In the Western world, recycling often feels like a chore. It is something we should do, like exercising and eating a healthy diet. This is in stark contrast to the situation in India where recycling is a livelihood for thousands of people who would otherwise have no way of making a living. The government does not run any recycling programs, and garbage is dumped in big containers outside of the cities.

Unemployed Indians often roam around the containers, looking for any material that can be recycled. The gathered waste is sold to small recycling plants that operate with basic technology and in poor conditions. Many of these plants are located in a slum town called Dharavi, in Mumbai, the economic capital of India. Employees work long hours for low salaries, but they are grateful to have jobs in a country where unemployment is high.

Muktar Hamed works for India’s informal recycling sector. He is 15 years old and earns a living by recycling aluminum scrap. Every day, he wakes up just before 7 a.m., washes, eats breakfast, and then starts his work. He has an hour for lunch and then continues working until 8 p.m. His job is to melt the aluminum scrap. At the end of the day, Muktar sleeps in a bed that is right next to the furnace.

Hamed is one of thousands of Indians who live in Dharavi, one of the largest slum towns in South Asia, and make money by recycling and reusing nearly every aluminum material they can find. Not only do these people support themselves, but they also created a multimillion-dollar industry that is changing the regional economy and is allowing people to earn money.

**Aluminum recycling in Dharavi**

In Dharavi, aluminum recycling involves three important steps. First, aluminum products that have been used and thrown away, especially old soda and beer cans, are collected. Second, the cans are soaked in acid, so the designs and brand names are removed. Third, the cans are crushed and melted in a furnace. Hamed works in a plant that receives crushed cans and then melts them in a coal-powered furnace. Once the cans have completely melted, the molten mixture is poured into molds, where it cools into solid aluminum bars called ingots. These bars are then transferred to another factory in Dharavi. There, they are melted again, and a special machine turns the liquid metal into blocks that are later used to make new aluminum items.

Hamed’s furnace is actually a hole in the ground, which is approximately one meter (3.3 feet) deep and half a meter (1.6 feet) wide. At the bottom of the hole is a vent, which is joined to the ground by a pipe. The purpose of the vent and the pipe is to enable oxygen to reach the lowest part of the furnace.
The furnace is filled with coal which is ignited and stoked to produce temperatures exceeding the 660 °C melting point of aluminum. Hamed places a crucible filled with the crushed scrap aluminum on the top of the furnace. The crucible is made of silicon carbide, which remains solid up to 2,730 °C.

**Why recycle aluminum?**

Aluminum recycling is profitable because extracting this metal from aluminum ore is expensive, it pollutes the environment, and it consumes a significant amount of energy. To understand how aluminum is used to make everyday products, let’s examine how an aluminum can is made (Fig. 1). When we recycle an aluminum can, we eliminate the initial steps, and the recycled aluminum becomes part of a cycle that can occur over and over again without loss of the aluminum’s properties.

Aluminum is extracted from an ore known as bauxite, which consists of aluminum oxide (Al₂O₃) and other compounds that contain aluminum, silicon, titanium, and iron. Aluminum oxide is separated from the other elements using the Bayer process, which consists of three stages. First, bauxite is dissolved in a solution of sodium hydroxide (NaOH) at high pressure and temperature. The resulting mixture contains a solution of sodium aluminate [NaAl(OH)₄] and undissolved bauxite residues containing iron, silicon, and titanium.

Sodium aluminate forms through the chemical reaction of aluminum oxide with sodium hydroxide and water, as follows:

\[
\text{Al}_2\text{O}_3 + 2 \text{NaOH} + 3 \text{H}_2\text{O} \rightarrow 2 \text{NaAl(OH)}_4
\]

The residues sink gradually to the bottom of the tank and are later removed.

In the second stage, the sodium aluminate solution is pumped into a huge tank and, as it cools, the sodium aluminate decomposes into aluminum hydroxide [Al(OH)₃] and sodium hydroxide:

\[
\text{NaAl(OH)}_4 \rightarrow \text{Al(OH)}_3 + \text{NaOH}
\]

The aluminum hydroxide forms a precipitate and sinks to the bottom of the tank, where it is removed.

In the third stage, the aluminum hydroxide is heated to 980 °C, which forms aluminum oxide according to the following reaction:

\[
2 \text{Al(OH)}_3 \rightarrow \text{Al}_2\text{O}_3 + 3 \text{H}_2\text{O}
\]

The aluminum is then produced from the aluminum oxide through a technique called aluminum smelting. It is based on a process known as electrolysis, in which an electrical current is used to produce the constituent elements of a chemical compound. In this case, aluminum oxide is separated into aluminum and oxygen (Fig. 2).

Electrolysis can be performed only on a liquid. Because aluminum oxide does not dissolve in water, it is dissolved in a vat of molten cryolite (Na₃AlF₆), which consists of the ions Na⁺ and AlF₆³⁻. Aluminum oxide dissolves into two ions, Al₂OF₆²⁻ and F⁻, by reacting with some of the AlF₆³⁻ ions from molten cryolite, as follows:

\[
\text{Al}_2\text{O}_3 + 4 \text{AlF}_6^{3-} \rightarrow 3 \text{Al}_2\text{OF}_6^{2-} + 6 \text{F}^-
\]

Aluminum (Al) is produced at the negative electrode, called the cathode, according to the following reduction reaction (gain of electrons):

\[
\text{AlF}_6^{3-} + 3 \text{e}^- \rightarrow \text{Al} + 6 \text{F}^-
\]

At the positive electrode, called the anode, the Al₂OF₆²⁻ ions react with the anode (which is made of carbon) to form carbon dioxide and carbon monoxide, for example by the following oxidation reaction (loss of electrons):

\[
\text{C} + 2 \text{Al}_2\text{OF}_6^{2-} + 12 \text{F}^- \rightarrow \text{CO}_2 + 4 \text{AlF}_6^{3-} + 4 \text{e}^-
\]

Combining the aluminum oxide dissolution reaction and the oxidation and reduction reactions gives the overall net reaction:

\[
2 \text{Al}_2\text{O}_3 + 3 \text{C} \rightarrow 3 \text{CO}_2 + 4 \text{Al}
\]

The next step consists of pouring molten aluminum into molds and letting the aluminum solidify into shape. These blocks of solid aluminum, or ingots, are forced through several rollers to become sheets that are less than 1-inch thick. The aluminum sheets are cut to make cans, which are sent to soft drink companies that fill and seal...
them. The canned soft drinks are sold to con-
sumers who drink them.

In the Western world, the cans are usually
collected and sent to a recycling center, where
they are cleaned, sorted, and crushed. Then,
they go to an aluminum manufacturing plant,
where they are shredded, remelted, and solidi-
fied again.

In India, the cans are collected from
garbage dumps and sent to small
private companies, where people
such as Hamed clean them using
acid at room temperature and
normal pressure. Then, they
melt the aluminum cans in a
furnace at 660 °C and pour
the molten aluminum into
a mold. The aluminum later
solidifies into shape.

Recycling aluminum is much
cheaper than extracting it.
Aluminum extraction requires
temperatures of 1,000 °C,
additional materials—such as
cryolite and sodium hydrox-
ide—need to be used, and a
significant amount of electricity
is needed.

**Advantages of recycling aluminum**

The key benefit of recycling is that it
reduces the amount of waste that needs to
be buried or burned. In the case of alumi-
num, there is also another advantage. If
old soda cans were simply buried, new
cans would have to be made from new
aluminum that would have to come from
aluminum ore. So, recycling aluminum has
an economic advantage as well as an environ-
mental one.

Not all materials are economically advanta-
geous to recycle. Plastic, for example, is often
cheaper to produce from raw materials than
it is to recycle. So, while plastic is endlessly
recyclable, it is often burned or simply buried
because it is not cost-effective to recycle it.

Other constraints also make materi-
als—such as green glass—less desirable
to recycle. It is not that the glass cannot be
endlessly recycled, it is because the color of
glass cannot be changed—once it is green, it
will be green forever. A lot of green glass
is imported into the United States, contain-
ing foreign-made beverages such
as wine and beer. But few
products are manufactured
from green glass in the
United States, meaning that
most of it is not recycled.

Another reason aluminum
is easier to recycle is because it does not cor-
rade, unlike other metals such as iron.

**Changing lives**

Thanks to Dharavi residents such as
Hamed, a high proportion of aluminum
is recycled in India. If it were not for their
efforts, nothing would be recycled there at all.
A big difference between India and the United
States is that in India, there is no government
recycling program. Indians do not have to
separate their waste, while U.S. residents are
encouraged to do so.

In India, it is a lifeline for people struggling
to survive. There, aluminum recycling has
helped transform local economies, which
serves to remind us that recycling not only
can improve the environment but can change
lives as well.

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Tom Husband is a science writer and chemistry
teacher in London, United Kingdom. His latest
ChemMatters article, “Recycling to Survive,”
appeared in the February 2011 issue.