Iron and Steel Manufacturing

Industry Description and Practices

Steel is manufactured by the chemical reduction of iron ore, using an integrated steel manufacturing process or a direct reduction process. In the conventional integrated steel manufacturing process, the iron from the blast furnace is converted to steel in a basic oxygen furnace (BOF). Steel can also be made in an electric arc furnace (EAF) from scrap steel and, in some cases, from direct reduced iron. BOF is typically used for high-tonnage production of carbon steels, while the EAF is used to produce carbon steels and low-tonnage specialty steels. An emerging technology, direct steel manufacturing, produces steel directly from iron ore. This document deals only with integrated iron and steel manufacturing; that on Mini Steel Mills addresses the electric arc steel process and steel finishing processes. Steel manufacturing and finishing processes discussed in that document are also employed in integrated steel plants. See also Coke Manufacturing.

In the BOF process, coke making and iron making precede steel making; these steps are not necessary with an EAF. Pig iron is manufactured from sintered, pelletized, or lump iron ores using coke and limestone in a blast furnace. It is then fed to a BOF in molten form along with scrap metal, fluxes, alloys, and high-purity oxygen to manufacture steel. In some integrated steel mills, sintering (heating without melting) is used to agglomerate fines and so recycle iron-rich material such as mill scale.

Waste Characteristics

Sintering operations can emit significant dust levels of about 20 kilograms per metric ton (kg/t) of steel. Pelletizing operations can emit dust levels of about 15 kg/t of steel. Air emissions from pig iron manufacturing in a blast furnace include particulate matter (PM), ranging from less than 10 kg/t of steel manufactured to 40 kg/t; sulfur oxides (SO_x), mostly from sintering or pelletizing operations (1.5 kg/t of steel); nitrogen oxides (NO_x), mainly from sintering and heating (1.2 kg/t of steel); hydrocarbons; carbon monoxide; in some cases dioxins (mostly from sintering operations); and hydrogen fluoride.

Air emissions from steel manufacturing using the BOF may include PM (ranging from less than 15 kg/t to 30 kg/t of steel). For closed systems, emissions come from the desulfurization step between the blast furnace and the BOF; the particulate matter emissions are about 10 kg/t of steel.

In the conventional process without recirculation, wastewaters, including those from cooling operations, are generated at an average rate of 80 cubic meters per metric ton ($m^{3/}t$) 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 mg/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.

Pollution Prevention and Control

Where technically and economically feasible, direct reduction of iron ore for the manufacture of iron and steel is preferred because it does not require coke manufacturing and has fewer environmental impacts. Wherever feasible, pelletizing should be given preferences over sintering for the agglomeration of iron ore. The following pollution prevention measures should be considered.

Pig Iron Manufacturing

- Improve blast furnace efficiency by using coal and other fuels (such as oil or gas) for heating instead of coke, thereby minimizing air emissions.
- Recover the thermal energy in the gas from the blast furnace before using it as a fuel. Increase fuel efficiency and reduce emissions by improving blast furnace charge distribution.
- Improve productivity by screening the charge and using better taphole practices.
- Reduce dust emissions at furnaces by covering iron runners when tapping the blast furnace and by using nitrogen blankets during tapping.
- Use pneumatic transport, enclosed conveyor belts, or self-closing conveyor belts, as well as wind barriers and other dust suppression measures, to reduce the formation of fugitive dust.
- Use low- NO_x burners to reduce NO_x emissions from burning fuel in ancillary operations.
- Recycle iron-rich materials such as iron ore fines, pollution control dust, and scale in a sinter plant.
- Recover energy from sinter coolers and exhaust gases.
- Use dry SO_x removal systems such as caron absorption for sinter plants or lime spraying in flue gases.

Steel Manufacturing

- Use dry dust collection and removal systems to avoid the generation of wastewater. Recycle collected dust.
- Use BOF gas as fuel.
- Use enclosures for BOF.
- Use a continuous process for casting steel to reduce energy consumption.

Other

Use blast furnace slag in construction materials. Slag containing free lime can be used in iron making.

Target Pollution Loads

The recommended pollution prevention and control measures can achieve the following target levels.

Liquid Effluents

Over 90% of the wastewater generated can be reused. Discharged wastewaters should in all cases be less than 5 m^3/t of steel manufactured and preferably less than 1 m^3/t.

Solid Wastes

Blast furnace slag should normally be generated at a rate of less than 320 kg / t of iron, with a target of 180 kg / t. The generation rate, however, depends on the impurities in the feed materials. Slag generation rates from the BOF should be between 50 and 120 kg / t of steel manufactured, but this will depend on the impurity content of feed materials. Zinc recovery may be feasible for collected dust.

Treatment Technologies

Air Emissions

Air emission control technologies for the removal of particulate matter include scrubbers (or semidry systems), baghouses, and electrostatic precipitators (ESPs). The latter two technologies can achieve 99.9% removal efficiencies for particulate matter and the associated toxic metals: chromium (0.8 milligrams per normal cubic meter, mg / Nm^3), cadmium (0.08 mg / Nm^3), lead (0.02 mg / Nm^3), and nickel (0.3 mg / Nm^3).

Sulfur oxides are removed in desulfurization plants, with a 90% or better removal efficiency. However, the use of low-sulfur fuels and ores may be more cost-effective.

The acceptable levels of nitrogen oxides can be achieved by using low-NO_x burners and other combustion modifications.

For iron and steel manufacturing, the emissions levels presented in Table 1 should be achieved.

Wastewater Treatment

Wastewater treatment systems typically include sedimentation to remove suspended solids, physical or chemical treatment such as pH adjustment to precipitate heavy metals, and filtration.

The target levels presented in Table 2 can be achieved for steel-making processes.

Solid Waste Treatment

Solid wastes containing heavy metals may have to be stabilized, using chemical agents, before disposal.

Emissions Guidelines

Emissions levels for the design and operation of each project must be established through the environmental assessment (EA) process on the basis of country legislation and the *Pollution Prevention and Abatement Handbook*, as applied to local conditions. The emissions levels selected must be justified in the EA and acceptable to the World Bank Group.

Table 1. Load Targets per Unit of Production, Iron and Steel Manufacturing

Parameter	*Maximum value*
PM_{10}	100 g/t of product (blast furnace, basic oxygen furnace); 300 g/t from sintering process
Sulfur oxides	For sintering: 1,200 g/t; 500 mg/m^3
Nitrogen oxides	For pelletizing plants: 500 g/t; 250–750 mg/Nm^3; for sintering plants: 750 mg/Nm^3
Fluoride	1.5 g/t; 5 mg/Nm^3

Table 2. Target Load per Unit of Production, Steel Manufacturing

(emissions per metric ton of product)

Parameter	*Blast furnace*	*Basic oxygen furnace*
Wastewater	0.1 m^3	0.5 m^3
Zinc	0.6 g	3 g
Lead	0.15 g	0.75 g
Cadmium	0.08 g	n.a.

n.a. Not applicable.

The guidelines given below present emissions levels normally acceptable to the World Bank Group in making decisions regarding provision of World Bank Group assistance. Any deviations from these levels must be described in the World Bank Group project documentation. The emissions levels given here can be consistently achieved by well-designed, well-operated, and well-maintained pollution control systems.

The guidelines are expressed as concentrations to facilitate monitoring. Dilution of air emissions or effluents to achieve these guidelines is unacceptable.

All of the maximum levels should be achieved for at least 95% of the time that the plant or unit is operating, to be calculated as a proportion of annual operating hours.

Air Emissions

For integrated iron and steel manufacturing plants, the emissions levels presented in Table 3 should be achieved.

Liquid Effluents

The effluent levels presented in Table 4 should be achieved.

Table 3. Air Emissions from Iron and Steel Manufacturing
(milligrams per normal cubic meter)

Parameter	*Maximum value*
PM	50
Sulfur oxides	500 (sintering)
Nitrogen oxides	750
Fluorides	5

Sludges

Sludges should be disposed of in a secure landfill after stabilization of heavy metals to ensure that heavy metal concentration in the leachates do not exceed the levels presented for liquid effluents.

Ambient Noise

Noise abatement measures should achieve either the levels given below or a maximum increase in background levels of 3 decibels (measured on the A scale) [dB(A)]. Measurements are to be taken at noise receptors located outside the project property boundary.

Receptor	*Maximum allowable log equivalent (hourly measurements), in dB(A)*	
	Day (07:00–22:00)	*Night (22:00–07:00)*
Residential, institutional, educational	55	45
Industrial, commercial	70	70

Table 4. Effluents from Iron and Steel Manufacturing
(milligrams per liter, except pH and temperature)

Parameter	*Maximum value*
pH	6–9
TSS	50
Oil and grease	10
COD	250
Phenol	0.5
Cadmium	0.1
Chromium (total)	0.5
Lead	0.2
Mercury	0.01
Zinc	2
Cyanide	
Free	0.1
Total	1
Temperature increase	£ 3°C[a]

Note: Effluent requirements are for direct discharge to surface waters.

a. The effluent should result in a temperature increase of no more than 3° C at the edge of the zone where initial mixing and dilution take place. Where the zone is not defined, use 100 meters from the point of discharge.

Monitoring and Reporting

Air emissions should be monitored continuously after the air pollution control device for particulate matter (or alternatively an opacity level of less than 10%) and annually for sulfur oxides, nitrogen oxides (with regular monitoring of sulfur in the ores), and fluoride. Wastewater discharges should be monitored daily for the listed parameters, except for metals, which should be monitored at least on a quarterly basis. Frequent sampling may be required during start-up and upset conditions.

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. Baseline data on fugitive PM emissions should be collected and used for comparison with future emissions estimates, which should be performed every three years based on samples collected. Records of monitoring results should be kept in an acceptable format. The results should be reported to the responsible authorities and relevant parties, as required.

Key Issues

The key production and control practices that will lead to compliance with emissions guidelines are summarized here.

- Prefer the direct steel manufacturing process where technically and economically feasible.
- Use pelletized feed instead of sintered feed where appropriate.

- Replace a portion of the coke used in the blast furnace by injecting pulverized coal or by using natural gas or oil.
- Achieve high-energy efficiency by using blast furnace and basic oxygen furnace off-gas as fuels.
- Implement measures (such as encapsulation) to reduce the formation of dust, including iron oxide dust; where possible, recycle collected dust to a sintering plant.
- Recirculate wastewaters. Use dry air pollution control systems where feasible. Otherwise, treat wastewaters.
- Use slag in construction materials to the extent feasible.

Sources

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