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reducing electricity requirement per tonne of steel, modifying equipment and practices to minimize consumption of the graphite electrodes, and improving the quality and range of steel produced from low quality scrap.

3.4 Industrial Processes in the Context of Environmental Pollution

3.4.1 Iron & steel industry (Ferrous metal industry)

Iron and steel industry which comprises preparation of raw materials, agglomeration of fines in sinter plant, feeding of burden to blast furnace, manufacturing of coke in coke ovens, conversion of pig iron to steel, making and shaping of steel, granulation of slag, recovery of chemicals in by-product plant etc. All the above mentioned processes add to air, water, solid waste and noise pollution. Flow chart of linking pollutants and principle processes is shown in Figure 3-13.

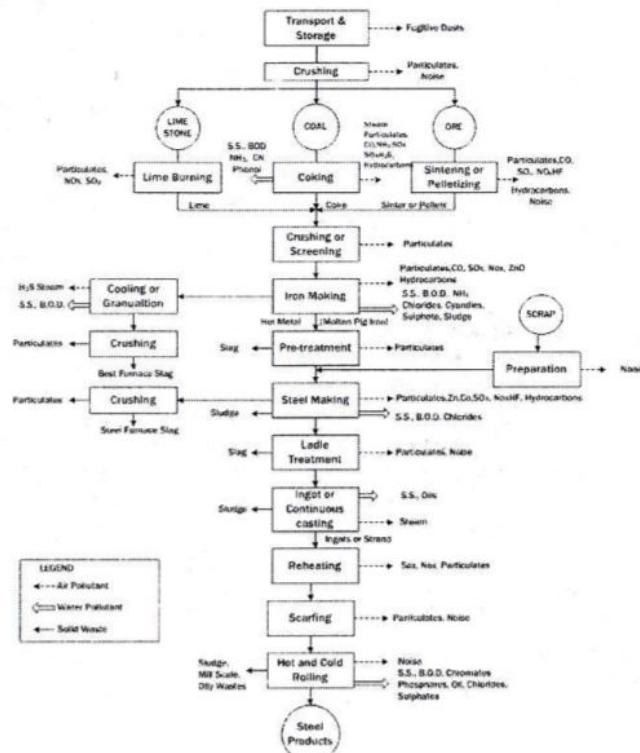


Figure 3-13: Flowchart Linking Pollutants and Principal Processes



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3.4.1.1 Air emissions

In addition to the process related air emissions discussed below, air emissions may be generated from captive power plants fueled with coal, by-product gas (e.g coke oven gas [COG], blast furnaces gas, and basic oxygen furnace [BOF] gas).

Particulate matter

Particulate matter (PM) may be generated in each of the process steps, and may contain varying concentrations of mineral oxides, metals (e.g arsenic, cadmium, mercury, lead, nickel, chromium, zinc, manganese), and metal oxides. Sources include melting and refining activities (BF, BOF, EAF) and heating furnaces (depending of type of fuels used); mechanical actions (e.g scarfing and grinding); and handling of materials (e.g raw materials, additive, recycled and waste materials, and by-products). Additional sources of particulate matter (PM) emissions include coal storage, conveying, charging, coking, pushing, and quenching.

Thermal Processes: Particulate matter emissions may arise from thermal processes including coke making, sintering, pelletizing, and direct reduction. Coke oven plants are another significant source of dust emissions. Continuous particulate matter emissions may result from the under-firing process through the combustion stack. Intermittent and fugitive emissions may arise from a large number of sources including oven and leveling doors, valves, and charging holes. Other emissions may arise from pushing, quenching and screening (discontinuous emissions) and from coke oven gas (COG) treatment.

Recommended measures to prevent and control particulate matter emissions from coke oven plants include:

- Installation of collection hoods for coke oven batteries;
- Maintenance and cleaning of all fugitive emissions sources associated with the coke oven (e.g oven chamber, oven doors, leveling doors, valves and charging holes, and frame seals ascension pipes) are essential for clean and safe operation;
- Good operational management to achieve steady state operation to, for example, avoid green push;
- Adoption of "smokeless" charging measures;
- Adoption of coke dry quenching (CDQ) system;
- Adoption of non recovery-coke battery;
- Reduction of the coke charge in the blast furnace, including use of pulverized coal injection.

For details in coke oven plants, a separate TGM on coke oven may be referred.

Sinter plants may generate the most significant quantity of particulate matter emissions in integrated steel plants. Emissions in the sinter plant arise primarily from materials-handling operations, which result in airborne particulate matter and from the combustion reaction on the strand.

Recommended measures to prevent and control particulate matter emissions from the sinter plant include:

- Implement partial or total recirculation of waste gas in the sinter plant, according to sinter quality and productivity;
- Use of electrostatic precipitator (ESP) pulse systems, ESP plus fabric filter, or adoption of pre-dedusting (ESP or cyclones) in addition to high pressure wet scrubbing system for waste gas de-dusting. The presence of fine dust, which consists mainly of alkali and lead chlorides, may limit the efficiency of ESPs.

The pelletization of iron ore (an alternative to sintering) may generate dust and particulate matter emissions from grinding of raw material; from the firing zone of the induration strand; and from screening and handling activities.

Recommended measures to prevent and control particulate matter emissions from pelletization are similar to those for sinter operations, as above.

Melting activities: Particulate matter emissions generated by the blast furnace plant include emissions from the cast house (primarily iron oxide particulates and graphite) and the cleaning of BF gas leaving the top of the furnace. Measures to prevent and control particulate matter emissions from the blast furnace include use of dedusting systems, typically including scrubbers and electrostatic precipitators (ESP), before reuse of the off-gas

Particulate matter emissions from the basic oxygen furnace (BOF) arise from hot metal pre-treatment (including hot metal transfer, desulphurization and deslagging processes); charging operations; oxygen blowing to reduce carbon level and oxidation of impurities; and tapping operations.

Recommended measures to prevent and control particulate matter emissions from the BOF include:

- Use of primary controls for the flue gas of the BOF, including venturi scrubbers with complete combustion techniques; with suppressed combustion systems, BOF gas is cleaned and stored to be used as a fuel.
- Installation of secondary controls to capture off-gas escaping from the BOF process;
- Electric arc furnaces (EAFs) generate particulate matter during melting; oxygen injection and decarbonizing phases (primary off gas emissions); and charging / tapping (secondary off-gas emissions) and is discussed in a separate TGM.
- In the casting area (ingots and continuous casting), particulate matter and metals arise from the transfer of molten steel to the mold and from the cutting to length of the product by oxy-fuel torches during continuous casting. Exhausts should be fitted to filters and other relevant abatement equipment, especially in the casting and rolling, and finishing shops, where relevant.
- Baghouse filters and ESP have higher particulate collection efficiency, whereas wet scrubbers also allow capturing water soluble compounds (*e.g.* sulphur dioxide [SO₂] and chlorides) but need additional effluent treatment facilities.
- Bag filters are typically installed to control melting shop emissions. They are often preceded by cyclones, which are installed to act as spark separators.
- Mechanical Actions: Scarfing and grinding activities may generate particulate matter emissions. Exhausts should be fitted to filters chosen based on the specified activity.

- Raw Material Handling: To reduce fugitive emissions of particulate matter during handling of materials, the following prevention and control techniques are recommended:
 - Use indoor or covered stockpiles or, when open-air stockpiles are unavoidable, use water spray system (not sea water, see 'Chlorides' section below), dust suppressants, windbreaks, and other stockpile management techniques;
 - Design a simple, linear layout for material handling operations to reduce the need for multiple transfer points;
 - Maximize use of enclosed silos to store bulk powder;
 - Enclose conveyer transfer points with dust-controls;
 - Clean return belts in the conveyor belt systems to remove loose dust;
 - Implement routine plant maintenance and good housekeeping to keep small leaks and spills to a minimum;
 - Implement correct loading and unloading practices.
- Fugitive emissions of coal dust are a significant concern.

Recommendations to prevent and control fugitive coal dust emissions during coal transfer, storage, and preparation include the following:

- Minimize the height of coal drop to the stockpile;
- Use of water spray systems and polymer coatings to reduce the formation of fugitive dust from coal storage (*e.g.* on stockpiles);
- Use of bag filter or other particulate control equipment for coal dust emissions from crushing / sizing activities;
- Installation of centrifugal (cyclone) collectors followed by high efficiency venturi aqueous scrubbers on thermal dryers;
- Installation of centrifugal (cyclone) collectors followed by fabric filtration for pneumatic coal cleaning equipment and activities;
- Use of enclosed conveyors combined with extraction and filtration equipment to prevent the emission of dust at conveyor transfer points;
- Rationalizing transport systems to minimize the generation and transport of dust on site.

Nitrogen oxides

Nitrogen oxides (NOx) emissions are caused by high furnace temperature and the oxidation of nitrogen. NOx emissions are associated with sinter operations; pelletization plant operations; fuel combustion for coke oven firing, including the combustion of recycled coke oven gas; cowper and hot stoves in the BF process; the use of process gases or high air combustion temperature in the re-heating and annealing furnace; and from mixed acid pickling, among other sources.

Specific recommended techniques for the prevention and control of NOx emissions in steel operations include:

- Application of waste gas recirculation



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- Use of oven batteries with multi-stage air supply systems
- Adoption of suppressed combustion in BOF

Sulphur dioxides

Sulphur dioxide (SO_2) emissions are mainly associated with combustion of sulphur compounds in the sinter feed, primarily introduced through the coke breeze. SO_2 emissions may also result during the induction process in pelletization, and from coke oven firing. The SO_2 emission level in waste gases from reheating and annealing furnaces depends on the sulphur in the available fuel.

Other specific recommended techniques for the prevention and control of SO_2 include the following

- Selection of raw feedstocks with low sulphur content
- Minimizing the sulphur content of the fuel
- Addition of absorbents such as hydrated lime [$\text{Ca}(\text{OH})_2$], calcium oxide (CaO), or fly ashes with high CaO content injected into the exhaust gas outlet before filtration
- Installation of gas wet scrubbing systems in dedicated collecting and dedusting system
- Use of a wet-scrubber injection of a slurry mix containing calcium carbonate (CaCO_3), CaO, or $\text{Ca}(\text{OH})_2$
- Use of a dry scrubber, if necessary

Carbon monoxide

Sources of carbon monoxide (CO) include waste gases from the sinter strand, coke oven, BOF, BF and EAF. CO is generated from the oxidation of coke in smelting and reduction processes, and from the oxidation of the graphite electrodes and the carbon from the metal bath during melting and refining phases in EAFs.

Recommended pollution prevention and control techniques to reduce CO emissions include the following:

- Full capture of off gases from coke oven, BF and BOF
- Recycling gases containing CO
- Use of foamy slag practices in EAF process

Chlorides and fluorides

Chlorides and fluorides are present in the ore and tend to form hydrofluoric acid (HF), hydrochloric acid (HCl), and alkali chlorides during the sintering and pelletization processes. HF and HCl may arise from off gas in the EAF process, depending on the quality of the scrap charged. Hydrogen chloride emissions arise from pickling lines (HCl type), and necessitate use of HCl recovery systems. Recommended pollution prevention and control techniques include:

- Use of dry dedusting or wet scrubbing techniques, which are also typically installed to control particulate matter and sulphur oxide emissions respectively
- Control the input of chlorine via raw materials through the materials selection process



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- Avoid spraying with sea water
- If it is necessary to exclude chlorine from the system, the chlorine-rich fine fraction of filter dust should not be recycled to the sinter feed (although it is generally favorable to recycle all iron-bearing process residues)

VOCs and organic HAPs

VOCs and polynuclear aromatic hydrocarbons (PAH) may be emitted from various stages in steel manufacturing including from off gas in the sintering and pelletization processes due to oil entering the sinter or pelletization feed (mainly through the addition of mill scale); from coke ovens, quenching, and the by-product plant; and from the EAF, especially when coal is added as a 'nest' to the scrap basket. PAH also may be present in the EAF scrap input, but may also be formed during EAF operation. Hydrocarbons and misted oil emissions may also arise from the cold rolling mill (tandem mill) operations.

Recommended pollution prevention and control techniques for VOC emissions include the following process integrated measures:

- Pre-treat mill scales through such practices as pressure washing to reduce oil content;
- Optimize operation practices, particularly combustion and temperature controls;
- Minimize oil input via dust and mill scale through use of "good housekeeping" techniques in the rolling mill;
- Use of advanced emission collection and demisting systems (e.g precoated bag filters);
- Recirculation of off-gas;
- Treat the captured off-gas through post combustion, chemical scrubbing, or biofiltration.

Dioxins and furans

Sinter plants are a significant potential source of polychlorinated dibenzodioxin and dibenzofuran (dioxins and furans or PCDD/F) emissions. PCDD/F may be produced if chloride ions, chlorinated compounds, organic carbon, catalysts, oxygen, and certain temperature levels exist simultaneously in the metallurgical process. In addition, high oil content in mill scale may give rise to higher emissions of PCDD/F. Another potential PCDD/F emissions source is off-gas in the EAF. The potential presence of polychlorinated biphenyls (PCB), PVC, and other organics in the scrap input (shredded scrap mainly obtained from old equipment) may be a source of concern, due to its high potential for PCDD/F formation.

Recommended techniques to prevent and control PCDD/F emissions include the following:

- Recirculation of waste gases may reduce pollutant emissions and reduces the amount of gas requiring end-of-pipe treatment;
- Fine feed material (e.g dust) should be agglomerated;
- In sintering plants: minimizing chloride input in the bed; use of additions such as burnt lime; and control of mill scale oil content (<1 %);
- Exclude the chlorine-rich fine fraction of filter dust from recycling in the sinter feed;



- Use of clean scrap for melting;
- Use of post combustion of the EAF off gas to achieve temperatures above 1200°C, and maximizing residence time at this temperature. The process is completed with a rapid quenching to minimize time in the dioxin reformation temperature range;
- Use of oxygen injection to ensure complete combustion;
- Injection of additive powders (*e.g.* activated carbons) into the gas stream to adsorb dioxins before the dust removal by filtration (with subsequent treatment as a hazardous waste);
- Installation of fabric filters with catalytic oxidation systems.
- Exhaust gas treatment through denitrification, desulphurization, and activated coke packed bed absorption
- Exhaust gas treatment through low-temperature plasma

Dioxins and furans from Sinter plant and monitoring

The sinter plant plays a central role in an integrated iron and steel work for recycling of wastes from production residues, which would have to be disposed otherwise. Sinter plants are, therefore, known as the dust bin of steel plants. Slags from steel production, filter dusts of diverse flue gas cleaning systems (including those applied to the sinter plant itself) and various iron-containing materials from residue treatment are recycled in the sinter plant. When sinter is charged in the blast furnace, its productivity increases. Proportion of sinter in the charge is now an index of productivity for blast furnaces.

Recycling may lead to an enrichment of relevant compounds, particularly heavy metals. Some residue materials like roll mill scale may be contaminated with organic compounds (oils) that could act as precursors for PAH and Polychlorinated Dibenzodioxin/difurans (PCDD/F) formation.

In a Sinter Plant, iron ore and additives are mixed in a mixing drum. Before they enter the sinter band this is protected by a layer of material that has already been sintered. On the sinter machine air is sucked through the mixture by several suction hoods which are connected to an electrostatic precipitator. This waste gas constitutes the main flue gas flow which could be more than 1 million m³/h. Further waste gas is collected from the feeding process at the front and from the sieving process at the end of the sinter band (so-called "room-dedusting").

Flue gas concentrations of PCDD/F measured at European sinter plants usually ranged from below 1 to more than 10 ng I-TEQ/m³, however, an extreme concentration of 43 ng I-TEQ/m³ was found at one plant leading to an estimate freight of 250 g I-TEQ/year generated by this particular sintering machine. When the high potential for dioxin emissions became public in Germany a special working group was founded by the operators of sintering plants. With subsidy from the Federal Agency for Environment (UBA) additional measurements were conducted at facilities of iron and steel industry. Besides a confirmation of the typical emission data these experiments also revealed that the PCDD/F homologue profile is determined by the lower chlorinated furans; dioxin emissions therefore are most probably due to de-novo-synthesis during the sintering process.

In Japan, Sintering exhaust gas containing SO_x, NO_x, dust and dioxins are processed, absorbed, decomposed and/or collected as non-toxic by-products to increase the quantity of steam recovery, and improve total fuel savings. Treatment methods to achieve these



include: (1) Denitrification Equipment, (2) Desulphurization Equipment, and (3) Activated Coke Packed Bed Absorption.

Energy/Environment/Cost/Other Benefits:

- SO_x is absorbed and recovered as useful by-product
- NO_x is decomposed to nitrogen, water and oxygen by ammonia
- Dust is collected in activated coke
- Dioxins are collected or absorbed in activated coke and decomposed at 400°C with no oxygen
- Activated coke absorption removes dioxins to <0.1 ng-TEQ/m³N, dust to <10 mg/m³N, and SO_x to <65 % absorbing ratio.

Also, as reported by Korea, active radicals of low temperature plasma remove SO_x, NO_x, and HCl simultaneously with significant efficiency. Commercial scale plant installed at an incinerator in Kwang works, has shown a substantial reduction of SO_x (>70%), NO_x (>95%) and HCl (>99%) respectively. Dioxin also decreased (<0.2 ng-TEQ/N m³) with the addition of Lignite in the process. Its reliability as well as the stability has been proved through the operation more than 5 years.

Metals

Heavy metals may be present in off gas fumes from thermal processes. The amount of metal emissions depends on the particular process type and on the composition of raw materials (iron ore and scrap). Particulates from the sinter plant, BF, BOF, and EAF may contain zinc (which has the highest emission factor in EAFs, particularly if galvanized steel scrap is used); cadmium; lead; nickel; mercury; manganese; and chromium. Metal particulate emissions should be controlled with high efficiency dust abatement techniques applied to particulate emissions control as discussed above. Gaseous metal emissions are typically controlled through the cooling of gases followed by bag filters.

Greenhouse gases (GHGs)

Steel manufacturing facilities are energy intensive and may emit significant amounts of carbon dioxide (CO₂). GHG emissions from integrated steel mills are mainly generated from the combustion of fossil fuels such as coal for energy (heat), ore reduction, electrical energy production, and the use of lime as feedstock. The average value of carbon dioxide intensity in the sector is estimated at 0.4 t C/T of crude steel.

Recommended carbon dioxide (CO₂) emission prevention and control techniques include the following:

- Minimize energy consumption and increase energy efficiency through primary measures, including, but not limited to:
 - Adequate surface insulation to limit heat dispersion
 - Control of the air / fuel ratio to reduce gas flow
 - Implementation of heat recovery systems
- Use of waste gas through a heat exchanger to recover gas thermal energy, and as a combustion gas to produce hot water and air, and / or steam and power



- Implement good practice for combustion, such as oxygen enrichment or preheating of blast air and automatic control of combustion parameters;
- Preheat clean scrap
- Reduce fuel consumption in heating and thermal treatment by using recovery gas and / or adopting good combustion control
- Select fuel with a lower ratio of carbon content to calorific value, such as natural gas (CH_4). CO_2 emissions from the combustion of CH_4 account for approximately 60 % of the emissions from coal or pet-coke
- Recover energy wherever possible, utilize all process gases (e.g. coke gas, blast furnace gas, basic oxygen furnace gas), and install a top gas pressure recovery turbine (TRT) in the blast furnace and coke dry cooling in coke oven
- Optimize intermediate storage logistics to allow for a maximum rate of hot charging, direct charging or direct rolling, thereby reducing reheating needs
- Use near-net-shape casting and thin slab casting processes, where feasible

3.4.1.2 Solid wastes and by-products

Most waste residue from the integrated iron and steel sector is recycled to obtain added value from various types of byproducts, slag, scales and dust. Waste materials may include slag from BF; fine dust and sludge from BF gas cleaning; fine dust from BOF gas cleaning; some BOF slag; high alkali chlorides and heavy metal chlorides from the last field of electrostatic precipitators; and treatment of the off-gas from sinter strands.

Tar and other organic compounds (e.g BTX) recovered from COG in the coke oven gas treatment plant should be managed so as to avoid leaks or accidental releases, according to the Hazardous Waste (Management and Handling) Rules and Manufacture, Storage and Import of Hazardous Chemicals Rules of Government of India, and recycled into the coke making process or sold for use in other industrial activities.

Slag

Slag residues may be sold as by-products (e.g. slag from BF for cement production if granulated or from BOF for use in civil engineering, road construction, and as railway ballast after processing). Slag is a by-product of iron and steelmaking, not a waste. Slag pulverization is a process during which water is sprayed when the slag temperature is at 600-800°C. The water spray produces hot steam, which reacts with free calcium oxide and magnesium oxide. Consequently, the slag is pulverized due to the volume expansion, thus making the iron and steel separate naturally from the slag. Slag is also used outside of steel making, e.g. in water/bottom muck purification materials to reduce phosphate concentration in red tides and as marine block to help grow seaweed. Some amount of BOF slag can also be reused in BF. EAFs produce a significant amount of slag. Where reuse of EAF slag is not financially or technically feasible, it should be disposed of, along with the dust from the treatment of off-gas, in a landfill designed with consideration of slag and dust characteristics. Local geological conditions also should be considered when locating slag heaps.

Metallic waste

Metallic waste and by-products from rolling and finishing operations (e.g. scarfing scale / swarf, dusts from scarfing, rolling mill scale, water treatment and mill scale sludge,



grinding sludge, and oil / greases) should be reused in the process. Some by-products (e.g oily mill scale and grinding sludge from water treatment plants), should be conditioned before internal recycling, such as reduction of oil content and depending on process requirements. Metals from filter dust, slag, and waste metals should be recovered and recycled to sinter feed.

Acids

Pickling acid regeneration sludge can be recycled in steel plants (EAF and blast furnace) or processed for the production of iron oxides. The iron oxide from hydrochloride acid regeneration can be used in several industries as production of ferromagnetic materials, iron powder, or construction material, pigments, glass and ceramics.

Sludge

Sludge from wastewater treatment may contain heavy metals (e.g. chromium, lead, zinc, and nickel) and oil and grease. Part of the sludge from wastewater treatment may be internally recycled or else deposited in special landfills. Sludge reuse may require a pre-treatment stage, which typically consists of pressing, drying, and granulation.

3.4.1.3 Wastewater

Effluent streams normally present in the sector include cooling water, stormwater, rinse water, and several different process effluent streams. Cooling water is normally recycled within the process. Rinse water may contain suspended solids, dust, lubricating oil, and other pollutants depending on the process.

Recommended measures to prevent effluent generation from cooling and rinsing water activities include the following:

- Prepare a plant wide water recycling plan to maximize efficiency of water use. More than 95 % recycling of water is normally achievable;
- Dry techniques for removal of dust from plant equipment and premises should be used where possible, and rinse water should be collected and treated before discharge or reuse;
- Collect spillages and leakages (e.g. using safety pits and drainage systems).

Industrial process wastewater

Process effluent sources include the coke oven plant, the rolling process, and the pickling plant.

Coke Oven Plant: Please also refer TGM on Coke Oven. Effluent streams generated in the coke oven plant include water from the tar / water separator (consisting of water vapor formed during the coking process and condensate water used in coolers and for cleaning the COG); water from wet oxidative desulphurization system; and water from the closed cooling system. Effluent from the tar/water separator contains high concentrations of ammonia. This effluent should be treated with an ammonia stripper, and the resulting stream contains various organic (such as phenols) and inorganic compounds (such as residual ammonia and cyanides). A phenol-specific biological treatment (BOD plant) should be employed at the coke plant.

Batch emissions to water can in some cases be generated by wet coke quenching operations. Excess quenching water should be collected and used for the next quenching operation. Effluent from the wet oxidative desulphurization processes may contain suspended solids (including heavy metals), PAHs, sulphur compounds, and fluorides / chlorides, depending on the adopted dedusting systems. This effluent stream may have a detrimental effect on the biological wastewater treatment plant. Indirect gas cooling water is recirculated and will not influence the wastewater quantity. In the case of direct gas cooling, the cooling water should be considered as washing liquor and eventually drained via the still.

Compliance to effluent standards for cyanides and phenols:

The overall efficiency of biological treatment of coke oven wastewater, even after employing well acclimatized microorganisms, is far from satisfactory due to its resistance to biodegradability and inhibition. As all steel plants have a BOD plant for phenolic effluents, it will be advantageous if these can be made more efficient without totally changing the technology.

SAIL, R&D, (RDCIS), Ranchi, has observed that it is essential to increase biodegradability of the effluents by breaking the refractory chemicals prior to biological process in order to achieve high level of overall efficiency. Advanced Oxidation Processes (AOPs) have the potential to enhance biodegradability of toxic constituents and can be a viable pre-treatment and /or post treatment technology for treatment of coke oven wastewater. AOPs are of special interest for wastewater treatment due to their efficiency in minimizing a great variety of pollutants, including recalcitrant compounds, through the oxidation by generated hydroxyl radicals. AOPs are suited for destroying dissolved organic contaminants such as halogenated hydrocarbons, aromatic compounds (BTX), pentachlorophenols, detergents, pesticides, etc. AOPs can also be used to oxidize inorganic contaminants such as cyanides, sulphides, and nitrates.

A partial list of AOP techniques include:

- homogeneous ultraviolet irradiation
- using semiconductor catalysts
- X-ray or gamma ray radiolysis
- ultrasonic irradiation
- electro hydraulic cavitations

Of all these, photochemical and electrochemical techniques were chosen for experiment. The experiment done by RDCIS focused on key parameters like COD, cyanide, ammonia, TSS, turbidity, colour etc.

RDCIS recommended the following;

- Electrolytic coagulation coupled with electro-oxidation was found to be having potential application in the steel plant wastewater treatment system. Arrangements can be introduced just before mixing units.
- It was observed that significant amount of floc was generated during electrolysis, which was found to float. This may lead to easier removal of constituents.
- The process needs to be optimized on a plant scale by controlling reaction chamber materials (iron, aluminum, titanium, graphite, etc.), amperage, voltage, flow rate, and the pH of water. The technology can handle mixed waste streams (oil, metals, and bacteria).

Rolling Process: Effluent from scale removal contains suspended solids and emulsified oil, in addition to coarse scale. Treatment of effluent includes a sedimentation basin in which solids, mainly iron oxides, are allowed to settle at the bottom of the basin and the oil pollutants on the surface are removed by means of skimmers and discharged to collecting basins. Cooling water from rolling processes should be collected and treated prior to reuse.

Pickling plants: Pickling plants generate three streams of process effluent, including rinse water, spent pickle baths, and other wastewaters (e.g. water from fume absorbers of the pickling tank exhaust system and flushing water from plant cleaning). The largest volume of wastewater derives from rinsing, whereas the most significant contamination load comes from the continuous or batch exchange of pickle baths.

Recommended techniques to prevent effluent from pickling plants include the following:

- Install acid recovery and recycling unit;
- Reduce effluent volume and minimize contaminant loading of the waste streams through optimization of the pickling process;
- Apply counter flow cascading and, in some cases, recycling of acid-pickling rinse water discharges to the acid regeneration plant.

Process wastewater treatment

Techniques for treating industrial process wastewater in this sector include source segregation and pretreatment of wastewater streams for (i) reduction in ammonia using air stripping, (ii) reduction in toxic organics, such as phenols using biological treatment and (iii) reduction in heavy metals using chemical precipitation, coagulation and flocculation, etc. Typical wastewater treatment steps include oil water separators or dissolved air floatation for separation of oils and floatable solids; filtration for separation of filterable solids; flow and load equalization; sedimentation for suspended solids reduction using clarifiers; dewatering and disposal of residuals in designated hazardous waste landfills. Additional engineering controls may be required for (i) advanced metals removal using membrane filtration or other physical/chemical treatment technologies, (ii) removal of recalcitrant organics using activated carbon or advanced chemical oxidation, and (iv) reduction in effluent toxicity using appropriate technology (such as reverse osmosis, ion exchange, activated carbon, etc.). Wastewater treatment methods typically include coagulation / flocculation / precipitation using lime or sodium hydroxide; pH correction / neutralization; sedimentation / filtration / flotation and oil separation; and activated carbons

Other wastewater streams & water consumption

Contaminated streams should be routed to the treatment system for industrial process wastewater. Contaminated stormwater may result from coal, coke and other material storage areas. Soil surrounding outdoor coal storage areas may be impacted by highly acidic leachate containing PAHs and heavy metals. Industry-specific recommendations include:

- Store scrap and other materials, (e.g. coke and coal) under cover and / or in bunded area to limit contamination of stormwater and collect drainage



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- Pave process areas, segregate contaminated and non-contaminated stormwater, and implement spill control plans. Route stormwater from process areas into the wastewater treatment unit
- Design leachate collection system and location of coal storage facilities to prevent impacts to soil and water resources*. Coal stockpile areas should be paved to segregate potentially contaminated stormwater for pretreatment and treatment in the wastewater treatment unit.

Noise

Integrated steel manufacturing facilities generate noise from various sources including scrap and product handling; waste or by-product gas fans; process cooling and draft fans; rotating equipment in general; dedusting systems; furnace charging; EAF melting processes; fuel burners; cutting activities; wire rod pay-off units; and transport and ventilation systems.

Recommended techniques to reduce, prevent, and control noise includes the following:

- Enclose the process buildings and/or insulate structures
- Cover and enclose scrap and plate/slab storage and handling areas
- Enclose fans, insulate ventilation pipes, and use dampers
- Adopt foaming slag practice in EAFs
- Limitation of scrap handling and transport during nights, where required
- Noise abatement measures should achieve the ambient noise levels as per Environment (Protection) Act, 1986

3.4.2 Non-ferrous industry

All non-ferrous industrial processes for aluminum, copper, lead, zinc etc. follow material handling, pyroprocessing, leach processing, pyro-refining, melting and casting etc. and pass through similar conditions of release to environment except pollutants and its severity. As such they have been bundled here for description by mentioning the process whenever felt necessary.

Significant environment aspects:

- Air emissions
- Wastewater
- Hazardous materials
- Residues and waste
- Noise

3.4.2.1 Air emissions**Particulate matter**

Like any industry where material handling is involved, emissions of particulate matter (which may contain metals) may result from fugitive and point sources, including receiving, conditioning, handling, transport (e.g., conveyors, vehicular traffic), and storage (e.g., outdoor piles) of ores, concentrates, and secondary raw materials; from hot gases during pyroprocessing (e.g., sintering, smelting, roasting, and converting); during



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leach processing (e.g., dry material handling, filtering, storage of leach residues); during pyro-refining (e.g., furnace processing and transfer of the hot materials); during collection and transport of contents of abatement systems (e.g., baghouse filters); and during melting and casting (e.g. molten metal and dross handling). Fugitive emissions can be greater than those that are collected and abated; therefore, control of fugitive emissions is particularly important. Measures to prevent and control particulate matter emissions include the following:

- Characterize all feed materials with regard to risk reduction potential
- Store dust-forming materials in enclosed buildings or containers and transfer using pneumatic or enclosed conveyor systems. Cover all transport vehicles
- Reduce the quantity of materials transported, and transport distances, through efficient plant layout and design
- Reduce off-gas volumes where possible (e.g. by employing oxygen-smelting processes)
- Design for continuous operation where possible, and ensure environmental control systems are adequate to optimize smooth, consistent operation
- Use sealed furnaces and reactors with reduced pressure, or retrofit existing furnaces with maximum sealing (e.g. use of a "fourth hole" in the roof of an electric arc furnace to extract the process gases as efficiently as possible)
- Enclose, contain, or use hoods to collect emissions from process vessels, feed and discharge points, and conveyor systems
- Use systems that maintain the sealing or hood deployment during transfer of materials, such as through electrode additions of material; additions via tuyeres or lances; and the use of robust rotary valves on feed systems
- Use damper controls that change the extraction points automatically during different stages of the process in order to target the extraction effort to the fume source and thereby minimize energy consumption. Extraction of fumes at the roof ventilator should generally only be used as an additional mitigation if needed (like roof mounted canopy hoods over EAFs to collect charging and tapping fugitive emissions which the fourth hole cannot achieve) and not as an alternative to fourth hole, because of the high energy use and reduced collection efficiency
- Control particulate matter emissions using electrostatic precipitators, bagfilters, scrubbers, or cyclones that are appropriate for the exhaust stream characteristics (e.g., considering temperature, size fraction of particulate matter)
- Maintain the collector hood, ducts, and filter system to ensure that collection or extraction rates remain at the designed level
- Cover all transport vehicles and enclose storage and process equipment
- Employ a watering program (dust suppression system) to minimize airborne particulate matter emissions from on-site roadways, storage piles, and other sources where hoods cannot be provided
- Diligent housekeeping and providing vehicle wash facilities to prevent the migration of materials within the facility and offsite.



Metals

In addition to the primary base metals, feed materials may contain trace amounts of other metals (e.g., aluminum, arsenic, antimony, bismuth, cadmium, chromium, copper, germanium, gold, indium, lead, mercury, nickel, selenium, silver, thallium, tin and zinc). Emissions of metals in various forms and compounds, which may be mobilized as contaminants in particulate matter, mists, fumes or in liquids, may be generated throughout all of the production stages including pyro-processing (e.g., large volumes of hot gas are generated containing particulate matter and metal fumes during sintering, smelting, roasting, and converting); pyrorefining (e.g., fine particulate matter and metal fume are generated during the furnace processing and transfer of the hot materials); electro-refining (e.g., acid mist emissions from electrolyte solutions); and melting and casting (e.g., metal fume emissions from molten metal and dross handling, and baghouse particles). The degree to which these metals may impact the environment depends on their form, toxicity and concentration. Emissions of metals are controlled through the application of measures to control particulate matter.

Mercury: A special note is made for metal emissions that are generated from smelting and refining processes that have the potential to release mercury. While most exhaust streams that contain metals are effectively controlled using the same abatement controls as particulate matter, mercury remains as a vapor at ambient temperatures and pass through some control equipment. It is important to significantly cool the inlet gas to the particulate matter control system to ensure efficient capture of mercury or to use an activated charcoal media to adsorb mercury.

Sulphur dioxide

Sulphur dioxide (SO_2) is produced from the combustion of fossil fuels and when metal sulphide concentrates are roasted, sintered, smelted, converted or refined. The concentration of SO_2 in off-gas streams is an important characteristic for managing SO_2 emissions. If the concentrations are within the range of 5–7% in raw gas stream, SO_2 can be processed into sulphuric acid. Lower concentrations in gas streams require the use of raw materials containing lower amounts of sulphur, or some form of scrubbing to fix sulphur and minimize SO_2 emissions to the atmosphere and achieve appropriate ambient air concentrations. Oxygen smelting processes reduce the volume of off-gases and increase the concentration of SO_2 , which result in greater conversion efficiency and reduced contaminant emissions with lower volume. Measures to prevent and control sulphur dioxide emissions include the following:

- Process (fix) the sulphur for safe storage and/or use as a product (e.g., sulphuric acid, liquid sulphur dioxide, fertilizer, and elemental sulphur);
- Consider technology choices to reduce gas volumes and increase SO_2 concentration
- Implement process control systems to ensure consistent operation
- Install gas scrubbing processes that remove SO_2 from low concentration streams
- Enclose process equipment and vessels to prevent fugitive emissions
- Use pre-treatment (e.g., flotation) to remove unwanted sulphide and reduce sulphur in feeds
- Use low-sulphur fuels (e.g., natural gas instead of heavy fuel oil or coke) and raw materials (e.g., lower sulphur raw materials)



Nitrogen oxides

NOx emissions are primarily related to the combustion of fuels (e.g., coal in smelting and natural gas in pyro-refining). NOx may be formed from nitrogen components that are present in the fuel or the concentrates, or as thermal NOx. In aluminum production, NOx is also produced during electrolysis due to the presence of nitrogen at anode.

- Minimize NOx generation by using low NOx gas burners and staged combustion air in pyro-refining furnaces and other combustion facilities.
- Treat roasting gases to remove NOx (e.g., using oxidizing scrubber) if high levels of NOx are present to enhance the quality and usability of sulphuric acid produced from off-gasses containing SO_2 ;
- Use of oxy fuel burners can result in reduced NOx formation. When using oxygen enrichment, consider introducing oxygen downstream of the burner if the higher temperatures caused by using pure oxygen at the burner result in additional NOx formation.

Dioxins and furans

Polychlorinated dibenzodioxins (PCDDs) and dibenzofurans (PCDFs) may be generated during the production of metals (e.g., pyro-processing), particularly with respect to production from secondary raw materials or in processes that require chlorination. Impurities in the scrap material may result in PCDD/F formation during incomplete combustion or de-novo synthesis. Measures to prevent and control dioxins and furans include the following:

- Cull metal scrap to eliminate or minimize the presence of organic materials (e.g., plastics and wood) prior to any combustion and / or heating involving metal scrap;
- Implement procedures for the operation and maintenance of combustion equipment to ensure efficient combustion at the designed temperatures and residence times to ensure destruction of dioxins, and avoid reformation as gases cool;

Consider use of activated carbon in a fixed bed or moving bed reactor or by injection into the gas stream, and subsequent removal as filter dust.

Volatile organic compounds

Volatile Organic Compounds (VOCs) are produced by poor combustion and during operations such as degreasing of components, solvent extraction processes, and from the venting of tanks used to store solvents and fuel. VOCs can also be released during smelting and refining of secondary metals if the feed includes organic materials. Recommended measures to prevent, minimize, and control releases of VOCs include:

- Use water-based solvents where possible, or use the least toxic solvent suitable for the application
- Contain emissions (e.g., by use of sealed equipment or hoods)
- Use mixer / settlers that minimize contact with air to minimize evaporation of VOCs
- Control VOC emissions using afterburners, scrubbers, biofilters or bioreactors, activated carbon traps, or chiller / condenser systems, depending on, for example, the composition of the gas stream



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- Removal of tar and PAHs utilizing alumina scrubbers and fabric filters
- Use of dry anode paste and maintenance of anode tops at cold temperatures to reduce PAH emissions

Anode preparation (aluminum only)

The electrolysis of alumina into aluminum results in the consumption of the anode, during which the released oxygen will burn away the carbon. These anodes are normally prepared onsite in an anode baking facility where the carbon containing materials (including petroleum pitch) are attached to a metal core and baked to increase the strength. The baking will release volatile hydrocarbons and also other contaminants such as sulphur from the raw materials. If feasible, the heating value from VOC emissions could be used by combusting these substances within the baking furnace. The off-gas from the baking house should be treated by scrubbing or by absorption followed by filtering in plants integrated with a primary aluminum smelter, where hydrocarbons are returned to the production process; alternatively afterburners and wet ESPs can be used depending on the site and scale of production.

3.4.2.2 Wastewater**Industrial process wastewater**

The main sources of wastewater in the smelting and refining sector include process water from hydro-metallurgical processes (e.g., roasting gas cleaning, leaching, purification, and electrolysis); wet off-gas cleaning; slag granulation; cooling water; and surface runoff/stormwater. Wastewaters typically contain soluble and non-soluble metal compounds, oil and organic material. Direct contact cooling water (e.g., for some casting operations) may contain elevated levels of metals and suspended solids, and should be routed through a process wastewater treatment system.

Process wastewater treatment

Techniques for treating industrial process wastewater in this sector include source segregation and pretreatment of wastewater streams for reduction in heavy metals using chemical precipitation, coagulation and flocculation, etc. Typical wastewater treatment steps include oil water separators or dissolved air floatation for separation of oils and floatable solids; filtration for separation of filterable solids; flow and load equalization; sedimentation for suspended solids reduction using clarifiers; dewatering and disposal of residuals in designated hazardous waste landfills. Additional engineering controls may be required for (i) advanced metals removal using membrane filtration, electrolysis or other physical/chemical treatment technologies, (ii) removal of recalcitrant organics using activated carbon or advanced chemical oxidation, and (iii) reduction in effluent toxicity using appropriate technology (such as reverse osmosis, ion exchange, activated carbon, etc.).

Other wastewater streams & water consumption

Non-contact cooling water systems in smelting and refining sector may be a direct once-through design, or a recirculation route involving the use of evaporative cooling towers. Water from a once through system is typically discharged to surface waters after appropriate consideration/reduction of temperature effects on the receiving water body. Stormwater may become contaminated through contact with material stockpiles and



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surface deposition of airborne contaminants. Contaminated streams should be routed to the treatment system for industrial process wastewater.

3.4.2.3 Hazardous materials

The smelting and refining sector utilizes a number of acids, alkalis, and chemical reagents (in leaching and precipitation of metals, and for pollution control systems); and process gases (e.g., oxygen, carbon dioxide, argon, nitrogen, chlorine, hydrogen, among others). Guidance on the safe storage, transport, and use of hazardous materials is addressed in the Manufacture, Import and Storage of Hazardous Chemicals Rules, Government of India

3.4.2.4 Residues and waste

Sources of hazardous and non-hazardous residues and waste in the smelting and refining sector include slag, drosses, mattes, and skimmings from pyrometallurgical processes; spent linings and refractories from furnaces; waste from abatement systems (e.g., flue gas dust, sludge, and spent filter material); sludge from wastewater treatment (e.g., from wet scrubber systems and process water treatment, which may contain gypsum [CaSO₄] and metal hydroxides and sulphides); and sludge from leaching, purification, and electrolysis activities. Opportunities to recycle the by-products and waste from smelting and refining activities back to the process (e.g., drosses, mattes, and skimmings, pot and furnace linings, cleanouts) should be maximized. Large quantities of slag produced at the smelting stage may be processed (e.g., fuming to recover residual metals) to produce an inert granular material that can be sold for industrial use, such as cement manufacturing and insulation products. Waste from abatement systems, and sludge from leaching and wastewater treatment may be recycled into pyro-processing stages depending on the level of process integration available at the facility. Anode and tank bottom sludge may be recycled for residual metals recovery. Guidance for management and safe disposal of hazardous industrial waste is addressed in the Hazardous Waste (Management and Handling) Rules, Government of India. Generation and management of selected wastes specific to the non-ferrous metals smelting and refining sector are described below.

Spent cathodes (aluminum only)

Spent cathodes, also known as spent potlinings, are the major source of waste in primary aluminum manufacturing. A spent cathode consists of a carbon portion which was formerly the cathode from the electrolysis cell, and the refractory material which consists of various types of insulating material. The spent potlinings contain soluble fluoride and cyanide, and can produce an alkaline leachate if the material is rendered wet. Spent potlinings should be treated and reused (e.g., in pyrometallurgical furnaces, in cryolite production, in the cement industry, or as a fuel source) where possible, or disposed of according to the Hazardous Waste (Management and Handling) Rules, Government of India.

Red mud (aluminum only)

Red mud is generated from the extraction of aluminum from bauxite and is an alkaline substance which requires controlled storage, typically in sealed (lined) ponds, to minimize potential for contamination of surface and ground water. Excess water from the mud is returned to the process.

- Use back venting of displaced gases to the delivery vehicle when filling solvent or fuel tanks, and use of automatic resealing of delivery connections to prevent spillage

Acid mist and arsine

Electro winning and other processes such as pressure leaching and production of sulphuric acid may produce acid mist containing soluble metals. Acid mists can also be generated during of breaking lead-acid batteries. Arsine gas may be produced when certain trace metals and acid are mixed (e.g., during the leaching process). Acid mist is produced by the reactions in the electro winning cells, as well as by any aeration or aggressive mixing and / or chemical reactions in subsidiary processes and / or at open drop points handling liquid flows. Measures to prevent and control acid mist and arsine emissions include the following:

- Monitor process control parameters to reduce and / or eliminate upset conditions
- Install hoods on tanks, maintaining an adequate foam layer on the surface of the electrolyte solution, and treatment of the exhaust gases and mists using control equipment (e.g., scrubbers)
- Use stack and candle filters to control acid mist emissions at sulphuric acid plants
- Collect and treat acid mist (e.g., using wet scrubbers or mist filters) generated in the milling stages of battery breaking

Carbon monoxide

Some pyrometallurgical processes (*i.e.* the carbo-thermic production of ferroalloys in closed submerged electric arc furnaces) produce a carbon monoxide rich off-gas as a byproduct. The amount of CO varies largely depending on the metal and production process. Measures to control and minimize CO emissions include collecting and cleaning the CO rich gas (e.g., using a cascade wet scrubber), and use or sale of the gas as fuel. CO may also be produced by incomplete combustion and from smelting and refining of secondary feedstocks containing organic material. Control of CO from these sources is similar to control of VOCs, described above.

Carbon dioxide

Carbon dioxide (CO₂) is produced in significant quantities during smelting and refining operations. Main sources include smelting of concentrates, direct combustion of fossil fuels for power & heat generation, and indirect emissions resulting from fossil fuels used to generate electrical energy for facility operations (e.g., for electrolysis in aluminum smelting). Further indirect contributions to greenhouse gases in this sector are associated with the use of chemical reagents that release a significant quantity of greenhouse gases during offsite manufacturing. Opportunities to reduce greenhouse gas generation are closely linked to measures to increase energy efficiency and reduce energy consumption, both of which are addressed in the 'Energy Consumption and Efficiency' section below.

Perfluorocarbons (Aluminum only)

Two perfluorocarbons (PFCs) - tetra-fluoromethane (CF₄) and hexa fluoroethane (C₂F₆), are formed during the anode effects (temporary imbalance of raw material feed-in rate and the aluminum production rate) stage of aluminum manufacturing and, once formed, they cannot be removed from the gas stream with existing technology. Anode effects occur when the alumina content of the electrolyte falls below 1 - 2 % which results in the

formation of a gas film on the electrode. The formation of the film on the anode results in stoppage of metal production and increases cell voltage from the 4 – 5 volt range to 8 - 50 volts. The generation of PFCs is dependent upon the frequency and duration of the anode effects.

Measures to control perfluorocarbons (and reduce overall GHG emissions) include the following:

- Increased use of recycled aluminum (use of recycled aluminum requires significantly less energy than is required for primary production)
- better electrical conversion efficiency
- Reduce anode effects that produce PFS
 - Control anode effects by adjustment of cell voltage and alumina additions
 - Use of semi-continuous point feeding of the alumina combined with process control
 - Change the reduction technology to minimize use of fossil carbon.

Energy consumption and efficiency

Smelting and refining facilities require large amounts of energy, notably the fuel energy used for drying, heating, smelting, fuming, melting and transportation, and the electrical energy used in electrolysis and for powering utilities / equipment. The following recommendations are specific to this sector:

- Assess alternative smelting and processing technologies that optimize energy use (e.g., flash smelting requires about half the energy of conventional blast furnace smelting, and use of recycled aluminum typically requires significantly less energy than needed for primary production);
- Employ heat and energy recovery techniques to maximize energy utility (e.g., waste heat boilers, heat exchangers, steam-driven drives), for example from gases generated by pyrometallurgical processes. Heat recovery techniques will vary between facilities but may include use of oxygen rich air to reduce energy consumption; use of waste heat boilers to capture hot gases generated by smelting or roasting; and use of heat generated by smelting and refining processes to melt secondary material.

Fluorides (aluminum only)

The main source of gaseous fluorides is the pots during electrolysis. The majority of the gaseous fluorides produced are in the form of hydrogen fluoride, which results from the reaction of aluminum fluoride and cryolite with hydrogen. Control of fluoride emissions can be achieved through fume capture. Captured fumes (typically greater than 98 % of total fumes) can be cleaned using alumina injection in the off gas for the absorption of the fluoride, followed by use of bag filters (the dust is returned to the pots) or wet scrubbers (typically greater than 99.5 to 99.9 % efficient).

Tar and polycyclic aromatic hydrocarbons (aluminum only)

Tar and PAHs may be released (mainly from the anode baking plants). Measures to prevent and control these emissions include the following:

- Improve combustion efficiency
- Switch to another type of anode



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The main environmental problems in alumina production are the disposal of the bauxite residue, saturated with caustic soda ("red mud"), and emissions of gases and particles from boilers, calcinations furnaces and bauxite dryers.

Red mud from bauxite refining are precipitated from a caustic suspension of sodium aluminate in a slurry and routed to large on-site surface impoundments known as red mud pond. The mud settles to bottom and the water is removed, treated, and either discharged or reused. The muds dry to solid with a very fine particle size, sometimes less than 1 micron. These muds contain significant amounts of iron(20-50%), aluminum(20-30%), silicon(10-20%), calcium(10-30%), and sodium. Red muds may also contain trace amounts of elements such as barium, boron, cadmium, chromium, cobalt, gallium, vanadium, scandium and lead as well as radionuclides. The types and concentrations depend on type of ores and the operating condition in the digesters.

Red muds can not be considered as hazardous wastes. Several processes have been developed to recover iron from red mud residues, and the potential exists to use mud in the iron and steel production. Alumina and titanium recovery is also technically feasible. Recovery of metals other than iron is, however, not cost effective.

Other than recovery of iron, other methods of potential utilization of red mud is in making construction blocks, bricks, Portland cement, in light weight aggregate to make concrete, in plastic and resin as filler, pigments, and application in making ceramic products. Research has also been conducted on the potential use of red muds as a reagent in various proposed waste treatment processes.

3.4.2.5 Noise

Smelting and refining operations are inherently noisy due to the large amount of mechanical equipment, transport vehicles, physical activities, and energy usage, notably furnaces and steam. The significant sources are transport and handling of raw materials and products; the production processes involving pyro-metallurgy, grinding and milling operations; the use of pumps and fans; the venting of steam and the existence of unattended alarm systems.

3.5 Qualitative and Quantitative Analysis

3.5.1 Waste characteristics of iron and steel manufacturing industry (Ferrous metal)

3.5.1.1 Sintering/pelletising

Sintering operations can emit significant dust levels of about 20 kilograms per tonne (kg/T) of steel as average (24-26 kg/T of agglomerate without cooling facilities and with cooling facilities 18-20 kg/T agglomerate from sintering strand and 25-31 kg/T of agglomerate from cooling strand with 80% particle of size less than 100µm in diameter); the concentration of CO in sintering gases should be taken to be 8-15 g/m³ or 30-50 kg/T of agglomerate; of SO₂, 0.8 – 9 g/m³ or 3-25 kg/T of agglomerate depending on the sulphur content of charge; some levels of dioxins and furans which is presently under study by CPCB. Pelletizing operations can emit dust levels of about 13-15 kg/T of pellet or 4-5g/m³; and approximately 6 kg of SO₂, 14 kg of CO and 0.8 kg of NO/T agglomerate.



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3.5.1.2 Iron making

During the manufacture of iron in the blast furnace, some hydrogen cyanide, HCN, and cyanogen gas, C₂N₂, are formed as a result of the reaction of nitrogen in the blast with coke. Blast furnace gas contains 200–2000 mg/m³ of these cyano compounds which are highly toxic. In the dust collecting system, the gases are scrubbed with water and some of this water finds its way in waste disposal. Before discharging this water, cyanide compounds dissolved in it must be destroyed. Blast furnace slag contains CaS which originates mainly from the sulphur in the coke. It emits H₂S during quenching and stock piling. H₂S has the smell of foul eggs and is highly poisonous.

The amount of dust emitted with blast furnace gases is on the average 10 kg/T of cast iron; 24-30 % CO; and 4% of sulphur content of the materials charged is emitted as H₂S.

The amount of non-process dust and gases are as follows:

Table 3-16: Amount of Harmful Substance from Blast Furnace Plant

Location	Amount of harmful substances (g/T of cast iron)			
	Dust	CO	SO ₂	H ₂ S
Stock yard and high lines	50	Nil	Nil	Nil
Underneath overhead beams	Up to 1200	Nil	Nil	Nil
Casting yard	400-700	700-1150	110-170	Nil
Stove building	- Nil	11-44	Nil	Nil
Casting machine	40	60	Nil	Nil
Slag processing	20	8	20	50
Inter cone space (leakages)	4000	200	Nil	0.5-3

3.5.1.3 Steelmaking

Open hearth process

During the manufacture of steel by the open hearth process, fluorspar, CaF₂ was used as a flux. The presence of water in the combustion gases in the furnace results in its decomposition to form HF gas, which finds its way in the stack. Hydrogen fluoride concentration in the stack gas was about 3000 ppm. About 100 000 t of hydrogen fluoride were emitted annually from this source. Fluorosis in cattle or damage to vegetation has occurred in the vicinity of iron and steel plants. This was one of the reasons why this process has been abandoned in the 1970s.

Oxygen steelmaking

During the manufacture of steel by oxygen top blowing (LD Process) thick brown fumes of iron oxide are formed. Because of their extremely fine particle size they were difficult to remove from the stack gases and thus they cause nuisance to the inhabitants of the neighborhood. Bottom oxygen blowing process is now competing with the LD Process because of this, among other reasons.

BOF

The amount of gases that escape from a converter is directly related to the content of carbon in the pig iron and the amount of ore and lime added. The amount of converter gases evolved per tonne of iron varies from 70 to 90 m³. The content of CO in the gases varies from 85 to 95 %. The temperature of the gases at the mouth of the converter is 1550 to 1650 °C. The amount of dust varies from 13 to 25 kg/T steel for heats cooled with ore and from 12 to 32 kg/T steel for heats cooled with scrap and ore. The average concentration of dust is from 150 to 350 g/m³ but it may increase to 1500 g/m³ for short time when the fluxes are added. Sulphur passes in the converter gas as SO₂. Up to 14% of the sulphur contained in the charge is carried away by the converter gases but only 1% or less of this sulphur passes into gaseous phase, the remainder into the dust. Practically, no oxide of nitrogen is formed in the converter.

Raw materials/resources required and wastes generated for the production of tonne of crude steel from a well managed steel plant is given in Figure 3-14.

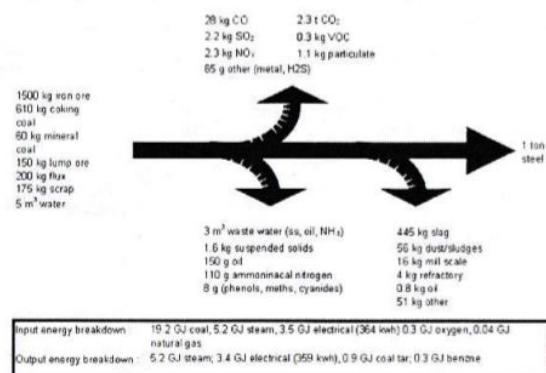


Figure 3-14: Resources and Waste Generation for Production of 1 tonne Crude Steel

3.5.1.4 Ferroalloys

The amount of process gases evolved in ferroalloy furnaces depends on the kind of ferroalloy being produced, the composition of the charge, and the rate at which the process is carried out. In smelting processes, 140 to 900 m³ of gas is evolved per tonne of ferroalloys; in refining processes, 50,000 to 70,000 m³ of gas/ t of alloys; in the aluminothermic process, 1100 m³/T of alloys when producing metallic chromium; 42,000 m³ when producing carbon free ferrochromium (in the melting period) and 600 m³/T (in reducing period). The actual amount should be determined from material balance.

The process gases in smelting furnace mostly consist of CO from 70 to 90%. Other harmful substances are SO₂, H₂S, PH₃, AsH₃, HCN, CN₂ etc. but no reliable data is presently available.

3.5.1.5 Hot & cold rolling mills**Heating furnace**

The main source of emission is the reheating furnace, annealing furnaces and soaking pits and the main pollutant is SO₂ and NO_x. They are used to reheat the different metals to prepare it for the hot rolling processes or annealing of cold rolled products for surface treatment. These furnaces are utilized to heat the metal to a proper temperature (1100-1250°C, before hot formation. Inputs to heating furnaces are slabs, blooms, bars, billets and rounds.

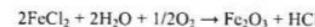
In both hot and cold rolling, one can expect nitrogen oxides (NO_x) emissions resulting from combustion in reheat furnaces, in annealing furnaces, or from boilers. The primary means of controlling NO_x emissions is through combustion modification or selective catalytic reduction. Nitrogen oxides formed from combustion of air constituents are referred to as thermal NO_x. In both hot and cold forming, one can expect nitrogen oxides (NO_x) emissions resulting from combustion in reheat furnaces, in annealing furnaces, or from boilers. The general technique to control thermal NO_x is to suppress combustion temperature to below 140°C. Above this temperature, NO_x formation is exponential, while below this temperature, it is linear at a very limited rate. NO_x concentration is approximately 100 to 150 mg/m³ of flue gas evolved. SO₂ depends on the concentration of sulphur in the fuel being used and can be calculated from the following table:

Table 3-17: Generation of Combustion Products from fuels

Kind of fuel	Maximum Content of Sulphur in Fuel, % v/v	Heat Value Assumed (kJ/m ³)	Amount of SO ₂ (g/m ³)
Natural gas	Nil	35,800	Nil
Blast furnace gas	Nil	3720	Nil
Coke Oven Gas (COG)	0.4	20,700	11.4
Mixture of BFG and COG	0.04 to 0.34	5000 to 14,700	1.2 to 9.7
Fuel oil, Low sulphur/ High sulphur	0.5-2.9/ 5% v/v	39,000	10-58 g/kg

Pickling

Before surface treatment, steel must be pickled, i. e., treated in an acid solution to remove the thin oxide film. Sulphuric acid was universally used for this purpose because it was the cheapest acid. The waste acid, now containing ferrous sulphate, was thrown away. With increased regulations, the waste acid was neutralized by lime at the same time precipitating the iron before disposal. It became a costly operation. The problem was solved in the 1960s by switching over to hydrochloric acid instead of sulphuric, although it was more expensive. The reason was that ferrous chloride could be economically converted to Fe₂O₃ which is suitable as pigment, and HCl for recycle by oxyhydrolysis:





Rolling, extrusion, drawing and forging

During the state-of-the-art of forming, the metal is introduced onto the line and passes through the major processing steps. Uncontrolled emission estimates, calculated controlled emissions, the types of air pollution control utilized, and the techniques expected control efficiencies are summarized in Table (3-18). Continuous Cold Mill with current best available control technology (BACT) Controls.

Table 3-18: Continuous Cold Mill with BACT Controls

Purpose	Emission Type	Expected Uncontrolled Emissions, mg/nm ³	Control Technology	Calculated Controlled Emissions mg/m ³	% Control
Flattens steel	Particulate matter	1000	Fabric filter	10	99
Connects coil	Particulate matter	300	Fabric filter	3.6	99
Remove oxidation	Particulate matter	1000	Fabric filter	10	99
Cleans surfaces	HCl vapor	3250	Counter current packed tower scrapper with missed eliminator	6.5	99
Reduces thickness of strip	Roll coolant spray (water & oil)	100	Baffle plate collision mist eliminator	20	80
Removes oil from strip	Alkali mist	100	Horizontal air washer	5	95
Removes light Oxide	HCl vapor	140	Gas washing tower	1.7	99
Temps/ restores/flattens	Negligible	-	Non	-	-
Applies protective oil coat	Oil aerosols	13	mist eliminator	1.3	90

Source: Egyptian Pollution Abatement Project (EPAP)

Continuous Casting

Ladle emissions are negligible. The molten steel is sometimes driven a cover of inert material such as rice hulls to provide thermal insulation. In addition, many modern casting facilities employ refractory-lined lids. The molten steel stream from the ladle bottom generates almost no emissions, particularly when a ceramic submersion tube surrounds it. Some emissions are seen to emerge from the molds. The emissions are caused by mold powders and mold lubricating oils. These emissions are mostly a white-blue haze generated by evaporated oil condense or mold powder combustion products.



The emissions are greater if the molten steel stream is nitrogen shrouded because nitrogen prevents the burn-off of combustibles. The caster cut-off torches may also generate minor emissions because a traveling torch with an oxidizing flame cuts the red-hot steel section that emerges from the casting machine. Other emissions are generated during the maintenance of tun dishes and casting ladles. These are mostly dust and iron oxide fumes from dumping and oxygen lancing sculls.

The amount of harmful substances emitted to atmosphere is as follows:

Table 3-19: Emission from Continuous Casting Shop

Zone	Composition (g/T steel)			
	CO	CH ₄	NO	Dust
Pouring area	0.6	360	-	-
Gas cutting zone	120	-	90	240

The table below indicates the international benchmark emissions from steel plants.

Table 3-20: Air Emission Levels for Integrated Steel Plants^c

Pollutant	Units	Guideline Value
Particulate Matter	mg/Nm ³	20-50 ^a
Oil Mist	mg/Nm ³	15
NOX	mg/Nm ³	500 750 (coke oven)
SO ₂	mg/Nm ³	500
VOC	mg/Nm ³	20
PCDD/F	ng TEQ/ Nm ³	0.1
Carbon Monoxide (CO)	mg/Nm ³	100 (EAF) 300 (coke oven)
Chromium	mg/Nm ³	4
Cadmium (Cd)	mg/Nm ³	0.2
Lead (Pb)	mg/Nm ³	2
Nickel (Ni)	mg/Nm ³	2
Hydrogen Chloride (HCl)	mg/Nm ³	10
Fluoride	mg/Nm ³	5
Hydrogen Fluoride (HF)	mg/Nm ³	10
H ₂ S	mg/Nm ³	5
Ammonia	mg/Nm ³	30

Pollutant	Units	Guideline Value
Benzo(a)pyrene	mg/Nm ³	0.1
Tar fume ^b	mg/Nm ³	5

Notes:

a Lower value where toxic metals are present

b Tar fume measured as organic matter extractable by solvent from total matter collected by membrane filter

c Reference conditions for limits. For combustion gases: dry, temperature 273K (0°C), pressure 101.3 kPa (1 atmosphere), oxygen content 3% dry for liquid and gaseous fuels, 6% dry for solid fuels. For non-combustion gases: no correction for water vapor or oxygen content, temperature 273K (0°C), pressure 101.3 kPa (1 atmosphere)

3.5.1.6 Liquid and solid wastes from steel production

In the conventional process without recirculation, wastewaters, including those from cooling operations, are generated at an average rate of 80 cubic meters per tonne (m³/T) of steel manufactured. Major pollutants present 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 g/l), cadmium (0.4 mg/l), zinc (14 mg/l), fluoride (20 mg/l), and oil and grease. Mill scale may amount to 33 kg/T. The process generates effluents with high temperatures. Process solid waste from the conventional process, including furnace slag and collected dust, is generated at an average rate ranging from 300 kg/T of steel manufactured to 500 kg/T, of which 30 kg may be considered hazardous depending on the concentration of heavy metals present. Approximately, 65% of BOF slag from steel manufacturing can be recycled in various industries such as building materials and, in some cases, mineral wool. An example of slag utilization in Japan is as follows. As can be seen, about 95% of slag is re-cycled in other industries and about 5% is reused in the plant. India needs to follow such a model.

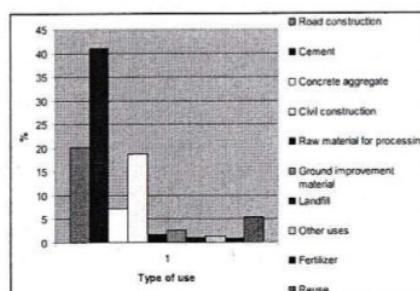


Figure 3-15: Typical Use of Iron & Steel Slag in Japan

3.5.2 Waste characteristics of Non-ferrous industry

3.5.2.1 Smelting and refining

Nickel production

Pyrometallurgical processes for processing sulphides ores are generally dry, and effluents are of minor importance, although wet electrostatic precipitators (ESPs) are often used for gas treatment, and the resulting wastewater could have high metal concentrations. Process bleed streams may contain antimony, arsenic, or mercury. Large quantities of water are used for slag granulation, but most of this water should be recycled. The smelter contributes a slag that is a dense silicate. Sludges that require disposal will result when neutralized process effluents produce a precipitate.

Sulphur dioxide (SO₂) is a major air pollutant emitted in the roasting, smelting, and converting of sulphide ores. (Nickel sulphide concentrates contain 6-20% nickel and up to 30% sulphur.) SO₂ releases can be as high as 4 tonnes of sulphur dioxide per tonne of nickel produced, before controls. Reverberate furnaces and electric furnaces produce SO₂ concentrations of 0.5-2.0%, while flash furnaces produce SO₂ concentrations of over 10%-a distinct advantage for the conversion of the sulphur dioxide to sulphuric acid. Particulate emission loads for various process steps include 2.0-5.0 kg/T for the multiple hearth roaster; 0.5-2.0 kg/T for the fluid bed roaster; 0.2-1.0 kg/T for the electric furnace; 1.0-2.0 kg/T for the Pierce-Smith converter; and 0.4 kg/T for the dryer upstream of the flash furnace. Ammonia and hydrogen sulphide are pollutants associated with the ammonia leach process; hydrogen sulphide emissions are associated with acid leaching processes. Highly toxic nickel carbonyl is a contaminant of concern in the carbonyl refining process. Various processes of gases contain fine dust particles and volatilized impurities. Fugitive emissions occur at furnace openings, launders, casting molds, and ladles that carry molten product. The transport and handling of ores and concentrates produce windborn dust.

Lead and zinc production

The principal air pollutants emitted from the processes are particulate matter and SO₂. Fugitive emissions occur at furnace openings and from launders, casting molds, and ladles carrying molten materials, which release sulphur dioxide and volatile substances into the working environment. Additional fugitive particulate emissions occur from materials handling and transport of ores and concentrates. Some vapors are produced in hydrometallurgy and in various refining processes. The principal constituents of the particulate matter are lead/zinc and iron oxides, but oxides of metals such as arsenic, antimony, cadmium, copper, and mercury are also present, along with metallic sulphates. Dust from raw materials handling contains metals, mainly in sulphidic form, although chlorides, fluorides, and metals in other chemical forms may be present. Off-gases contain fine dust particles and volatile impurities such as arsenic, fluorine, and mercury. Air emissions for processes with few controls may be of the order of 30 kg/T of lead or zinc produced. The presence of metals in vapor form is dependent on temperature. Leaching processes will generate acid vapors, while refining processes result in products of incomplete combustion (PICs).

Emissions of arsine, chlorine, and hydrogen chloride vapors and acid mists are associated with electro refining. Wastewaters are generated by wet air scrubbers and cooling water. Scrubber effluents may contain lead/zinc, arsenic, and other metals. In the electrolytic



refining process, by-products such as gold and silver are collected as slimes and are subsequently recovered. Sources of wastewater include spent electrolytic baths, slimes recovery, spent acid from hydro metallurgy processes, cooling water, air scrubbers, wash downs, and storm water. Pollutants include and suspended solids, metals, and oil and grease. The larger proportion of the solid waste is discarded slag from the smelter. Discard slag may contain 0.5-0.7% lead/zinc and is frequently used as fill or for sandblasting. Slag with higher lead/zinc content say, 15% zinc can be sent for metals recovery. Leaching processes produce residues, while effluent treatment results in sludge that require appropriate disposal. The smelting process typically produces less than 3 tonnes of solid waste per tonne of lead/zinc produced.

The disposal of Lead/Zinc bearing wastes requires scientific procedures to avoid contamination, following the Hazardous Waste Management Rules.

Copper production

The principal air pollutants emitted from the processes are sulphur dioxide and particulate matter. The amount of sulphur dioxide released depends on the characteristics of the ore-complex ores may contain lead, zinc, nickel, and other metals and on whether facilities are in place for capturing and converting the sulphur dioxide. SO₂ emissions may range from less than 4 kilo grams per tonne (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. Some vapors, such as arsine, are produced in hydrometallurgy and various refining processes. Dioxins can be formed from plastic and other organic material when scrap is melted. The principal constituents of the particulate matter are copper and iron oxides. Other copper and iron compounds, as well as sulphides, sulphates, oxides, chlorides, and fluorides of arsenic, antimony, cadmium, lead, mercury, and zinc, may also be present. Mercury can also be present in metallic form. At higher temperatures, mercury and arsenic could be present in vapor form.

Leaching processes will generate acid vapors, while fire refining processes result in copper and SO₂ emissions. Emissions of arsine, hydrogen vapors, and acid mists are associated with electro refining. 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 hydro metallurgy processes, cooling water, air scrubbers, wash downs, storm water, and sludge from wastewater treatment processes that require reuse/recovery or appropriate disposal. The main portion of the solid waste is discarded slag from the smelter. Discard slag may contain 0.5-0.7% copper and is frequently used as construction material or for sandblasting. Leaching processes produce residues, while effluent treatment results in sludge, which can be sent for metals recovery. The smelting process typically produces less than 3 tonnes of solid waste per tonne of copper produced.



Aluminum manufacturing

At the bauxite production facilities, dust is emitted to the atmosphere from dryers and materials-handling equipment, through vehicular movement, and from blasting. Although the dust is not hazardous, it can be a nuisance if containment systems are not in place, especially on the dryers and handling equipment. Other air emissions could include nitrogen oxides (NOx), sulphur dioxide (SO₂), and other products of combustion from the bauxite dryers. Ore washing and beneficiation may yield process wastewaters containing suspended solids. Runoff from precipitation may also contain suspended solids. At the alumina plant, air emissions can include bauxite dust from handling and processing; limestone dust from limestone handling, burnt lime dust from conveyors and bins, alumina dust from materials handling, red mud dust and sodium salts from red mud stacks (impoundments), caustic aerosols from cooling towers, and products of combustion such as sulphur dioxide and nitrogen oxides from boilers, calciners, mobile equipment, and kilns. The calciners may also emit alumina dust and the kilns, burnt lime dust.

Although alumina plants do not normally discharge effluents, heavy rainfalls can result in surface runoff that exceeds what the plant can use in the process. The excess may require treatment. The main solid waste from the alumina plant is red mud (as much as 2 tonnes of mud per tonne of alumina produced), which contains oxides of alumina, silicon, iron, titanium, sodium, calcium, and other elements. The pH is 10-12. Disposal is to an impoundment. Hazardous wastes from the alumina plant include spent sulphuric acid from descaling in tanks and pipes. Salt cake may be produced from liquor purification if this is practiced. In the aluminum smelter, air emissions include alumina dust from handling facilities; coke dust from coke handling; gaseous and particulate

Comparison of technologies for Aluminium making

The Hall-Heroult process for aluminum production:

Hall and several associates started the Pittsburgh Reduction Company in 1888 in Pittsburgh. They had two electrolytic cells in series, operating at about 1750 amperes and 16 volts across the two cells, producing 50 lb/day (~23 kg/day). The cell line was powered by two steam-powered dynamos in parallel, rated at 1000 amperes and 25 volts each. The plant was enlarged to 475 lb/day (~215 kg/day) in 1890 and in 1891 a new plant was built at New Kensington, near Pittsburgh (Figure 3-16).

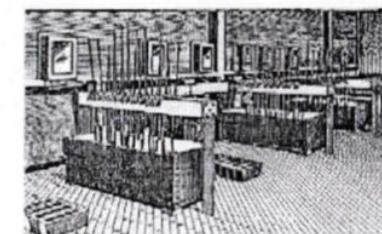


Figure 3-16: The Pittsburgh Reduction Company's First Cell Room

The new plant produced 1000 pounds per day (lb/day) (~453 kg/day) in 1893 and 2000 lb/day (~906 kg/day) in 1894. In 1907, the company changed its name to Aluminum Company of America, now known as Alcoa. Plants were built at Niagara Falls and other

places where inexpensive water power was available. In 1901, a plant was built in Canada, which later became part of Aluminum Company of Canada, Alcan. Meanwhile, the Heroult process was commercialized in France and Switzerland. Other plants were built in England, Germany, Italy, and Norway early in the 20th century where water power was available.

Hall's first electrolytic cells, or "pots," were of cast iron, 24 inches (~61 cm) long, 16 inches (~41 cm) wide and 20 inches (~51 cm) deep, with a 3-inch (~8-cm) baked carbon lining. Six to ten carbon anodes, 3 inches (~8 cm) in diameter and 15 inches (~38 cm) long when new, were suspended in the electrolyte (bath) from a copper busbar above. The pots held 300 to 400 lbs (~136 to ~181 kg) of cryolite bath in which alumina was dissolved. The pots were arranged so that they could be heated from below by a gas flame, but it was found that they were self sustaining by the electrical heat generated. It is interesting that present-day cells are qualitatively of the same design, although considerably larger and under more precise quality control. The overall cell reaction is:



Aluminum reduction cells today are of two types: those with prebaked anodes and those with baked-in-place anodes (Soderberg). Both types of anodes are made of baked petroleum coke and coal-tar or petroleum pitch. Prebaked anodes are baked in brick-lined pits and the hydrocarbon off gases can be captured and burned. Soderberg anodes are baked by the heat generated in the cells, and the off gas are more difficult to collect. Modern cell rooms with prebaked and with Soderberg anodes are shown in Figures 3-17 and Figure 3-18.

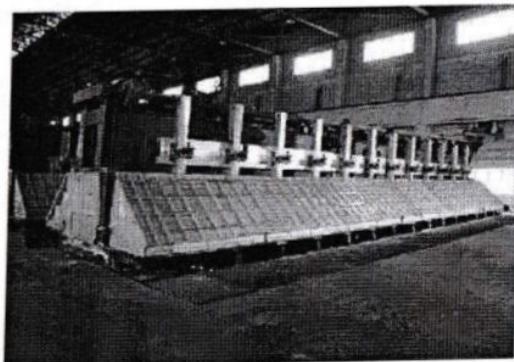


Figure 3-17: Electrolytic Cell for 300 kA Prebaked Carbon Anode Technology in the Cell Room

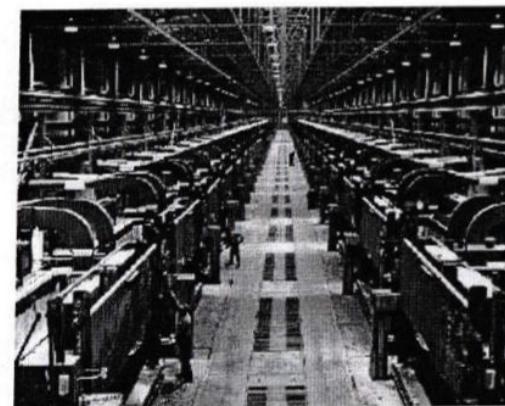


Figure 3-18: Soderberg Electrolytic Cell Line - Kaiser Chalmette Plant

The components of a prebaked anode cell are described as follows. A carbon lining contains the bath and a pool of molten aluminum on the bottom. Carbon anodes suspended from an anode bus conduct current into the cell. Anode rods carry the current from the anode bus through steel stubs cast with iron into holes in the tops of the anodes. Current is conducted out of the cell through steel collector bars to the cathode bus and on to the next cell. The aluminum metal pad is the cathode where aluminum is deposited from the bath. Oxygen from the alumina dissolved in the bath combines with the bottom surface of the carbon anode to form carbon dioxide. The anodes are consumed in the process and replacements are added at individual locations on a regular schedule. The anode butts are sent back to the anode plant to be ground and mixed into new anode paste to be pressed and baked. Aluminum is siphoned out of the cells on a daily basis into vacuum crucibles and sent to the cast house. The carbon lining is contained in a steel shell with a thermal insulation of alumina or insulating brick.

In operation, cryolite freezes on the sidewalls of the cells forming a "ledge" which protects the sidewall from severe attack by aluminum and molten cryolite. Cryolite also freezes over the top of the bath and forms a "crust" to support a top layer of alumina thermal insulation. Alumina is fed to the bath through holes punched in the crust. The carbon dioxide exits through holes in the crust and is collected under hoods. The carbon dioxide and air leaking in is now ducted to dry scrubbers which remove fluorides from the gas stream. Fresh alumina contacting the gases removes the hydrogen fluoride and evaporated fluoride particulate. This alumina, fed to the cells, returns fluoride to the cells. The hydrogen fluoride comes from residual hydrocarbons in the anodes and traces water in the alumina and air humidity reacting with the fluoride bath.

Control of alumina concentration in the cells is accomplished by a slight underfeeding. When the alumina reaches a critical level the cell goes on anode effect, caused by a limiting rate of diffusion of alumina to the anode surfaces. The cell voltage then rises and some fluorocarbons are generated. A light bulb connected across the cell lights up with increased cell voltage as a signal for the operators to feed the cell with alumina and kill the anode effect. Cells now run a day or longer between anode effects. The ratio of



sodium fluoride to aluminum fluoride in the cryolite bath changes over time and corrective additions are added based on laboratory analyses.

Since inception of the process, cells in new plants have increased with time. This increase is driven by a need to reduce labor costs and to increase energy efficiency. On the average, cell size has doubled about every 18 years in the 20th century. As a result of increasing cell size and better process control, energy consumption has improved with time as shown in Figure 6. Energy efficiency is approaching about 50% based on the heat of reaction for the cell reaction. Significant further improvements in energy efficiency may be hard to achieve with the existing cell design. As cells have become larger, electromagnetic effects caused by interaction of the current through the cell with the magnetic field of the bus work have resulted in swirling of the metal pad and vertical distortions in the metal-bath interface. This effect has limited the minimum anode-cathode distance (ACD) to about 4.5 cm because of spurious short circuits by metal contacting the anodes. Since a major voltage drop in the cell is caused by bath resistance, this effect limits energy efficiency.

The industry has largely solved the fluoride emission problem with dry scrubbing but economical disposal of used carbon cell linings remains a problem. The linings contain highly alkaline bath, aluminum carbide, cyanides, and other materials. A small part is ground and added to cement kilns as a source of fluoride, but most of it still end-up in landfills. Two improvements to the Hall-Heroult process have been under development for many decades but have not reached commercial application yet: wetted cathodes, and non-consumable anodes. Titanium diboride is a material with good electrical conductivity, is wetted by aluminum and is highly-resistant to corrosion by aluminum and bath if kept cathodic. By coating a slightly-sloping carbon cell bottom with titanium diboride and providing a sump to collect aluminum, the electromagnetic problem is eliminated and a smaller ACD (anode-cathode distance) can be used, with lower bath voltage loss. Many materials have been tested as non-consumable anodes, such as hematite (an oxide of iron), tin oxide and a cermet of nickel ferrite and copper. The cell reaction would then be:



Energetically this reaction requires a one-volt increase in the cell, but this is partially offset by a lower anode over voltage. The saving would be in eliminating the manufacture and changing carbon anodes. The production of greenhouse gases, carbon dioxide and fluorocarbons in the cells, would be eliminated. By combining titanium diboride cathodes and non-consumable anodes as vertical electrodes the anode-cathode spacing could be further decreased and cell voltage could be less than for the conventional Hall-Heroult cells.

Alternative processes

In the past half century there have been a number of attempts at alternatives to the Hall-Heroult process. Several alternatives have been developed almost to industrial scale, and then abandoned because of technical problems and lack of overall economic advantage over the Hall-Heroult process. In the 1960's Alcan developed a carbothermic subhalide (aluminum monochloride) process. Bauxite or low-grade ores were reduced with carbon and the resulting impure aluminum was purified with an aluminum sub-chloride process. It turned out that the energy costs were higher than for the Hall-Heroult process and severe corrosion problems were encountered. The Toth Company in the same period did a carbothermal chlorination of clay and reduced the aluminum chloride produced with



manganese. The manganese chloride formed was converted to manganese oxide and chlorine with air. The chlorine was recycled and the manganese oxide carbothermally reduced to manganese and recycled. A manganese-aluminum alloy formed that was uneconomical to separate. Alcoa had a large-scale development program in the 1970s for an aluminum chloride (aluminum trichloride) process. Alumina was carbothermally chlorinated to aluminum chloride, which was electrolytically decomposed to aluminum and chlorine in bipolar cells with graphite electrodes. It was said that the cells worked well but there were technical problems with the plant to produce aluminum chloride. Thus the Hall-Heroult process remains to be displaced.

Table 3-21 indicates international benchmark values for air emissions from non-ferrous industry. Emission values of dust given are for specific metals. For total dust emission, Environment (Protection) Act may be referred.

Table 3-21: Air Emissions for Nickel, Copper, Lead, Zinc, and Aluminum Smelting & Refining*

Pollutant	Emission Source (By Metal Type / Smelting Process)	Units	Guideline Value
SO ₂	<ul style="list-style-type: none"> ▪ Copper: Primary smelting and converting ▪ Lead and Zinc: Primary smelting, roasting and sintering ▪ Nickel: Roasting and smelting of sulphide concentrates and intermediates 	>99.1% conversion efficiency (for ~ 1 – 4 % SO ₂ off gas)	>99.7 % conversion efficiency (for >5 % SO ₂ off gas)
NOx	<ul style="list-style-type: none"> ▪ Copper: Secondary smelting and converting, primary and secondary fire refining, electric slag cleaning and melting ▪ Aluminum: Holding and de-gassing of molten metal from primary and secondary aluminum ▪ Lead and Zinc: Materials pre-treatment, secondary smelting, thermal refining, melting, slag fuming, and Waelz kiln operation 	mg/Nm ³	<50 – 200 _{1,2,3}
	<ul style="list-style-type: none"> ▪ Copper: Secondary smelting and converting, primary and secondary fire refining, electric slag cleaning and melting ▪ Aluminum: Holding and de-gassing of molten metal from primary and secondary aluminum, materials pre-treatment, and from melting and smelting of secondary aluminum ▪ Lead and Zinc: Melting of clean material, alloying, and zinc dust production; From materials pre-treatment, secondary smelting, thermal refining, melting, slag fuming, and Waelz kiln operation ▪ Nickel: Leaching, chemical extraction and refining, electro-winning and solvent 	mg/Nm ³	100 – 300 _{4,5,6}

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Pollutant	Emission Source (By Metal Type / Smelting Process)	Units	Guideline Value
	extraction; From materials pre-treatment incineration or after-burning, roasting, smelting thermal refining, and melting.		
Acid Mists / Gases	<ul style="list-style-type: none"> ▪ Copper: Hydrometallurgical and electro-winning processes ▪ Lead and Zinc: Chemical refining, electro-winning, and solvent extraction ▪ Nickel: Leaching, chemical extraction and refining, electro-winning and solvent extraction 	mg/Nm ³	50 _{1,7}
VOC / solvents (as C)	<ul style="list-style-type: none"> ▪ Copper: Hydrometallurgical and electro-winning processes ▪ Lead and Zinc: Chemical refining, electro-winning, and solvent extraction ▪ Nickel: Leaching, chemical extraction and refining, electro-winning and solvent extraction 	mg/Nm ³	5 – 15 ₉
Dust22	<ul style="list-style-type: none"> ▪ Copper: Secondary smelting and converting, primary and secondary fire refining, electric slag cleaning and melting, secondary fume collection systems, and drying. ▪ Aluminum: Primary aluminum electrolysis, from holding and de-gassing of molten metal from primary and secondary aluminum, materials pre-treatment, and from melting and smelting of secondary aluminum ▪ Lead and Zinc: Melting of clean material, alloying, and zinc dust production; From materials pre-treatment, secondary smelting, thermal refining, melting, slag fuming, and Waelz kiln operation ▪ Nickel: Materials pre-treatment incineration or after-burning, roasting, smelting thermal refining, and melting. 	mg/Nm ³	1 – 5 _{3,6}
TOC (as C)	<ul style="list-style-type: none"> ▪ Copper: Secondary smelting and converting, primary and secondary fire refining, electric slag cleaning and melting ▪ Aluminum: Materials pre-treatment, and from melting and smelting of secondary aluminum ▪ Lead and Zinc: Melting of clean material, alloying, and zinc dust production; From materials pre-treatment, secondary smelting, thermal refining, melting, slag fuming, and Waelz kiln operation ▪ Nickel: Materials pre-treatment incineration or after-burning, roasting, smelting thermal refining, and melting. 	mg/Nm ³	5 – 50 _{12,13}

Metallurgical Industry

Pollutant	Emission Source (By Metal Type / Smelting Process)	Units	Guideline Value
Dioxins	<ul style="list-style-type: none"> ▪ Copper: Secondary smelting and converting, primary and secondary fire refining, electric slag cleaning and melting, secondary fume collection systems, and drying. ▪ Aluminum: Materials pre-treatment, and from melting and smelting of secondary aluminum ▪ Lead and Zinc: Melting of clean material, alloying, and zinc dust production; From materials pre-treatment, secondary smelting, thermal refining, melting, slag fuming, and Waelz kiln operation ▪ Nickel: Materials pre-treatment incineration or after-burning, roasting, smelting thermal refining, and melting. 	ngTEQ/m ³	0.1 – 0.5 _{3,10,1}
Ammonia	Nickel: Leaching, chemical extraction and refining, electro-winning and solvent extraction	mg/Nm ³	5 ₁₇
Chlorine		mg/Nm ³	0.5 _{2,18}
CO and carbonyls		mg/Nm ³	5 ₁₉
Arsine	Lead and Zinc: Chemical refining, electro-winning, and solvent extraction	mg/Nm ³	0.5 ₆
Mercury	All types of metals / smelting processes	mg/Nm ³	0.02
Hydrogen Chloride	<ul style="list-style-type: none"> ▪ Aluminum: Holding and de-gassing of molten metal from primary & secondary aluminum, materials pre-treatment, melting and smelting of secondary aluminum 	mg/Nm ³	5 ₁
Hydrogen Fluoride	Aluminum: Primary aluminum electrolysis, materials pre-treatment, and from melting and smelting of secondary aluminum	mg/Nm ³	0.5 _{10,20}
Total Fluoride		mg/Nm ³	0.8 _{10,22}
Polyfluorinated hydrocarbons	Aluminum: Primary aluminum electrolysis	0.1 (anode effects / cell / day)	
1. Alkali scrubber (semi-dry and fabric filter, wet scrubber or double alkali using lime, magnesium hydroxide, sodium hydroxide). 2. Combinations of sodium or alumina/aluminum sulphate in combination with lime. 3. For copper smelting, an SO ₂ emission concentration of 500 mg/m ³ can be achieved through use of a fabric filter with lime injection. 4. Low NO _x burner 5. Oxy-fuel burner 6. Oxidizing scrubber 7. De-mister 8. Excluding Aluminum smelting 9. Containment, condenser, carbon and bio-filter			



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Pollutant	Emission Source (By Metal Type / Smelting Process)	Units	Guideline Value
10. Fabric filter			
11. Temperature control			
12. Afterburner			
13. Optimized combustion			
14. Afterburner followed by quenching			
15. Adsorption by activated carbon			
16. Oxidation catalyst			
17. Acidic scrubber			
18. Collection and re -use			
19. Process control and sealed reactor			
20. Alumina scrubber			
21. Excluding Aluminum smelting			
22. Emissions of metals are dependent on the composition of the dust produced by the processes. The composition varies and is influenced by the process source of dust and by the raw materials that are being processed.			
Source: Based in part on EU BREF in the Non-Ferrous Metals Industries (2001) *Associated emissions to air are given as daily averages based on continuous monitoring and standard conditions of 273 K, 101.3 kPa, measured oxygen content and dry gas without dilution of the gases with air. In cases where continuous monitoring is not practicable the value should be the average over the sampling period. If thermal cleaning and pyrolysis systems (e.g., swarf drying and decoating) are used to destroy combustion products (e.g., VOCs and dioxins) oxygen content 6 % dry.			

3.5.3 Emissions, effluents and solid wastes from secondary metallurgical industries

3.5.3.1 Sponge iron plants

Air emissions

The coal based sponge iron plants are considered to be highly polluting. Most of the small size plants in India do not use any pollution control equipment. The old rotary kiln DRI plants have used Gas Cleaning Plant (GCP) based on Venturi Scrubbers (wet cleaning) for the treatment of DRI gases. This system generates dust bearing sludge that needs separate handling and disposal. However, this system can take care of particulate matter as well as gaseous pollutants. Some plants have Gas Conditioning Tower (GCT) to cool the gases before taking to dry pollution control equipment. In some of the bigger size plants, the heat content of hot gases is utilized to generate steam through Waste Heat Recovery Boilers (WHRB). The steam is used to operate small size turbines to produce electricity. The exhaust gases coming out of WHRB, having temperature around 150-175°C is taken to Electrostatic Precipitators (ESP).

Rotary kiln DRI plants have emergency stack/safety cap above the ABC of feed end column. The safety cap is required to maintain the positive pressure inside the kiln and



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avoid chances of CO related explosion. This is not to be used to by-pass pollution control equipment but is occasionally done by entrepreneurs who do not care for environment. SPM concentration before cleaning is about 25 g/m³. The SPM concentration after cleaning is found to be in the range of very low (47 mg/m³) to high (727 mg/m³); SO₂ from 51 to 92 mg/m³ and NOx from 45 to 11 mg/m³.

Fugitive dust generation

The sources of fugitive dust generation in rotary kiln based DRI plants are the Raw Material Handling Yard (unloading, stacking, reclaiming operations) and Product discharge system (cooler discharge conveyors, transfer points, junction house, screens, magnetic separators, storage silos, truck loading and packing operations). The dust at RMH yard is controlled by using water sprinklers in bigger sized plants. Covered Product House further reduces the wind blown dust. Skirt boards and covered conveyor belts also generates less fugitive dust. Typical work zone concentration values varied between 9000 to 47000 µg/m³ – indicating very high values; SO₂ between 17 to 47 µg/m³; and NOx between 22 to 68 µg/m³.

Water pollution

In the coal based sponge iron plants, water is used mainly in three areas namely cooler, ABC and wet scrubber (in case dry type equipment are not in operation). The water requirement in rotary kiln DRI plant is mainly for cooling the discharge feed from 950-1050°C to below 100°C. Water is continuously sprinkled over the rotary cooler shell and is allowed to fall on a settling tank located below the rotary cooler/ near the cooler. Make-up water is added in the tank to cool the hot water and compensate evaporation loss. The water from settling tank is re-circulated for sprinkling over the rotary cooler. The water requirement varies from 5-6 kl/h/100 TPD DRI. In ABC water is sprayed through the nozzles in the form of fine spray. This controls the temperature of the gasses. The quantity of water required is 2 kl/h/100 TPD DRI. Normally, no wastewater is discharged from the plants.

Some of the big plants are using water for fugitive dust suppression in RMH yard, haul roads and other places. The water requirement varies from 1-1.5 kl/h/100 TPD DRI. Some of the plants are having wet scrubber as pollution control system for kiln off gas (instead of ESP). Here after ABC the gas is passed through scrubber/venturi scrubber wherein the gas is scrubbed with plain water. The water with finer particles is collected and taken to thickener. The water from thickener is recirculated to scrubber unit. Underflow of thickener is cleaned periodically for small plants and for big plants it is taken to sludge settling ponds. Plants coming up now are mostly with ESP system. The water requirement varies from 3-3.5 kl/h/100 TPD DRI. The domestic water consumption is for cooling, washing and sanitary purpose. About 50-100 kl/person/day water is used for domestic purpose. About 5-10% water is generated as sanitary wastewater. The sanitary wastewater is disposed into soak pits / septic tanks.

Solid waste generation and disposal

Char, flue dust, GCP sludge and kiln accretions are the solid wastes generated from DRI plants. Char comprises unburnt carbon, oxides and gangue and is segregated from the product during magnetic separation. The material deposited on the inner surface of kiln, comprising metallic oxides is called accretion. Flue dust is generated from air pollution



control systems like DSC, ESP and Bag Filter. Sludge is generated from the GCP, if the plant is based on wet scrubber for dust treatment.

Char contains moderate calorific value (1500-1600 kcal/kg) because of the presence of fixed carbon content. Char do not have volatile matter and cannot be independently used as fuel. It is washed to free the impurities, mixed with coal fines, pulverized and then used as fuel in Fluidized Bed Combustion Boilers (FBC). In India very few plants are using char to produce electricity. Most of the plants (up to 100 TPD) dump it in low-lying area creating pollution problems. Some of the plants sell it to local entrepreneurs for making coal briquettes. It can also be mixed with coal fines, converted to briquette and used in brick kiln.

The kiln accretions are dislodged from the shell at periodic intervals because it hampers the feed movement and heat transfer inside kiln. It also reduces the surface area of kiln. The dislodged accretions are heavy solid lumps and are being used as landfill. However this material can be used as sub-base material for road construction. The flue dust and sludge collected from air pollution control equipment are non-hazardous, non-toxic oxides that are mainly dumped in near by areas. These can be used for brick making and land filling.

3.5.3.2 Mini steel plants

Mini steel plants having mini blast furnace and BOF produce the same types of pollutants that are produced by such units of primary producers.

3.5.3.3 Re-rolling mills

Major pollutants present in the air emissions include particulates (1,000 milligrams per normal cubic meter, mg/Nm³), nitrogen oxides from cutting, scarfing, and pickling operations, and acid fumes (3,000 mg/Nm³) from pickling operations. Both nitrogen oxides and acid fumes vary with steel quality. Mini mills generate up to 80 cubic meters of wastewater per tonne (m³/T) of steel product. Untreated wastewaters contain high levels of total suspended solids (up to 3,000 milligrams per liter, mg/l), copper (up to 170 mg/l), lead 10 mg/l, total chromium (3,500 mg/l), hexavalent chromium (200 mg/l), nickel (4,600 mg/l), and oil and grease (130 mg/l). Chrome and nickel concentrations result mainly from pickling operations. The characteristics of the wastewater depend on the type of steel, the forming and finishing operations, and the quality of scrap used as feed to the process. Solid wastes, excluding EAF dust and wastewater treatment sludge, are generated at a rate of 20 kg/T of steel product. Sludge and scale from acid pickling, especially in stainless steel manufacturing, contain heavy metals such as chromium (up to 700 mg/kg), lead (up to 700 mg/kg), and nickel (400 mg/kg). These levels may be even higher for some stainless steels.

3.5.3.4 Secondary aluminum processing

Secondary aluminum processing also results in air emissions, wastewaters, and solid wastes. Atmospheric emissions from reverberatory (chlorine) smelting/refining represent a significant fraction of the total particulate and gaseous effluents generated in the secondary aluminium industry. Typical furnace exhaust gases contain combustion products, chlorine, hydrogen chloride and metal chlorides of zinc, magnesium, and aluminium, aluminium oxide and various metals and metal compounds, depending on the quality of scrap charges. Emissions from reverberatory (fluorine) smelting/refining are

similar to those from reverberatory (chlorine) smelting/refining. The use of AlF₃ rather than chlorine in the demagging step reduces demagging emissions. Fluorides are emitted as gaseous fluorides or as dusts. Baghouse /scrubbers are usually used for fluoride emission control.

Solid wastes are also generated during secondary scrap aluminium smelting. The slag generated during smelting contains chlorides resulting from the use of fluxes and magnesium. Waste waters are also generated during secondary aluminium processing when water is added to the smelting slag to aid in the separation of metallics. The waste waters are also likely to be contaminated with salt from the various fluxes used.

3.5.3.5 Secondary copper processing

Secondary copper processing produces the same types of wastes as primary pyrometallurgical copper processing. One type of secondary processing pollutant that differs from primary processing is the air emissions. Air pollutants are generated during the drying of chips and borings to remove excess oils and cuttings fluids and causes discharges of large amounts of dense smoke containing soot and unburned hydrocarbons. These emissions can be controlled by baghouses and/or direct-flame afterburners.

3.5.3.6 Secondary lead processing

Secondary lead processing, results in the generation of air emissions and solid-phase wastes. As with primary lead processing, reverberatory and blast furnaces used in smelting account for the vast majority of the total lead emissions. Other emissions from secondary smelting include oxides of sulphur and nitrogen, antimony, arsenic, copper, and tin. Smelting emissions are generally controlled with a settling and cooling chamber, followed by a baghouse. Other air emissions are generated during battery breaking. Emissions from battery breaking are mainly sulphuric acid and dusts containing dirt, battery case material, and lead compounds. Emissions from crushing are also mainly dusts.

The solid wastes generated by secondary processing are emission control dust and slag. Slag is generated from smelting, and the emission control dust, when captured and disposed of, is considered to be hazardous waste.

3.5.3.7 Secondary zinc processing

Secondary zinc processing generates air emissions and solid wastes. Air pollution control can be an area of concern when pyrometallurgical processes are employed in the secondary recovery of zinc. When the recovery process used is simply an iron pot re-melt operation to produce zinc metal, fumes will not be normally generated. If slab zinc is needed and a rotary furnace is used, any air emissions are captured directly from the venting system (a rotating furnace sweats, or melts, the zinc separating it from drosses with different melting points, which allows it to be poured off separately). Air emissions become more of a concern when more complicated processes are used to produce zinc powder. Retort and muffle furnaces used to produce zinc powder heat the zinc and other charges to such a high temperature that the zinc vaporizes and is captured in the pollution control equipment. It is this zinc oxide dust that is the process' marketable product. Hoods are employed around the furnace openings used to add additional charge. The fumes collected from the hoods are not normally of high quality and will be used for products like fertilizer and animal feed. Zinc fumes are negligible at low furnace temperatures.

Substantial emissions may arise from incomplete combustion of carbonaceous material in the zinc scrap. These contaminants are usually controlled by afterburners, and particulate emissions are most commonly recovered by fabric filters. Emissions from refining operations are mainly metallic fumes. Distillation/oxidations operations emit their entire zinc oxide product in the exhaust dust. Zinc oxide is usually recovered in fabric filters.

The secondary zinc recovery process generates slag that contains metals such as copper, aluminum, iron, and lead. Therefore if secondary processing slag exhibits a characteristic (e.g., toxicity for lead), it would need to be managed as a hazardous waste.

3.5.4 Exposure pathways

Exposure pathway is the path due to which exposure of the receptor takes place. The "Exposure" has been defined as contact with a chemical or physical agent. It is the process by which an organism acquires a dose. The estimation of exposure of a target organism requires an exposure scenario that answers to four questions:

- given the output of fate models, which media (ecosystem components) are significantly contaminated?
- to which contaminated media are the target organisms exposed?
- how are they exposed (pathways and rates of exposure)? and
- Given an initial exposure, will the organism modify its behavior to modify exposure pathways or rates (attraction or avoidance)?

Table 3-21 identifies some of the major exposure pathways.

Table 3-21: Exposure Pathways

Media	Pathways	Comment
Air-Gases and Aerosols	Respiration	Assuming accurate fate model estimates, exposure is relatively predictable based on assumption of homogenous distribution in air
Water – Soluble Chemicals	Respiration	Assuming accurate fate model estimates, exposure is relatively predictable based on assumption of homogenous distribution in water
Sediment (Solids and pore water)	Benthic animals absorb chemicals, respire pore water or food or food from the water column. Plants rooted in the sediment may take up material from sediments, surface water and air	Processes are very complicated and usually simplifying assumptions are required
Soil (solids, pore water and pore air)	Organisms in soils may absorb material from soil, pore water, pore air, ingest soil, soil – associated food.	Processes are very complicated and usually simplifying assumptions are required.
Ingested Food and Water	Consumption by fish and wildlife	Assume the test animal consumption rates in laboratory for a given availability of food or water are the same as those occurring naturally in the environment.
Multimedia	More than one of the above pathways	It is often possible to assume one pathway is

	dominant. In some cases, it will be necessary to estimate the combined dosage.
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For Environmental Risk Management there are three major risk factors and exposure Pathway is one of three factors. To determine whether risk management actions are warranted, the following assessment approach should be applied to establish whether the three risk factors of 'Contaminants', 'Receptors', and 'Exposure Pathways' co-exist, or are likely to co-exist, at the project site after the operational phase of the proposed development.

- Contaminant(s): Presence of pollutants and/or any hazardous materials, waste, or oil in any environmental media at potentially hazardous concentrations
- Receptor(s): Actual or likely contact of humans, wildlife, plants, and other living organisms with the contaminants of concern
- Exposure pathway(s): A combination of the route of migration of the contaminant from its point of release (e.g., leaching into potable groundwater) and exposure routes

Metallurgical industries emissions or rejects (gaseous, solid & hazardous as well as liquid effluents) can cause damage to human health, aquatic and terrestrial ecology as well as material due to various exposure routes (pathways). For example, adverse effects of metallurgical industries on human health can derive from the direct impact of noxious gases on the organism and/or their indirect impact via the food chain and changes in the environment. Especially in connection with high levels of fine particulates, noxious gases like SO₂ and NO_x can lead to respiratory diseases. SO₂ and NO_x can have health-impairing effects even at concentrations below those of standard of 120 µg/m³. The duration of exposure is decisive. Injurious heavy metals (e.g., lead, mercury and cadmium) can enter the food chain and, hence, the human organism by way of drinking water and vegetable and animal products. Climatic changes such as warming and acidification of surface waters, Forest depletion can occur due to acid rain and/or the greenhouse effect of CO₂ and other trace gases can have long-term detrimental effects on human health. Similarly important are the effects of climatic changes on agriculture and forestry (and thus on people's standard of living), e.g., large-scale shifts of cultivation to other regions and/or deterioration of crop yields due to climate change impacts. Hence, the construction and operation of metallurgical industries can have both socioeconomic and socio-cultural consequences; appropriate preparatory studies, gender-specific and otherwise, are therefore required, and the state of medical services within the project area must be clarified in advance. Beside, noise pollution generated from operational equipment is an important source of occupational exposure, has direct effects on humans and animals. The main sources of noise in metallurgical industries are the mouth of the smokestack, belt conveyors, fans, motors/engines, transformers, flues, piping and turbines.

3.6 Technological Aspects

3.6.1 Clean technologies

In the middle of the 1960s environmental groups started pressing for cleaner environment. The metallurgical industry responded in a variety of ways. The steel industry closed open hearth furnaces and switched over to other cleaner technology. The aluminium industry switched over from Soderberg to pre-baked electrodes in the electrolytic cells. The copper industry abandoned the reverberatory furnace to a flash smelting technology. Tall stacks were constructed to dispose of SO₂, but the zinc industry eliminated SO₂ emissions

completely by using pressure leaching technology which may well be applied to other nonferrous industries.

Beside government legislation against pollution, residents in many communities now protest against the erection of industrial plants in their regions. The construction of tall stacks has been a new development in the past decades. The problem of dust has been generally solved by adding efficient scrubbers and electrostatic precipitators. This not only improved the local environment but also allowed the recovery of valuable particulates. In most cases the value of these particulates offsets the capital investment in the dust recovery system. The metallurgist is now trying to cope with the environmental problems by adding new equipment in existing plants that would abate pollution, by improving equipment design, and in some cases is forced to develop new processes that are less polluting than the conventional ones. Closely related to these attempts is the need to conserve the national resources through recycling of scrap metal, valorization of mineral waste, and recovery of metals that would otherwise be lost in process streams.

3.6.1.1 Clean technologies in iron and steel

Considerable advancement in the field of clean technologies has taken place in the iron & steel sector. The following clean technologies are possible in the iron & steel sector:

1) Sintering

Sinter plant heat recovery

Description: Heat recovery at the sinter plant is a means for improving the efficiency of sinter making. The recovered heat can be used to preheat the combustion air for the burners and to generate high pressure steam, which can be run through electricity turbines. Various systems exist for new sinter plants (e.g. Lurgi Emission Optimized Sintering (EOS) process) and existing plants can be retrofitted.

Energy/environment/cost/other benefits:

- Retrofitted system at Hoogovens in the Netherlands:
- Fuel savings in steam and coke of 0.55 GJ/T sinter, with increased electricity use of 1.5 kWh/T sinter
- NOx, SOx and particulate emissions reduced
- Capital costs of approximately \$3/T sinter
- Wakayama sintering plant trial operation in Japan:
 - 110-130 kg/T of sinter recovered in steam
 - 3-4% reduction in coke
 - 3-10% reduction in SOx
 - 3-8% reduction in NOx
 - About 30% reduction in dust
 - Increased productivity, yield, and cold strength
- Taiyuan Steel in Japan:
 - Recovered exhaust heat equaled 15 t/h (or 12,000 KL/year crude oil)
 - SO₂ reduced

2) Dust emissions control

Description: Production increase leads to increased dust generation, thereby increasing particulate emissions. These emissions - off/gas - are dust-laden, containing a wide

variety of organic and heavy metal hazardous air pollutants (HAPs). Total HAPs released from individual sinter manufacturing operations may exceed ten tonnes per year. By sending waste gas to Electrostatic Precipitators (ESPs) through negatively charged pipes, the particulate matter (PM) in the waste stream becomes negatively charged. Routing the stream past positively charged plates will then attract and collect the negatively charged PM, thereby producing clean waste gas and increasing the quantity of steam recovery. Course dusts are removed in dry dust catchers and recycled.

Energy/environment/cost/other benefits:

- Can achieve over 98% efficiency, reducing dust load in off-gas of a typical plant from 3,000 mg/m³ to about 50 mg/m³
- ESP removal of fine dust may reduce PM emission levels at sinter plants to about 50 – 150 mg/m³ depending on actual specific dust resistivity and/or sinter basicity
- ESPs can be installed at new and existing plants
- ESPs cause increased energy consumption of about 0.002 to 0.003 GJ/T sinter
- Kashima Steel Works in Japan installed ESP

3) Exhaust gas treatment through denitrification, desulphurization, and activated coke packed bed absorption

Description: Sintering exhaust gas contains SOx, NOx, dust and dioxins. These contaminants are processed, absorbed, decomposed and/or collected as non-toxic by-products to increase the quantity of steam recovery, and improve total fuel savings. Treatment methods to achieve these include:

- (1) Denitrification Equipment
- (2) Desulphurization Equipment
- (3) Activated Coke Packed Bed Absorption

Energy/environment/cost/other benefits:

- SOx is absorbed and recovered as useful by-product
- NOx is decomposed to nitrogen, water and oxygen by ammonia
- Dust is collected in activated coke
- Dioxins are collected or absorbed in activated coke and decomposed at 400oC with no oxygen
- Activated coke absorption removes dioxins to <0.1 ng-TEQ/m³N, dust to <10 mg/m³N, and SOx to <65 % absorbing ratio.

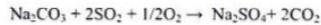
4) Exhaust Gas Treatment through Selective Catalytic Reduction

Description: SOx and dioxins contained in the sinter flue gas are removed in this process by adding sodium bicarbonate and Lignite. NOx is removed by the selective catalytic reduction reaction at around 200–450oC:



For SOx removal the reactions are:





Lignite Injection produces dioxin < 0.2 ng-TEQ/Nm³.

Energy/environment/cost/other benefits

- High SOx and NOx removal efficiency

5) Exhaust Gas Treatment through Low-Temperature Plasma

Description: Active radicals of low-temperature plasma remove SOx, NOx and HCl simultaneously. Dioxin also decreased with the addition of Lignite to the process. Reliability and stability have been proven (over five years of operation). Core technology includes full-scale magnetic pulse compressor, stabilizing pulse width and rising time, proper reactor capacity design, and energy saving technology through additives.

Energy/environment/cost/other benefits

- Low cost with high pollutants removal efficiency
- Compact - less space required than other technologies
- A commercial scale plant installed at an incinerator in Kwang Works showed a substantial reduction of SOx (>70%), NOx (>95%) and HCl (>99%)
- Dioxin also decreased to less than 0.2 ng-TEQ/Nm³

6) Improvements in Feeding Equipment

Description: An additional screen is installed on the conventional sloping chute, which promotes a more desirable distribution of granulated ore on the palette.

Energy/environment/cost/other benefits

- The screen with a sloping chute places coarser granulated ore in the lower part of the palette and finer ore on the upper part, which achieves high permeability

7) Segregation of raw materials on pellets

Description: Segregation and granulation reinforcement of raw materials on sintering pellets improve permeability and decrease return rate to sintering pellets, thus increasing productivity and saving energy.

Energy/environment/cost/other benefits:

- Effective in improving permeability and decrease return rate to sintering
- Increases productivity and saves energy

8) Multi-slit burner in ignition furnace

Description: Multi-slit burners produce one wide, large stable flame, which eliminates "no flame" areas and supplies minimum heat input for ignition, therefore saving energy.



Energy/environment/cost/other benefits

- Total heat input for ignition was reduced by approximately 30% in Wakayama Steel Works of Sumitomo Metals in Japan

9) Equipment to reinforce granulation

Description: A high-speed mixer and a drum mixer are added to the conventional systems for producing granulated ore.

Energy/environment/cost/other benefits

- Reinforced granulation at Wakayama Steel works found:
 - Productivity increased from 34.7 to 38.3 t/day m²
 - Water content increased from 7.0 to 7.3%
 - Granulation rate increased by 45%
 - Permeability increased by 10%
 - Flame front speed increased by 10%
 - Return fine rate decreased less than 1%

10) Biomass for iron and steel making

Description: Biomass utilization practices for iron and steelmaking are being developed to replace coke breeze in the sintering process. Charcoal has been found to be an effective fuel and reductant as high rank coals for the bath smelting of iron ores and wood char has been shown to be a suitable replacement for coke breeze in the sintering process, resulting in process improvements and reduction of acid as levels in process emissions.

Energy/environment/cost/other benefits

- Substantial reductions in CO₂ emissions
- Reductions in acid gas emissions
- Improved carburization rates and increased product quality
- Reduced demand for fluxing agents
- Lower slag volume and levels of process wastes
- Higher productivity through use of more reactive carbon

11) Coke ovens

Coke dry quenching

Description: Coke dry quenching is an alternative to the traditional wet quenching of the coke. It reduces dust emissions, improves the working climate, and recovers the sensible heat of the coke. Hot coke from the coke oven is cooled in specially designed refractory lined steel cooling chambers by counter-currently circulating an inert gas media in a closed circuit consisting of a cooling chamber, a dust collecting bunker, a waste heat boiler, dust cyclones, a mill fan, a blowing device (to introduce the cold air from the bottom) and circulating ducts. Dry coke quenching is typically implemented as an environmental control technology. Various systems are used in Brazil, Finland, Germany, Japan, India and Taiwan, but all essentially recover the heat in a vessel where the coke is quenched with an inert gas (nitrogen). The heat is used to produce steam, which may be used on-site or to generate electricity.



Dry Coke Quenching - CDM Benefits

As described in the TGM, sensible heat of hot coke is lost in wet quenching as steam. In dry quenching, this can be used to produce steam in waste heat recovery boilers and then can be used to produce electricity. Such energy conservation projects are permitted to be taken as CDM projects, where Certified Emission Reduction (CERs) will be issued by UNFCCC to encourage such voluntary energy conservation efforts. CERs can be traded in the international market at the prevailing market rate of carbon (carbon trading). Each CER is issued for saving 1 t of CO₂ emission, directly or indirectly. For CDQ projects, the CO₂ reduction is indirect, as it will replace power needs from grid and therefore burning of coal and consequently emission of CO₂ at the grid connected power plants, which is a predominant fuel in Indian power sector. The project activity contributes significantly to the sustainable development in the following ways:

- Reclaim the sensible heat of red coke, improve the quality of coke, reduce the air pollution caused by the traditional wet quenching, increase the energy utilization efficiency, reduce the energy loss and protect environment
- Prevent the dust pollution caused by the general wet quenching technology
- Reduce the rely on fossil fuel
- Reduce the pollution emission caused by burning fossil fuel
- Reduce the greenhouse gas emission caused by burning the fossil fuel
- Reduce the demand from the power grid, thus mitigate the electricity shortage
- Provide working opportunity for local residents and increase their income

Energy/environment/cost/other benefits

- Energy recovered is approximately 400-500 kg steam/T, equivalent to 800-1200 MJ/T coke. Others estimate energy conservation through steam generation (0.48T/T coke) for Electricity generation.
- New plant costs are estimated to be \$50/T coke, based on the construction costs of a recently built plant in Germany; retrofit capital costs depend strongly on the lay-out of the coke plant and can be very high, up to \$70 to \$90/GJ saved
- Decreased dust, CO₂ and SOx emissions
- Increased water efficiency
- Better quality coke produced, improved strength of coke by 4%

Pollution problems from the by-product recovery type coke ovens

- The gaseous emissions from the coke ovens during the coking process are drawn off and are subjected to various operations for separating ammonia, coke oven gas, tar, phenol, light oil (benzene, toluene, and xylene), and pyridine. After separation, these gases become a potential energy source for other areas of the steel plant. However, if the coke oven gas is not desulphurized, the combustion process will emit SO₂.
- The cleaned coke oven gases are taken to a by-product plant for extraction of by-products. The major solid wastes and by products generated are tar, ammonia products, sulphur, light oil, ammonia still sludge and sludge from the biological treatment plant.
- Waste water generated in the by-product plant is mostly treated by biological processes.



- In case of by-product recovery type coke ovens, USEPA developed a model treatment process which mixes benzol plant waste waters, naphthalene crystallizer blow down, and final cooler blow down and are treated with waste pickle liquor. This effluent is combined with other by-product plant wastewaters and treated with lime in ammonia still to remove both free and fixed ammonia. The ammonia recovered from the still is injected into the coke oven gas stream. The pH of the effluent is lowered by addition of acid and treated in a two stage biological reactor with sludge recycle.

Waste minimization and pollution prevention opportunities in by-products plant:

- Usage of caustic soda rather than lime in the ammonia still; though more costly, it minimizes sludge formation, reduces down time due to scaling problems, and may solve disposal problems.
- Indirect cooling of the coke oven gas to eliminate any contact of the process water with pollutants in the coke oven gas with the exception of flushing liquor.
- Elimination of the recovery of naphthalene and the naphthalene sump.
- The use of an indirect type system for light oil recovery eliminates process wastewater streams since no water comes into contact with the gas, the wash oil, the light oil or the final cooler.
- All pumping stations, oil storage tanks and oil transfer points should be located on impervious, dyked pads with the pad effluent directed to the waste ammonia liquor steam for treatment in order to prevent contamination of ground water.
- Wet oxidation sulphur removal processes for coke oven gas has created highly contaminated waste water streams. Alternative processes like Zimpro Modified Wet Air Oxidation Process, the Dofasco Fixed Salts Recovery Process, or the Nippon Steel HIROHAX process exists.
- Tar by products should be recycled in-plant after processing (e.g., for use as a fuel) or sold as a by-product.
- Sludge generated by the biological treatment system can be recycled to the coke oven.
- Tar decanter sludge can be circulated through a solvent grinding pump and then sprayed onto the coal prior to charging into oven.

12) Coal moisture control

Description: Coal moisture control uses the waste heat from the coke oven gas to dry the coal used for coke making. The moisture content of coal varies, but it is generally around 8-9% for good coking coal. Drying further reduces the coal moisture content to a constant 3-5%, which in turn reduces fuel consumption in the coke oven. The coal can be dried using the heat content of the coke oven gas or other waste heat sources.

Energy/environment/cost/other benefits:

- Fuel savings of approximately 0.3 GJ/T 8, 9
- Coal moisture control costs for a plant in Japan were \$21.9/T of steel
- Coke quality improvement (about 1.7%)
- Coke production increase (about 10%)
- Shorter cooking times
- Decrease in water pollution (ammonia reduction)



13) High pressure ammonia liquor aspiration system

Description: The High Pressure Ammonia Liquor Aspiration System (HPALA) is effective for controlling charging emissions in coke oven batteries. In this system, the ammoniacal liquor, which is a byproduct in the coke oven, is pressurized to about 35-40 bar and injected through special nozzles provided in the gooseneck at the time of charging. This creates sufficient suction inside the oven, thereby retaining pollutants from being released into the atmosphere. The system consists of high-pressure multistage booster pumps, sturdy pipe-work, specially designed spray nozzles, suitable valves and control instruments.

Energy/environment/cost/other benefits

- Emissions control
- High reliability and simplicity of operation
- Low operational and maintenance costs
- Appreciable saving in quantity of process steam required and increased raw gas yield/byproducts generation, due to elimination of gases vented into the atmosphere

14) Modern leak-proof door

Description: Coke oven leaking doors can be a major source of pollution. With the advent of recovery type ovens, the design of oven doors has gone through a process of evolution, beginning from luted doors to the present generation self-regulating zero-leak doors. The important features of the leak-proof door include: (1) a thin stainless steel diaphragm with a knife edge as a sealing frame built in between the door body and the brick retainer, (2) spring loaded regulation on the knife edge for self-sealing, (3) provision for air cooling of the door body, and (4) large size gas canals for easier circulation of gas inside oven.

Energy/environment/cost/other benefits

- Minimization of door leakage
- Regulation free operation
- Longer life due to less warping of the air cooled door body
- Reduced maintenance frequency
- Conventional doors can be replaced by leak-proof doors without altering battery/door frame design

15) Land-based pushing emission control system

Description: The smoke and fumes produced during the pushing of red hot coke contains a huge amount of coke dust (estimated at 11% of the total pollution in the coke oven). Land based pushing emission control systems mitigate this pollution. It consists of three parts: (1) a large gas suction hood fixed on the coke guide car and moving with the coke guide, sending fumes to the coke side dust collecting duct; (2) the dust collection duct; and (3) the final equipment for smoke purification on the ground (ground piping, accumulator cooler, pulse bag dust collector, silencer, ventilation unit, stack, etc.). The large amount of paroxysmal high-temperature smoke produced during coke discharging is collected under the hot float fan into the large gas suction hood installed in the coke guide car, and enters the dust collection duct through the other equipment. The air is dissipated into the atmosphere after purification by the pulse dust collector and after being cooled by the accumulator cooler. The total de-dusting system is controlled by PLC.



Energy/environment/cost/other benefits

- Elimination of pushing emission up to the large extent

16) Iron making

Blast Furnace Iron making

Top pressure recovery turbine

Description: Top pressure recovery turbine (TRT) is a power generation system, which converts the physical energy of high-pressure blast furnace top gas into electricity by using an expansion turbine. Although the pressure difference is low, the large gas volumes make the recovery economically feasible. The key technology of TRT is to secure the stable and high-efficiency operation of the expansion turbine in dusty blast gas conditions, without harming the blast furnace operation.

Energy/environment/cost/other benefits

- Generates electric power of approximately 40-60 kWh/T pig iron
- Japanese Integrated Steel Works:
 - Generates more than 8% of electricity consumed in Japanese ironworks (about 3.33 TWh)
 - Excellent operational reliability, abrasion resistant
 - Suitable for larger furnaces and higher temperature gases compared to Bag filter systems
 - Wet TRT System (US):
 - Typical investments of about \$20/T power recovery of 30 kWh/T hot metal
 - No combustion of BF gas
 - Dry TRT System, e.g., Venturi Scrubber- Electrostatic Space Clear Super (VS-ESCS):
 - Lower water consumption compared with wet type
 - Raises turbine inlet temperature, increasing power

17) Pulverized coal injection (PCI) system

Description: PCI replaces part of the coke used to fuel the chemical reaction, reducing coke production, thus saving energy. The increased fuel injection requires energy from oxygen injection, coal, and electricity and equipment to grind coal. The coal replaces the coke, but coke is still used as a support material in the blast furnace. The maximum injection depends on the geometry of the BF and impact on the iron quality (e.g., sulphur).

Energy/environment/cost/other benefits

- Reduces emissions of coke ovens
- Increased costs of oxygen injection and maintenance of BF and coal grinding equipment offset by lower maintenance costs of existing coke batteries and/or reduced coke purchase costs, yielding a net decrease in operating and maintenance costs, estimated to be \$15/T¹⁸, but a cost savings of up to \$33/T are possible, resulting in a net reduction of 4.6% of costs of hot metal production



- Decreased frequency of BF relining
- Improved cost competitiveness with cost reduction of hot metal
- Investment of coal grinding equipment estimated at \$50-55/T coal injected
- High reliability and easy operation
- Increased productivity
- Uniform transfer of pulverized coal
- No moving parts in injection equipment
- Even distribution to tuyeres

18) Blast Furnace Heat Recuperation

Description: Recuperation systems, e.g., Hot Blast Stove, BFG Preheating System, etc., are used to heat the combustion air of the blast furnace. The exit temperature of the flue gases, approximately 250°C, can be recovered to preheat the combustion air of the stoves.

Energy/environment/cost/other benefits

- Hot blast stove
 - Fuel savings vary between 80-85 MJ/T hot metal
 - Costs are high and depend strongly on the size of the BF, estimated at \$18-20/(GJ saved), equivalent to \$1.4/T hot metal
 - Efficient hot blast stove can run without natural gas
- BFG Preheating System at POSCO in Korea:
 - Anti-corrosion technology with high surface temperatures
 - Economic recovery for low to medium temperature grade heat
 - 102 kcal/kWh reduction in fuel input; thermal efficiency increase of 3.3%
 - Energy savings of 3-5% for boiler, with payback period of within 1.5 years
 - Proven reliability and stability for more than 10 years of operation

19) Improve blast furnace charge distribution

Description: Charging systems of old blast furnaces and new blast furnaces are being retrofitted or equipped with the Paul Wurth Bell Less Top (BLT) charging systems. Input materials like coke and sinter are screened before charging. Proper distribution of input materials improves the coking rate and increases production.

Energy/environment/cost/other benefits

- Increased fuel efficiency
- Reduced emissions
- Increased productivity
- Improved coking rate

20) Blast furnace gas and cast house dedusting

Description: When blast furnace gas leaves the top of the furnace it contains dust particles. Dust particles are removed either with a conventional wet type dedusting system or a dry type dedusting system. Both systems consist of a gravity dust catcher to remove dry large particulate from the BFG stream. The wet fine particulate is then removed in wet type dedusting with a two stage Venturi or Bishoff scrubber, whilst dry type



dedusting does not require water scrubbing and instead employs an electro-precipitator or a bag filter to clean the BFG.

Energy/environment/cost/other benefits

- Dust catcher removes about 60% of particulate from BFG
- Wet Type Dedusting:
 - Produces gas containing less than 0.05 grams/m³ of particulate
 - Pressure and noise control devices not necessary
- Dry Type Dedusting:
 - 30% increase in power generated with dry-type TRT system compared to wet type
 - dedusting
 - 7-9 Nm³/T HM reduction in recirculated water consumption, of which 0.2m³ is fresh water
 - Eliminates generation of polluted water and slurry
 - Improved gas cleanliness with dust content of <5mg/Nm³
 - 50% less occupied land area than wet type dedusting
 - Minimized investment cost and accelerates project construction, as only accounts for 70% in investment compared to wet type dedusting

21) Cast house dust suppression

Description: The primary source of blast furnace particulate emissions occurs during casting. Molten iron and slag emit smoke and heat while traveling from the taphole to ladle, or the slag granulator to pit. The cast house dust suppression system is designed to contain emissions. "Dirty" air is drawn through the baghouse, which contains separate collection chambers each with a suction fan, and is then exhausted into the atmosphere. The system has multiple collection hoods: overhead hoods above each taphole and skimmer, and below-floor hoods above each tilting spout.

Energy/environment/cost/other benefits

- Individual baghouse collection chambers can be shut down without affecting operation

22) Direct iron making

Smelting Reduction Processes

Description: Smelting reduction processes, including Aumelt Ausiron®, HiSmelt®, CCF, DIOS and COREX, involve the pre-reduction of iron ore by gases coming from a hot bath. The pre-reduced iron is then melted in the bath, and the excess gas produced is used for power generation, production of direct reduced iron (an alternative iron input for scrap), or as fuel gas. In this way, smelting reduction eliminates the need for coke and sintering, and future processes will also eliminate ore preparation.

Energy/environment/cost/other benefits:

- Low capital and operating costs:
 - 5-35% below production cost of conventional route
 - Direct use of iron ore fines/steel plant dusts and thermal coals
 - No coke ovens, sinter plants, blending yards

- Single furnace with direct waste energy recovery
- Low environmental impact:
 - No coke-oven or sinter plant emissions, and reduced CO₂, SO₂ and NO_x, no production of dioxins, furans, tars or phenols
 - Recycling of steel plant dusts and slag, making effective uses of coal energy
- High quality iron product, with impurities reported to the slag not the metal
- Greater flexibility in the range of raw materials accepted, including steel plant wastes and high phosphorous ores

23) Direct reduction processes

Description: Direct reduced iron (DRI) is produced through the reduction of iron ore pellets below the melting point of the iron. This is achieved with either natural gas (MIDREX® process) or coal-based (FASTMET® process) reducing agents. The DRI produced is mainly used as a high quality iron input in electric arc furnace (EAF) plants.

Energy/environment/cost/other benefits

- Pre-treatment of raw material not necessary
- Eliminates coke oven
- Low capital and operating costs
- FASTMET® Process:
 - Faster speed and lower temperatures for reduction reaction
 - Fuel usage can be reduced; not necessary to recover and reuse exhaust gases as secondary combustion of close to 100% is achieved in the rotary hearth furnace
 - Low heat loss, as reduced iron is fed to the melting furnace for hot metal production without cooling
 - Low emissions – 0.3-1.5 kg/THM NO_x, 2.4 kg/THM SO_x, and 0.3 kg/THM PM10 (-particulate matter less than 10.0 microns in diameter)
 - Energy consumption is 12.3 GJ/T-hot metal less than mini blast furnace; CO₂ is reduced by 1241 kg/T hot metal

24) Corex process

The chief source of metallic iron today, globally, is through Blast furnace, as the technology is most established, energy efficient, and versatile both technologically and economically. However, due to metallurgical coal to produce BF grade coke, and setting up of coke ovens which pollutes the environment with its NO_x and SO_x emissions, and rigid quality BF has become highly capital intensive. The economic, environmental and cost pressures led to the development of Smelting-Reduction processes like COREX, ROMELT, HISMELT, DIOS, AUSMELT etc. COREX is the only Smelting-Reduction process so far commercialized and in India has been adopted by Jindal Vidyanagar Steel Limited.

COREX consists of two reactors, the reduction shaft to produce DRI and the melter-gasifier to produce hot metal. The reduction shaft is placed above the melter-gasifier and reduced iron bearing material descends by gravity. The hot DRI at around 600-800°C along with partially calcined limestone and dolomite are continuously fed into the melter-gasifier through DRI down pipes. The hot metal and slag are collected in the hearth. The stable and highly successful operation of four COREX plants (POSCO, Korea, JVSL, India, SALDANHA, South Africa) confirms that COREX process is a proven and viable alternative to conventional blast furnace technology.

Thus in COREX, liquid hot metal is produced from DRI, whereas in Sponge Iron plants solid DRI in the form of sponge iron is produced.

25) Steel making

Electrochemical dezincing – dezincing of steel scrap improves recycling

Description: This electrochemical dezincing process provides an environmentally friendly economic method of removing zinc from steel scrap to reuse both the steel and zinc. With the use of zinc-coated scrap increasing, steelmakers are feeling the effect of increased contaminant loads on their operations. The greatest concerns are the cost of treatment before disposal of waste dusts and the water associated with remelting zinc-coated scrap. This technology separates steel scrap into dezinced steel scrap and metallic zinc in two basic steps:

- dissolving the zinc coating from scrap in a hot, caustic solution, and
- recovering the zinc from the solution electrolytically. Through a galvanic process, the zinc is removed from the steel and is in solution as sodium zincate ions rather than zinc dust. The steel is then rinsed with water and ready for reuse. Impurities are removed from the zinc solution, and then a voltage is applied in order to grow metallic zinc via an oxidation-reduction reaction. All waste streams in this process are reused.

Energy/environment/cost/other benefits

- The removal of zinc from steel scrap increases the recyclability of the underlying steel, decreases steelmaking dust, and decreases zinc in waste-water streams.
- Reduction of steelmaking dust to air and wastewater streams
- Removing zinc prior to processing of scrap saves time and money in disposal of waste dusts and water; without the zinc, this high quality scrap does not require extra handling, blending or sorting for remelting in steelmaking furnaces
- Improves the quality of steel scrap
- Produces 99.8% pure zinc for resale

26) BOF steelmaking

Increase thermal efficiency by using BOF exhaust gas as fuel

Description: BOF gas and sensible heat recovery (suppressed combustion) is the single most energy-saving process improvement in this process step, making the BOF process a net energy producer. By reducing the amount of air entering over the converter, the CO is not converted to CO₂. The sensible heat of the off-gas is first recovered in a waste heat boiler, generating high-pressure steam. The gas is cleaned and recovered.

Energy/environment/cost/other benefits

- Energy savings vary between 535 and 916 MJ/T steel, depends on the way in which the steam is recovered; with increased power of 2 kWh/T the total primary energy savings is 136%
- CO₂ reduction of 12.55 kg C per tonne crude steel
- \$20 per tonne crude steel investment costs and increased operations and maintenance costs



- Significant reduction of CO and PM emissions, as well as dust which can be recycled in the sinter or steel plant

27) Use enclosures for BOF

Description: BOF enclosures operate by covering mixer shop filling, mixer pouring, deslagging station, converter charging, converter tapping and bulk material handling system on BOF top platform. On the charging top side, a dog house enclosure captures secondary fumes generated during charging. Rectangular high pick-up velocity suction hoods above charging side are connected to duct lines below the operating platform. Suction hoods capture dust during tapping operations above the receiving ladle. Deflector plates guide fumes towards suction hoods. Below the operating platform is a header duct that connects to a centralized fume extraction system of electrostatic precipitators, fans and a stack. Capacity varies between 1,000,000 m³/h to 2,600,000 m³/h, depending on heat capacity and operating sequence. Space can sometimes be a limited factor for this technology.

Energy/environment/cost/other benefits

- Better working conditions in terms of temperature and dust control
- Visibility of steel making operation and safety improves
- Accumulation of dust over building roofs can be avoided
- Collected dust can be recycled in steel plant

28) Control and automation of converter operation

Description: As converters have become larger, operational control and automatic operation have been promoted with various advantages, which are discussed below. Along with the advancement of processing computers and peripheral measuring technology, blowing control for converters has shifted from a static control system to a dynamic or fully automatic operational control system. Indirect measurement of the exhausted gas method is employed in Europe and the United States, whereas direct measurement by the sublance method – direct measurement of the temperature of molten steel simultaneously during blowing – is employed in Japan. Sublance is used for bath leveling, slag leveling, measurement of oxygen concentration and slag sampling.

Energy/environment/cost/other benefits

- Increase productivity and product quality
- Decreased labor
- Improved working environment

29) OG-boiler system (non-combustion)/dry-type cyclone dust catcher

Description: Since steel refining is conducted in a short period of time, about 35 minutes per charge, the dust concentration is very high. In non-combustion-type converters with a gas recovery function, the dust concentration is 70-80 g/m³N at the inlet of the first dedusting device. Non-combustion-type converters, without combusting CO gas, manage the volume of intake air from the throat, and control the concentration to below the explosion limit, thereby recovering CO as fuel. Exhaust gas treatment consists of an exhaust gas cooling system and a cleaning system. Non-combustion-type systems can be largely divided into the OG-type and the IC (RSIDCAFL) type. The OG-type system basically has no space between the throat and the hood skirt, and controls pressure at the closed throat. The IC-type system has a gap of several hundred millimeters between the



throat and the hood skirt (which has a slightly larger diameter than that of the throat), and controls pressure at the throat opening. The non-combustion type system keeps gas temperature low and shuts out combustion air; therefore, the cooling device and dedusting device installed in the system are smaller than those installed in the combustion-type system. Since the system handles gas that mainly consists of CO, attention is paid to sealing for the flux and coolant input hole and the lance hole, and leak control at the periphery of devices, as well as purge at the gas retention part.

As the volume of converters increases, exhaust gas treatment equipment becomes larger.

Large converters adopt the non-combustion-type system for various reasons, such as the relatively small size of the system as a whole, ease of maintenance, and stable dedusting efficiency. The OG-type system is frequently used because of its operational stability.

The OG-type cooling system makes it possible not only to recover the sensible heat of exhaust gas as steam, but also to increase the IDF efficiency by lowering the temperature of the exhaust gas by use of a cooling device.

Energy/environment/cost/other benefits

- OG-boiler system recovers 65% of the sensible heat of the total exhaust gas, about 70 kg/T
- Increases the IDF efficiency by lowering the temperature of the exhaust gas, achieving high-speed oxygen feeding

30) Casting - Castrip® technology

Description: The Castrip® process has been developed to allow the direct casting of thin strip from liquid steel, in gauges currently ranging from 0.8mm to 2.0 mm.

Energy/environment/cost/other benefits

- Potential energy savings of 80 to 90% over conventional slab casting and hot rolling methods
- More tolerant of high residual elements without loss of quality, enabling greater flexibility in ferrous feed sourcing
- Higher scrap recycling rates potential and less dependence on pig iron and HBI

31) Reducing fresh water use

Description: To reduce steel works dependence on fresh water, the following efforts have been made at Port Kembla Steelworks, Australia:

- Municipal waste-water reclamation – The treatment of sewerage water using microfiltration and reverse osmosis technology for re-use as industrial water, up to 20 ML/day
- Internal waste-water recycling schemes – Cooling tower blowdown water from the hot strip mill and slab casters does not go to the drain, but is treated and reused for dust collection in steelmaking
- Stormwater containment initiatives – 13ML synthetic lined water recovery basin in coke ovens area collects rainwater, coal stockpile run-off water, and spent water from coke quenching for re-use at gas processing and coke quenching

**Energy/environment/cost/other benefits**

- Using recycled sewerage water has reduced fresh dam water use on site by 20ML/day
- Hot strip mill and slab caster blowdown water saves steelmaking 0.5ML/day
- Recycling reduces fresh dam water use from 2.3kL/slab tonne to 1.0kL/slab tonne

32) Rotary hearth furnace dust recycling system

Description: Dust recycling in the rotary hearth furnace (RHF) was applied at Nippon Steel's Kimitsu Works in 2000. The dust and sludge, along with iron oxide and carbon, are agglomerated into shaped articles and the iron oxide is reduced at high temperatures. Zinc and other impurities in the dust and sludge are expelled and exhausted into off-gas.

Energy/environment/cost/other benefits

- DRI pellets made from the dust and sludge have 70% metallization and are strong enough to be recycled to the blast furnaces
- Waste reduction and decreased disposal costs
- Extended landfill life
- Recovery of unused resources (recycling iron, nickel, zinc, carbon, etc.)
- Increase in productivity: 1kg of DRI charged per tonne of BF smelt pig iron
- Decrease in fuel ratio to BF to 0.2kg/T-pig
- Decrease in coke ratio by charging DRI to BF

33) Activated carbon absorption

Description: Use of activated carbon to remove high pollutant concentrations has been proven successful in many cases. In coke making, activated carbon absorption system is used not only to eliminate the yellow brown color typical of coke wastewater (which may cause complaints from stakeholders) but also to reduce the COD of the secondary wastewater treatment plant.

Energy/environment/cost/other benefits

- Eliminate the yellow brown color of coke wastewater
- Significant reduction of COD of the secondary wastewater treatment plant to below 5 mg/l
- Heavy metals removal

34) Variable speed drives for flue gas control, pumps and fans

Description: Variable speed drives (VSDs) better match speed to load requirements for motor operations. VSD systems are offered by many suppliers and are available worldwide.

Energy/environment/cost/other benefits

- Based on experience in the UK:
 - Electricity savings of 42% are possible through the use of VSDs on pumps and fans
 - Payback of 3.4 years, assuming an electricity price of 3pence/kWh, under U.S. 1994 conditions
 - Costs of \$1.3/T product

**35) Regenerative Burner**

Description: A regenerative burner is a heat recovery system that recovers the waste heat of the furnace exhaust gas to heat-up the combustion air of the furnace. The regenerative burner uses heat reservoirs and dual heat-recovering generators at each burner to channel heat more efficiently. During combustion, one side of a burner combusts fuel while the other accumulates the exhaust heat into the heat-recovering generator. Then the burners switch so that the one accumulating heat combusts the fuel and the other now accumulates exhaust heat.

Energy/environment/cost/other benefits

- 20-50% of energy reduction possible, depending on types of furnace and condition of fuel
- Up to 50% NOx reduction possible with high temperature combustion
- Excellent operational reliability, with introduction of regenerative burner systems in over 540 furnaces in various Japanese industries

36) Technology for Effective Use of Slag

- Description: Slag is a by-product of iron and steelmaking, not a waste. The fresh SMS slag absorbs moisture and expands. Thus its use for Road making and as rail ballast gets restricted unless it is matured. Slag which is already dumped outside and exposed to rain loses this characteristic and is useful if broken from large uneven lumps to required sizes by installing crushers at old dump sites. This is being practiced and SMS dump sites have started declining. However, the process needs to be made scientifically acceptable including the measures for control of leaching from the dumps.
- SMS slag is also partly used in blast furnaces as input/charging material.
- Fresh SMS slag, which is at 600-800°C can be directly pulverized in automatic pulverizers by spraying water on it. The water spray produces steam, which reacts with free calcium oxide and magnesium oxide. Consequently, the slag is pulverized due to the volume expansion, thus separating steel from slag, and steel falls through a chute. Pulverized slag is sucked through a slag separator by an exhaust fan and collected for use as road materials, construction and rail ballast.

Slag is also used for applications beyond steel making, e.g., in water/bottom muck purification materials to reduce phosphate concentration in red tides and as marine block to help grow seaweed. Slag can be employed for various applications i.e.

- Converting slag as a purification catalyst can help restore ecosystems in water areas.
- In concrete and as a low-quality aggregate
- For land improvement
- In Japan, through an emerging technology, techniques for formation of carbonates of steel slag are under development. Carbonates of steel slag are formed when slag solidifies by absorbing CO₂ in a carbonation reactor. Then can be used as marine blocks, which help grow sea weeds. The process of carbonization of slag is shown in Figure.

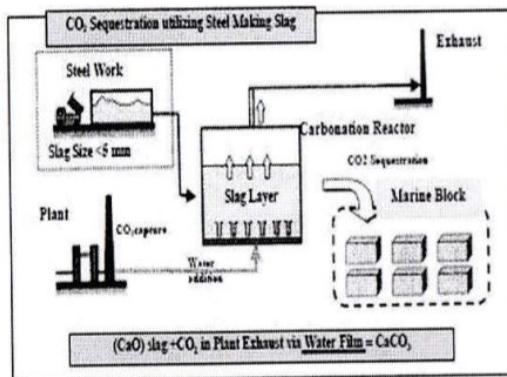


Figure 3-19: Carbonization of slag

Energy/environment/cost/other benefits

- Around 3.8 million t/year of scrap steel is recovered from slag produced
- Revenue generated is equivalent to 3.8 billion Yuan/year, based on 1,000 Yuan (\$130 2006 US)/T scrap steel
- Substitute for cement in building industry, thereby minimizing CO₂ emissions generated by cement production
- Land area occupied by piled slag minimized by slag reutilization
- Application of slag in Japan (marine block and water/bottom mud purification materials)
 - Reduce phosphate concentration that causes red tide
 - Fix hydrogen sulphide (cause of blue tide)
 - Grow seaweed to restore lost shallows in seaweed beds
- Slag usage in marine applications is a new field with huge potential for shoreline improvement and restoration of lost shallows and seaweed beds
- Using BF slag in cement manufacturing helps to reduce energy use by eliminating granulation and heating [340 kg-CO₂/T slag]

Other applications include concrete aggregate, railroad ballast, agricultural use, sewage trickling filters, and construction.

37) Hydrogen production

Description: Coke oven gas (COG), a byproduct gas of the iron-making process, contains around 55% hydrogen. It is easy to produce hydrogen with high purity from COG by a very simple process called pressure swing adsorption (PSA). Significant efforts to recover sensible heat of COG as hydrogen enrichment are under way. Developing proper catalysts is the key to success.

Energy/environment/cost/other benefits:

- Hydrogen is expected to be an important energy carrier for fuel cells

- Because of its ease of production, its abundance, and its distribution, COG is one of the major candidates for a hydrogen source in the future

38) Carbonation of steel slag

Description: Carbonates of steel slag are formed when slag solidifies by absorbing CO₂. This sequesters the CO₂ in the slag, which can then be used in marine applications.

Energy/environment/cost/other benefits

- Steel slag carbonates can be used to make "marine blocks" which can improve the coastal environment by helping to grow seaweed [which improves sea surroundings]
- Marine blocks are also used for coral nursery beds, which may help to revive dead coral areas

3.6.1.2 Clean technologies in non-ferrous sector

Pollution prevention through clean technologies, whether through source material reduction/reuse, or waste recycling, is practiced in various sectors of the nonferrous metals industry. Pollution prevention techniques and processes currently used by the nonferrous metals industry can be grouped into the following general categories:

- Process equipment modification
- Raw materials substitution or elimination
- Solvent recycling
- Precious metals recovery

It is interesting to note that while the stated rationale for the use of many of these techniques or processes is applicable environmental regulations; their use is both fairly universal and profitable.

Process equipment modification is used to reduce the amount of waste generated. Many copper, lead, and zinc refiners have modified their production processes by installing sulphur fixation equipment. This equipment not only captures the sulphur before it enters the atmosphere, but also processes it so that a marketable sulphuric acid is produced. Another example is the use of pre-baked anodes in primary aluminum refining. When a pre-baked anode is used, the electrolytic cell, or pot, can be closed, thereby increasing the efficiency of the collection of fluoride emissions. In addition, new carbon liners have been developed which significantly increase the life of the aluminum reduction cell. This has resulted in large reductions in the amount of spent pot liner material generated by the aluminum industry.

Raw material substitution or elimination is the replacement of raw materials with other materials that produce less waste, or a non-toxic waste. Material substitution is inherent in the secondary nonferrous metals industry primarily by substituting scrap metal, slag, and baghouse dust for ore feedstock. All of these materials, whether in the form of aluminum beverage cans, copper scrap, or lead-acid batteries, are commonly added to other feedstock or charges (usually slag containing residual metals) to produce marketable grades of metal. Primary nonferrous metals refining also uses previously refined metals as feedstock, especially zinc-containing electric arc furnace dust (a by-product of the iron and steel industry).

Precious metals recovery is the modification of a refining process to allow the capture of marketable precious metals such as gold and silver. Like sulphur fixation, precious

metals recovery is a common waste minimization practice. During primary copper smelting, appreciable amounts of silver and gold present in copper ore will be concentrated into the anode copper and can be recovered as a by-product in the electro-refining process (as the copper anode is electrochemically dissolved and the copper attaches itself to the cathode, silver and gold drop out and are captured in the slime at the bottom of the tank). In the lead refining process the copper often present in lead ore is removed during the initial lead bullion smelting process as a constituent of dross. Silver and gold are removed from the lead bullion later in the process by adding certain fluxes which cause them to form an impure alloy. The alloy is then refined electrolytically and separated into gold and silver. Precious metals recovery also takes place during zinc refining to separate out copper, a frequent impurity in zinc ore. Copper is removed from the zinc ore during the zinc purification process (after zinc undergoes leaching, zinc dust is added which forces many of the deleterious elements to drop out; copper is recovered in a cake form and sent for refining).

Important pollution prevention case studies

Various pollution prevention case histories have been documented for nonferrous metals refining industries. In particular, the actions of the AMPCO Metal Manufacturing Company, Inc. typify industry efforts to simultaneously lessen the impact of the industrial process on the environment, reduce energy consumption, and lower production costs.

(i) AMPCO Metal Manufacturing Company, Inc., in Ohio is participating in the development of pollution prevention technologies. The project, sponsored by the U.S. DOE and EPA, consists of researching and developing the use of electric induction to replace fossil fuel combustion currently used to heat tundishes. Tundishes are used to contain the heated reservoir of molten alloy in the bar stock casting process. The fossil fuel combustion processes currently used requires huge amounts of energy and produces tremendous amounts of waste gases, including combustion bases and lead and nickel emissions. According to new OSHA regulations, lead emissions from foundries must be reduced by 80 % by 1998.

Heating the tundish by electric induction instead of fossil fuel combustion will substantially improve the current process, saving energy and reducing pollution. Energy efficiency will jump to an estimated 98 %, saving 28.9 billion Btu/yr/unit. Industry-wide energy savings in 2010 are estimated to be 206 billion Btu/yr, assuming a 70 % adoption at U.S. foundries.

In addition to the energy savings, the new process also has substantial environmental benefits. Along with the elimination of lead and nickel gases, carbon dioxide, carbon monoxide, and nitrogen oxide emissions from combustion will decrease. The consumption of refractory (a heat-resistant ceramic material) will decline by 80 %, resulting in a similar reduction of refractory waste disposal. In all, prevention of various forms of pollution is estimated to be 147 million lb (66.7 million kg)/yr by 2010.

(ii) In an experiment at NML, Jamshedpur, the whole mass of battery scrap was washed with water with a view to remove the sulphuric acid and then with a concentrated solution of soda ash at the ambient temperature in order to remove the sulphur. The temperature of the smelting zone was around 1250 to 13000 C and lead was trapped periodically. To control pollution, the pilot plant was provided with a suction point at the top of the furnace and a hood to capture tapping emissions and connected to a exhaust fan through a 1st stage dust catcher and a bag filter. This was to capture lead dust. In another

experiment, a Flue Gas Desulphurization plant was provided with activated carbon for adsorbing lead and lime scrubber to catch SO₂. Lead recovery of 86.5% was obtained.

Economically, the elimination of lead and nickel emissions will result in an improved product because exposure of the metal to combustion gases in the current process results in porosity and entrainment of hydrogen gas in the metal. Overall, AMPCO estimates an annual savings in operations and maintenance expenses of \$1.2 million with the use of this technology. Assuming the same 70 % industry adoption, economic savings by 2010 could reach \$5.8 million. Without the new electric induction heating process, the capital costs required for compliance could be \$3 million.

3.6.2 Pollution control technologies

The following tables indicate existing management system v/s clean technology requirements for aluminum industry and steel industry.

Table 3-22: Existing Management System v/s Requirements for Steel Industry

Technologies/Current Practices	Requirements
Coke Oven In coke ovens the volatile materials released during cooking flows from the oven to the by-product plants where ammonia, benzol, xylene, toluene, tar, pitch and tar acids are recovered. The operations are associated with fugitive and stack emissions. The PAH compounds released during coking operation as fugitive emissions are carcinogenic in nature. The technologies available to control the pollution are <ul style="list-style-type: none"> ▪ HPLA system ▪ Hydraulic door and door frame cleaner ▪ Doors with double knife edge and rope sealing ▪ Water sealed AP caps ▪ Screw feeder 	<ul style="list-style-type: none"> ▪ Land based pushing and charging emission control with dust extraction system ▪ Automation for process operations ▪ Self sealing air cooled doors ▪ Possibility of coke dry quenching needs to be tried out ▪ Effluent treatment plant to treat cyanide, phenol, ammonia, COD etc. ▪ Hazardous waste (tar sludge and ETP sludge) handling and disposal following Hazardous Waste Handling, Rules; or, tar sludge / ETP sludge charging along with the coal fines in the coke ovens
Sintering Plant <ul style="list-style-type: none"> ▪ ESP / bag filter / wet scrubber for process emissions ▪ ESP / bag filter / wet scrubber for work zone environment 	<ul style="list-style-type: none"> ▪ ESP / bag filters with higher efficiency of removal for process emissions. ▪ System for removal of SO₂, NO_x, dioxins and furans.
Thermal Power Plant <ul style="list-style-type: none"> ▪ ESP for the emissions 	<ul style="list-style-type: none"> ▪ Proper management and utilization of fly ash
Steel Melting Shop <ul style="list-style-type: none"> ▪ Suppressed combustion system ▪ ESP/bag filter wet scrubber for the process emissions ▪ Effluent treatment comprising settling unit and re-circulation system for the treated effluent 	<ul style="list-style-type: none"> ▪ Proper operation and maintenance of air emission control and effluent treatment systems. ▪ Secondary ventilation systems to control charging and tapping fugitive emissions. ▪ Collection of BOF gas for use as fuel. BOF slag processing for better acceptance

Technologies/Current Practices	Requirements
Blast Furnace	<ul style="list-style-type: none"> ▪ Proper operation and maintenance of ESP / bag filter / wet scrubber for air emissions ▪ Cast house BF slag granulation Utilization ▪ Coal dust injection ▪ High top pressure BF with TRT
Lime / dolomite plant	<ul style="list-style-type: none"> ▪ Effective operation and maintenance of ESP / bag filter / multiclones for process and work zone dust emissions ▪ High efficiency kilns
Mills	<ul style="list-style-type: none"> ▪ API separators and settling tanks for wastewater treatment ▪ Use regenerative burners ▪ Hot charging of slab
Raw material handling units	<ul style="list-style-type: none"> ▪ Improvements in the systems for controlling fugitive emissions. ▪ Enclosures and water sprinkling system ▪ Processing of dust and sludge for reuse

Source: CPCB/APPCD Handbook on Steel

The methods or technologies or equipments used to control and treatment of other metallurgical industries are as shown in table below.

Table 3-23: Existing Management System v/s Requirements for Aluminum Industry

Existing Management System	Requirements
Red Mud :	Dry disposal in secured land fill, as dry disposal requires much less space(1/3 to 1/5 of Wet disposal) and less seepage is expected.
a) Wet disposal : In this method, washed red mud slurry containing 10 – 30% solids is pumped to the pond.	
b) Dry disposal : In this method, the red mud disposed contains 30 – 50% moisture and also known as thickened tailing disposal	
Spent Pot Lining :	<ul style="list-style-type: none"> a) Fluoride recovery followed by reuse for carbon portion (Impact of such reuses need to be investigated). b) Disposal in secured landfill to avoid leakage of fluoride and cyanide.
Fluoride emission :	Dry scrubbing, as this helps in recycling fluoride and also there is no water pollution.

Source: CPCB

Table 3-24: Required Management System for Other Non-Ferrous Industry

Nickel	
Flash smelting	Control of sulphur dioxide emissions
Impervious clothing	To protect workers against contact of liquid nickel carbonyl.
Encapsulation of furnaces and conveyors	To prevent emissions of particulate matter.
Cyclones followed by wet scrubbers, ESPs, or bag filters	To control discharge of particulate matter
Fabric filters	To reduction of gas temperature
Mini Steel	
Improving feed quality	Reduces the pollutants
Fabric filters	Dry dust collection
Cyclones, baghouses, and electrostatic precipitators (ESPs). Scrubbers	Dust emission control
Lead and zinc	
Oxidizing scrubber	Reduces NOx
Adsorption by activated carbon	Reduces dust and acid mist
Alkali scrubber (semi -dry and fabric filter, wet scrubber or double alkali using lime, magnesium hydroxide, sodium hydroxide).	Reduces SO ₂
Fabric filter	Reduces dust
Copper	
Fabric filter with lime injection	Reduces SO ₂
Fabric filter	Reduces dust
Adsorption by activated carbon	Reduces dioxin
Scrubber	Reduces acid mist

Table 3-26: Comparison of New Technologies for Pollution Control

S.No.	Standard Technology	Alternative Technology
1	Coke Making:	<p>Super Coke Oven For Productivity and Environmental Enhancement towards the 21st Century (SCOPE21), established through a ten year national program in Japan, replaces existing coke ovens with a new process that expands upon the previous choices for coal sources, while increasing productivity, decreasing environmental pollution, and increasing energy efficiency compared to the conventional coke making process.</p> <p>SCOPE21 has three sub-processes: (1) rapid</p>



Metallurgical Industry

S.No.	Standard Technology	Alternative Technology
		<p>preheating of the coal charge; (2) rapid carbonization, and (3) further heating of coke carbonized up to medium temperatures. The aim of dividing the whole process into three is to make full use of the function of each process in order to maximize the total process efficiency.</p> <p>Energy/Environment/Cost/Other Benefits:</p> <ul style="list-style-type: none"> • Improved coke strength; Drum Index increased by 2.5 (DI150) over conventional coking • Reduced coking time from 17.5 hours to 7.4 hours • Increased potential use of poor coking coal from 20 to 50% • Productivity increased 2.4 times • NOx content reduced by 30% • No smoke and no dust • Energy consumption reduced by 21% • Reduction in production cost by 18% and construction cost by 16% Coke dry quenching is an alternative to the traditional wet quenching of the coke. It reduces dust emissions, improves the working climate, and recovers the sensible heat of the coke. Hot coke from the coke oven is cooled in specially designed refractory lined steel cooling chambers by counter-currently circulating an inert gas media in a closed circuit consisting of a cooling chamber, dust collecting bunker, a waste heat boiler, dust cyclones, a mill fan, a blowing device(to introduce the cold air form the bottom) and circulating ducts. Dry coke quenching is typically implemented as an environmental control technology. Various systems are used in Brazil, Finland, Germany, Japan and Taiwan, but all essentially recover the heat in a vessel where the coke is quenched with an inert gas (nitrogen). The heat is used to produce steam, which may be used on-site or to generate electricity.
	<p>Coke Quenching:</p> <p>Wet in old plants; red hot coke cooled with water in Quenching Tower; effluents cleaned and reused; emission of carcinogenic pollutants possible if phenolic water used for quenching.</p>	<p>Energy/Environment/Cost/Other Benefits:</p> <ul style="list-style-type: none"> • Energy recovered is approximately 400-500 kg steam/T, equivalent to 800-1200 MJ/T coke. Others estimate energy conservation through steam generation (0.4K/T coke). Electricity generation.



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S.No.	Standard Technology	Alternative Technology
2		<p>Iron Making:</p> <p>Blast furnace charged from top with ore, sinter, coke and additives; molten hot metal and slag taken out from bottom; BF gas from top extracted and cleaned and used as a fuel; proven technology; sizes vary from mini BF (250^{m3}) to large BF (5000^{m3}); high top pressure BFs with TRT for steam generation possible.</p> <p>Energy/Environment/Cost/Other Benefits:</p> <ul style="list-style-type: none"> • Low capital and operating costs: <ul style="list-style-type: none"> - 5-35% below production cost of conventional route - Direct use of iron ore fines/steel plant dusts and non coking coals - No coke ovens, sinter plants, blending yards - Single furnace with direct waste energy recovery • Low environmental impact: <ul style="list-style-type: none"> - No coke-oven or sinter plant emissions, and reduced CO₂, SO₂ and NO_x, no production of dioxins, furans, tars or phenols - Recycling of steel plant dusts and slag, making effective uses of coal energy • High quality iron product, with impurities reported to the slag not the metal • Greater flexibility in the range of raw materials accepted, including steel plant wastes and high phosphorous ores <p>Direct reduced iron (DRI) is produced through the reduction of iron ore pellets below the melting point of the iron. This is</p>


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	<p>Sponge Iron (Direct Reduced Iron): Rotary kilns 50 to 500 tpd; non coking coal as fuel; hot waste gases cleaned in scrubbers/water spray cooled and cleaned in ESPs; small kilns are without waste heat recovery; char normally dumped and used as low CV fuel cakes; can be used for AFBC/CFBC for steam/power generation; Pre-treatment of raw material not necessary; Eliminates coke oven; Low capital and operating costs; India world's largest coal based sponge iron producer. From amongst various solid based processes, only a few have attained commercial significance. Most of the processes such as SL/RN, KRUPP-CODIR, DRC, TDR, SII, JINDAL, OSIL, Popuri utilize rotary kiln for reduction whereas Kinglor Metor process utilizes an externally heated vertical retort. In India, the standard DRI processes are modified in a minor way and thereafter referred as customized / indigenous technology. Only trivial changes in terms of the feed ratio, length and the diameter of the kiln are made in the name of customized technology. These customized technologies are dominating the coal based sponge iron process in India. Jindal, TDR, Sponge Iron India Limited (SII), Orissa Sponge Iron Limited (OSIL), Popuri Engineering, etc have customized and adopted and market such technology. Except OSIL none of the customized processes are patented.</p>	<p>achieved with either natural gas (MIDREX® process) or coal-based (FASTMET® process) reducing agents. Rotary hearth furnace is used in this process. The DRI produced is mainly used as a high quality iron input in electric arc furnace (EAF) plants.</p> <p>Energy/Environment/Cost/Other Benefits:</p> <ul style="list-style-type: none"> ▪ Pre-treatment of raw material not necessary ▪ Eliminates coke oven ▪ Low capital and operating costs ▪ FASTMET® Process: <ul style="list-style-type: none"> – Faster speed and lower temperatures for reduction reaction – Fuel usage can be reduced; not necessary to recover and reuse exhaust gases as secondary combustion of close to 100% is achieved in the rotary hearth furnace – Low heat loss, as reduced iron is fed to the melting furnace for hot metal production without cooling – Low emissions – 0.3-1.5 kg/THM NOx, 2.4 kg/THM SOx, and 0.3 kg/THM PM10 (- particulate matter less than 10.0 microns in diameter) – Energy consumption is 12.3 GJ/T-hot metal less than mini blast furnace; CO₂ is reduced by 1241 kg/T hot metal


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3.6.3 Pollution prevention and control

The most effective pollution prevention option is to choose a process that entails lower energy usage and lower emissions. Modern flash-smelting processes save energy, compared with the conventional sintering and blast furnace process. Process gas streams containing over 5% sulphur dioxide are usually used to manufacture sulphuric acid. The smelting furnace will generate gas streams with SO₂ concentrations ranging from 0.5% to 10%, depending on the method used. It is important, therefore, to select a process that uses oxygen-enriched air or pure oxygen. The aim is to save energy and raise the SO₂ content of the process gas stream by reducing the total volume of the stream, thus permitting efficient fixation of sulphur dioxide. Processes should be operated to maximize the concentration of the sulphur dioxide. An added benefit is the reduction (or elimination) of nitrogen oxides (NO_x).

- Use doghouse enclosures where appropriate; use hoods to collect fugitive emissions.
- Mix strong acidic gases with weak ones to facilitate production of sulphuric acid from sulphur oxides, thereby avoiding the release of weak acidic gases.
- Maximize the recovery of sulphur by operating the furnaces to increase the SO₂ content of the flue gas and by providing efficient sulphur conversion. Use a double-contact, double-absorption process.
- Desulphurize paste with caustic soda or soda ash to reduce SO₂ emissions.
- Use energy-efficient measures such as waste heat recovery from process gases to reduce fuel usage and associated emissions.
- Recover acid, plastics, and other materials when handling battery scrap in secondary lead production.
- Recycle condensates, rainwater, and excess process water for washing, for dust control, for gas scrubbing, and for other process applications where water quality is not of particular concern.
- Give preference to natural gas over heavy fuel oil for use as fuel and to coke with lower sulphur content.
- Use low-NO_x burners.
- Use suspension or fluidized bed roasters, where appropriate, to achieve high SO₂ concentrations when roasting zinc sulphides.
- Recover and reuse iron-bearing residues from zinc production for use in the steel or construction industries.
- Give preference to fabric filters over wet scrubbers or wet electrostatic precipitators (ESPs) for dust control.

Good housekeeping practices minimize losses and prevent fugitive emissions. Losses and emissions are minimized by enclosed buildings, covered conveyors and transfer points, and dust collection equipment. Yards should be paved and runoff water routed to settling ponds.

3.6.4 Pollution reduction targets

Implementation of cleaner production processes and pollution prevention measures can yield both economic and environmental benefits. The following production-related targets can be achieved by measures such as those described above. The figures relate to



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the production processes before the addition of pollution control measures. All efforts should be made to voluntarily reduce dust emission level to 50 mg/m³ and less and control SO₂ and NOx emissions as given in this TGM. This should be followed by reducing dioxin and furan emissions to the TGM levels.

BF and SMS slag reuse and recycling should be given priority to reach 100% level by adopting international best practices.

Dust and sludge processing by applying international technology must be adopted.

Entire plant waste water and sanitary waste water must be treated and reused in the plant.

The target pollutant load for lead and zinc smelting operations for particulate matter is 0.5 kg/T of concentrated ore processed. ESPs are used to recover dust. Pollutant load factors for lead in air emissions are 0.08 kg/T from roasting, 0.08 kg/t from smelting, and 0.13 kg/T from refining.

A double-contact, double-absorption plant should emit no more than 2 kg of sulphur dioxide per tonne of sulphuric acid produced, based on a conversion efficiency of 99.7%. Sulphur dioxide should be recovered to produce sulphuric acid, thus yielding a marketable product and reducing SO₂ emissions. Fugitive emissions are controlled by using enclosed conveyors.

Treatment technologies

ESPs and baghouses are used for product recovery and for the control of particulate emissions. Dust that is captured but not recycled will need to be disposed of in a secure landfill or in another acceptable manner.

Arsenic trioxide or pentoxide is in vapor form because of the high gas temperatures and must be condensed by gas cooling so that it can be removed in fabric filters.

Collection and treatment of vent gases by alkali scrubbing may be required when sulphur dioxide is not being recovered in an acid plant.

Effluent treatment of process bleed streams, filter backwash waters, boiler blow down, and other streams is required to reduce suspended and dissolved solids and heavy metals and to adjust pH. Residues that result from treatment are recycled to other industries such as the construction industry, sent to settling ponds (provided that groundwater and surface water contamination is not a concern), or disposed of in a secure landfill.

Slag should be either landfilled or granulated and sold for use in building materials.

3.6.5 Occupational Health and Safety of ferrous metal industry

Occupational health and safety issues during the construction, operation, maintenance, and decommissioning of integrated steel manufacturing facilities are common to those of large industrial facilities. The following occupational health and safety issues are specific to steel manufacturing activities:

- Physical hazards
- Heat and hot liquids
- Radiation



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- Respiratory hazards
- Chemical hazards
- Electrical hazards
- Noise
- Entrapment hazards
- Fire and explosions

Physical hazards

Industry specific physical hazards are discussed below. Potential physical hazards in integrated steel plant operations are related to handling of large and heavy raw materials and product (e.g. blast furnace and EAF charging, storage and movement of billets and thick slabs, movement of large ladles containing liquid iron and steel); heavy mechanical transport (e.g. trains, trucks and forklifts); grinding and cutting activities (e.g. contact with scrap material ejected by machine-tools); rolling processes (e.g. collision and crushing high speed rolled materials and processes); and work at heights (e.g. platforms, ladders, and stairs). Heavy Loads / Grinding & Cutting / Rolling Lifting and moving heavy loads at elevated heights using hydraulic platforms and cranes presents a significant occupational safety hazard in steel plants. Recommended measures to prevent and control potential worker injury include the following:

- Clear signage in all transport corridors and working areas;
- Appropriate design and layout of facilities to avoid crossover of different activities and flow of processes;
- Implementation of specific load handling and lifting procedures, including:
 - Description of load to be lifted (dimensions, weight, position of center of gravity), specifications of the lifting crane to be used (maximum lifted load, dimensions).
 - Train staff in the handling of lifting equipments and driving mechanical transport devices.
- The area of operation of fixed handling equipment (e.g. cranes, elevated platforms) should not cross above worker and pre-assembly areas;
- Material and product handling should remain within restricted zones under supervision;
- Regular maintenance and repair of lifting, electrical, and transport equipment should be conducted.
- Prevention and control of injuries related to grinding and cutting activities, and use of scrap, include the following:
 - Locate machine-tools at a safe distance from other work areas and from walkways;
 - Conduct regular inspection and repair of machine-tools, in particular protective shields and safety devices / equipment
 - Train staff to properly use machines-tools, and to use appropriate personal protection equipment (PPE).

Prevention and control of hazards associated with rolling processes and activities include the following:

- Provide grids around stands and shields where rolled material could accidentally come off rolling guides;



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- Provide rails along transfer plate with interlocked gates that open only when machine is not in use.

Heat and hot liquid

High temperatures and direct infrared (IR) radiation are common hazards in integrated steel plants. High temperatures can cause fatigue and dehydration. Direct IR radiation also poses a risk to sight. Potential contact with hot metal or hot water may occur from the cooling spray zone of continuous casting, from splashes of melted metal, and from contact with hot surfaces. Recommended measures for prevention and control of exposure to heat and hot liquids / materials include the following:

- Shield surfaces where close contact with hot equipment or splashing from hot materials is expected (e.g. in coke oven plants, blast furnaces, BOF, EAF, continuous casting and heating oven in rolling plants, and ladles);
- Implement safety buffer zones to separate areas where hot materials and items (e.g. billets, thick slabs, or ladles) are handled or temporarily stored. Rail guards around those areas should be provided, with interlocked gates to control access to areas during operations;
- Use appropriate PPE (e.g. insulated gloves and shoes, goggles to protect against IR and ultraviolet radiation, and clothing to protect against heat radiation and liquid steel splashes);
- Install spot cooling ventilation systems to control extreme temperatures work zones;
- Implement work rotations providing regular work breaks, access to a cool rest area, and drinking water/ anti-dehydration drinks.

Radiation

Gamma ray testing of steel plant equipment and products during operation is typically required to determine the steel composition and integrity. The following techniques may be used as per AERB guidelines to limit the worker exposure risk:

- Gamma ray testing should be carried out in a controlled, restricted area using a shielded collimator. No other activities should be undertaken in the testing area;
- All incoming scrap should be tested for radioactivity prior to use as feedstock material;
- If the testing area is near the plant boundary, ultrasonic testing (UT) should be considered as an alternative to gamma ray techniques; Regular maintenance and repair should be conducted on testing equipment, including protective shields.

Respiratory hazards

Insulation materials

Asbestos and other mineral fibers have been widely used in older plants and may pose a risk from inhalation of cancer causing substances. Recommended management practices include:

- A plant-wide survey and a management plan for asbestos containing insulation materials should be completed by certified professionals;



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- Damaged or friable material should be repaired or removed while other materials may be monitored and managed in-situ. Any handling of insulation materials deemed to contain asbestos or any other hazardous material should only be performed by properly trained and certified contractors and personnel following BIS accepted procedures for their repair or removal;
- Use of asbestos must be avoided in new installations or upgrades;
- An LDPE sheet should be placed under the item to be insulated (e.g. tube or vessel) and under the stock of insulation material to be layered, to prevent surface contamination with fibers.

Dust and Gases

Dust generated in integrated steel mills includes iron and metallic dusts, which are mainly present in BF, BOF, EAF, continuous casting buildings, pelletization and sinter plants; and mineral dusts which are mainly present in raw material storage, BF, and the coke oven plant. In the former case, workers may be exposed to iron oxide and silica dust that can be contaminated with heavy metals such as chromium (Cr), nickel (Ni), lead (Pb), and manganese (Mn), zinc (Zn), and mercury (Hg). The most significant is the dust present in the melting and casting processes (e.g. BF, BOF, continuous casting), where the dust, which is generated by high temperature operations, is finer and more easily inhaled than in the rolling processes. In raw material storage, blast furnace and coke oven plant, workers are exposed to mineral dust, which may contain heavy metals. In addition, BF tapping results in graphite release. In the melting and casting processes where high temperature operations are conducted, workers may be exposed to gas inhalation hazards, which may contain heavy metals. In the BF, BOF and coke oven plant, workers may be exposed to gas inhalation hazards of carbon monoxide. Further inhalation hazards in the coke oven plant include sulphur oxides and Volatile Organic Compounds (VOC). In the COG refinery plant, the presence of ammonia, aromatic hydrocarbons, naphthalene and polycyclic aromatic hydrocarbons (PAH) may present other inhalation hazards. Recommendations to prevent exposure to gas and dust include the following:

- Sources of dust and gases should be separated and enclosed;
- Design natural ventilation system in hot shops to maximize air circulation.
- Exhaust ventilation should be installed at the significant point sources of dust and gas emissions, particularly the BF tapping area, the BOF or the EAF;
- Provide a sealed cabin with filtered air conditioning if an operator is needed in a contaminated area;
- Provide separated eating facilities that allow for washing before eating;
- Provide facilities that allow work clothes to be separated from personal clothes, and for washing / showering after work; Implement a policy for periodic health checks. Respiratory hazard control technologies should be used when exposure cannot be avoided with other means, such as operations for refilling the coke oven; manual operations such as grinding or use of non-enclosed machine-tools; and during specific maintenance and repair operations. Recommendations for respiratory protection include the following:
 - Use of filter respirators when exposed to heavy dust (e.g. fettling works);
 - For light, metallic dust and gases, fresh-air supplied respirators should be used. Alternatively, a complete facial gas mask (or an "overpressure" helmet) may be used, equipped with electrical ventilation as per BIS guidelines;

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- For carbon monoxide (CO) exposure, detection equipment should be installed to alert control rooms and local personnel. In case of emergency intervention in areas with high levels of CO, workers should be provided with portable CO detectors, and fresh-air supplied respirators.

Chemical hazards

In addition to inhalation hazards addressed above, workers in integrated steel plants may be exposed to contact and ingestion hazards from chemical substances, particularly in the coke oven and COG refinery plant, where naphthalene, heavy oil compounds, and aromatic hydrocarbons are present. Recommended measures to prevent contact or ingestion of chemical substances are provided in the Factories Act.

Electrical hazards

Workers may be exposed to electrical hazards due to the presence of heavy-duty electrical equipment throughout integrated steel plants. Recommendations to prevent and control exposure to electrical hazards are provided in the Factories Act.

Noise

Raw and product material handling (e.g. ore, waste metals, plates, and bars), as well as the production processes themselves (e.g. blast furnace, BOF, EAF, continuous casting, rolling, etc.) may generate excessive noise levels. Recommended measures to prevent and control noise emissions are discussed in the Factories Act / Environment (Protection) Act, Government of India.

Entrapment

Risk of entrapment may occur in storage areas and in particular during maintenance operation (e.g. inside large mineral hopper). Measures to prevent burials include the following:

- Ensure proper containment wall for mineral heaps;
- Ensure distance between heaps and transit way;
- Develop and adopt specific safety procedures for working inside hoppers (e.g. verification systems / procedures to stop refilling belt and to close refilling hole);
- Train staff to make stable heaps and to follow procedures.

Explosion and fire hazards

Handling of liquid metal may result in explosions causing melt runout, and burns, especially if humidity is trapped in enclosed spaces. Other hazards include fires caused by melted metal, and the presence of liquid fuel and other flammable chemicals. Recommended techniques to prevent and control explosion and fire hazards include the following:

- Ensure complete dryness of materials prior to contact with liquid iron and steel;
- Design facility layout to ensure adequate separation of flammable gas, oxygen pipelines, and combustible materials and liquids from hot areas and sources of ignition (e.g. electrical panels);

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- Protect flammable gas, oxygen pipelines and combustible materials during 'hot work' maintenance activities; Design electrical equipment to prevent risk of fire in each plant area (e.g. voltage / ampere design and degree of cable insulation; protection of cables against hot liquid exposure; use of cable types that minimize fire propagation);
- Provide Disaster Management Plan (DMP) Guidance on emergency preparedness and response. Coal is susceptible to spontaneous combustion due to heating during natural oxidation of new coal surfaces. Coal dust is combustible and represents an explosion hazard in coal handling facilities associated with integrated steel mills. Recommended techniques to prevent and control explosion risks due to coal dust storage include the following:
 - Coal storage times should be minimized;
 - Coal piles should not be located above heat sources such as steam lines or manholes;
 - Covered coal storage structures should be made of noncombustible materials;
 - Storage structures should be designed to minimize the surface areas on which coal dust can settle, and dust removal systems should be provided;

Ignition sources should be kept to an absolute minimum, providing appropriate equipment grounding to minimize static electricity hazards. All machinery and electrical equipment inside the storage area or structure should be approved for use in hazardous locations and provided with spark-proof motors

3.6.6**Occupational health and safety for non-ferrous metal industry**

Occupational health and safety issues should be considered as part of a comprehensive hazard or risk assessment, including, for example, a hazard identification study [HAZID], hazard and operability study [HAZOP], or other risk assessment studies. The results should be used for health and safety management planning, in the design of the facility and safe working systems, and in the preparation and communication of safe working procedures. Occupational health and safety issues for consideration in smelting and refining operations include:

- Chemical exposure
- Physical hazards
- Noise
- Radiation
- Confined space entry

Chemical exposure

The smelting and refining sector utilizes a number of hazardous materials including acids, alkalis, and chemical reagents (e.g., in leaching and precipitation of metals, and for pollution control systems); and process gases (e.g., oxygen, carbon dioxide, argon, nitrogen, chlorine, hydrogen, among others). Workers may be exposed to hazardous materials in organic and inorganic dusts, vapors, gases, mists and fumes released as part of operations and / or human activities in all stages of production and maintenance. Inorganic hazardous materials typically include soluble and insoluble base metals (e.g. nickel, copper, and trace contaminants such as arsenic, antimony, thallium, mercury, and cadmium, among others). Trace contaminants and their metals depend on the nature of the ore being processed and the specific process being used. Exposure to acid mists may occur during leaching and / or electro-refining. Exposure to organic materials may include dioxins and furans, residual organic solvents used as reagents, and polycyclic