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Disaster for people and the environment: 10 people died and more than 100 were injured when the dam of a red mud landfill burst near the village of Kolontár in western Hungary. More than 300 houses had to be demolished and several tonnes of contaminated soil had to be removed. The heavy-metal-containing corrosive mud also tainted the Torna and Marcal rivers.

GREEN STEEL FROM RED MUD

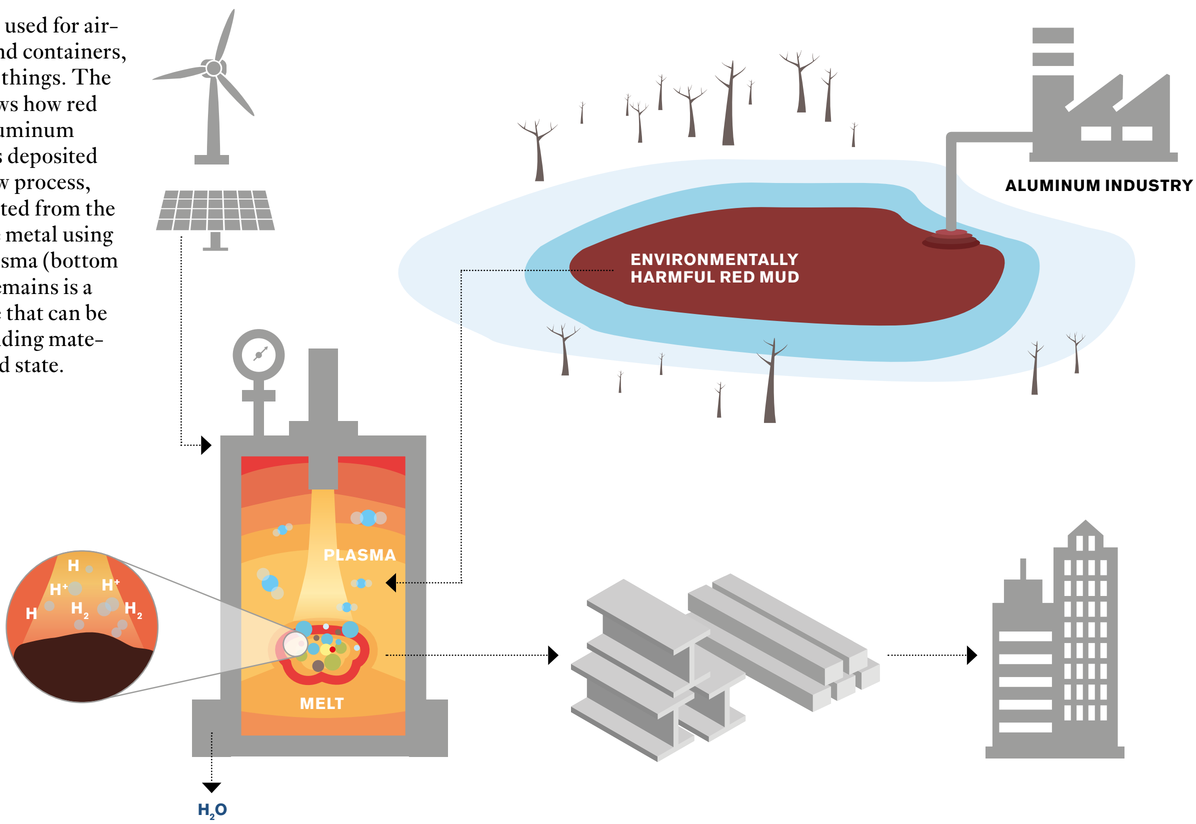
TEXT: PETER HERGERSBERG

Aluminum production generates massive quantities of toxic red mud. Moreover, the steel industry is a huge contributor to climate change with its CO_2 emissions. A team from the Max Planck Institute for Sustainable Materials has discovered a way to tackle both problems with a single process – one which would also be economically viable.

The devastating flood occurred around midday, at 12:25 p.m. on October 4, 2010, the dam of a reservoir, into which the company MAL AG was disposing of toxic red mud from aluminum production, burst near the western Hungarian town of Ajka. Several hundred thousand cubic meters of heavy metal-containing, corrosive mud surged into the surrounding countryside, burring parts of the villages of Kolontár, Devecser, and Somlóvasárhely. Ten people died, well over 100 were injured, and many more lost their homes. The disaster in Hungary illustrates the dangers of red mud and its disposal, and up to 180 million tonnes of it are produced each year. At best, in many countries the waste is dried and disposed of in gigantic concrete-bound basins at great expense, if not also simply disposed of in nature. Around 4 billion tonnes have accumulated in such landfills around the world over the past decades. However, the highly alkaline red mud attacks the concrete walls of the landfills that can become structurally weak over time. Additionally, during bouts of heavy rain, the basins can overfill and thus the red mud is often washed out and spilled into the surrounding area. Furthermore, when red mud dries, it can be dispersed into the environment as airborne dust by gusts of wind.

However, red mud does not need to end up as hazardous waste, collected in large piles inside gigantic ponds. A team from the Max Planck Institute for Sustainable Materials in Düsseldorf, previously known as the Max-Planck-Institut für Eisenforschung, have tackled the topic of how to make valuable resources out of red mud by targeting its high iron oxide content, which can be as high as 60 percent. Recently, in a study published in the journal Nature, they demonstrated a method for producing green steel from red mud in a relatively simple way. The scientists melt the red mud as it comes from the landfill in an electric arc furnace – the steel and aluminum industries have used such furnaces for decades to melt down scrap metal. At the same time, the researchers reduce the iron oxide to iron using a plasma containing ten percent hydrogen. This transformation, referred to in technical terms as "plasma reduction," takes just ten minutes, in which time the liquid iron separates from the liquid oxides and can then be easily refined. The iron is so pure that it can be processed directly into steel. "Our process could solve the waste problem of aluminum production and, at the same time, improve the steel industry's carbon footprint," explains Matic Jovičevič-Klug, who played a key role in the research. Almost 700 million tonnes of steel could be ex- →

Aluminum is used for aircraft, cars, and containers, among other things. The diagram shows how red mud from aluminum production is deposited (top). In a new process, iron is extracted from the waste as pure metal using hydrogen plasma (bottom left). What remains is a neutral oxide that can be used as a building material in its solid state.



GRAPHIC: GCO ADAPTED FROM THE MPI FOR SUSTAINABLE MATERIALS GMBH

tracted from the approximately four billion tonnes of red mud that have accumulated worldwide. This equates to a good third of global annual steel production. "If green hydrogen is used for this, the steel industry could save around 1.5 billion tonnes of CO_2," says Isnaldi Souza Filho, research group leader at the Max Planck Institute for Sustainable Materials. The steel industry is the largest contributor to greenhouse gas emissions, accounting for 8 percent of global CO_2 emissions from its smelters. If the research outcome is transferred to an industrial scale, the metal industry of the future could use a much larger proportion of the red mud material than the few million tonnes that are currently used annually in cement production or iron production.

Mitigated heavy metals

The metal oxides that remain from the reduced red mud are no longer corrosive and solidify into a glass-like material when cooled. This can be used as a filling material in the construction industry, for example. Other research groups have used coke to produce iron from red mud, a method that produces iron with high levels of impurities and large quantities of CO_2. However, if green hydrogen is used as a reducing agent instead of coke, these greenhouse gas emissions are prevented. The heavy metals in the red mud can also be mitigated to a certain extent using this process. "We detected chromium in the iron after reduction," says Matic Jovičević-Klug. "Other heavy and precious metals are also likely to pass into the iron or into a separate area. We will investigate this in further studies. Valuable metals could then be separated and reused." Additionally, any heavy metals that remain in the metal oxides portion are strongly bonded in them and can therefore no longer be washed out with water, as can naturally happen with red mud.

However, producing iron with hydrogen directly from red mud is not just doubly beneficial for the environment, the process is also economically profitable, as the research team demon-

Widely used in the metal industry: steel and aluminum scrap is already melted down in electric arc furnaces, making it possible to recycle it.

strated in a cost analysis. With hydrogen and an electricity mix for the electric arc furnace that is partially renewable, the process is already profitable if the red mud contains 50 percent iron oxide. If the costs for the disposal of the red mud are also considered, 35 percent iron oxide content is sufficient to make the process economically viable. Using green hydrogen and electricity, a 30 to 40 percent proportion of iron oxide is needed at today's costs – factoring in the cost of landfilling the red mud – to enable the resulting iron to stay competitive on the market. "These are conservative estimates, as the cost of red mud disposal is probably underestimated," says Isnaldi Souza Filho. Using red mud as a raw material rather than landfilling it could become increasingly attractive for the aluminum and steel industries, especially given the anticipated significant rise in metal demand in the coming years. The industry predicts that the demand for aluminum and steel will increase by at least 50 percent by 2050, resulting in a correspondingly higher environmental impact. Using red mud as a raw material for CO_2-free iron could help ensure that the growth of the metal industry is more economical and sustainable. "Considering the economic aspects in our study was also important for us," says Dierk Raabe, Director at the Max Planck Institute for Sustainable Materials. "Now it's up to the industry to decide whether it will also subject red mud to plasma reduction in order to produce iron."

SUMMARY

Aluminum production generates up to 180 million tonnes of highly corrosive, heavy metal–containing red mud every year.

Using an electric arc furnace, the iron oxide present in the mud can be reduced to very pure iron using hydrogen in an economically viable way.

This could make it possible to extract 700 million tonnes of CO_2-free steel from the approximately four billion tonnes of red mud dumped worldwide – this is the same as one third of global annual production.

PHOTO: ADOBESTOCK/DAVIT85