

Pyrometallurgy Versus Hydrometallurgy

Pyrometallurgy, or the use of heat for the treatment, includes smelting and roasting. It involves heating in a blast furnace at temperatures above 1500°C to convert waste to a form that can be refined. The oxide waste is heated with a reducing agent, such as carbon in the form of coke or coal; the oxygen of the metal combines with the carbon and is removed in carbon dioxide gas. The waste material in e-waste (non-metallic parts) is called gangue; it is removed by means of a substance called a flux which, when heated, combines with it to form a molten mass called slag. Being lighter than the metal, the slag floats on it and can be skimmed or drawn off.

Hydrometallurgy, sometimes called leaching, involves the selective dissolution of metals from their waste. It involves the use of aqueous chemicals and much lower temperatures to separate metal. Metal is recovered by electrolysis of the solution. If metal obtained from waste still contains impurities, special refining processes are required.

The decision whether to use hydrometallurgy or pyrometallurgy can be seen from various concerns including environment and economy. Low waste technology solutions provide a real answer to the increasing requirements of environmental legislation. Instead of waste treatment and waste disposal, new technologies for waste avoidance are a challenge today. Such technologies should meet the demand for economical use of raw materials and an energy poor future and contribute to efficiency in industry.

Environmental regulations will be more restrictive in the future. The expenditure for waste disposal and water use as well as energy, materials and labour will increase and internal recycling processes will become indispensable tools for successful industrial operations. A low waste technology solution should always be preferred as it minimizes the threat of environmental legislation.

Low waste technology solutions can be directed towards material recycling and heat recovery which contributes to economy. Chemical treatments improve on minimising impurity build-up, and toxic compounds may be substitutable for less harmful constituents.

Environment Impact:

1) Gas Emission

Pyrometallurgy - The basic operation is the direct introduction of e-waste into a furnace mixed with a reducer and smelting agent. This operation is accompanied with strong gas emissions including:

-CO₂ –CO coming from oxidation of carbon used as the reducer

- dust of scrap metals and other components
- green house effect gases like SO₂, Cl₂, HCl and NO_x
- Organic volatile compounds
- Dioxins.

The burning of waste in the presence of oxygen, especially waste with plastic and other organic material content generate toxic gases such as furans and dioxins. Such gases are carcinogenic and increase the risk of contracting respiratory disease. Incinerators have been found to be the largest producers of dioxins and furans. Incineration produces ash with concentrated amounts of heavy metals, such as lead, arsenic and cadmium. These chemicals are well known to cause birth defects, cancer, respiratory ailments and reproductive dysfunction among people who live near incineration plants. Beside this, incomplete combustion may generate carbon monoxide and also volatile compounds, including formaldehyde and acetaldehyde. The treatment of these gases involves large capital investments in advanced technologies and equipment.

The amount of sulfur dioxide released depends

1. On the characteristics of the type of waste —complex ones may contain lead, zinc and nickel
2. Whether facilities are in place for capturing and converting the sulfur dioxide.

SO₂ emissions may range from less than 4 kilograms per metric ton (kg/t) of copper to 2,000 kg/t of copper. Particulate emissions can range from 0.1 kg/t of copper to as high as 20 kg/t of copper. Fugitive emissions occur at furnace openings and from launders, casting molds, and ladles carrying molten materials. Additional fugitive particulate emissions occur from materials handling and transport of ores and concentrates. The smelting furnace will generate process gas streams with SO₂ concentrations ranging from 0.5% to 80%, depending on the process used. Vapors of arsenic and mercury are also present at high gas temperatures, which required additional scrubbing for removal.

Modern plants using good industrial practices should set as targets total dust releases of 0.5–1.0 kg/t of copper and SO₂ discharges of 25 kg/t of copper.

Hydrometallurgy generates some hazardous gases such as chlorine, noxious and hydrogen cyanide gases which is possible to be treated by a simple 1-3 stage scrubber system with a chemical scrubbing solution. In contrast to a furnace process, chemical process also generates wastewater. However, as the treatment of these gases and wastewater utilizes common established technology, its efficiency can be justified with much lower capital investment. No gases can escape and solvents are fully trapped at

room temperature, where it is not in position to produce dioxins or other greenhouse effects. Hydrometallurgy is more environmentally friendly also as sulphur is presented as either a stable sulphate or elemental sulphur rather than sulphur dioxide emissions

There are global environmental concerns to smelting activities, which spew extremely harmful pollutants into the atmosphere. Smelting with pollution control equipment is extremely expensive, which contributes directly to the high cost.

2) Solid Waste Generation

In pyrometallurgy, almost all waste content is burnt to ashes or carbon and leaving behind also a mixture of heavy metals. Useful materials such as plastics, which might otherwise be further recycled into re-engineering plastic are also being burnt (this is in the event that feed materials did not go through initial mechanical separation stage). Other lesser important content such as paper, ceramics, glass and fibers which could also be reused as filler or flux in certain products are also non-recoverable. It is estimated that for every three tonnes of waste that is incinerated, one ton of ash is generated. The main portion of the solid waste is discarded slag from the smelter. This ash is very toxic, containing concentrated amounts of heavy metals and dioxins which, when buried, will eventually leach into the soil, potentially polluting groundwater.

The end product of ashes or carbon eventually ends up in landfill, while the mixture of heavy metals undergoes further segregation and refining via chemical process or smelting process. The heavy metals mixture recovered may be covered or trapped within carbon residue, which makes it more complicated for downstream refining. Slag requires special treatment, e.g., slow cooling, grinding, and flotation or treatment in an electric furnace to recover its copper content which represents a heavy recycling load.

By using hydrometallurgy, almost all waste components (not only heavy metals) could be segregated and recovered for further recycling or re-use. Each component refining stage could be accomplished in one process, without the need for diversion to another process. Leaching processes produce residues, while effluent treatment results in sludges which can be sent for metals recovery.

3) Wastewater Discharge

Wastewater from primary copper production contains dissolved and suspended solids that may include concentrations of copper, lead, cadmium, zinc, arsenic, and mercury and residues from mold release agents (lime or aluminum oxides). Fluoride may also be present, and the effluent may have a low pH. Normally there is no liquid effluent from the smelter other than cooling water; wastewaters do originate in scrubbers (if used), wet electrostatic precipitators, cooling of copper cathodes, and so on.

In the electrolytic refining process, by-products such as gold and silver are collected as slimes that are subsequently recovered. Sources of wastewater include spent electrolytic baths, slimes recovery, spent acid from hydrometallurgy processes, cooling water, air scrubbers, washdowns, stormwater, and sludges from wastewater treatment processes that require reuse/recovery or appropriate disposal.

Mass Balance & Energy Consumption

In terms of mass balance, smelting leads to higher loss of metals as compared to hydrometallurgy. The main factors are:

- loss of metals into the slags
- loss of metals on the refractories,
- loss of dust and high volatility products.

Large amounts of fuel are required for the melting process. The route for production of cathode copper requires large amounts of energy per ton of copper: 30–40 million British thermal units (Btu) per ton cathode copper. In terms of energy use, there is no doubt that smelting = high energy consumption.

Hydrometallurgy leads to a higher recovery rate due to relative ease in leaching of product and the possibility of cascading – re-circulating solid waste to the next step and achieving a high recovery rate with chemical precipitation of electro-winning.

Compared to pyrometallurgy, direct fuel consumption of hydrometallurgy is almost negligible. On the other hand, it should be noted that to produce a ton of copper cathode, this process requires around 3,400 kWh. This means that, if the present fuel mix in electricity generation remains constant, indirect emissions due to hydrometallurgy production in the year 2001 would probably attain 3.6×10^6 ton of CO₂, considering unit emissions of 0.68 kg CO₂/kWh and a production of 1.56 million tons of cathodes.

Hydrometallurgical routes have become more popular to research because: energy costs are lower; more pollution-conscious communities require "zero discharge" type conditions; whether for air or water, as smelting processes are made "leak proof" the impurities become more of a problem in concentrating copper; hydrometallurgical processes by contrast can separate impurities better and operating temperatures are much lower making plants easier to operate.

Summary

Hydrometallurgy allows a real sustainable growth process considering the following aspects:

Parameter	Pyrometallurgy	Hydrometallurgy
Gas emission	High, varies from CO ₂ , greenhouse gaseous, volatile organic carbon	Low (room temperature) and easy to treat
Dioxin potential	High	No dioxins
Dust potential	High, during material handling and transport	Low, dissolve in solution or taken care off by pollution control equipment
Economics	Huge investment capital and low job creation	High job creation as processes involved are labour intensive
Social acceptance	Low, due to high environmental liabilities	High, cleaner environment with highly effective and mature pollution control methodology
Energy	High (up to 1200°C)	Low (room temperature)
Recovering rate	Low (only fraction of metals), useful non-metals are incinerated and impossible to recover	High recovery, clean separation of material types enable individual effective recovery
Final residue	High. (slag and dusts), potential metal trapped to reduce recovery effectiveness	Low. Only mixed plastics, which could be recycled into engineered plastic
Conditions of work place	Hard conditions around furnaces	Clean condition

In conclusion, Hydrometallurgy will displace inefficient Pyrometallurgy processes in time. There are at least two examples which bear witness to this:

1) Zinc was produced for over 400 years by a fully pyrometallurgical route. Since 1980, a fully hydrometallurgical process was invented (Sherritt autoclave process) and four plants are now in operation using this technology.

2) Alumina was first produced by a high temperature sintering process (Le Chatelier, 1855) was replaced by Bayer's hydrometallurgical process in 1892 - - the process used today world wide

Hydrometallurgy has also broadened the metal extraction options, as a more obvious extraction option as compared to pyrometallurgy.

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