

# Metallurgical treatment processes of metals (Fe and Steel, Al, Cu, Au) and their detrimental environmental issues- A mini review

Rafiqueel Islam<sup>1\*</sup> and Md. Abdul Hye<sup>2</sup>

<sup>1</sup>Department of Applied Chemistry and Chemical Engineering,  
Islamic University, Kushtia 7003, Bangladesh  
Email\*: [rafiq.acct@gmail.com](mailto:rafiq.acct@gmail.com)

<sup>2</sup>Department of Mathematics & Statistics,  
Bangladesh University of Business & Technology, Dhaka- 1216, Bangladesh  
Email: [hye\\_abdul@yahoo.com](mailto:hye_abdul@yahoo.com);

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## Abstract

The aims of this study are to evaluate the fruitful process and industrial production of common metals (Fe and Steel, Al, Cu, Au) and possible environmental issues through their production which is detrimental for human beings. First of all, iron and steel are the most important materials for human, especially of making constructions, furniture, cooking materials, etc. even we cannot think a single day without it. But, due to production of it, iron ores impurities, slags, lime stones, blast furnace flue, sulfur dioxide, hydrogen sulphide gases, suspended solids and metals, oil, greases, and mill scales etc. are produced as major serious by-product wastages which have active and passive effects of mankind. Similarly, aluminium is another important metal for mankind which can be mixed with almost any other metal and form alloys typically good strength, however, greenhouse gases (carbon dioxide, perfluorocarbons, sodium fluoride, sulfur dioxide, polycyclic aromatic hydrocarbon and a vast list of other problematic elements), caustic red sludge, toxic mine tailings, red muds etc. are produced significantly. In addition, as a red metal, copper is the extensively used in architectural focal point of many modern buildings, energy-saving applications, making cookeries, ornaments etc., sulfuric acid, sulfur dioxide (SO<sub>2</sub>), sulfur trioxide (SO<sub>3</sub>) etc. come from their production. In contrast, gold is the most precious metal which has prominent attraction as a jewellery product, in particular for women due to their good colours and non-reactive to environment. But, the usage and disposal of cyanide and cyanide gas come from gold industry would have extremely toxicity nature and adverse environmental risks. Through this review, good production-based literature knowledge will appear as well as identify specific hazard materials due to general concern which have life time risk for human exposure.

**Index Terms:** Metals (Fe and Steel, Al, Cu, Au) productions, Hazard chemicals, detrimental effects, Environmental issues

## 1. The metallurgical treatment processes of Iron (Fe) and Steel and Environmental issues.

From Sun to Planets, microorganisms to human being, and some metabolic systems of human body, it could lesser be thought without iron. It is the part and parcel in human's daily life for various reasons. To advance growth and development of human life style, steel is the great collaborator working together with all other materials. It contributes the last 100 years of betterment. Further, it will take the significant rules to meet the challenges of the next 100 years. [1]. Based on World Steel Association (World steel) reports, Global steel production rose by 1.9% from a year ago in August, saw the 1.5% growth in July. China was the main contributor for this outstanding achievement, but global output ex-China too has risen in the past few months. Right now, China dominates the steel discussion; for instance, its productivity rose by 3% versus 0.9% for the rest of the world in August [2].

In iron (Fe) main interstitial carbon constituent is in the range of 0.12–2.0%. However, steel or iron alloy is classified as: Low-carbon steel (C is up to 0.3%); Medium-carbon steel (C is approximately 0.3–0.6%); High-carbon steel (C is approximately 0.6–1.0%) and Ultra-high-carbon steel (C is approximately 1.25–2.0%) [3]. It contains some other ingredients as a trace amount like- Mn, Si, Cr, S, P, N, Cr, Ni, Mo, Cu etc. [4]. Here, it would be discussed step wisely about generations of carbon steel and the difference between the various steel making techniques.

First steelmaking was started by Egypt to stabilize Charcoal kilns through the production of charcoal and the reduction of iron ores. In early middle ages, it was developed by introducing bloomery technology that was invented in 2000 years BC in Anatolia and did continue in Middle Ages in Europe. For more than 3000 years, therefore, iron was smelted from ore in bloomery and further steeled by cementation and case hardening and formed sophisticated blades by forge welding. It was the solid-state transformation. Further improvement was 'Catalan Forge', a precursor to the Blast Furnace by its shape and then Wolf Furnace which produced 100 to 150 tons of iron/year surpassing the production capability of a Catalan forge [5]. In 18th century, another breakthrough came from Europe which is 'Blast Furnace' technology by which liquid metal production was possible. Steel making thus evolved over a period extending from the High Middle Ages to the end of the 20th century. Furthermore, this technology was updated as puddling furnace, Siemens-Martin furnace/ Open Hearth Process and Induction furnaces which are frequently used in different countries right now. However, it was a main drawback such as, steel was not yet liquid all throughout the route [6].

Coming back to European timeline, Open hearth Process rapidly did breakthrough by Bessemer process which was continued until the middle of the 20th century. However, electricity had not been invented yet. After then, Scientist Paul Heroult invented the Electric Arc Furnace in 1905 [7]. We are now traveling to present (Middle age of the 20th century), in present technology, scientists are ensuring for mankind the iron units stem from ore and scrap, liquid steel is processed by either Oxygen Converter or Electric Arc Furnace, solidification is carried out by a series of Continuous Casting process, coated and composite materials are produced by specialized plants. However, Green House Gas (GHG), especially CO<sub>2</sub> emission is quite high using this technology. Hence, CO<sub>2</sub> emission presumably takes part for Global warming issue which would be the most alarming [8, 9].

### 1.1. Raw materials:

The major raw materials of iron and steel productions are iron ore, coking coal, Silica, limestone and dolomites, Ferrous scrap, alloying elements- ferromanganese, and silicomanganese etc.

### 1.2. Major Reactions:

- i.  $3 \text{Fe}_2\text{O}_3 + \text{CO} = \text{CO}_2 + 2 \text{Fe}_3\text{O}_4$  (Temperature 850° F)
- ii.  $\text{Fe}_3\text{O}_4 + \text{CO} = \text{CO}_2 + 3 \text{FeO}$  (Temperature 1100° F)
- iii.  $\text{FeO} + \text{CO} = \text{CO}_2 + \text{Fe}$  (Temperature 1300° F)
- iv.  $\text{FeO} + \text{C} = \text{CO} + \text{Fe}$
- v.  $\text{C} + \text{O}_2 = \text{CO}_2 + \text{Heat}$
- vi.  $\text{CO}_2 + \text{C} = 2\text{CO}$
- vii.  $\text{CaCO}_3 = \text{CaO} + \text{CO}_2$
- viii.  $\text{FeS} + \text{CaO} + \text{C} = \text{CaS} + \text{FeO} + \text{CO}$
- ix. The CaS becomes part of the slag. The slag is also formed from any remaining Silica (SiO<sub>2</sub>), Alumina (Al<sub>2</sub>O<sub>3</sub>), Magnesia (MgO) or Lime (CaO) as silicates, Aluminates, Phosphates etc.

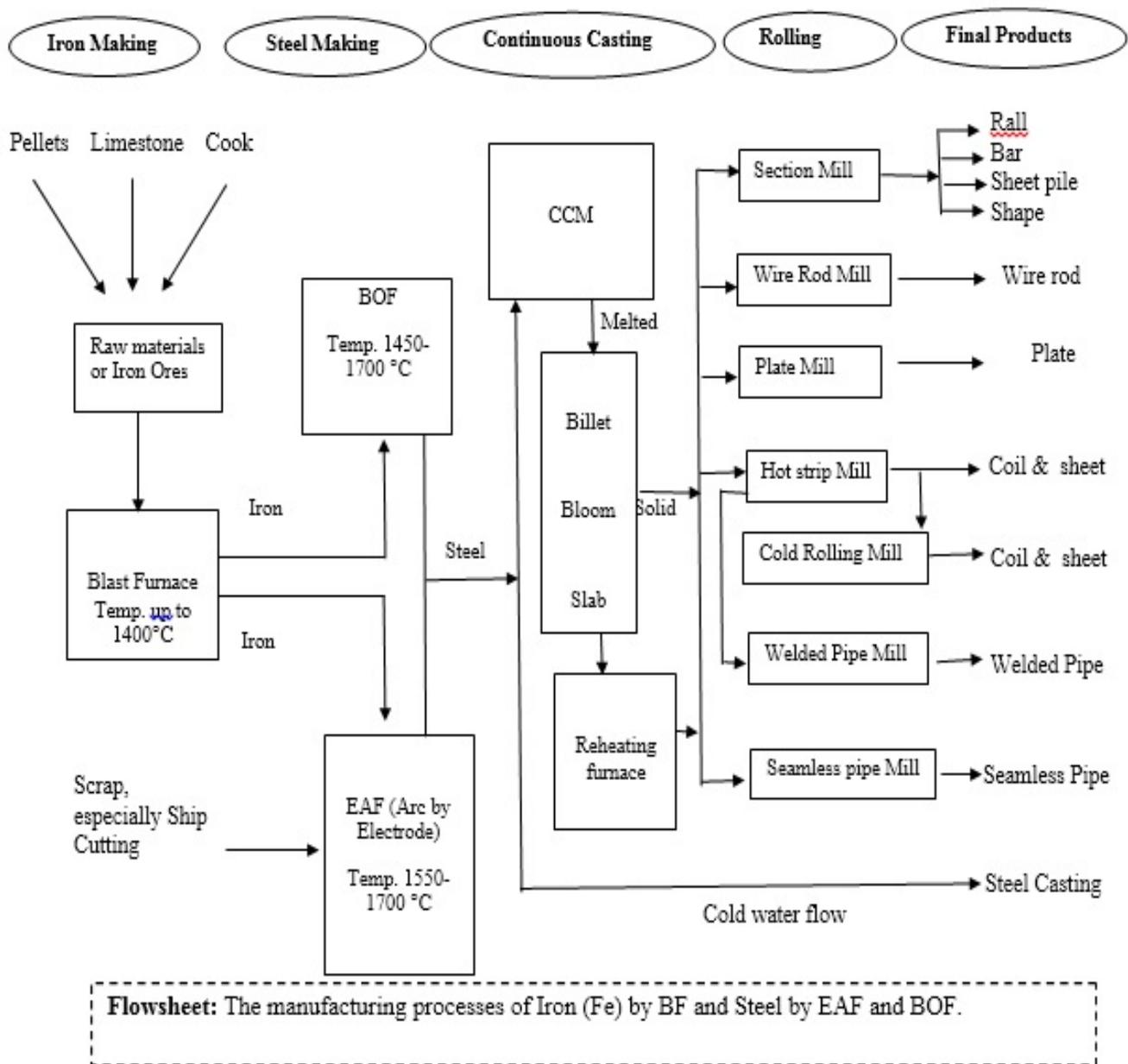
### 1.3. Composition of Iron, making by Blast Furnace:

Normally iron contains some alloying element where carbon percentages are a little bit higher which affects the characteristics of metals. The compositions are: Iron (Fe)= 93.5-95.0%; Silicon (Si)=0.30-0.90%; Sulfur (S)=0.025-0.050%; Manganese (Mn)= 0.55-0.75%; Phosphorus (P)= 0.03-0.09%; Titanium (Ti)=0.02-0.06%; Carbon (C)= 4.1-4.4%.

However, Steel by electric Arc Furnace (EAC) is only reducing of Carbon (0.15- 1.70%, based on iron carbon phase diagram) and increasing alloying elements based on the requirement of using various purposes [10].

### 1.4. Treatment process or Methodology:

No table of figures entries found.



**Figure 1: The manufacturing process of Iron (Fe) by BF and Steel by EAF and BOF**

**1.4.1. Process Description:** The figure 1 shows a flowchart of the integrated manufacturing process of iron and steel using the blast furnace (BF) and basic oxygen furnace (BOF) which are the most commonly used method (51% of global steel production) at present. After the BF-BOF process, molten steel is controlled to a target composition by maintaining the desire temperature and then cast by continuous casting machine to produce slabs, blooms and billets. These solid materials are reheated and rolled to the required dimensions by the rolling mill to produce steel products. The smelting and refining process for iron and steel in the BF-BOF process involves the carbon reduction of iron ore ( $Fe_2O_3$ ) in the BF to make molten iron, and decarburization of molten iron in the BOF to make molten steel.

Major reducing agent in the BF is the carbon monoxide gas (CO) generated by the oxidation of the carbon (C) in coke. The main reaction in this process is the oxidization of the carbon in the hot metal by both pure oxygen gas ( $O_2$ ) and iron oxide ( $Fe_2O_3$ ). The

residual oxygen, after contributing to this decarburization reaction, remains in the molten steel. This oxygen is fixed and removed by deoxidation reagents such as silicon and aluminum as  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  or is removed as carbon monoxide gas in the subsequent vacuum degassing process.

In addition to the BF-BOF process, there is another process which utilizes mainly scrap as an iron source, with some direct reduced iron whenever necessary. The direct reduced iron is produced by reducing iron ore with reformed natural gas, whose principal components are hydrogen, carbon monoxide, and methane. The scrap, along with direct reduced iron, is then melted in an electric arc furnace (denoted EAF hereinafter) to produce molten steel which is subsequently processed by the continuous casting machine, as mentioned above.

The molten steel from the Basic Oxygen Furnace (BOF) and Electric Arc Furnace (EAF) is then deoxidized and alloying elements (ferromanganese, and silicomanganese) are added with the prescribed amounts. The molten steel is then held at the target temperature and continuously cast through Continuous Casting Machine (CCM), and the obtained castings are cut to the prescribed length. After heating to the rolling temperature in a reheating furnace, these castings are hot-worked to the required products. Steel shapes, bars, and wire rods are worked on section and bar mills and wire-rod mills equipped with caliber rolls, plates are worked on reversing mills, and hot-rolled steel sheets are worked on hot strip mills. After pickling to remove scale from the surface, the hot-rolled steel sheets are worked to cold-rolled steel sheets on reversing mills or tandem rolling mills, and the cold-rolled steel sheets are tinned or galvanized as required to produce various surface-treated steel sheet products. Steel pipe is produced by forming and welding steel sheets or plates, or by piercing a billet and rolling to the final dimensions without a seam.

### 1.5. Environmental Issues:

Slags, limestones, and iron ores impurities (by-products), blast furnace flue, Sulfur dioxide, and hydrogen sulphide gases, suspended solids and metals, oil, greases, and mill scales etc. are the major serious by-products from steel industries.

- ✓ Researchers measure that Sintering operations can emit significant dust levels of about 20 kilograms per metric ton (kg/t) of steel. Pelletizing operations can emit dust levels of about 15 kg/t of steel. Air emissions from pig iron manufacturing in a blast furnace include particulate matter (PM), ranging from less than 10 kg/t of steel manufactured to 40 kg/t; sulfur oxides ( $\text{SO}_x$ ), mostly from sintering or pelletizing operations (1.5 kg/t of steel) [11].
- ✓ Nitrogen oxides ( $\text{NO}_x$ ), mainly from sintering and heating (1.2 kg/t of steel); hydrocarbons; carbon monoxide; in some cases dioxins (mostly from sintering operations); and hydrogen fluoride (HF). Wastewaters, including those from cooling operations, are generated at an average rate of 80 cubic meters per metric ton ( $\text{m}^3/\text{t}$ ) of steel manufactured [12].
- ✓ Major pollutants remains in untreated wastewaters generated from pig iron manufacture include total organic carbon typically 100–200 milligrams per liter, mg/l; total suspended solids (7,000 mg/l, 137 kg/t); dissolved solids; cyanide (15 mg/l); fluoride (1,000 mg/l); chemical oxygen demand, or COD (500 mg/l); and zinc (35 mg/l). Major pollutants in wastewaters generated from steel manufacturing using the BOF include total suspended solids (up to 4,000 mg/l, 1030 kg/t), lead (8 mg/l), chromium (5 mg/l), cadmium (0.4 mg/l), zinc (14 mg/l), fluoride (20 mg/l), and oil and grease. Besides, mill scale may amount to 33 kg/t. The process generates effluents with high temperatures [11].
- ✓ Process solid waste from the conventional process, including furnace slag and collected dust, is generated at an average rate ranging from 300 kg/t to 500 kg/t, of which 30 kg may be considered hazardous depending on the concentration of heavy metals present. However, 65% of BOF slag from steel manufacturing can be recycled in various industries such as building materials and, in some cases, mineral wool [11].

## 2. The metallurgical treatment processes of Aluminum (Al) and Environmental issues

Aluminium or aluminum (in North American English) is a chemical element of the boron group with symbol Al and atomic number 13. The Earth's crust contains the valuable Aluminium (Al) metals about 8.2%. It is the third most abundant element in the crust and the most plentiful metallic element; however, it never be found on its own in nature. Bauxite is the most commonly ore mined for aluminium in which aluminium occurs as hydroxide minerals. Aluminium is a silvery-white, tough and lightweight metal that's specific gravity is 2.7. It is a good conductor of heat and electricity, and very resistant to atmospheric corrosion. It is also nontoxic, inflammable, nonmagnetic, non-sparking, malleable and ductile. Due to these properties, it has become an important metal of this globe.

Aluminium can be mixed with almost any other metals and these alloys typically combine lightness with strength. As a result, they are used in a great variety of industries. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 270 different minerals. [13] The Bayer process is the principal industrial means of refining bauxite to produce alumina (aluminium oxide). Bauxite, the most important ore of aluminium, contains only 30–54% aluminium oxide, (alumina),  $\text{Al}_2\text{O}_3$ , the rest being a mixture of silica, various iron oxides, and titanium dioxide.[14, 14] The aluminium oxide must be purified before it can be refined to aluminium metal.

### 2.1. Raw materials:

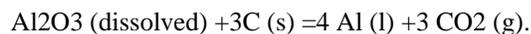
Bauxite, Corundum, Cryolite, Nepheline are the major raw materials of Aluminum. The process of extracting aluminium from its oxide, alumina, generally by the Hall-Héroult process. Alumina is extracted from the ore bauxite by means of the Bayer process at an alumina refinery. Aluminum ores especially composition of Bauxite are 30~50%  $\text{Al}_2\text{O}_3$ , 3~13%  $\text{SiO}_2$ , and 10~18%  $\text{TiO}_2$ .

### 2.2. Major Reactions:

(a) Bauxites Production (Bayer Process):

- i.  $\text{SiO}_2 + 2\text{NaOH} \rightarrow 2 \text{NaSiO}_3 + \text{H}_2\text{O}$
- ii.  $2 \text{NaSiO}_3 + 2 \text{NaAlO}_2 \rightarrow 2 \text{Na}_2\text{Al}_2\text{Si}_2\text{O}_8. 2\text{H}_2\text{O} + \text{NaOH}$
- iii.  $\text{Al}_2\text{O}_3 + 2 \text{NaOH} \rightarrow 2 \text{NaAlO}_2 + \text{H}_2\text{O}$
- iv.  $2 \text{NaAlO}_2 + \text{CO}_2 \rightarrow 2 \text{Al}(\text{OH})_3 + \text{Na}_2\text{CO}_3 + \text{H}_2\text{O}$
- v.  $2 \text{H}_2\text{O} + \text{NaAlO}_2 \rightarrow \text{Al}(\text{OH})_3 + \text{NaOH}$
- vi.  $2 \text{Al}(\text{OH})_3 \rightarrow \text{Al}_2\text{O}_3 + 3 \text{H}_2\text{O}$  Temperature at 1200 °C

(b) Aluminum Production (Hall- Heroult process):



### 2.3. Treatment process or Methodology:

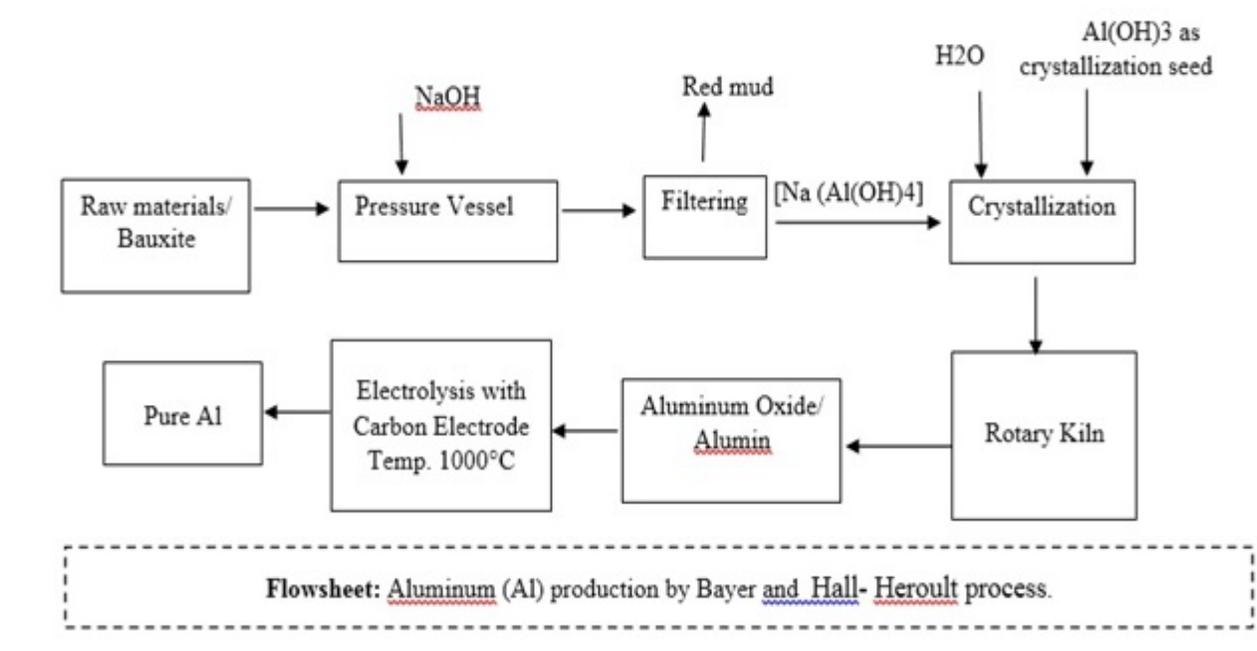


Figure 2: Aluminum Production by Bayer and Hall-Heroult process

### 2.3.1. Process Description:

In the Bayer process (Figure 2), bauxite ore is heated in a pressure vessel along with a sodium hydroxide solution at a temperature of 150 to 200 °C. At these temperatures, the aluminium is dissolved as sodium aluminate in an extraction process. The aluminium compounds in the bauxite may be present as gibbsite (Al(OH)<sub>3</sub>), boehmite (AlOOH) or diaspor (AlOOH); the different forms of the aluminium component will dictate the extraction conditions. After separation of the residue by filtering, gibbsite (aluminium hydroxide) is precipitated when the liquid is cooled and then seeded with fine-grained aluminium hydroxide. This treatment also dissolves silica, but the other components of bauxite do not dissolve. Sometimes lime is added at this stage to precipitate the silica as calcium silicate. The solution is clarified by filtering off the solid impurities, commonly with a rotary sand trap and with the aid of a flocculant such as starch, to remove the fine particles. The undissolved waste after the aluminium compounds are extracted, bauxite tailings, contains iron oxides, silica, calcia, titania and some unreacted alumina. The original process was that the alkaline solution was cooled and treated by bubbling carbon dioxide through it, a method by which aluminium hydroxide precipitates. But later, this gave way to seeding the supersaturated solution with high-purity Al(OH)<sub>3</sub> crystal, which eliminated the need for cooling the liquid and was more economically feasible.

Bauxites containing more than 10% silica; the Bayer process becomes uneconomic due to insoluble sodium aluminium silicate being formed, which reduces yield, and another process must be chosen. Over 90% of the aluminium oxide so produced is used in the Hall-Hérault process to produce aluminium.

The Hall- Heroult process is an example of Aluminium smelting process and is used industrially. Aluminium cannot be produced by an aqueous electrolytic process because hydrogen is electrochemically much nobler than aluminium. Thus, liquid aluminium is produced by the electrolytic reduction of alumina (Al<sub>2</sub>O<sub>3</sub>) dissolved in an electrolyte (bath) mainly containing Cryolite (Na<sub>3</sub>AlF<sub>6</sub>).

### 2.4. Environmental Issues:

Overall, the entire process of extracting aluminium from raw bauxite, many hazards produce which have the detrimental effects on living beings. The effects are as follows:

- ✓ Since pure aluminum ore is so stable, an extraordinary amount of electricity is required to produce the final product and, at least in the U.S., half of the smelting energy consumed is courtesy of coal, one of the most notoriously polluting fuel sources known to mankind.
- ✓ The EPA says that the release of perfluorocarbon during the aluminum smelting process is 9,200 times more harmful than carbon dioxide in terms of its effect on global warming [16].
- ✓ When bauxite is extracted from the earth, the strip-mining process removes all native vegetation in the mining region, resulting a loss of habitat and food for local wildlife as well as significant soil erosion.
- ✓ The remaining caustic red sludge and toxic mine tailings are commonly deposited into excavated mine pits where they ultimately seep into aquifers, contaminating local water sources.
- ✓ Greenhouse gas released during smelting and processing (which have been found to blanket surrounding regions with toxic vapors) include carbon dioxide, perfluorocarbons, sodium fluoride, sulfur dioxide, polycyclic aromatic hydrocarbon and a vast list of other problematic elements.
- ✓ Particulates released during processing that are known to compromise air quality include combustion by products, caustic aerosols, dust from bauxite, limestone, charred lime, alumina and sodium salt [17].
- ✓ Compare to producing virgin aluminum from raw bauxite, recycling old aluminum consumes just 5% of the energy and releases a mere 5% of the greenhouse gases.
- ✓ Landfills across the globe may be the final resting place for infinite numbers of aluminum beverage cans. When these cans are incinerated they contaminate air with toxic compounds and take up to 500 years to fully decompose.
- ✓ Red mud is a toxic solid waste by-product generated in the industrial production of alumina through the digestion of bauxite ore. The auto production of caustic red mud makes the Bayer process a complex calculation for an environmentally challenging process. It is quite alarming issue in the term of environmental pollution for modern civilization. Chemical analysis shows that red mud contains silicium, aluminium, iron, calcium, titanium, sodium as well as an array of minor elements namely K, Cr, V, Ba, Cu, Mn, Pb, Zn, P, F, S, As and etc. The variation in chemical composition between red muds worldwide is high. Typical composition of red mud is Fe<sub>2</sub>O<sub>3</sub> (30-60% w/w), Al<sub>2</sub>O<sub>3</sub> (10-20% w/w), SiO<sub>2</sub> (3-50% w/w), Na<sub>2</sub>O (2-10% w/w), CaO (2-8% w/w) and TiO<sub>2</sub> (trace-25% w/w) [18]. Generally, the major mineralogical phases of red mud from the Bayer process are gibbsite (Al(OH)<sub>3</sub>), boehmite ( $\gamma$ -AlOOH), hematite (Fe<sub>2</sub>O<sub>3</sub>), goethite (FeO(OH)), quartz (SiO<sub>2</sub>), anatase (TiO<sub>2</sub>), rutile (TiO<sub>2</sub>) and calcite (CaCO<sub>3</sub>), and the principal mineralogical constituents of red mud from the sintering process are  $\beta$ -2CaO.SiO<sub>2</sub>, calcite (CaCO<sub>3</sub>), aragonite (CaCO<sub>3</sub>), hematite (Fe<sub>2</sub>O<sub>3</sub>), gibbsite (Al(OH)<sub>3</sub>) and perovskite (CaTiO<sub>3</sub>) [19].

### 3. The metallurgical treatment processes of Copper (Cu) and Environmental issues:

Copper is one of the basic chemical elements. Pure copper is a reddish-orange metal known for its high thermal and electrical conductivity. It is commonly used to produce a wide variety of products, including electrical wire, cooking pots and pans, pipes and tubes, automobile radiators, and many others. The energy efficiency resulting from the use of copper in high efficiency motors, electrical transformers, underground power lines, air conditioning and refrigeration equipment, electric vehicles, etc. has a significant impact on the release of greenhouse gases resulting from the generation and use of fossil fuel based electrical power. Likewise, newly developed, high efficiency automobile radiators reduce fuel consumption by being smaller, lighter and having a lower pressure drop than their aluminum counterparts [20].

Copper was first used as early as 10,000 years ago. Copper pearls were found in Northern Iraq near 8700 B.C. It has been proved that that near 6400 B.C. copper was being melted and then cast into objects in the area now known as Turkey. By 4500 B.C., this technology was also being practiced in Egypt. Most of the copper used before 4000 B.C. came from the random discovery of isolated outcroppings of native copper or from meteorites that impacted Earth. The first mention of the systematic extraction of copper ore came from about 3800 B.C. when an Egyptian reference described mining operations on the Sinai Peninsula. In about 3000 B.C., large deposits of copper ore were found on the island of Cyprus in the Mediterranean Sea. When the Romans conquered Cyprus, they gave the metal the Latin name aescyprium, which was often shortened to cyprium[21]. In the United States, the first copper mine was opened in Branby, Connecticut, in 1705, followed by one in Lancaster, Pennsylvania, in 1732. Despite this early production, most

copper used in the United States was imported from Chile until 1844, when mining of large deposits of high-grade copper ore around Lake Superior began. The development of more efficient processing techniques in the late-1800s allowed the mining of lower-grade copper ores from huge open-pit mines in the western United States. Today, the United States and Chile are the world's top two copper producing countries, followed by Russia, Canada, and China [22].

Owing to its natural color, Copper is traditionally known as the red metal. However, it is also known as a "green" metal because it forms green patina react with environment. Indeed, patinized copper is the architectural focal point of many modern buildings for its natural look. Beyond this, however, copper can truly be cited as the "green" metal both for its role in protecting the natural environment through its use in energy-saving applications and for the achievements that have been realized in the production of the metal in an environmentally sound manner [23].

### 3.1. Raw materials:

Pure copper is rarely found in nature; but it is usually combined with other chemicals in the form of copper ores. There are about 15 copper ores mined commercially in 40 countries around the world. The most common are known as sulfide ores in which the copper is chemically bonded with sulfur. Others are known as oxide ores, carbonate ores, or mixed ores depending on the chemicals present. Many copper ores also contain significant quantities of gold, silver, nickel, and other valuable metals, as well as large quantities of commercially useless material. Most of the copper ores mined in the United States contain only about 1.2-1.6% copper by weight.

The most common sulfide ore is chalcopyrite,  $\text{CuFeS}_2$ , also known as copper pyrite or yellow copper ore. Chalcocite,  $\text{Cu}_2\text{S}$ , is another sulfide ore. Cuprite, or red copper ore,  $\text{Cu}_2\text{O}$ , is an oxide ore. Malachite, or green copper ore,  $\text{Cu}(\text{OH})_2 \cdot \text{CuCO}_3$ , is an important carbonate ore, as is azurite, or blue copper carbonate,  $\text{Cu}(\text{OH})_2 \cdot 2\text{CuCO}_3$ . Other ores include tennantite, boronite, chrysocolla, and atacamite. In addition to the ores themselves, several other chemicals are often used to process and refine copper. These include sulfuric acid, oxygen, iron, silica, and various organic compounds, depending on the process used.

### 3.2. Major Reactions:

- i. Anode-oxidation: Cu metal (impure)  $\rightarrow \text{Cu}^{+2} + 2\text{e}^-$
- ii. Cathode - reduction:  $\text{Cu}^{+2} + 2\text{e}^- \rightarrow \text{Cu metal (pure)}$

### 3.3. Treatment process or Methodology:

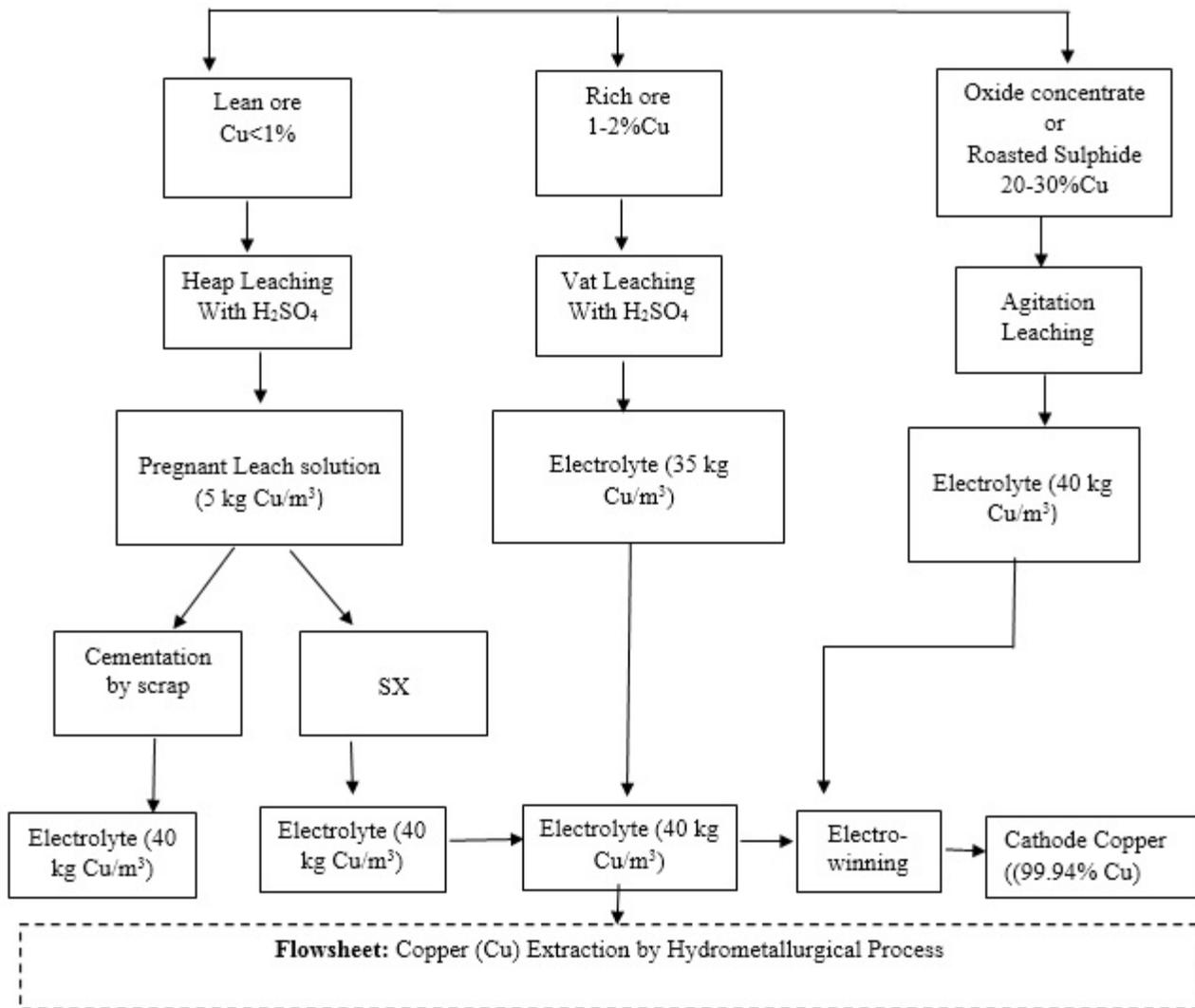


Figure 3: Copper (Cu) Extraction by Hydrometallurgical Process

**3.3.1. Process Description:** The SX/EW Process (shown in Figure 3) is a hydrometallurgical process since it is operated at ambient temperatures and the copper is in either an aqueous environment or an organic environment during its processing to get the metal.

The process involves leaching the material with a weak acid solution. This solution, known as pregnant liquor, is recovered and then contacted with an organic solvent, referred to as the extractant, in the solvent extraction stage (SX). Here the copper is extracted from the aqueous phase leaving behind most of the impurities that were in the leach solution. Since the copper ion is exchanged for hydrogen ion, the aqueous phase is returned to its original acidity and recycled to the leaching step of the process. Meanwhile, the copper-bearing organic phase is stripped of its copper by contacting it with a strongly acidified aqueous solution at which time the copper is moved to the aqueous phase while the organic phase is reconstituted in its hydrogen form. The copper-bearing aqueous phase is advanced to the electrowinning (EW) stage of the process while the barren organic phase is returned to the extraction stage of the process. In the electrowinning stage of the process the copper is reduced electrochemically from copper sulphate in solution to a metallic copper cathode. Electrowinning copper cathodes are as pure as or purer than electro refined cathodes from the smelting process. Thus, they are well received by the market.

**3.4. Advantages of these Methods:**

The electro winning of copper requires considerably more electrical energy than the electro refining process. Electro winning process requires about 8 MJ/kg while electro refining process requires about 1.5 MJ/kg. In electro winning process, the copper must be reduced from the cupric form to metal; whereas, in electro refining process the copper is already in metallic form and is merely transported from the anode to the cathode to purify it. Steps are under development to reduce the energy requirement in electro winning process by about 40% through a modification of the anode reaction [20, 24].

Another advantage of the electro winning process is its low capital investment requirement relative to the smelting process and its ability to be operated economically in a small scale. In China, for example, where copper deposits are not plentiful and tend to be small, there are 40 to 50 "mom & pop" leaching operations involving SX/EW.

### 3.5. Disadvantages of these methods:

Because of its dependence on sulphuric acid, the at present not SX/EW Process is not used as substitute, but rather an adjunct to conventional smelting. However, it is also applicable in locations where smelter acid is not available by the purchasing of sulphuric acid or the manufacturing of sulfuric acid from sulphur or pyrite.

In addition, it offers the opportunity to recover copper from an entirely different set of ores and smelting mined by-products namely, oxidized materials. These may be mined copper minerals that are in oxidized form - minerals such as Azurite ( $2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_3$ ), Brochantite ( $\text{CuSO}_4$ ), Chrysocolla ( $\text{CuSiO}_3 \cdot 2\text{H}_2\text{O}$ ) and Cuprite ( $\text{Cu}_2\text{O}$ ), residual copper in old mine waste dumps whose sulphide minerals have been oxidized by exposure to the air or sulfidic copper minerals that have been oxidized by another new technology-bacterial leaching. In addition, the process can be used to extract copper in situ [23]. That is, without removing the material from the waste pile or from the ground. The net result of the usage of this process is that copper can be produced from sources that in the past would have gone untouched, thus reducing the reliance on conventional ore bodies. Further, the process is capable of removing copper from waste materials where otherwise it would have been considered a contaminant to the environment.

### 3.6. Environmental Issues:

The production of copper, as in the utilization of any other natural resource, has an impact on the environment. This cannot be avoided since the earth must be disturbed in order to extract copper from it; however, the object of the copper mining industry has been to make this impact as small as possible. Significant improvements have been made in environmental impact as new technologies have been applied to the production of copper. Great strides have been accomplished in the conventional treatment of copper ores, such as at the Bingham Canyon mines, in Utah and the adjoining copper smelters.

- ✓ Acid plants convert the sulphur dioxide in emissions to sulfuric acid ( $\text{H}_2\text{SO}_4$ ). Other conversions, including to gypsum, elemental sulphur, and liquid  $\text{SO}_2$  are technologically feasible, but usually not economically viable [25].
- ✓ In making sulfuric acid, the hot gases are first collected from the roasters, furnaces, and converters. The gases are cooled, cleaned (through three series of dust collection systems) to recover copper from the dust and prevent fouling of the acid plant, and then treated with sulfuric acid to remove any water vapor. Catalysts convert the  $\text{SO}_2$  gas to sulfur trioxide ( $\text{SO}_3$ ), which is absorbed in a circulating stream of 98.5 percent sulfuric acid and 1.5 percent water, and reacts with the water to form more concentrated acid. There are two basic types of acid plants. In single contact/single absorption (SC/SA) plants, the gas goes through the system once; such plants average conversion ( $\text{SO}_2$  to  $\text{H}_2\text{SO}_4$ ) efficiencies of 96 to 98 percent. Double contact/double absorption (De/DA) plants maximize  $\text{SO}_2$  capture by returning the gas stream to the converters through an intermediate absorption tower. These plants are capable of 99.7 to 99.8 percent conversion efficiencies [26].
- ✓ The design of an acid plant is unique to each smelter. The key variables affecting the efficiency and economics of acid production are the total gas volume; and the  $\text{SO}_2$  concentration, water vapor concentration, and free oxygen content of the treated gases. The physical dimensions and energy requirements of the acid plant are largely determined by the maximum volume and minimum concentration of  $\text{SO}_2$  gas.
- ✓ There are several reasons why acid plants are so widely used by the U.S. copper industry. The technology is well proven and is the least expensive method of smelter  $\text{SO}_2$  control. Sulfuric acid is used in solution mining, and also is the most common form in which other industries consume sulphur; thus it can be a salable byproduct rather than a waste. However, non-leaching markets for sulfuric acid generally are a long way from the smelters in the United States, and the resulting transportation costs can turn the by-product credit into a deficit. Moreover, it often is cheaper for industrial consumers to buy sulphur and produce the sulfuric acid themselves than to purchase acid produced elsewhere.

- ✓ In the United States, for example, copper is considered as toxic material released to the environment once it is mined under Emergency Planning and Community Right-to-Know Act (EPCRA) and the Environmental Protection Agency's Toxic Release Inventory (TRI). Copper mine dumps and flotation tailings constitute a significant inventory of copper that is considered to be a contaminant to the environment under TRI.
- ✓ In some countries, such as Japan, a very high level of SO<sub>2</sub> control is achieved by copper smelters as part of a government policy to provide sulfuric acid for industrial development [27].

#### 4. The metallurgical treatment processes of Gold (Au) and Environmental issues:

Gold, recognizable by its yellowish cast, is one of the oldest metals used by human civilization. As far back as the Neolithic period, humans had collected gold from stream beds, and the actual mining of gold was traced as far back as 3500 B.C., when early Egyptians (the Sumerian culture of Mesopotamia) used mined gold to craft elaborate jewelry, religious artifacts, and utensils such as goblets [28]. Gold's aesthetic properties combined with its physical properties have long made it a valuable metal. Throughout history, gold had often been the cause of both conflict and adventure: the destruction of both the Aztec and Inca civilizations, for instance, and the early American gold rushes to Georgia, California, and Alaska. The largest deposit of gold is found in South Africa in the Precambrian Witwatersrand Conglomerate. This deposit of gold ore is hundreds of miles across and more than two miles deep. It is estimated that two-thirds of the gold mined comes from South Africa. Other major producers of gold include Australia, the former Soviet Union, and the United States (Arizona, Colorado, California, Montana, Nevada, South Dakota, and Washington) [29].

About 65 percent of processed gold is used in the arts industry, mainly to make jewelry. Besides making jewelry, gold is also used in the electrical, electronic, and ceramics industries. These industrial applications have grown in recent years and now occupy an estimated 25 percent of the gold market. The remaining percentage of mined gold is used to make a type of ruby coloured glass called purple of Cassius, which is applied to office building windows to reduce the heat in the summer, and to mirrors used in space and in electros copy so that it reflects the infrared spectrum [30].

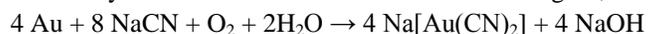
Cyanide (CN), a single carbon atom triple-bonded to a nitrogen atom, has proved extremely useful in extracting gold from ore [31]. However, with a toxic reputation dating back to the Holocaust, its use in mining has been very controversial. Through a process called "gold cyanidation", "the cyanide process", or "cyanide leach mining", cyanide is used to extract gold from the surrounding rock. While cyanide is both effective and economical, its use and transportation present significant environmental risks.

##### 4.1. Raw materials:

The most important gold mines are native gold and electrum. Besides, calaverite (AuTe<sub>2</sub>), sylvanite [(Au, Ag) Te<sub>2</sub>], muthmannite [(Au, Ag)Te] are also the sources of Au. (Te-tellurium). The main Ag mine is sulphide ore such as argentite, chaorargyrite, stephanite, etc. which always accompanying in (lead, zinc, copper, antimony) sulfide minerals. Silver has a higher grade of mineral deposits, while more than 50% gold symbiosis scattered in the lead, zinc, copper, nickel minerals. Secondary resources are also the main source of gold and silver.

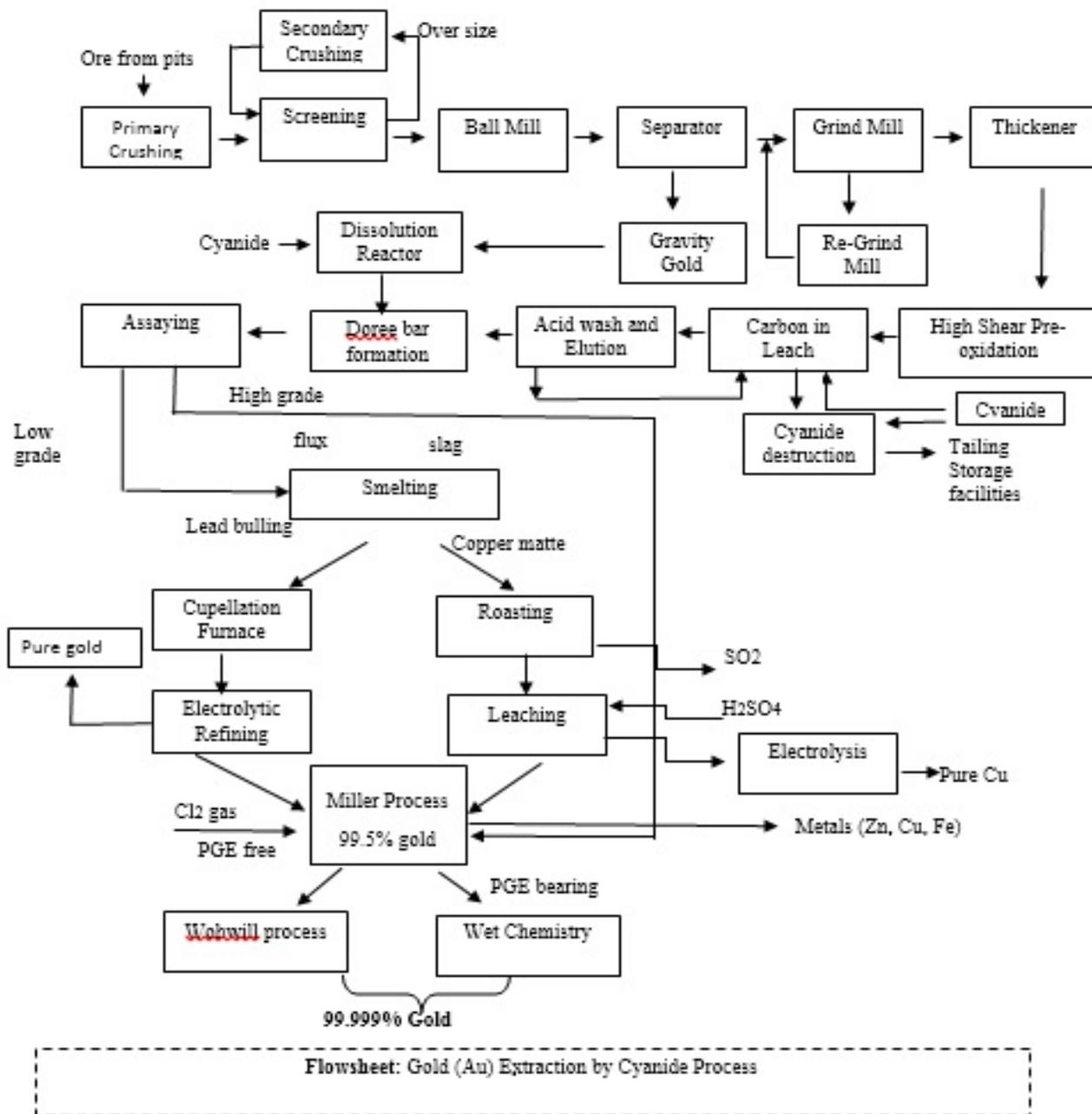
##### 4.2. Major Reactions:

The chemical reaction of Cyanidation methods for the dissolution of gold, the "Elsner Equation", follows:



In this redox process, oxygen removes, via a two-step reaction, one electron from each gold atom to form the complex Au(CN)<sub>2</sub><sup>-2</sup> ion.

##### 4.3. Treatment process or Methodology:



**Figure 4:Gold (Au) Extraction by Cyanide Process**

**4.3.1. Process Descriptions:**

Cyanide can be used to extract gold, either in a controlled mill environment, or more crudely on rock piles in the open. Cyanide "vat leaching" mixes crushed ore with a cyanide salt finely in water. The cyanide binds to the gold ions, and makes them soluble in water, thereby allowing separation from the rock. This process usually takes place inside a mill or other mining facility. Cyanide, in the form of a very dilute sodium cyanide solution, is used to dissolve and separate gold from ore. Cyanidation also involves using chemicals to separate the gold from its contaminants. In this process, the ground ore is placed in a tank containing a weak solution of cyanide. Next, zinc is added to the tank, causing a chemical reaction in which the end result is the precipitation (separation) of the gold from its ore. The gold precipitate is then separated from the cyanide solution in a filter press. A similar method is amalgamation, which uses the same process with different chemicals. First, a solution carries the ground ore over plates covered with mercury. The mercury attracts the gold, forming an alloy called an amalgam. The amalgam is then heated, causing the mercury to boil off as a gas and leaving behind the gold. The mercury is collected, recycled and used again in the same process.

#### 4.4. Environmental Issues:

Gold is a precious metal which is prominent attraction as a jewellery product specially for women due to its good colours and non-reactive with environment. However, the production of gold sometimes produces some toxic wastes which have detrimental effects on the environment. Besides, both the usage and disposal of cyanide have significant safety and environmental risks. Cyanide and cyanide gas are both extremely toxic and great care has to be taken during ore processing to avoid exposure for workers which are given below:

- ✓ Modern industrial gold mining destroys landscapes and creates huge amounts of toxic waste. Due to the use of dirty practices such as open pit mining and cyanide heap leaching, mining companies generate about 20 tons of toxic waste for every 0.333-ounce gold ring. The waste, usually a gray liquid sludge, is laden with deadly cyanide and toxic heavy metals [32].
- ✓ Many gold mines dump their toxic waste directly into natural waterbodies. The Lihir gold mine in Papua New Guinea dumps over 5 million tons of toxic waste into the Pacific Ocean each year, destroying corals and other ocean life. Mining companies for gold and other metals dump at in total least 180 million tons of toxic waste into rivers, lakes, and oceans each year—more than 1.5 times the waste that U.S. cities send to landfills on a yearly basis [33].
- ✓ To minimize the environmental damage, mines often construct dams and place the toxic waste inside. But these dams do not necessarily prevent contamination of the surrounding environment. Toxic waste can easily seep into soil and groundwater, or be released in catastrophic spills. At the world's estimated 3,500 dams have been built to hold mine waste, one or two major spills occurs every year.
- ✓ Toxic waste spills have had devastating consequences in Romania, China, Ghana, Russia, Peru, South Africa, and other countries. In 2014, a dam collapsed at the Mount Polley gold and copper mine in British Columbia, sending about 25 million cubic meters of cyanide-laden waste into nearby rivers and lakes—enough to fill about 9,800 Olympic-sized swimming pools. The spill poisoned water supplies, killed fish, and harmed local tourism.
- ✓ One of the common breakdown products is nitrate, which itself can cause both environmental and human health problems. Lastly, cyanide can form complexes with certain metals, such as cobalt, and these can persist for many years in groundwater.
- ✓ Many old mines, and some current mines, simply place cyanide waste into the mine tailings ponds along with other mining waste. Failure of a tailings dam containing cyanide can be a massive environmental problem, resulting in the sterilization of large areas downstream. In 2000, a tailings dam failure in Romania dumped an estimated 100 tons of cyanide into a river system, contaminating drinking water and killing fish up to 250 miles downstream, with effects purportedly lasting for years.
- ✓ In comparison to acid mine drainage, cyanide has a higher toxicity, but is shorter lived. Acid mine drainage can last for thousands of years, whereas cyanide will break down within a few years at most. However, its high toxicity means that even a relatively small spill can have major consequences.
- ✓ Many modern mines now use a "de-toxification" process that converts cyanide into the less toxic cyanate before combining it with the mine tailings waste. In addition, the majority of cyanide gold mines use "impermeable" liners in their tailings ponds and underneath their heap leaching operations. However, leaks and tears in these liners have been a continual problem at many mines. Mining companies often argue that the combination of de-toxification and the use of liners makes the use of cyanide an acceptable risk, but there have been numerous accidents over the last decade.

As a result of these environmental concerns, a few countries and US states have banned the use of gold cyanidation. In response, the gold mining industry has promoted adherence to a voluntary "cyanide management code" with strict independent audits of signatory companies. Some environmental organizations have applauded the code for increasing transparency and others have condemned it as "greenwashing". Considering its environmental effects another modern concepts can be find out which would be the effective solution for environmental issues [34].

#### Conclusion:

To sum up, we need to optimize the previous processes of metal production (Fe and Steel, Al, Cu, Au) and develop new methods to reduce the environmental pollution so that we save this beautiful globe from the harmful effects of pollutants of those industries. Since

industrialization is booming, in parallel, environmental pollution is increasing, modern research should be needed to overcome or capture these contamination products so as to ensure tidy and healthy environment for all living beings.

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