

# Environmental, Health, and Safety Guidelines for Integrated Steel Mills

## Introduction

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP)<sup>1</sup>. When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These industry sector EHS guidelines are designed to be used together with the **General EHS Guidelines** document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary. A complete list of industry-sector guidelines can be found at: [www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines](http://www.ifc.org/ifcext/enviro.nsf/Content/EnvironmentalGuidelines)

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them. The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account.

<sup>1</sup> Defined as the exercise of professional skill, diligence, prudence and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity as well as varying levels of financial and technical feasibility.

The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons. When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

## Applicability

The EHS Guidelines for Integrated Steel Mills include information relevant to the manufacture of pig iron and raw or low-alloy steel from iron ore and iron-based alloys. It is applicable to the manufacture of metallurgical coke; primary iron and steel production in Blast and Basic Oxygen furnaces (BF and BOF); scrap metal recycling in the electric arc furnace (EAF) process; the production of semifinished products; and hot and cold rolling activities. It does not include extraction of raw materials and further processing of the semifinished products into finished products. Guidance applicable to lime kilns, which may be present in integrated steel mills, is presented in the EHS Guidelines for Cement and Lime Manufacturing. This document is organized according to the following sections:

- Section 1.0 — Industry-Specific Impacts and Management
- Section 2.0 — Performance Indicators and Monitoring
- Section 3.0 — References
- Annex A — General Description of Industry Activities

## 1.0 Industry-Specific Impacts and Management

The following section provides a summary of EHS issues associated with steel manufacturing, which occur during the operational phase, along with recommendations for their management. Recommendations for the management of EHS issues common to most large industrial facilities during the construction and decommissioning phases are provided in the **General EHS Guidelines**.

### 1.1 Environmental

Environmental issues associated with steel manufacturing primarily include the following:

- Air emissions
- Solid waste
- Wastewater
- Noise

#### Air Emissions

In addition to the process related air emissions discussed below, air emissions may be generated from captive power plants fueled with by-product gas (e.g. coke oven gas [COG], blast furnaces [BF] gas, and basic oxygen furnace [BOF] gas). Guidance for the management of emissions from small combustion sources with a capacity of up to 50 megawatt thermal (MWth), including guidelines for exhaust emissions, is provided in the **General EHS Guidelines**. Guidance for facilities with power generating capacities in excess of 50 MWth is provided in the **EHS Guidelines for Thermal Power**.

#### *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<sup>2</sup>:

- 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;

<sup>2</sup> EC BREF (2001) on the Production of Iron and Steel

- Reduction of the coke charge in the blast furnace, including use of pulverized coal injection.

Sinter plants may generate the most significant quantity of particulate matter emissions in integrated steel mills. 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.<sup>3</sup>

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 (BF) 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

<sup>3</sup> The grain size distribution of the PM from a sinter strand before abatement consists of two types: coarse PM (with a grain size about 100 µm) and fine PM (0.1-1 µm). EC BREF (2001) on the Production of Iron and Steel.

include use of dedusting systems, typically including scrubbers and electrostatic precipitators (ESP), before reuse of the off-gas.

In direct reduction (direct reduction is an alternative route in primary steel production and may reduce overall emissions of dust and other pollutants significantly), dust releases are of similar character, though less than those of blast furnaces.

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 or without complete combustion techniques;<sup>4</sup>
- Installation of secondary controls to capture off-gas escaping from the BOF process;
- Encapsulation of metal pouring lines with fitted extractors.

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).

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

<sup>4</sup> Venturi scrubbers may achieve a particulate matter concentration of 5-10 mg/Nm<sup>3</sup>, although concentrations up to 50 mg/Nm<sup>3</sup> are also possible. This corresponds to particulate matter emission loads of 1 grams per ton (g/t) liquid steel (LS). When full combustion is used, particulate matter emissions to the atmosphere are in the range 25 to 100 mg/Nm<sup>3</sup> after treatment, corresponding to particulate matter emission loads of up to 180 g/t LS. EC BREF (2001) on the Production of Iron and Steel.

- Quick cooling of gas followed by bag filters. The bag filters can be primed with absorbents (e.g. lime or carbon) to further capture volatile impurities;
- Use of direct off-gas extraction and canopy hood enclosures and cleaning.

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. sulfur dioxide [SO<sub>2</sub>] and chlorides). Bag filters are typically installed to control melting shop emissions. They are often preceded by cyclones, which are installed to act as spark separators.<sup>5</sup>

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 (NO<sub>x</sub>) emissions are caused by high furnace temperature and the oxidation of nitrogen. NO<sub>x</sub> emissions are associated with sinter operations<sup>6</sup>; pelletization plant operations;

<sup>5</sup> The adoption of ESP or/and cyclones, as pre-treatments, and bag filters may typically achieve emissions levels from 10 to 20 mg/Nm<sup>3</sup>.

<sup>6</sup> EC BREF (2001) on the Production of Iron and Steel

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.

General recommended techniques to prevent and control the generation of NO<sub>x</sub> are addressed in the **General EHS Guidelines**. Other specific recommended techniques for the prevention and control of NO<sub>x</sub> emissions in steel operations include:

- Application of waste gas recirculation;
- Use of oven batteries with multi-stage air supply systems;
- Adoption of suppressed combustion in BOF.

### *Sulfur Dioxides*

Sulfur dioxide (SO<sub>2</sub>) emissions are mainly associated with combustion of sulfur compounds in the sinter feed, primarily introduced through the coke breeze<sup>7</sup>. SO<sub>2</sub> emissions may also result during the induration process in pelletization, and from coke oven firing.<sup>8</sup> The SO<sub>2</sub> emission level in waste gases from reheating and annealing furnaces depends on the sulfur-content in the available fuel.

General recommended techniques to prevent and control the generation of SO<sub>2</sub> emissions are addressed in the **General EHS Guidelines**. Other specific recommended techniques for the prevention and control of SO<sub>2</sub> include the following:

- Selection of raw feedstocks with low sulfur content;
- Minimizing the sulfur content of the fuel;

- Addition of absorbents such as hydrated lime [Ca(OH)<sub>2</sub>], 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<sub>3</sub>), CaO, or Ca(OH)<sub>2</sub><sup>9</sup>;
- Use of a dry scrubber, if necessary<sup>10</sup>.

### *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:

<sup>7</sup> EC BREF (2001) on the Production of Iron and Steel

<sup>8</sup> The level of SO<sub>2</sub> emissions is related to the sulfur content of the fuel (enriched blast furnace gas or coke oven gas) and the sulfur content of the coke oven gas depends on the desulfurization performance of the coke oven gas treatment plant.

<sup>9</sup> This technique can commonly achieve a SO<sub>2</sub> removal efficiency of up to 90 percent. Its implementation also allows reduction of hydrogen chloride (HCl), hydrogen fluoride (HF), ammonia (NH<sub>3</sub>), and metals emissions.

<sup>10</sup> This is a more expensive and therefore less common technique than wet scrubbers.

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

Volatile organic compounds (VOC) 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<sup>11</sup>. 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.<sup>12</sup>

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 percent);
- 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

<sup>11</sup> EC BREF (2001) on the Production of Iron and Steel

<sup>12</sup> Ibid.

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.

### 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.<sup>13</sup>

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 (CO<sub>2</sub>). 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. In addition to the sector specific information below, the **General EHS Guidelines**

contains recommendations for energy efficiency and the management of greenhouse gases.

Recommended carbon dioxide (CO<sub>2</sub>) 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<sub>4</sub>). CO<sub>2</sub> emissions from the combustion of CH<sub>4</sub> account for approximately 60 percent 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;
- 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.

<sup>13</sup> EC BREF (2001) on the Production of Iron and Steel; EC BREF (2001) on the Ferrous Metals Processing Industry.

## 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 by-products, 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 materials storage guidance presented in the **General EHS Guidelines**, and recycled into the coke making process<sup>14</sup> or sold for use in other industrial activities. Additional guidance on management of solid and hazardous waste is provided in the **General EHS Guidelines**.

### *Slag*

Slag residues may be sold as by-products (e.g. slag from BF or from BOF for use in civil engineering, road construction, and in the cement industry). 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 sludges 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 a high quality input (e.g. production of ferromagnetic materials, iron powder, or construction material, pigments, glass and ceramics)<sup>15</sup>.

### *Sludge Treatment*

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.

### *Decommissioning Waste*

Decommissioning wastes in steel manufacturing facilities may include insulation materials containing asbestos, as well as contaminated soil and groundwater media from areas such as the coal storage stockpiles, the coke oven and coke oven gas treatment plant. Guidance on the management of waste materials, decommissioning activities, and contaminated land is presented in the **General EHS Guidelines**.

## 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

<sup>14</sup> Hazardous process wastes containing organics should be recycled into coke ovens.

<sup>15</sup> EC BREF (2001) on the Ferrous Metals Processing Industry.

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 percent 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: 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 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 desulfurization processes may contain suspended solids (including heavy metals), PAHs, sulfur 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 a washing liquor and eventually drained via the still.<sup>16</sup>

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 waste water derives from rinsing, whereas the most significant contamination load comes from the continuous or batch exchange of pickle baths<sup>17</sup>.

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;

<sup>16</sup> EC BREF (2001) on the Production of Iron and Steel

<sup>17</sup> EC BREF (2001) on the Ferrous Metals Processing Industry

- Apply counterflow 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.<sup>18</sup> Additional guidance on wastewater management techniques is presented in the **General EHS Guidelines**.

Management of industrial wastewater and examples of treatment approaches are discussed in the **General EHS Guidelines**. Through use of these technologies and good practice techniques for wastewater management, facilities should meet the Guideline Values for wastewater discharge as

indicated in the relevant table of Section 2 of this industry sector document.

### *Other Wastewater Streams & Water Consumption*

Guidance on the management of non-contaminated wastewater from utility operations, non-contaminated stormwater, and sanitary sewage is provided in the **General EHS Guidelines**. 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.<sup>19</sup> Soil surrounding outdoor coal storage areas may be impacted by highly acidic leachate containing polycyclic aromatic hydrocarbons (PAHs) and heavy metals. Industry-specific recommendations include:

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

Recommendations to reduce water consumption, especially where it may be a limited natural resource, are provided in the **General EHS Guidelines**.

<sup>18</sup> EU IPPC BREF Document on BAT in the Ferrous Metals Processing Industry

<sup>19</sup> EC BREF (2001) on the Production of Iron and Steel

## 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 include 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 nighttime, where required.

Noise abatement measures should achieve the ambient noise levels described in the **General EHS Guidelines**.

## 1.2 Occupational Health and Safety

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, and their prevention and control is discussed in the **General EHS Guidelines**.

In addition, the following occupational health and safety issues are specific to steel manufacturing activities:

- Physical hazards
- Heat and hot liquids
- Radiation
- Respiratory hazards
- Chemical hazards

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

## Physical Hazards

Recommendations for the prevention and control of general physical hazards are presented in the **General EHS Guidelines**. Industry specific physical hazards are discussed below.

Potential physical hazards in integrated steel mill 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 mills. 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;
- 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 mills. 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 cooling ventilation to control extreme temperatures;
- Implement work rotations providing regular work breaks, access to a cool rest area, and drinking water.

## Radiation

Gamma ray testing of steel mill equipment and products during operation is typically required to determine the steel composition and integrity. The following techniques may be used 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;
- 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 internationally 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 sulfur 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 facility ventilation to maximize air circulation. Outlet air shall be filtered before discharge to the atmosphere;
- Exhaust ventilation should be installed at the significant point sources of dust and gas emissions, particularly the BF topping 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;
- 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 mills 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 **General EHS Guidelines**.

### Electrical Hazards

Workers may be exposed to electrical hazards due to the presence of heavy-duty electrical equipment throughout integrated steel mills. Recommendations to prevent and control exposure to electrical hazards are provided in the **General EHS Guidelines**.

### 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 **General EHS Guidelines**.

### 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);
- 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);
- Guidance on emergency preparedness and response is provided in the **General EHS Guidelines**.

Coal is susceptible to spontaneous combustion due to heating during natural oxidation of new coal surfaces<sup>20,21</sup>. 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 non-combustible 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.

### 1.3 Community Health and Safety

Community health and safety issues during the construction, operation, and decommissioning of integrated steel mills are

<sup>20</sup> NFPA 850: Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations (2000 Edition).

<sup>21</sup> NFPA 120: Standard for Fire Prevention and Control in Coal Mines (2004 Edition).

common to those of most industrial facilities, and are discussed, along with recommended management actions for prevention and control, in the **General EHS Guidelines**.

## 2.0 Performance Indicators and Monitoring

### 2.1 Environment

#### Emissions and Effluent Guidelines

Tables 1 and 2 present emission and effluent guidelines for this sector. Guideline values for process emissions and effluents in this sector are indicative of good international industry practice as reflected in relevant standards of countries with recognized regulatory frameworks. These guidelines are achievable under normal operating conditions in appropriately designed and operated facilities through the application of pollution prevention and control techniques discussed in the preceding sections of this document.

Emissions guidelines are applicable to process emissions. Combustion source emissions guidelines associated with steam and power generation activities from sources with a capacity equal to or lower than 50 megawatts thermal input (MWth) are addressed in the **General EHS Guidelines** with larger power source emissions addressed in the **EHS Guidelines for Thermal Power**. Guidance on ambient considerations based on the total load of emissions is provided in the **General EHS Guidelines**.

Effluent guidelines are applicable for direct discharges of treated effluents to surface waters for general use. Site-specific discharge levels may be established based on the availability and conditions in the use of publicly operated sewage collection and treatment systems or, if discharged directly to surface waters, on the receiving water use classification as described in the **General EHS Guidelines**. These levels should be achieved,

without dilution, at least 95 percent of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours. Deviation from these levels in consideration of specific, local project conditions should be justified in the environmental assessment.

### Environmental Monitoring

Environmental monitoring programs for this sector should be implemented to address all activities that have been identified to have potentially significant impacts on the environment, during normal operations and upset conditions. Environmental monitoring activities should be based on direct or indirect indicators of emissions, effluents, and resource use applicable to the particular project.

Monitoring frequency should be sufficient to provide representative data for the parameter being monitored. Monitoring should be conducted by trained individuals following monitoring and record-keeping procedures and using properly calibrated and maintained equipment. Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Additional guidance on applicable sampling and analytical methods for emissions and effluents is provided in the **General EHS Guidelines**.

### Resource Use and Emission / Waste Generation

Table 3 provides examples of resource consumption indicators for energy and water in this sector, whereas Table 4 provides examples of emission and waste generation indicators. Industry benchmark values are provided for comparative purposes only and individual projects should target continual improvement in these areas.

Table 1. Air Emission Levels for Integrated Steel Mills <sup>c</sup>		
Pollutant	Units	Guideline Value
Particulate Matter	mg/Nm <sup>3</sup>	20-50 <sup>a</sup>
Oil Mist	mg/Nm <sup>3</sup>	15
NO <sub>x</sub>	mg/Nm <sup>3</sup>	500 750 (coke oven)
SO <sub>2</sub>	mg/Nm <sup>3</sup>	500
VOC	mg/Nm <sup>3</sup>	20
PCDD/F	ng TEQ/ Nm <sup>3</sup>	0.1
Carbon Monoxide (CO)	mg/Nm <sup>3</sup>	100 (EAF) 300 (coke oven)
Chromium (Cr)	mg/Nm <sup>3</sup>	4
Cadmium (Cd)	mg/Nm <sup>3</sup>	0.2
Lead (Pb)	mg/Nm <sup>3</sup>	2
Nickel (Ni)	mg/Nm <sup>3</sup>	2
Hydrogen Chloride (HCl)	mg/Nm <sup>3</sup>	10
Fluoride	mg/Nm <sup>3</sup>	5
Hydrogen Fluoride (HF)	mg/Nm <sup>3</sup>	10
H <sub>2</sub> S	mg/Nm <sup>3</sup>	5
Ammonia	mg/Nm <sup>3</sup>	30
Benzo(a)pirene	mg/Nm <sup>3</sup>	0.1
Tar fume <sup>b</sup>	mg/Nm <sup>3</sup>	5
Notes:		
<sup>a</sup> Lower value where toxic metals are present		
<sup>b</sup> Tar fume measured as organic matter extractable by solvent from total matter collected by membrane filter		
<sup>c</sup> 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).		

**Table 2. Effluents Levels for Integrated Steel Mills Sector**

Pollutants	Units	Guideline Value
pH	-	6-9
TSS	mg/L	35
Oil and grease	mg/L	10
Temperature increase	°C	<3 <sup>a</sup>
COD	mg/L	250
Phenol	mg/L	0.5
Cadmium	mg/L	0.01
Chromium (total)	mg/L	0.5
Chromium (hexavalent)	mg/L	0.1
Copper	mg/L	0.5
Lead	mg/L	0.2
Tin	mg/L	2
Mercury	mg/L	0.01
Nickel	mg/L	0.5
Zinc	mg/L	2
Cyanides (free)	mg/L	0.1
Cyanides (total)	mg/L	0.5
Total Nitrogen	mg/L	30
Ammonia	mg/L (as N)	5
Total Phosphorous	mg/L	2
Fluoride	mg/L (as F)	5
Sulfides	mg/L	0.1
Iron	mg/L	5
PAH	mg/L	0.05
Toxicity	To be determined on a case specific basis	

<sup>a</sup> At the edge of a scientifically established mixing zone which takes into account ambient water quality, receiving water use, potential receptors and assimilative capacity

**Table 3. Resources and Energy Consumption (1)**

Inputs per unit of Product	Mass Load Unit	Industry Benchmark					
		Sinter	Coke Ovens	BF	BOF	EHF	Rolling
Electricity, direct	MJ/t product	90-120	20-170	270-370	40-120	1250-1800	70-140 kWh/t
Fuel	MJ/t product	60-200	3,200-3,900	1,050-2,700	20-55	-	1,100-2,200
Water	m <sup>3</sup> /t product	0.01-0.35	1-10	1-50	0.5-5	3	1-15

Sources:

- European Commission, IPPC, "BREF Document on the Production of Iron and Steel" and "Reference Document in BAT in the Ferrous Metals Processing Industry". December 2001
- UK Environmental Agency. 2001, 2002. Technical Guidance Notes. IPPC S2.01, S2.04. Benchmark values.

**Table 4. Emission / Waste Generation**

Outputs per unit of product	Unit	Industry Benchmark					
		Sinter	Coke Ovens	BF	BOF	EHF	Rolling
Emissions (1) (2)							
Particulate Matter	Kg/T product	0.04-0.4	0.05-3.5	0.005	0.2	0.02	0.002-0.040
CO	Kg/T product	12-40	0.40-4.5	0.8-1.75	1.5-8	0.75-4	0.005-0.85
NO <sub>x</sub>	Kg/T product	0.4-0.65	0.45-0.7	0.01-0.6	-	0.12-0.25	0.08-0.35
VOC	Kg/T product	0.15	0.12-0.25	-	-	-	-
PCDD/F	µg-TEQ/T product	1-10	--	-	-	0.07-9	-
Waste (1)							
Solid Waste	Kg/T product	0.9-15	-	200-300	85-110	110-180	70-150
Sludge	Kg/T product	0.3	-	3-5	-	-	-
Waste Water	m <sup>3</sup> /T product	0.06	0.3-0.4	0.1-3	-	-	0.8-15

Sources:

- European Commission, IPPC, "BREF Document on the Production of Iron and Steel" and "Reference Document in BAT in the Ferrous Metals Processing Industry" December 2001
- UK Environmental Agency. 2001, 2002. Technical Guidance Notes. IPPC S2.01, S2.04. Benchmark values.

## 2.2 Occupational Health and Safety

### Occupational Health and Safety Guidelines

Occupational health and safety performance should be evaluated against internationally published exposure guidelines, of which examples include the Threshold Limit Value (TLV<sup>®</sup>) occupational exposure guidelines and Biological Exposure Indices (BEIs<sup>®</sup>) published by American Conference of Governmental Industrial Hygienists (ACGIH),<sup>22</sup> the Pocket Guide to Chemical Hazards published by the United States National Institute for Occupational Health and Safety (NIOSH),<sup>23</sup> Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United States (OSHA),<sup>24</sup> Indicative Occupational Exposure Limit Values published by European Union member states,<sup>25</sup> or other similar sources.

### Accident and Fatality Rates

Projects should try to reduce the number of accidents among project workers (whether directly employed or subcontracted) to a rate of zero, especially accidents that could result in lost work time, different levels of disability, or even fatalities. Facility rates may be benchmarked against the performance of facilities in this sector in developed countries through consultation with published sources (e.g. US Bureau of Labor Statistics and UK Health and Safety Executive)<sup>26</sup>.

### Occupational Health and Safety Monitoring

The working environment should be monitored for occupational hazards relevant to the specific project. Monitoring should be

designed and implemented by accredited professionals<sup>27</sup> as part of an occupational health and safety monitoring program. Facilities should also maintain a record of occupational accidents and diseases and dangerous occurrences and accidents. Additional guidance on occupational health and safety monitoring programs is provided in the General EHS Guidelines.

<sup>22</sup> Available at: <http://www.acgih.org/TLV/> and <http://www.acgih.org/store/>

<sup>23</sup> Available at: <http://www.cdc.gov/niosh/hpg/>

<sup>24</sup> Available at:  
[http://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDAR DS&p\\_id=9992](http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDAR DS&p_id=9992)

<sup>25</sup> Available at: [http://europe.osha.eu.int/good\\_practice/risks/ds/oel/](http://europe.osha.eu.int/good_practice/risks/ds/oel/)

<sup>26</sup> Available at: <http://www.bis.gov/iif/> and  
<http://www.hse.gov.uk/statistics/index.htm>

<sup>27</sup> Accredited professionals may include Certified Industrial Hygienists, Registered Occupational Hygienists, or Certified Safety Professionals or their equivalent.

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[http://www.nfpa.org/aboutthecodes/list\\_of\\_codes\\_and\\_standards.asp](http://www.nfpa.org/aboutthecodes/list_of_codes_and_standards.asp)

## **Annex A: General Description of Industry Activities**

The main methods used in steel and iron production include the blast-furnace / basic oxygen furnace (integrated steelworks), direct melting of scrap or pig iron (electric arc furnace), and the less frequently used method of Direct Reduction of Iron (DRI) process. Integrated steelworks are a complex process and involve material and energy flows among various production units, including the sinter or pelletization plant, the coke oven plant, the blast furnace (BF), the basic oxygen furnace (BOF), and continuous casting. The cast steel is then rolled (cold and / or hot) to produce final products.

### **Sinter Plants<sup>28</sup>**

Physical and metallurgical preparation of the ore burden is undertaken in order to improve permeability and reducibility. Prior to the sintering operation, raw materials are blended and some flux materials may also be added. After blending, the ore blend is transferred from the preparation bunkers to storage bunkers. Coke breeze (small-grade coke with particle sizes of < 5 mm) is the most commonly used fuel for the sintering process. The ore blend and the coke breeze are mixed and dampened to enhance the formation of micro pellets, which improve the permeability when placed on the sinter bed.

The sinter plant essentially consists of a large traveling grate of heat resistant cast iron. The material to be sintered is layered to form a 400-600 mm deep bed, although shallower beds are common in older plants, which is placed on top of a thin layer of recycled sinter. This bottom layer protects the grate from the direct heat of the burning mixture. The grate passes through a canopy of gas burners that ignites the coke breeze in the mixture, starting a down-draft process through the entire length of the sinter bed. As the sinter mixture proceeds along the grate, the combustion front is drawn downwards through the mixture. This generates sufficient heat (1300-1480°C) to sinter the fine

particles together into a porous clinker referred to as sinter. Exhausted gases are treated to remove dust before being emitted to atmosphere. The produced sinter is then crushed and riddled to obtain the proper dimension for the burden of the blast furnace.

### **Pelletization Plant<sup>29</sup>**

Pelletization is another process for the preparation of iron oxide raw materials for primary iron and steel making. Pellets are formed from the raw materials (fine ore and additives of < 0.05 mm) into 9-16 mm spheres, using high temperatures, typically at the mining site or its shipping port.

The pelletization process consists of grinding and drying or dewatering, balling and induration. Prior to the pelletization, the ore is crushed and grinded to achieve the necessary properties to form pellets. The moisture content is adjusted to 8–9 percent. The pellet feed is mixed with additives and then processed into 9 – 16 mm (green) balls followed by heating to approximately 1250 °C (induration) during oxidation and sintering to obtain high strength pellets. Before exiting the induration process, pellets are cooled by air. Undersize or broken pellets are generally recycled.

### **Coke Making**

Integrated steel mills that manufacture steel by reducing iron ore in a blast furnace need a steady supply of coke. The primary function of coke is to chemically reduce iron oxide to iron metal in the blast furnace. Coke acts as a fuel, provides physical support, and allows the free flow of gas through the furnace. Coke manufacture is therefore closely connected to integrated steel mills that use iron ore. Coke is produced by the pyrolysis (e.g. heating in the absence of air) of suitable grades of coal. In the coke-making process, bituminous coal is fed into a series of

<sup>28</sup> EC BREF (2001) on the Production of Iron and Steel

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ovens (batteries), which are sealed and heated at high temperatures, in the absence of oxygen. The operation comprises the following steps: coal charging, heating / firing of the chambers, coking, coke pushing, and coke quenching.<sup>30</sup>

The individual coke oven chambers are separated by heating walls. These consist of a certain number of heating flues with nozzles for fuel supply and with one or more air inlet boxes. Usually, cleaned coke oven gas is used as a fuel, but other gases such as (enriched) blast furnace gas can also be used. Regenerators are located under the ovens, to allow heating of combustion air and fuel gas by flue gas, and improve energy efficiency.

The carbonization process starts immediately after coal charging. Volatile organic compounds (VOC) are eliminated from the coal, and forms a coke oven gas (COG). The solid carbon which remains in the oven is the coke. Depending on oven width and heating conditions the coking process lasts for approximately 14 to 24 hours. The coke is pushed out of the oven into a container by the ram of a pusher machine. The container transports the hot coke to a quenching tower, where it is cooled by dry quenching which consists of circulating an inert gas (nitrogen).<sup>31</sup> If wet quenching is used (typically in older units), treated (phenol-free) effluent water should be used.

The process also includes the treatment of the by-product coke oven gas (COG) to remove tar, ammonia (usually recovered as ammonium sulfate), phenol, naphthalene, BTX, light oil, and sulfur, before the COG can be used as fuel for heating the ovens or used elsewhere in the plant.

To reduce environmental impacts from coke production, green push (coal that is not fully carbonized) should be avoided and coals with low sulfur content or desulfurized (washed) coals are

preferred. Gases and tar in the coke process should be collected and recovered and sulfur dioxide (SO<sub>2</sub>) gas cleaning should be applied, especially if coals with high sulfur content are used.

## **Blast Furnaces (BF)**

A blast furnace (BF) is an enclosed system into which the raw materials enter at the top, while the products (molten iron and slag) are tapped from the bottom (the hearth). The raw material mixture of iron bearing materials (iron ore rubble, sinter and / or pellets) and additives (slag former, such as limestone) is called the "burden". The burden and the coke are fed into the top of the furnace via a sealed charging system to prevent furnace gases from escaping. The solid burden moves downwards, countercurrent of a rising stream of hot reducing gas. The hot reducing gas is provided by hot stoves and is needed to transfer heat to the solid burden in order to raise the temperature for reaction. The BF gas with residual calorific value is collected from the top of the furnace for treatment and use.<sup>32</sup>

The blast furnace is periodically tapped to remove the molten pig iron and slag from the hearth. For this purpose a tap-hole is opened in the side wall of the hearth. The tapped metal has a temperature of approximately 1440-1500 °C. In modern blast furnaces, pig iron and slag are tapped together (typically the slag starts to run after the hot metal). The slag and pig iron from the furnace flows along refractory or low cement covered runners and they are subsequently separated at the skimmer in the cast house, after which each continues in a separate runner. Molten pig iron is poured into ladles or torpedo cars. Slag flows in runners to a granulation plant, to slag ladles, or to an open pit. At the end of the casting cycle, the tap-hole is closed by

<sup>30</sup> EC BREF (2001) on the Production of Iron and Steel

<sup>31</sup> Ibid.

<sup>32</sup> Ibid.

injecting a heat resistant tap hole clay mixture, using a so-called "mudgun".<sup>33</sup>

The main emissions from the BF occur during tapping operations and primarily constitute iron oxide particulates and graphite. These particulates are usually controlled by local hooding within the cast house and emissions are directed to a fabric filter. Variable quantities of hydrogen sulfide and SO<sub>2</sub> are emitted from slag cooling and treatment. Some fugitive emissions, including iron oxides and graphite flakes, occur during hot metal transport to the steel melt shop. Collected dust and sludge from the gas cleaning system may be recycled to a sinter plant or sent to a solid waste disposal site.

Wastewater effluents result from BF gas cleaning, slag cooling, and processing operations. Recirculation is used and the remaining stream is treated to remove solids, metals, and oil before discharge. Slag is the main solid by-product. It can be processed in a variety of ways, including granulating and pelletizing, or it can be quench cooled, crushed, and screened. The slag is sold as a by-product, primarily to the cement and construction industries.

### Basic Oxygen Furnaces (BOF)<sup>34</sup>

The Basic Oxygen Furnace (BOF) and the electric arc furnace (EAF) processes, comprise the commonly used methods to convert pig iron produced by BF into steel. Oxygen injection oxidizes undesirable impurities contained in the metallic feedstock. The main elements converted into oxides are carbon, silicon, manganese, phosphorus, and sulfur. Oxidation reduces the carbon content to a specified level (from approximately 4 percent to less than 1 percent, but often lower), and removes impurities. The production of steel by the BOF process is a discontinuous process including pre-treatment of hot metal (desulfurization); oxidation in the BOF (decarburization and

oxidation of impurities); secondary metallurgical treatment after the BOF in the ladle furnace, and casting (continuous and / or ingot).

The desulfurization process is performed at separate treatment stations before the BOF. The most common hot metal desulfurization method is based on calcium carbide, blown through a lance into the hot metal with the aid of nitrogen. The sulfur is bound in the slag, which floats to the top of the hot metal. The slag is then removed. In some cases, a second slag removal is performed, using slag scrapers. The pig iron is then charged into the BOF.<sup>35</sup>

The operation of a basic oxygen furnace (BOF) is a batch operation. A complete cycle consists of the following phases: charging scrap and molten pig iron; oxygen blowing; sampling and temperature recording; and tapping. In a modern steelworks, approximately 300 tonnes of steel are produced in a 30-40 minute cycle. During the process several additives are used to adapt the steel quality and to form slag. The energy required to raise the temperature and melt the input materials is supplied by the exothermic oxidation reactions when oxygen is blown, so that no additional heat input is needed and scrap or ore have been added to balance heat.

The amount of oxygen consumed depends on the composition of the hot metal (e.g. mainly carbon, silica and phosphorous content). When the steel quality meets the demands, the oxygen blowing is stopped and the crude steel is tapped from the BOF into a ladle.

The oxidizing process in the BOF is usually followed by post-treatment comprising diverse metallurgical operations, and referred to as "secondary metallurgy". This post-treatment phase was developed in response to increasing quality requirements. The main objectives of secondary metallurgy

<sup>33</sup> EC BREF (2001) on the Production of Iron and Steel

<sup>34</sup> Ibid.

<sup>35</sup> Ibid.

include mixing and homogenizing; adjustment of chemical compositions; temperature adjustment; deoxidation; removal of undesirable gases (e.g. hydrogen and nitrogen); and improvement of the oxidic purity by separating non-metallic inclusions. These operations are performed in the ladle or ladle furnace, in a vacuum system, or in specially designed furnaces. After post-treatment, the molten steel is transported to the casting machine.<sup>36</sup>

### **Electric Arc Furnaces (EAF)**

Steel can be produced from scrap steel in an electric arc furnace (EAF) in which the scrap is melted. The scrap is usually pre-heated in a specific furnace and loaded together with lime or dolomite, which are used as a flux for the slag formation. It is normal to charge about 50-60 percent of the scrap initially. The electrodes are then lowered to the scrap. Within 20-30 mm above the scrap they strike an arc. After the first charge has been melted, the remainder of the scrap is added.<sup>37</sup>

During the initial period of melting, the applied power is kept low to prevent damage to the furnace walls and roof from radiation, while allowing the electrodes to bore into the scrap. As soon as the arcs have become shielded by the surrounding scrap, the power is increased to complete melting. Oxygen lances and / or oxy-fuel burners are frequently used to assist in the early stages of melting. Oxygen may be added to the liquid steel by specific nozzles in the bottom or side wall of the EAF. Fuels include natural gas and oil.

The fugitive emissions from scrap charging, oxygen blowing, tapping, hot metal transfer, and slag handling are usually collected by local hooding and de-dusted in fabric filters. Minor emissions of particulates arise from ladle metallurgy processes and vacuum degassing and they are usually collected and cleaned by fabric filters.

Some wastewater effluent may be generated by the degassing process. The main solid wastes include steel skulls, slag, and waste refractories. Other solid wastes include the wastewater treatment sludge and dust from dry dust collectors. Dust may contain dioxins and furans due to largely external (dirty) scrap consumption. The steel skulls are usually recycled, the slag is crushed and screened for recycle or sale, and other solid wastes are recycled, when appropriate, or disposed of in a landfill site. The EAF uses a large amount of electric power.

The open-hearth furnace technology, also known as the Siemens-Martins process, is outdated and no longer considered good industry practice. It has a detrimental effect on steel quality and significant environmental impacts.

### **Direct Reduction**

In the direct reduction process, lump iron oxide pellets and lump iron ore are reduced (oxygen is removed) to metallic iron in the solid state by a reducing gas. Process temperatures are less than 1000°C. A solid product, called direct reduced iron (DRI), is produced. The process is advantageous from an environmental point of view, largely because it allows the use of pelletized or lump ore, however, this process has primarily been used for special steel grades or where natural gas is available at competitive prices.

### **Casting, Rolling, and Finishing**

Further steel processing includes casting, hot rolling, forming, pickling, cold rolling, wire drawing, and coating. The continuous casting process bypasses several steps of the conventional ingot process by casting steel directly into slabs or billets and typically achieves 10 – 12 percent higher yield. Hot steel is transformed in size and shape through a series of hot rolling and forming steps to manufacture semifinished and finished steel products.

<sup>36</sup> EC BREF (2001) on the Production of Iron and Steel

<sup>37</sup> EC BREF (2001) on the Production of Iron and Steel

The liquid steel after secondary metallurgy is transported to the so called "tundish" of the continuous casting machine (CCM). This is an intermediate ladle with controllable outlet. The ladles are preheated prior to accepting a liquid steel charge in order to avoid temperature stratification in the tundish. When the liquid steel has reached the desired temperature, it is poured into the tundish. From the tundish it passes to a short water-cooled copper mold in which no air is present and which performs oscillating movements to prevent the steel from sticking. The mold gives the metal the desired shape. When the metal leaves the casting mold, a "skin" of solidified steel has formed and a large number of rolls guide the cast steel with a gentle curve toward a horizontal position. At this point, the endless casting is cut in pieces with a torch cutter. Slabs, blooms and billets are cast in this way.

In ingot casting, the liquid steel is cast into casting molds. After cooling, the ingots are taken out of the casting mold and transported to the rolling mills. Subsequently, following pre-heating, the ingots are rolled into slabs, blooms or billets. Ingot casting is currently largely replaced by continuous casting except for products which require ingot casting to achieve the necessary quality (e.g. producing heavy weights for forging).

The hot rolling process consists of slab-heating (as well as billet and bloom), rolling, and forming operations. Several types of hot forming mills (primary, section, flat, pipe and tube, wire, rebar, and profile) manufacture diverse steel products. Long products are manufactured by hot rolling billets into reinforcement bars, or for further rolling and drawing into wire rods and sometimes coating. To prepare the steel for cold rolling or drawing, acid pickling (inorganic acid water solutions with sulfuric or hydrochloric acid) is performed to chemically remove oxides and scale from the surface of the steel. Other methods to remove scale include salt pickling and electrolytic pickling.

Cold rolling follows hot rolling operations, for the manufacture of a thin strip or a strip with a high-quality finish. Lubricants emulsified in water are used to achieve high surface quality and to prevent overheating. Water, oil, or lead baths are used for cooling and to create desired features.

Air emissions of PM and metals arise during the transfer of the molten steel to the mold and cutting the product to length by oxy-fuel torches. Air emissions from hot forming include gases generated by the combustion of fuel in the heating furnaces and VOC from rolling and lubrication oils. Other important air emissions include acid aerosols from the acid-pickling operations and the acid regeneration plant, if acid regeneration is used. Wastewater effluents are generated when cooling the hot metal and include scale particles and oil generated from the high-pressure water descaling of the hot steel, as well as suspended solids, oil, and grease. The major sources of wastewater effluents are the acid-pickling rinse water, acid fume scrubber, acid regeneration plant scrubber, and alkaline cleaning. Solid waste is generated while cutting the steel, but this is generally recycled within the plant.

*Figure A.1: Integrated Steel Production Processes*



