overfilled bins, polluted air and water and litter landscape of towns.

Pollution is a global threat to the world. Lives have been lost due to pollution of the environment. Environmental pollution occurs as a result of the introduction of any material into the environment in quantities greater than its natural concentration and which has a damaging effect on the environment (Okonkwo, 1999).

Much of its escalation arises from the increased production and consumption of materials that eventually become wastes. Its effect is doubled by the fact that the quantity of material that is recycled is of low percentage, aluminium inclusive.

Pollution results from the large numbers of used aluminium cans that are disposed of indiscriminately. Failing to recycle aluminium, therefore, is a prelude to environmental pollution. The failure to recycle aluminium contributes to millions of tons of greenhouse gases such as carbon (IV) oxide, which contributes to global warming. Global warming presently affects many parts of the world with its resultant effects including alarming sea and ocean rise, bush burning and ultimate destruction of the ecosystem.

The production of new aluminium from bauxite ore to replace existing ones creates about five tons of caustic mud that can pollute both surface water and groundwater and in turn affect the health of the people (www.thefirstgroup.com, 2012).

Smelting aluminium also produces two toxic gases sulphur oxide and nitrogen oxide that are key elements in acid rain and smog (Environmental Global warming and Greenhouse effect, world almanac, 2000).

The production of electricity for aluminum refining regularly includes consuming fossil fuels, this activity discharges carbon dioxide, an ozone-depleting substance into the air. Moving the bauxite mineral from the mining site to the processing plant likewise requires a lot of energy. It takes what might be compared to around 1,740 gallons of gas to create one ton of crude aluminum therefore discharging a lot of ozone-depleting substance into the air. Recycling a ton of aluminium cans, by contrast, only uses about 90 gallons of gasoline or the equivalent in fossil fuels. Recycling aluminium

cans, therefore, has a considerable net positive environmental impact (John, 2017).

#### 2.1.0 Greenhouse Gases (GHGs)

Globally, the aluminium industry emits millions of tons of greenhouse gases which add to global warming yearly (Larry, 2018). The production of new aluminum results in around 1% of global annual greenhouse gas (GHG) emissions. Mining, refining, smelting and casting primary aluminum releases about 0.4 billion tons of carbon dioxide equivalent emissions per year (GNCS, 2012). Greenhouse gases are gases that possess the property of absorbing infrared radiation emitted from the earth's surface and reradiating it back to the earth's surface (Mann, 2019). A number of processes have influenced considerably the concentration of greenhouse gases. Some of these processes include anthropogenic activities among others. The effect of each greenhouse gas on earth's climate is dependent upon its chemical nature and relative concentration in the atmosphere. Some gases possess a high ability to absorb infrared radiation, while others have considerably lower capacities for absorption

Percentage composition of major greenhouse gases is given in table 3

Table 3: Greenhouse gases

GHGs	% composition
Carbon (iv) oxide (CO <sub>2</sub> )	9 – 26%
Methane (CH <sub>4</sub> )	4 – 9%
Ozone (O <sub>3</sub> )	3 – 7%
Water vapour (H <sub>2</sub> O <sub>(g)</sub> )	36 – 72%

#### 2.1.1 Acid Rain

Any form of precipitation which is acidic in nature gives rise to acid rain. Acid rain is a form of pollution that can cause a lot of damage to the natural ecosystem, man-made objects as well as harm to human health. It is caused by both anthropogenic and natural sources and forms when chemical pollutants in the surroundings react with oxygen and water vapour in the atmosphere to form nitric acid and sulphuric acid (Savage, 2017). Acid rain gave rise to a number of inorganic and a biochemical reaction which has deleterious effects on the environment, thus making it an increasing environmental problem worldwide (Cassidy and Frey, 1998).

Acid rain results into acidification of soil which increases the exchange between hydrogen ion and nutrient cations such as potassium, Magnesium and Calcium in the soil (Singh and Agrawal, 2008). Atmospheric pollutants are easily moved by wind currents so acid-rain effects may be felt far from where pollutants are generated.

### III. ENERGY CONSERVATION

Aluminium and energy have been intertwined since the initial isolation of the metal from its ore, and industry growth has depended on great quantities of inexpensive, available

energy. In response to the modern need, the industry has significantly decreased the energy required for the chemical steps in aluminium production (Russel, 1983)

Recycling aluminium saves 90 – 95% of the energy required to produce aluminium from its ore (Aluminium association 2011). Recycling existing aluminium to create aluminium needed for other products is more energy-efficient than producing aluminium from virgin natural resources. About 7KWh of electricity is saved by recycling one pound of aluminium (container-recycling.org, 2006).

#### IV. ALUMINUM RECYCLING

Since aluminum was first commercially produced just over 100 years ago, the North American aluminum industry has evolved from limited production of products and alloys to high-volume manufacture of a wide variety of products (Aluminium industry vision, 2001). Recycling was a low-profile activity until the late 1960s, when the growing use of aluminium beverage cans brought it to public awareness (Schlesinger, 2006). In an asset compelled world, reusing is basic to feasible advancement. It enables assets to be saved and waste to be reduced to the barest minimum.

The aluminium can is the most recycled consumer product in the world. The contribution of recycled metal to the global output of aluminium products has increased from 17 per cent in 1960 to 34 per cent today, and expected to rise to almost 40 per cent by 2020. Global recycling rates are high, with approximately 90 per cent of the metal used for transport and

construction applications recovered, and over 60 per cent of used beverage cans are gathered (Salman, 2017).

Aluminium scrap can be reprocessed to be used in products after its initial production. Used beverage containers (UBC) are one of the principal components of aluminium scrap with most of the scrap metal recycled back into cans. Recyclers in the aluminium industry work with individuals, communities and businesses to enable both curbside and industrial recycling programs. UBC (used beverage container) recycling is the most readily recognized of the recycling programs. Aluminium is also recycled at the end of life from products such as cars and building parts. Window frames, wire, tubing and electronics are additional examples of aluminium that is recycled at the end of life.

Aluminium recycling is both monetarily and ecologically valuable, as recycled aluminium requires just 5% of the energy expended in making aluminium from the scratch (Damgaard *et al*, 2009). Aluminium can, as a matter of fact, be reused unendingly without loss of material properties. Increasingly alloying components are brought into the metal cycle in the cause of recycling.

This impact is put to good use in the generation of casting alloys, which generally need these elements to attain the desired alloy properties (Salman, 2017)

Over the years, the USA and European countries have developed robust separate collection systems for aluminium packaging with a good degree of success. In Nigeria today, aluminium collection has become a lucrative venture

4.1 Schematic diagram of the recycling process

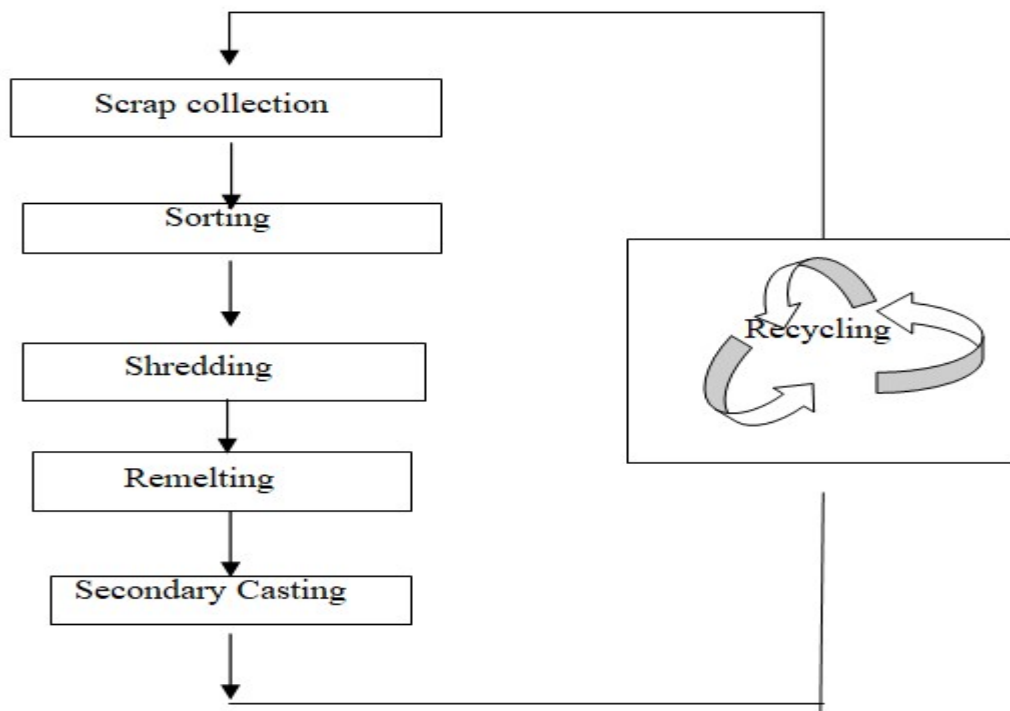






Fig 2 Aluminum cans stacked by scavengers  
Source: www.theweek.com

## V. THE FUTURE OF ALUMINIUM

Aluminium which has the electronic configuration of  $1S^2, 2S^2, 2P^6, 3S^2, 3P^1$  is a less reactive metal belonging to group 3 and period 3 of the periodic table and having an atomic number and atomic weight of 13 and 26.98153 respectively. When properly used, it contaminates the environment less. The world at large needs this metal and therefore recycling it would only serve well in protecting the environment from metallic contamination (Residential waste system, 2014)

Globally, close to 70% of all aluminium beverage cans are recycled, making it the world's most recycled packaging product. Because aluminium is infinitely recyclable, it can be reused in applications different from its previous use, and it can also be recast into its initial form.

These properties make aluminium an ideal material for use in premium applications, even after being recycled many times. For example, a 50-year-old building facade can be recycled into the aluminium needed for the engine block of a new car with no degradation in quality.

Nearly 90% of the beverage cans sold in the UK are made of aluminium and the current recycling rate (2011) for beverage cans stands at 55% so there's still plenty out there to collect and recycle (www.novelisrecycling.co.uk)

## VI. CONCLUSION

One of the most talked about problems in the world today is global warming. As a result, nations across the globe are focusing on the reduction of carbon (iv) oxide emission in the environment. Aluminium is infinitely recyclable making it the material of choice for balancing the demand of a growing economy with the need to preserve the environment.

Recycling aluminium ultimately will conserve a significant amount of energy, create jobs for the ever growing population across the globe as well as preserve the ecosystem Other benefits of aluminium recycling include; preventing the depletion of bauxite ore, as well as reduction of municipal solid waste (MSW).

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