Steel Industry and the Environment

Technical and Management Issues

ECHNICAL REPORT N° 38

UNEP

UNITED NATIONS ENVIRONMENT PROGRAMME
INDUSTRY AND ENVIRONMENT

IISI

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TECHNICAL AND MANAGEMENT ISSUES

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Foreword

The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992 called upon business and industry to *"recognise environmental management as among the highest corporate priorities and as a key determinant to sustainable development."* Implicit in this is that a fundamental shift is required in the way we do business — on both a professional and personal level.

As early as 1984, the International Iron and Steel Institute (IISI) had worked with UNEP to produce guidance documents on the environmental aspects of iron- and steelmaking. However, as new environmental issues emerged and older ones broadened, UNEP and IISI believed that a new publication was needed. With the additional impetus now provided by Agenda 21, the steel industry has again collaborated with the United Nations Environment Programme to produce a publication to put the iron and steel industry now firmly on the road to sustainable development.

Although the iron and steel industry has come a long way in improving its environmental performance, further advances in even the most modern plants will be required to meet sustainability goals of tomorrow. In particular, efforts to improve environmental performance will be needed in those regions where industry is still being established or where action is needed to correct past unsatisfactory practices. In this report, case studies from iron and steel plants worldwide show how best practices can lead to environmental and economic benefits.

Increasing globalisation through international trade and foreign direct investment requires the transfer of knowledge and technology. With this document, the iron and steel industry - with the support of the international community - has a framework to ensure the transfer of the latest technology and techniques so that environmental mistakes from the past can be avoided.

Implementing environmental management requires the involvement and commitment of different stakeholders working in partnership. The publication is intended as a guide for:

- those with responsibility for day-to-day plant operations, who may particularly benefit from the advice on resource consumption and emissions, environment and occupational health issues, cleaner production, and pollution control and by-product management;
- those with general management roles, who in many countries will be ultimately responsible for effects on the environment, whether or not these effects were knowingly caused. They may find particularly useful the advice in the chapter on environmental management, with its emphasis on pre-emptive rather than "end-of-pipe" action to reduce environmental impacts;
- those in government, regulatory or standard-setting bodies - or those seeking to influence them, such as industry associations - who will find information on how some countries have gone about adopting environmental protection measures, and on the causes and implications of these measures.

Both UNEP and IISI believe that improvements in environmental performance can be accomplished through a comprehensive appraisal of resource consumption and emissions, the associated environmental and health impacts on a local and global scale as well as the adoption of a cleaner production approach complete with the implementation of new management practices and alternative technologies.

We hope all those who are, or who are likely to become, involved in the partnerships described here, will find this publication useful, and we look forward to our continued collaboration towards achieving the aims of Agenda 21.

Maarten C. van Veen, Chairman,
IISI Environment Policy Group;
Chairman, Board of Management,
Koninklijke Hoogovens N.V., Netherlands

Jacqueline Aloisi de Larderel, Director,
United Nations Environment Programme,
Industry and Environment, France

Editorial Foreword

Information and data contained within this report have come from many different sources worldwide. For this reason, the United Nations Environment Programme and the International Iron and Steel Institute wish to caution the reader that the data published and the environment and health impacts described do not necessarily reflect all steelmaking practices in all countries.

In particular, the data compiled should not be interpreted as being based on best or worst practices, but rather as representative of specific steel companies using specific technologies and operating under specific regulations.

In the near future consistent data will be available. IISI is currently compiling these data as part of its Life Cycle Inventory (LCI) project.

Charles Werner, Chairman,
IISI Editorial Group;
Manager, Environmental Affairs,
ProfilARBED S.A., Luxembourg

Hugh Carr-Harrris, Senior Consultant
United Nations Environment Programme,
Industry and Environment, France

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a. **Please state how the publication will affect or contribute to your work, illustrating your answers with examples.**

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Evaluation Questionnaire (UNEP IE)

ENVIRONMENTAL MANAGEMENT IN THE IRON AND STEEL INDUSTRY
Technical Report N° 38

As part of its continuing review of the impact of the publications it supports, the United Nations Environment Programme, Industry and Environment office (UNEP IE) would appreciate your co-operation in completing the following questionnaire.

Note: Please complete the questionnaire in the order in which it is presented and do not correct or erase your initial answers.

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Please rate the following quality aspects of the publication by ticking the appropriate box:

	Very Good	Adequate	Poor
Objectivity	❑	❑	❑
Rigour of Analysis	❑	❑	❑
Subject Coverage	❑	❑	❑
Up-to-Date	❑	❑	❑
Readability	❑	❑	❑
Organization	❑	❑	❑
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In general, how much of the publication is:

	Most	About Half	Little
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Will be used by you?	❑	❑	❑

3. Effectiveness in achieving the object

The objective of this publication is to give readers information on iron and steel operations and technologies that minimises environmental impact as well as policy and management guidelines for ensuring effective low-impact operation. In your opinion, to what extent will the publication contribute to the achievement of this objective?

Please tick one box ❑**Fully** ❑**Adequately** ❑**Inadequately**

Please state reasons for your rating:

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Chapter 1
Introduction

1.1 AGENDA 21

The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in June 1992 - 'The Earth Summit' - focused world attention on the close links that exist between the environment and socioeconomic development. The Summit dealt with global environmental issues and resulted in two conventions (the Framework Convention on Climate Change and the Convention on Biological Diversity), the Rio Declaration, and Agenda 21. The central message of Agenda 21 is the importance of cross-sector partnership, and it provides an overview of the wide-ranging socioeconomic and environmental challenges facing the world community.

The various disparate environmental problems that had for many years been addressed individually were thus put into a general global context during UNCED, and Agenda 21 is a document structured in a way to present issues simply to encourage action at a national level.

Pertinent issues of Agenda 21 to the iron and steel industry are listed below.

Agenda 21 environmental issues that pertain to iron- and steelmaking

- Protecting the atmosphere
- Managing land sustainably
- Conservation of biological diversity
- Protecting and managing the oceans
- Protecting and managing fresh water
- Safer use of toxic chemicals
- Managing hazardous wastes
- Managing solid wastes and sewage
- Managing radioactive wastes

Agenda 21 lists explicit recommendations for an international response, and identifies rôles for key partners. Responses include increased information exchange, enhanced transfer of environmentally sound technologies and, in particular, greater capacity building in developing countries to allow them to address their national problems. These issues are covered in the guide.

1.2 CLEANER PRODUCTION

Progress in the past in bringing about a cleaner environment relied heavily on a philosophy of pollution control. This has sometimes involved expensive measures and controversial political decisions. As a result, many countries, particularly those in the developing world, have argued that the environment is an expensive luxury that diverts resources from more immediate productive uses. This perspective is now giving way to the new paradigm of cleaner production which is the continuous application of an integrative preventive environmental strategy to processes and products. Adoption of cleaner production is being increasingly recognised as an opportunity for developing countries' industries to 'leap frog' over older more established industries which are still saddled with costly pollution control technologies. Cleaner production is not, however, only about technology but also management. An environmental management system can harness corporate momentum to implement cleaner production on a continuous basis, leading to both environmental and economic benefits.

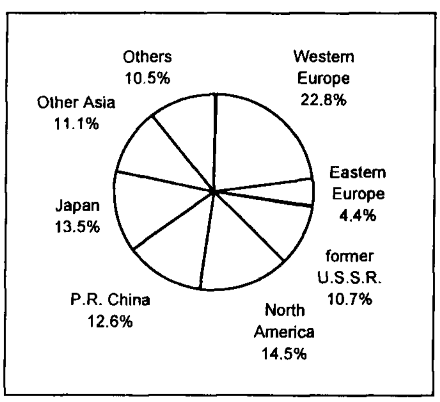
1.3 IRON AND STEEL INDUSTRY

Steel is an important material of the modern world economy. Its versatile range of physical properties and chemical resistance make it the main structural and engineering material today, and an indispensable component in the manufacture of cars, trucks, ships, oil and gas installations and pipelines, electrical and mechanical machines, environmental control equipment, household appliances, buildings, factories, roads and bridges.

The steel industry also recognises that it has a key role to play in sustainable development; by raising the living standards of people in both developed and developing countries while not damaging the environment. Steel has a positive environmental profile in many respects, particularly with regard to its recyclability (approximately 300 million tonnes of used steel is processed and remelted each year), however, the production process can be polluting.

Environmental issues facing the iron and steel industry may be local and global, and include: air emissions, habitat protection and biodiversity, effluent discharges, safety incidents, and soil and groundwater contamination. The industry has responded to these issues and much has been achieved but even more will need to be accomplished to meet the sustainability issues of tomorrow.

710 million tonnes of steel were produced worldwide in 1994 (**Figure 1.1**); a figure expected to grow to over 740 million tonnes by the end of the century. Most growth in consumption and production is expected to occur in the developing regions of South East Asia, China, and Latin America, where new steel is needed to meet the expanding infrastructure and business development needs.



Others:

Latin America	6.3%
Middle East	1.1%
Africa	1.8%
Australia and New Zealand	1.3%

Figure 1.1 **Global steel production by country, 1994**

1.4 STRUCTURE OF THE DOCUMENT

This guide provides an initial source and a single point overview of environmental issues and management approaches in the iron and steel industry, and defines the framework for environmental management against a background of existing information developed by industry and the United Nations Environment Programme (UNEP).

The text gives a detailed explanation of the processes involved in iron- and steelmaking including resources consumed and outputs generated. This approach provides a framework to highlight pollutants of concern and resources to monitor. Based on these pollutants, Chapters 3 and 4 consider environmental and health impacts and occupational health issues to be addressed. Chapter 5 illustrates cleaner production techniques for different unit processes, while Chapter 6 considers pollution control options available. Chapter 7 focuses on environmental management for corporate managers to increase environmental performance in steel plants, followed by what the government approaches can be in Chapter 8.

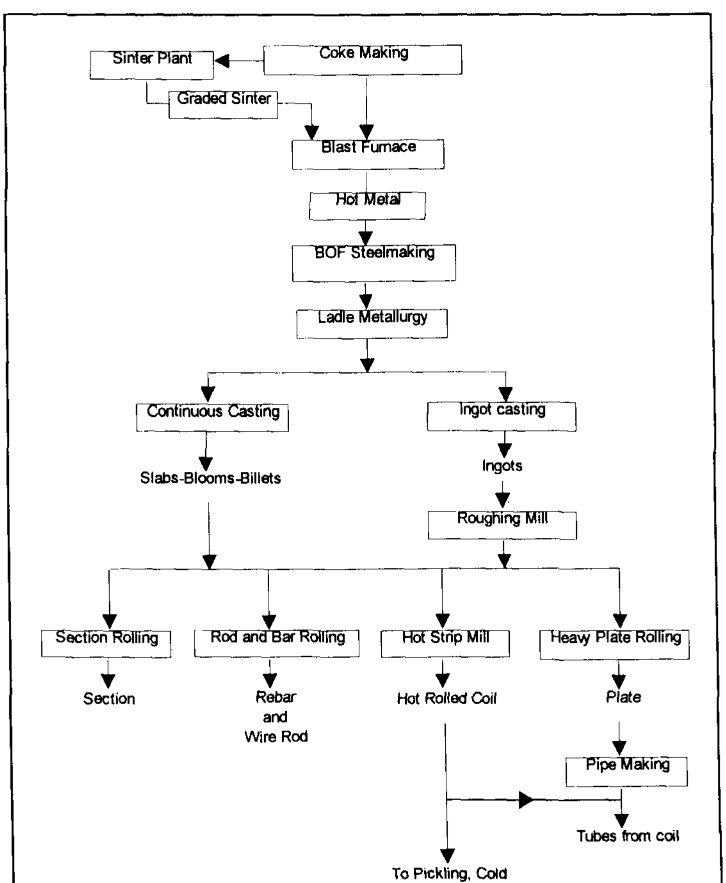
Chapter 2

Process Description, Resource Consumption and Emissions

2.1 OVERVIEW

Currently, there are two process routes that dominate global steel manufacture, although variations and combinations of the two exist. These are the 'integrated' and the electric arc furnace or 'EAF' routes the latter sometimes referred to as the 'mini-mill' route. The key difference between the two is the type of iron bearing feedstock they consume. In an integrated works this is predominantly iron ore, with a smaller quantity of scrap, while the arc furnace works uses mainly scrap steel or, increasingly, other sources of metallic iron such as directly reduced iron or DRI.

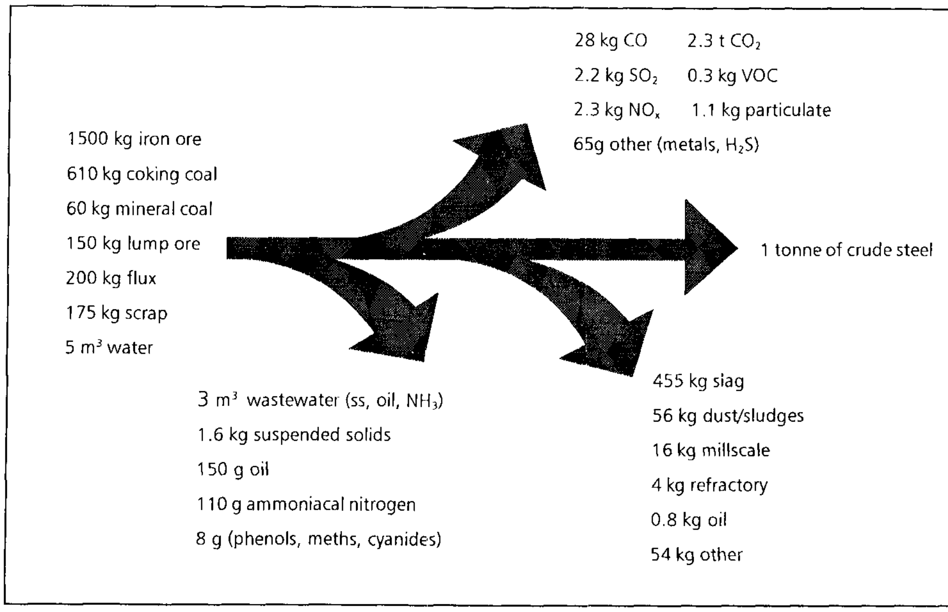
The integrated steelmaker must first make iron and, subsequently, convert this iron to steel. Raw materials for the process include iron ore, coal, limestone, recycled steel scrap, energy and a wide range of other materials in variable quantities such as oil, air, chemicals, refractories, alloys, refining materials, water, etc. As the process flowsheet below shows, iron from the blast furnace is converted to steel in the Basic Oxygen Furnace (BOF) and, after casting and solidification, is formed into coil, plate, sections or bars in dedicated rolling mills. The blast furnace / BOF route currently accounts for approximately 60 percent of world steel production.



Integrated works flowsheet

Integrated works are large. For example, a 3 million tonnes per year plant may cover an area of 4-8 square kilometres. (See **Photo 1**.)

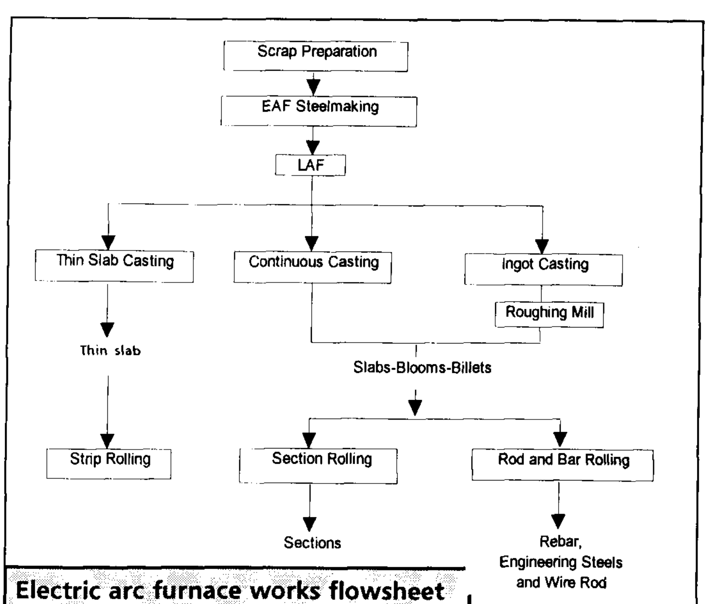
The production of steel in an integrated works involves a series of processes, each with different input materials and emitting various residual materials and wastes. The overall energy/material balance of the major components is shown in **Figure 2.1**. It should be noted that the figures given below, and throughout this chapter, have been obtained from a variety of sources and, therefore, are indicative only. They are not, and are not intended to be, representative of good/bad/best practice and should not be considered as such. IISI and some of its member companies are currently finalising a Life Cycle Inventory (LCI) for steel industry products whose results, when they are issued, will supersede the values presented here.



Input energy breakdown: 19.2 GJ coal; 5.2 GJ steam; 3.5 GJ electrical (364 kWh); 0.3GJ oxygen; 0.04 GJ natural gas

Output energy breakdown: 5.2 GJ steam; 3.4 GJ electrical (359 kWh); 0.9 GJ coal tar; 0.3 GJ benzene

Figure 2.1 **Energy/materials balance for an integrated works**

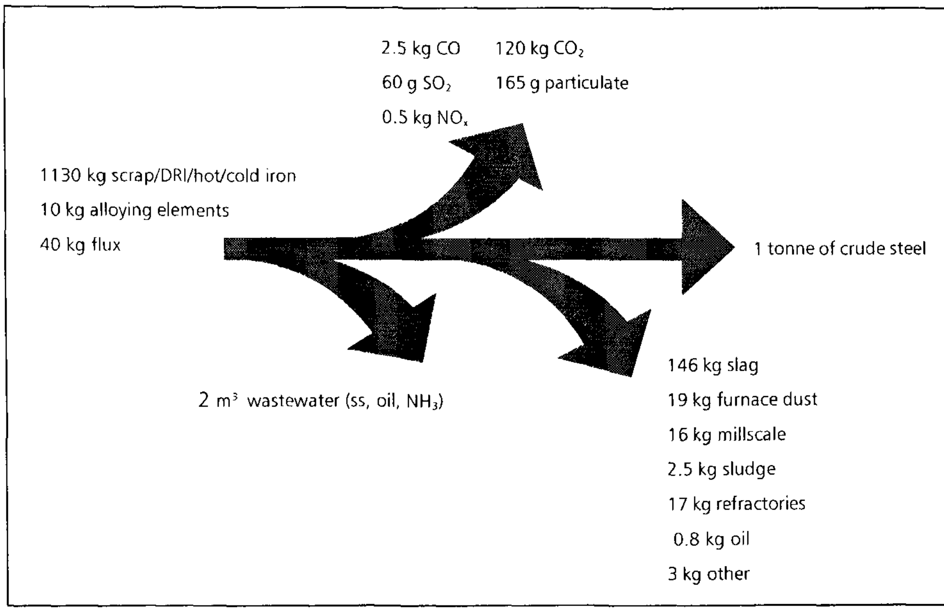


Electric arc furnace works flowsheet

Steel is made in an EAF works by melting recycled scrap in an electric arc furnace (EAF) and adjusting the chemical composition of the metal by adding alloying elements, usually in a lower powered ladle furnace (LF). The process flow sheet indicates that the ironmaking processes, operated on the integrated plant, are not required. Most of the energy for melting comes from electricity, although there is an increasing tendency to replace or supplement electrical energy with oxygen, coal and other fossil fuels injected directly into the EAF. An energy material balance showing the major inputs and outputs of the process is presented in **Figure 2.2**. As above, the figures used have been taken from a variety of sources and do not necessarily represent good/bad/best practice.

By contrast with an integrated works, a 1 million tonnes per year EAF works may cover an area up to 2 square kilometres depending on plant configuration.

In addition to steel scrap, metallic substitutes such as DRI are becoming increasingly important where scrap availability is limited, where the impurity content of the scrap is high or where a localised raw material resource is available. Downstream process stages, such as casting and reheating and rolling, are similar to those found in the integrated route.



Input energy breakdown: 5.5 GJ electrical (572 kWh); 1.3 GJ natural gas (40 m^3); 450 MJ coal/coke (15 kg); 205 MJ oxygen (30 m^3); 120 MJ electrode consumption (3.5 kg)

Figure 2.2 **Energy/materials balance for an EAF works**

2.2 IRONMAKING

2.2.1 Raw Materials Handling/Preparation

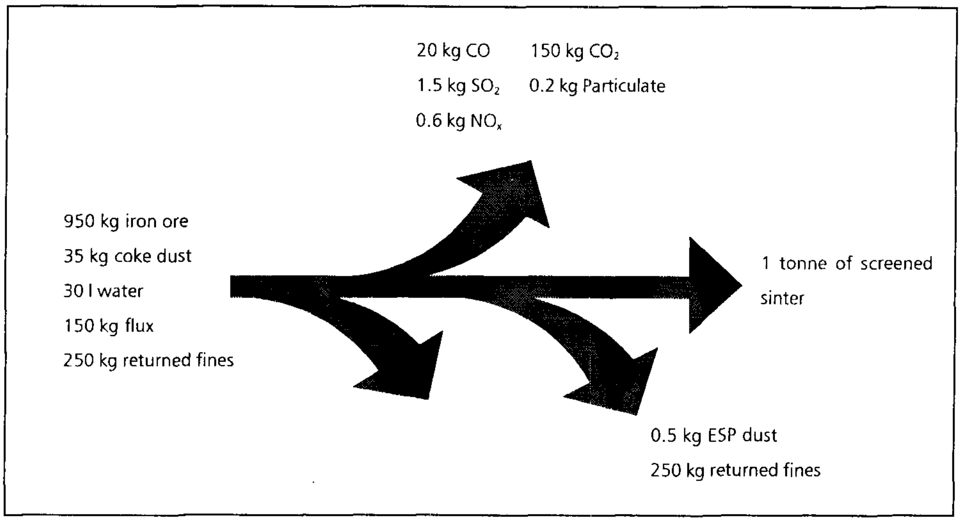
Material transport costs are a major factor when choosing the location of an integrated works as the transportation and handling of very large quantities of materials is required. Therefore, sites are mostly found in areas where there is a ready access to local ore and other raw materials or, more commonly, where there are the necessary port facilities. These facilities may also provide a route for the export of finished products. Thus, with the development of large scale, efficient seagoing ore carriers (up to 320,000 tonnes) integrated sites do not necessarily have to be located near ore supplies for cost effective operation.

Materials are most often transported to the steelworks by sea and then by road, rail or fluvial transport. Fine iron ore is unloaded (directly from sea going vessels or from rail/road/river wagons), stored and then blended outdoors. Blending provides a more homogeneous feed for enhanced process efficiency and reduces waste by allowing iron-bearing materials (that may otherwise have been disposed to landfill) to be usefully returned back into the process route. The blended ore is prepared for use in the blast furnace by fusing it into sinter or agglomerating it into pellets. The choice of whether to use sinter or pellets as a feed to the blast furnace depends on local circumstances such as the availability of raw materials, cost, operational requirements, environmental legislation etc. Coal preparation includes 'washing' to remove gangue minerals, before it is converted into coke in the coke ovens for use in the blast furnace (coking coals). Non-coking coals may be pulverised for direct injection into the blast furnace as a coke replacement. Limestone can be charged directly to the blast furnace or converted to burnt lime in special kilns and used in sinter or pellet production or as an additive in steelmaking. Scrap preparation operations include shredding, sorting and sizing for the bulk removal of unwanted nonferrous metals and the partial removal of organic coatings and other contaminants.

The main environmental issues relating to raw materials handling are dust lift off during unloading and from stockpiles and dust and noise generated by the movement of vehicles. These are usually controlled by spraying stockpiles with water or crusting agents, ensuring vehicle wheels and roadways are kept clean and by siting handling operations away from residential areas.

Water runoff from raw materials handling yards will normally be collected and treated to remove suspended solids and oil. (See **Photo 2.**)

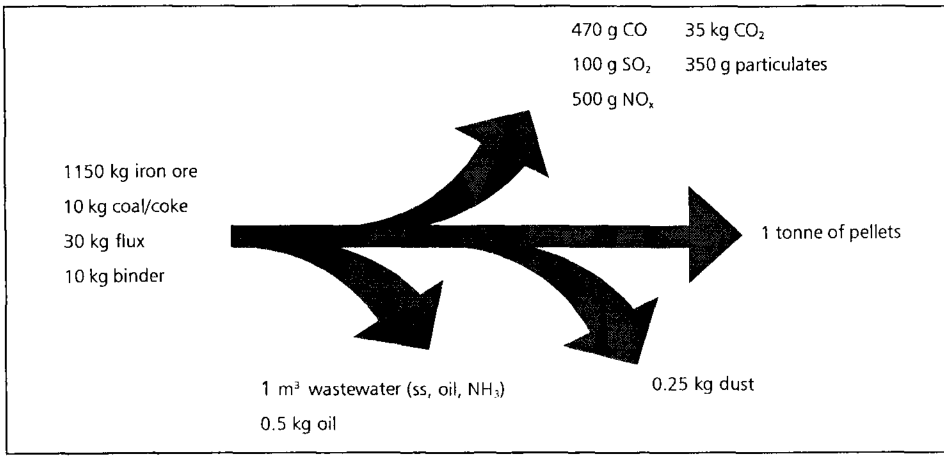
2.2.2 Sintering/Pelletising



Minor emissions of concern:	Dioxins, Pb, Cd, radioactive isotopes (^{210}Po, ^{210}Pb), volatile organic compounds (VOC), hydrocarbons, PM_{10}, HCl, HF
Input energy breakdown:	0.4 GJ electrical (4515 kWh); 64 MJ by-product gas; 1.2 GJ coke; 44 MJ flue dust
Output energy breakdown:	0.15 GJ (steam)

Figure 2.3 **Energy/materials balance for the sinter plant**

The chemical and physical characteristics of sinter and pellet are very important factors determining blast furnace operation and these materials are, therefore, critical components of the ironmaking process. Sintering involves the heating of fine iron ore with flux and 'coke breeze' to produce a semi-molten mass which solidifies into porous pieces of sinter with the size and strength characteristics necessary for feeding into the blast furnace. Moistened feed is delivered as a ~ 600mm thick layer onto a continuous moving grate or 'strand', typically measuring 4 metres wide by 50 metres long. The surface is ignited with gas burners at the start of the strand and air is drawn through the moving bed causing the coke to burn. Strand velocity and gas flow are controlled to ensure that 'burn through', the point at which the burning coke layer reaches the base of the strand, occurs just prior to the sinter being discharged. The solidified sinter is then broken into pieces in the crusher and cooled with air. Product outside the required size range is screened out and, if too large, is recrushed or, if too small, recycled back to the process. (See **Photo 3.**)



Minor emissions of concern:	Dioxins, Pb, Cd, radioactive isotopes (^{210}Pb, ^{210}Po), VOC, hydrocarbons, PM_{10}, HCl, HF.
Water constituents of concern:	Suspended solids, oil, dissolved metals.
Input energy breakdown:	192 MJ electrical (20 kWh); 650 MJ coal/coke; 120 MJ oil

Figure 2.4 **Energy/materials balance for the pelletising process**

Figure 2.3 presents an energy/material balance for the sintering operation, and **Figure 2.4** a balance for the pelletising process.

Emissions from the sintering process arise primarily from materials handling operations, which result in airborne dust, and the combustion reaction on the strand. Combustion gases from the latter source contain dust entrained directly from the strand along with products of combustion such as CO, CO_2, SO_x, NO_x and particulate. The levels of each will depend on the combustion conditions and raw materials used. Other emissions include VOCs, formed from volatile material in the coke breeze, oily millscale etc., dioxins, formed from organic material under certain operating conditions, metals (including radioactive isotopes), volatilised from the raw materials used, and acid vapours (e.g. HCl and HF), formed from the halide content of the raw materials used.

Combustion waste gases are most often cleaned using dry electrostatic precipitators (ESP), which are able to handle the large volumes of gases produced in the sintering process. These devices reduce dust emissions significantly, but have minimal effect on the other emissions mentioned which, to some extent, are controlled by process parameters and raw material choices. A smaller separate ESP is normally employed to clean dust laden air from the various material transfer points, crushing and sieving stations. The dusts collected in this ESP are normally recycled back to the process via the blending yard, unless specific operational restrictions prevent this.

The large fans associated with the sinter plant offgas system may give rise to noise problems if silencers are not fitted or properly maintained.

Pellets are made by rolling a mixture of ground iron ore, water and binder into small spheres of about 12 mm in diameter. The 'green pellets' are hardened by drying and heating to 1,300°C on a moving grate or in a kiln. Process fines are recycled to the drying and grinding stage along with other iron bearing dusts from around the steelworks.

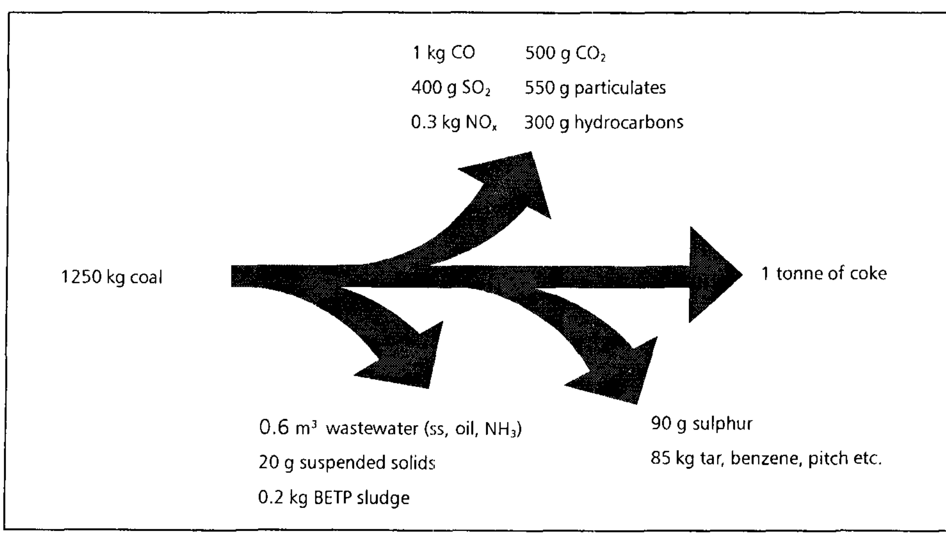
Process emissions arise from much the same sources as in the sinter plant and, again, these will be strongly dependent on process operating conditions and raw materials used. Water is used in the pelletising process for ore preparation and to aid pellet formation, but this will be largely recycled to the process with a bleed treated for suspended solids, oil and, potentially, dissolved metals prior to discharge.

2.2.3 Cokemaking

The primary function of coke in the blast furnace is to chemically reduce iron oxide to iron metal. Coke also acts as a fuel, provides physical support and allows the free flow of gas through the furnace. Coal cannot fulfil these functions as it softens and becomes impermeable under smelting conditions, therefore, it must be converted to coke by heating to ~1300°C in an oxygen free atmosphere for 15-21 hours. Only certain coals, for example coking or bituminous coals, with the right plastic properties, can be converted to coke and, as with ores, several types may be blended to improve blast furnace productivity, extend coke battery life, etc.

A coke oven battery may contain forty or more refractory-walled coke chambers interspaced with heating chambers. Each coking chamber typically measures 0.4-0.6 metres wide, 4-7 metres high and 12-18 metres deep and is fitted at both ends with removable full height doors. Coal is charged through four ~300 mm diameter holes above each coke chamber from a special car that runs along the top of the battery. Once charged, the coal is levelled, the doors and charge lids are sealed and heating (underfiring) commences. Distillation products in the form of tar and coke oven gas (COG), driven off during the heating process, are collected in mains which run the length of the battery and are transported to the by-products plant. When the heating cycle is complete, the oven is isolated from the main, the end doors are removed and solid coke is pushed into a 'coke-car'. The coke-car travels along the side of the battery to the quench tower where new or recycled water is sprayed onto the hot coke to reduce its temperature to ~200°C. An alternative dry quenching method involves recirculating an inert gas (N_2) through the hot coke; the recovered heat being used for steam generation. (See **Photo 5**.)

Atmospheric emissions from a coke works may be intermittent and continuous, associated with the operations of underfiring, charging, pushing, quenching, conveying and screening. An emission may appear from many numerous and diffuse sources, such as the oven doors, lids, off-takes, underfiring stack etc.



Minor emissions of concern:	Polyaromatic hydrocarbons (PAH) , benzene, PM_{10}, H_2S, methane
Waste water constituents of concern:	Suspended solids, oil, cyanide, phenol, ammonia
Input energy breakdown:	458 MJ electrical (48 kWh); 41.1 GJ coal; 0.5 GJ steam: 3.2 GJ underfire gas
Output energy breakdown:	29.8 GJ coke; 8.2 GJ COG; 1.9 GJ coal tar; 0.7 GJ benzene; 0.9 GJ electrical (90 kWh); 33 MJ steam

Figure 2.5 **Energy/materials balance for the coke oven works**

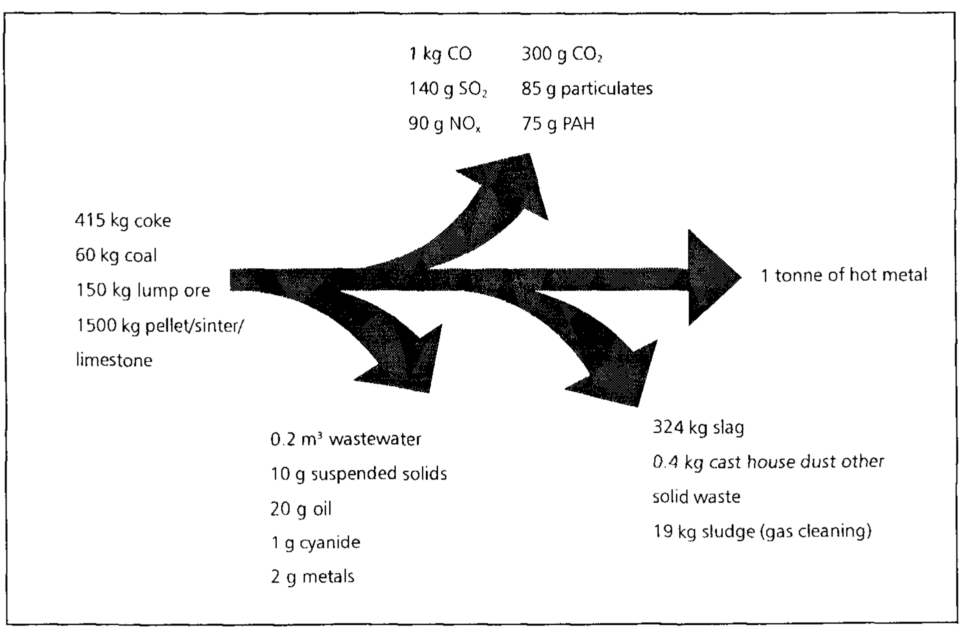
Particulate emissions arise from underfiring, charging, pushing and quenching operations. These are controlled by continued maintenance of oven refractory walls, improved charging practice, close control of the heating cycle and installation of extraction/gas cleaning systems for certain operations.

The COG that is driven off during the coking process is a complex mixture containing hydrogen, methane, carbon monoxide, carbon dioxide, nitrogen oxides, water vapour, oxygen, nitrogen, hydrogen sulphide, cyanide, ammonia, benzene, light oils, tar vapour, naphthalene, hydrocarbons, polyaromatic hydrocarbons (PAHs) and condensed particulate. Emissions of the gas may occur from doors, lids, caps etc. where gas tight seals are not obtained and these can only be reduced by paying close attention to maintenance and sealing operations. Odour may be a problem where the coke plant is sited close to residential areas.

Prior to distribution as a fuel gas, the COG is processed in a by-products plant where certain components (for example, benzene, tar or sulphur) are removed and collected. The various tanks, vents, pumps, valves etc. used for this are all a potential source of emissons. These tanks, which are often sited underground, are also a potential source of ground contamination if leaks go undetected over a long period.

Water used in the by-products plant is treated in a biological effluent treatment plant (BETP) to remove cyanides, phenols, thiocyanates and solids prior to discharge.

Solid wastes include used refractories, tank sludges, impure sulphur, BETP sludge etc. Some of these may be sold (sulphur, refractories), recycled (BETP sludge) or disposed of in a landfill.



Minor emissions of concern:	PM_{10}, H_2S
Waste water constituents of concern:	Suspended solids, oil
Input energy breakdown:	14 GJ coke; 1.7 GJ by-product gas; 1 GJ steam; 0.6 GJ pellets; 0.2 GJ electrical (22 kWh)
Output energy breakdown:	4.5 GJ by-product gas; 0.3 GJ heat recovery; 339 MJ electrical (35 kWh); 55 MJ flue dust

Figure 2.6 **Energy/materials balance for the blast furnace**

2.2.4 Blast Furnace

Globally, the vast majority of iron is made in the blast furnace, amounting to ~500 million tonnes of liquid 'pig iron' or 'hot metal' each year. The furnace consumes about 97 percent of all mined iron ore; the remainder being made into sponge iron in natural gas or coal based DRI plants for use in the EAF. The blast furnace is a closed system into which iron bearing materials (iron ore, sinter and pellets), additives (slag formers such as limestone) and a reducing agent (coke) are continually added to the top of the furnace shaft through a charging system that prevents escape of blast furnace gas. A hot air blast, sometimes enriched with oxygen, and auxiliary fuels are injected from the bottom providing a counter current of reducing gases. The air blast reacts with the coke to produce carbon monoxide (CO) which in turn reduces iron oxide to iron. The liquid iron is collected in the hearth along with the slag and both tapped on a regular basis. The liquid iron is transported in torpedo vessels to the steel plant and the slag is processed to produce aggregate, granulate or pellet for road construction and cement manufacture. The blast furnace gas is collected at the top of the furnace, cleaned and distributed around the works to be used as a fuel for heating or for electricity production.

The main emissions from the process include particulate material, essentially iron oxide and primarily emitted during tapping operations, but also during some ancillary operations such as plating, and, depending on the slag treatment process, variable quantities of H_2S and SO_2, which can give rise to odour problems. The cast house may be served by an extraction/bag filter cleaning system, use inert gas blanketting (e.g. CO_2, N_2) or have no system to reduce particulate formation and emission. In the case of the cast house extraction system, the collected particulate can normally be recycled entirely to the sinter plant.

Effluent arises from the gas cleaning and slag processing operations. These tend to use recirculating systems, but bleeds will be treated to remove solids, metals and oil prior to discharge.

The main solid by-product is slag. This can be treated in a variety of ways (air cooled, water cooled, granulated or pelletised) and is entirely sold to the cement and road construction industries. Sludges from the gas cleaning system are disposed to landfill unless equipment has been installed to remove tramp elements such as zinc. In this case a large percentage of the sludge can be recycled to the sinter plant. (See **Photo 4**.)

Noise may result from the operation of furnace pressure release valves and slag explosions.

2.3 STEELMAKING, SECONDARY REFINING AND CASTING

The aims of the three operations performed in the steelmaking plant are first to obtain liquid steel, secondly to give the steel the appropriate composition and cleanness for its further use and to solidify it into a shape amenable to hot rolling.

All steel is made by one of three major processes. In 1994:

- The Basic Oxygen Furnace (BOF) process produced 416 million tonnes
- The Electric Arc Furnace (EAF) process produced 228 million tonnes
- The Open Hearth Furnace (OHF), an obsolete process which is retained in areas where reinvestment capital is lacking, produced 87million tonnes.

2.3.1 Basic Oxygen Steelmaking

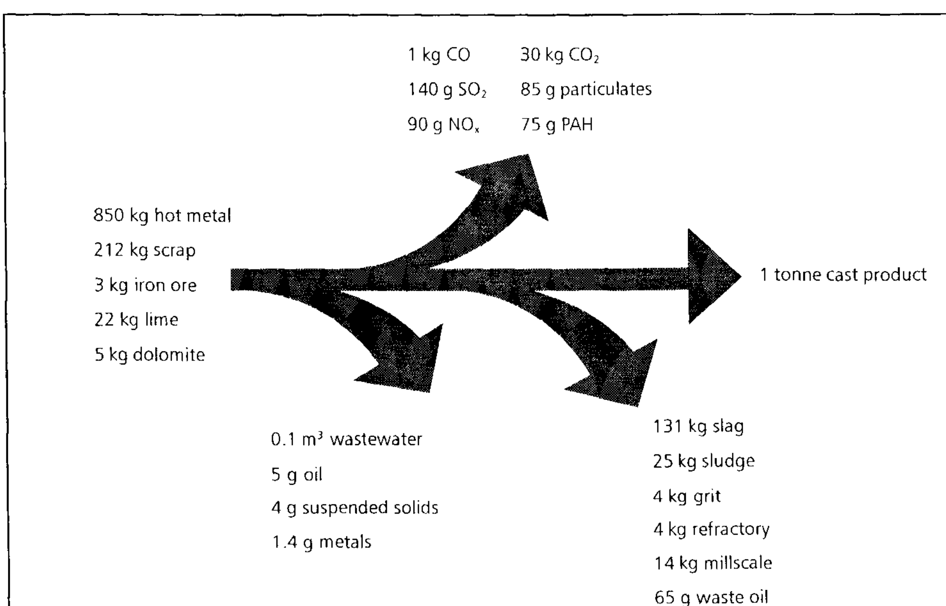
Basic oxygen steelmaking involves the conversion of iron, most often from the blast furnace, into steel by the application of pure oxygen (primarily to remove carbon, but also silicon and other elements) and the addition of fluxes and alloying elements to remove impurities and alter the composition respectively. The oxidation takes place in a vessel called the Basic Oxygen Furnace (BOF) which is lined with magnesia and dolomite refractories and the process is controlled to achieve the desired levels of carbon, silicon and phosphorous in the finished steel. Desulphurisation, and sometimes dephosphorisation, pretreatment of the hot metal may be carried out separately as these cannot be carried out efficiently in the BOF.

Initially, scrap is charged into the BOF and molten iron is poured in from a ladle. The quantity of scrap charged will depend on scrap availability, hot metal availability, hot metal chemistry, final steel quality, process operating conditions, economics, etc., but it rarely exceeds 30 percent. Pure oxygen is then top blown through a vertical lance (the LD process) or bottom blown with added fuel (e.g. propane or natural gas) through submerged tuyeres (OBM, LWS, Q-BOP processes). Inert gas may also be injected at the base to aid stirring. During the process carbon in the iron is oxidised and released as carbon monoxide and carbon dioxide gases. Silicon, manganese and phosphorous are also oxidised and captured in the slag formed from the flux. The reactions between silicon, carbon and oxygen are strongly exothermic and cause the temperature in the vessel to rise. This is counter-acted by the quantity of coolant scrap which is carefully controlled to ensure the correct tapping temperature. Modern plants also allow the steel composition and temperature to be fine-tuned at a separate refining station close to the main vessel (section 2.3.3). (See **Photos 10** and **11**.)

Once the final steel composition and temperature are achieved the liquid steel is transferred to the casting area (section 2.3.4).

Primary emissions of gas and dust emerge from the mouth of the BOF during oxygen blowing. The gas emission is mainly carbon monoxide, however, with further oxidation in the vessel, some carbon dioxide is produced. The intensity of the secondary reaction depends on the design of the fume hood over the vessel mouth (i.e. a close fitting hood minimises air ingress and, therefore, maximises the CO content of the offgas). If the CO content is sufficiently high the gas can be collected and used as a valuable energy source, otherwise it is flared. Hydrogen is also present, derived from the added hydrocarbons and moisture in the charge.

The dust emission, primarily made up of iron and calcium oxide, results from both the physical impact of the oxygen jet with the liquid bath and the fact that some iron is oxidised into fine iron



Minor emissions of concern	PM_{10}, zinc
Waste water constituents of concern:	Suspended solids, oil, pH
Input energy breakdown:	60 MJ by-product gas; 32 MJ natural gas; 0.3 GJ oxygen; 84 MJ steam; 0.4 GJ electrical (39 kWh)
Output energy breakdown:	0.8 GJ by-product gas; 0.1 GJ steam

Figure 2.7 **Energy/materials balance for the steelmaking plant**

oxide particles. Dust may contain scrap derived heavy metals such as zinc, as well as slag and lime particles. The quantity of dust generated depends on the blowing system, the operating conditions, such as flow rates and whether or not a foamy slag is used, and scrap quality.

The BOF primary offgas system may include wet or dry scrubbing techniques for the removal of dust and fume prior to flaring or collection of the gas for use as a fuel. The cleaning process generates BOF grit and a sludge or dust, which may be recycled to the process, depending on the tramp element component, sold as a cement additive or disposed of in a landfill.

Charging emissions occur when hot metal is poured over the scrap charge in the BOF vessel and molten iron comes into contact with air to produce a fine iron oxide dust. Other emissions will depend on the type of impurities in the scrap. These emissions generally rise to the BOF melting shop roof where they are collected and cleaned by electrostatic precipitator or bag filter cleaning systems prior to discharge to atmosphere.

Secondary emissions occur during the blowing process and result from leaks in the primary system from around the close fitting hood above the vessel. Generally, these emissions are collected and treated as charging emissions.

Other emissions in the BOF melting shop arise from hot metal transfer and pretreatment operations. These tend to rise to the roof where they are collected and cleaned along with charging and secondary emissions or are emitted directly to atmosphere. Some works have applied inert gas blanketting to reduce the formation of emissions from these sources.

The water used in the gas cleaning plant is recycled, but the bleed will be treated to remove suspended solids and oil and to control pH.

Solid wastes/by-products include steelskulls, slags, refractories, dusts and sludges. These are recycled (skulls/slag/dusts/sludges), reused (refractories), sold (some slags, dusts and sludges) or disposed of to landfill where the above does not apply.

2.3.2 Electric Arc Furnace Steelmaking

The major feedstock for the EAF is ferrous scrap, which may comprise of scrap from inside the steelworks (e.g. offcuts) and capital or post-consumer scrap (e.g. end of life products). DRI is also increasingly being used as a feedstock due both to its low residual content and variable scrap prices. As in the BOF, a slag is formed from lime to collect undesirable components in the steel.

Scrap is charged from 'baskets' into the open furnace shell which generally is refractory-lined below the slag layer with water-cooled panels above. The roof, which is also refractory-lined or water cooled, is then swung into position and lowered. The carbon electrodes are introduced through the roof and the scrap is melted by the heat generated by the electric arcs which form between the scrap and electrodes. The heat derived from the AC or DC electrical power supply is supplemented by injected natural gas, coal, oil and oxygen. Normally, a second basket of scrap is loaded on top of the first after it has melted, although new furnace designs allow additional feedstock to be added without opening the furnace roof. Examples of these new designs include the use of a charging belt for fragmented scrap, a chute for DRI additions and, when a shaft is used, a scrap preheater that forms part of the primary extraction system. (See **Photo 14**.)

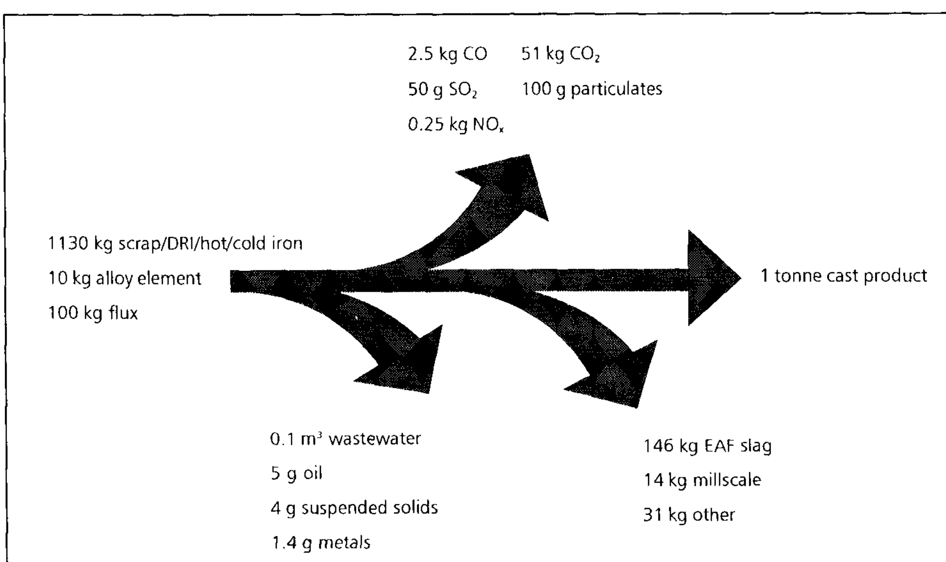
The energy efficiency of the system is greatly improved by maximising the quantity of molten steel produced (i.e. due to reduced time dependent heat losses etc.). Therefore, modern high powered EAF are used primarily for scrap melting and metal refining is carried out in a separate ladle furnace (LF).

Primary emissions from the EAF include dust and gases. These are generated inside the furnace and are extracted through the roof (through the so-called fourth hole) and/or scrap preheater. Exhaust gases than pass through a combustion chamber to burn any residual carbon monoxide and organic components, a process carried out primarily to protect the mild steel ducting of the extraction system from excessive temperatures, but which can be controlled to reduce both odour and the potential for the formation of toxic organic compounds. Oxygen injected above or within the slag layer can aid combustion of exhausted gases within the furnace shell itself, a process which increases the heat input to the furnace, thus reducing the overall electric energy requirement. Having left the furnace the combusted gases pass to a heat exchanger for cooling to filtering temperatures, they may then be mixed with secondary air collected in the melting shop roof above the furnace and the combined gas flow is normally cleaned in a bagfilter.

Thus, the primary emission consists of:

- A gas emission derived from air which enters the furnace through openings such as the slag door, electrode ports and areas between the furnace wall and the roof. Other gases include combustion products from the burning of fossil fuel and organic compounds present on the scrap charge.
- A dust emission composed mainly of iron oxide with other metals and metalloids, including zinc and lead, which are volatilised from coated or alloyed steels or derived from pieces of nonferrous metal in the scrap charge. The zinc content of EAF dusts can be as high as 30 percent and the total quantity of dust emitted from the furnace can range from 10 to 18 kg/tonne of steel. Approximately 90 percent of the total dust emission from the EAF is released in the primary emission.

Secondary emissions arise during charging and tapping operations, or as fugitive fume during melting. Although the charging time is short, charging emissions can account for the bulk of the secondary emissions. The composition of the emission is primarily related to scrap quality and the nature of the charging operation. For example, whether the first, second or, potentially, the third basket is being charged and whether the scrap is charged onto molten metal. The charging emission can range from 500 to 1,500 g/tonne steel and a large canopy hood or total roof sealing system is normally required if personnel are to be protected from emissions into the building. The extraction system must be designed to handle large volumes of gas as well as short-lived temperature surges that can arise during operations.



Minor emissions of concern:	Metals (Zn, Pb, Cd, Hg, Ni, Cr), dioxins, VOC, PM_{10}
Waste water constituents of concern:	Suspended solids, oil
Input energy breakdown:	5.2 GJ electrical (539 kWh); 0.2 GJ oxygen (30m^3); 0.2 GJ natural gas (7.5m^3) ; 0.3 GJ added carbon (9.5 kg); 0.1 GJ electrode consumption (4.6 kg)

Figure 2.8 **Energy/materials balance for the EAF process**

EAF tend to operate with closed-loop water cooling systems which require very little, if any, effluent treatment. The solid waste/by-products from EAF operations include slag, furnace dust and refractories. These may be sold (e.g. slags used in road construction, EAF dust to a zinc smelter), reused (e.g. EAF dust, refractories) or disposed of in a landfill (e.g. slag, dust and refractories).

Noise generated by the EAF and during scrap handling operations can cause problems if appropriate measures are not taken such as sound proofing or restricting scrap handling to certain times, for example.

2.3.3 Secondary Refining

After processing in the BOF or EAF the molten metal is tapped into a ladle and the composition adjusted with the addition of ferro-alloys. The metal may be subjected to further treatments for adjustment of composition and temperature before casting including ladle furnace refining, vacuum degassing or inert gas stirring.

Ladle furnaces (LF) have been installed in many plants for the fine adjustment of liquid steel specifications. They consist of a ladle cover with an electrode system which can be positioned over the steel in the ladle. Heating the steel makes up for the heat lost during alloy additions and gives the steelmaker more flexibility. The treatment is made under a synthetic slag formed by adding appropriate slagging agents and electromagnetic or inert gas stirring is used to integrate the alloying elements into the steel.

The use of LF have significantly increased the efficiency and productivity of EAF. By transferring the refining operation to the LF, a low powered unit, high powered EAFs are freed to melt scrap under optimum power input conditions. This results in greatly reduced tap-to-tap times which brings associated savings in reduced heat and power losses.

The lower power input of the LF and operating practice (i.e. no oxygen lances or oxy-fuel burners) mean that much less dust is generated and there is minimal potential for the emission of other components as no scrap is added.

The LF itself gives rise to no effluent as only closed circuit cooling systems are employed, however, other secondary refining operations (e.g. vacuum degassing etc.) may give rise to an effluent requiring treatment to remove suspended solids.

2.3.4 Casting

Currently, over two thirds of global steel production is continuously cast into semi-finished products such as slabs, blooms or billets, depending on the finished product and metallurgical and rolling requirements, while the balance is cast into discrete moulds to produce ingots. A continued rise is expected in the proportion of steel which is continuously cast because of the yield and quality improvements it brings.

In the continuous casting process a ladle containing liquid steel is positioned over a refractory lined vessel called a tundish into which steel is tapped to a pre-defined height. The steel flow can be shrouded by refractory tubes to minimise contact with air, thus reducing fume formation as well as increasing yield and improving quality. The tundish is often designed with a series of baffles to improve steel flow and to aid the flotation or removal of inclusions. Electromagnetic braking systems can also be applied for the same purpose. Stoppers or sliding gates in the base of the tundish are opened and the liquid steel flows into one or more water cooled oscillating copper moulds. Casting powders are added to the mould to improve steel flow across the copper surface and to insulate the steel. Insulating powders are also added to the surface of the tundish to reduce temperature losses.

A solid shell forms around the steel in contact with the mould and the shell and molten core is withdrawn through the bottom of the mould and carried through guiding rollers where solidification is completed with the help of water sprays. The flow rate of steel into the mould and the withdrawal speed of the strand are regulated so that the level of steel in the mould remains constant. The casting speed is normally between 0.5-2.0m/min depending on cast dimensions (e.g. the casting speed is much greater for thin slab processes) and steel quality. The completely solidified steel is subsequently cut to length with either mechanical shears or a flame cutting torch depending on the thickness of the product. (See **Photo 16**.)

Compared to ingot casting, continuous casting is a very smooth operation and there is almost no exposure of liquid steel to the atmosphere, since shrouds are normally used to prevent oxidation. Torch cutting presents an insignificant source of air pollution. In the case of billet casting, vegetable oils are used to lubricate the interface between the mould and the cast product. Combustion products from this oil should be exhausted from the top of the mould and properly cleaned. Dust emissions can arise from the casting operation, but these tend to be relatively minor and intermittent.

The cooling water in the spray chamber picks up scale from the surface of the cast product which must be allowed to settled before water can be reused. Chemicals from the lubricating mould, flux powders or oils are also picked up, requiring that any water bled from the system must be treated before discharge.

In the ingot casting process liquid steel is brought in ladles to a teeming bay where it is poured into iron moulds to solidify. After removal from the moulds the solid ingots are heated to rolling temperature (1,200°C) in a soaking pit.

The molten metal is exposed to the air during mould filling and copious quantities of fume are generated. Fume may also be generated from organic coatings which are sometimes placed on the mould surface to improve ingot quality. For some steels it is necessary to add thermally insulating or exothermic compounds to the mould surface, others require fluxes or degassing compounds to be added. All these operations are accompanied by potentially harmful fugitive emissions. Particular care should be taken with free-cutting steels to which lead and/or sulphur is added at the ladle or mould. In this case emission control is essential due to the potentially toxic emissions. The yield losses associated with ingot casting are relatively high, which leads to a higher unit energy cost by this route.

2.4 HOT ROLLING

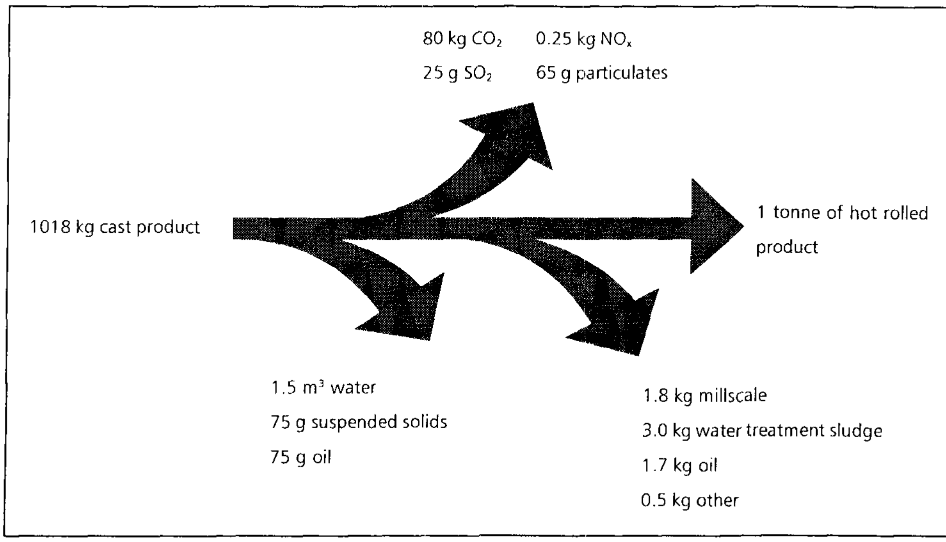
Hot rolling changes the shape and metallurgical properties of the steel slab, bloom or billet by compressing the hot metal repeatedly between electrically powered rollers. Rolled slabs and billets yield products which fall into the traditionally named flat and long product categories respectively following processing in the hot strip, wire rod, plate or section mills.

Prior to rolling, cast products are normally allowed to cool down for visual inspection. At this point defects and imperfections are removed by 'scarfing', a process involving the removal of defects with an oxy-acetylene torch. The cast product is then transferred to a reheating furnace where its temperature is raised for hot rolling.

A recent development is 'direct linkage' whereby hot cast products are transferred directly to the rolling mill. Although this process saves considerable energy, production needs to be carefully controlled and high quality cast material is required.

Hot rolling may require several rolling steps to transform the cast material to final product. The process starts at the roughing mill, which makes bulk changes to the size and shape of the product, and ends in the finishing mill where final product specifications are obtained. The plate mill is a special type of hot rolling mill in which sophisticated surface and heat treatments are carried out to obtain the correct metallurgical properties.

Following hot rolling, the hot rolled product is either sent in coil form to the cold rolling mill for further processing, sold as coil or cut and sold as sheet, plate, bars or sections.



Minor emissions of concern:	VOC
Waste water constituents of concern:	Suspended solids, oil
Input energy breakdown:	1 GJ by-product/natural gas; 1.1 GJ electrical (119 kWh); 33 MJ steam; 2 MJ oxygen

Figure 2.9 **Energy/materials balance for the hot rolling mill**

The major emissions from the hot rolling stage include combustion products from the reheat furnace/soaking pits (e.g. CO, CO_2, SO_2, NO_x, particulate), which will be dependent on fuel type and combustion conditions, and VOCs, derived from rolling and lubrication oils.

At each stage of the rolling process high pressure water jets are used to dislodge surface scale. This water can become contaminated by scale and oils and, although closed loop water systems tend to be used, bleeds from these systems must be treated to remove suspended solids and oil prior to discharge.

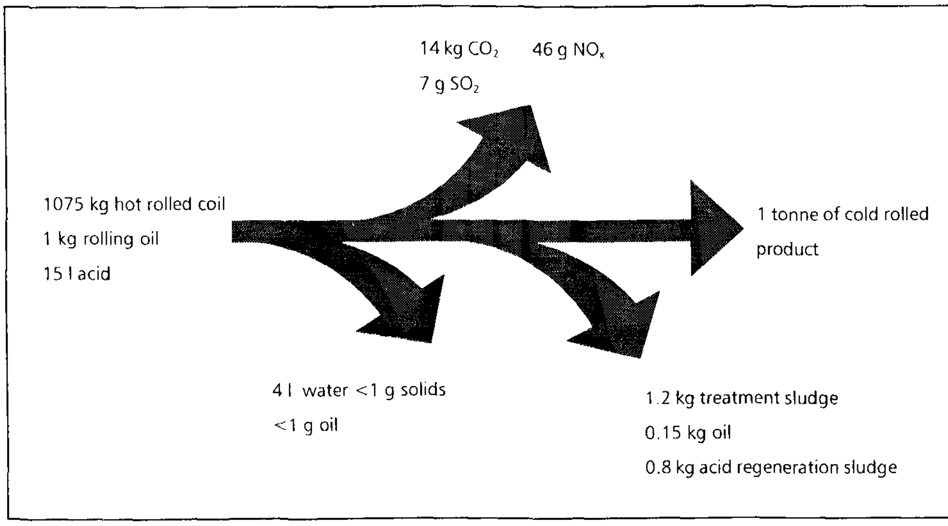
Solid wastes/by-products include scale and off-cuts which are routinely recycled back to the sinter plant and BOF respectively. Waste refractory material from the reheat furnaces is normally disposed to landfill.

2.5 PICKLING, COLD ROLLING, ANNEALING AND TEMPERING

Hot rolled products often undergo further processing in the cold rolling mill. The first process is pickling, in which hydrochloric, sulphuric or nitric acids are used to remove the oxide film which forms during hot rolling. The material is then cold reduced by compression between rollers and, following a degreasing stage, may have its metallurgical properties altered by annealing. A final rolling stage, or 'skinpass', flattens the product and improves surface hardness. Cold rolled products have a high quality surface finish and precise metallurgical properties for use in high specification products such as automobiles, white goods etc. (See **Photo 21**.)

Emissions from this process stage include combustion products from the annealing and tempering furnaces, VOCs and oil mists, derived from the rolling oils used, and acid aerosols generated during the pickling process.

Effluents may contain suspended solids and oil emulsions from the cold rolling stage and acid wastes from the pickling process. Emulsions require 'breaking' to facilitate oil removal and spent acids are neutralised, to precipitate dissolved metals, prior to pH adjustment, suspended solids



Minor emissions of concern:	VOCs, acid aerosol, oil fume, oil mist
Waste water constituents of concern:	Suspended solids, oil (including emulsions), pH, dissolved metals
Input energy breakdown:	0.9 GJ by-product gas; 0.2 GJ steam; 1.4 GJ electrical (146 kWh)

Figure 2.10 **Energy/materials balance for the cold rolling, pickling, annealing and tempering lines**

removal and discharge. Often, acid regeneration plant are installed that themselves may give rise to an acidic effluent that is treated as for waste acids, and pure iron oxide or iron sulphate, depending on the type of pickle acid used and/or regeneration process employed.

Solid wastes/by-products include off-cuts, pickle tank sludges, acid regeneration sludges and effluent treatment plant hydroxide sludge. These are either recycled (off-cuts), sold (acid regeneration sludges) or disposed to landfill.

2.6 COATING

Coatings are applied to the steel strip for protection and decoration. They may be metallic, including zinc, tin, nickel, aluminium, lead, Zn/Al alloys, chromium, or nonmetallic including paints, polymers, varnish and lacquer. Metallic coatings are applied by hot dipping the product into a molten bath of coating metal, such as in the case of zinc and Zn/Al alloy coatings, or by electrodeposition using the product as an electrode, as in the case of zinc, nickel, tin and copper coatings. Nonmetallic coatings are normally organic compounds in the form of powders, paints, films and liquids and are applied by brushing, rolling, spraying or immersion. Hot bitumen or rubber are also used in some cases. (See **Figure 2.11** overleaf, and **Photo 20**.)

Emissions from the coating process include VOCs (solvents), metal fume, acid aerosol (from associated pickling/cleaning lines), particulate, combustion products and odour (associated with fugitive VOCs). Many of these emissions are contained by local exhaust ventilation systems, but large coating lines may have an incinerator to burn waste VOC.

Effluents resulting from various cleaning operations and pickling require treatment to remove dissolved metals, oil and suspended solids. Particular waterborne contaminants (e.g. Cr VI), which cannot be removed by pH adjustment, may require specialised treatment or disposal.

Solid wastes/by-products include off-cuts, zinc dross, tin oxide, water treatment sludges, tank sludges etc.. These are either recycled (off-cuts), sold (zinc dross, tin oxide) or disposed to landfill.

2.7 ALTERNATIVE IRONMAKING PROCESSES

2.7.1 Direct Reduction

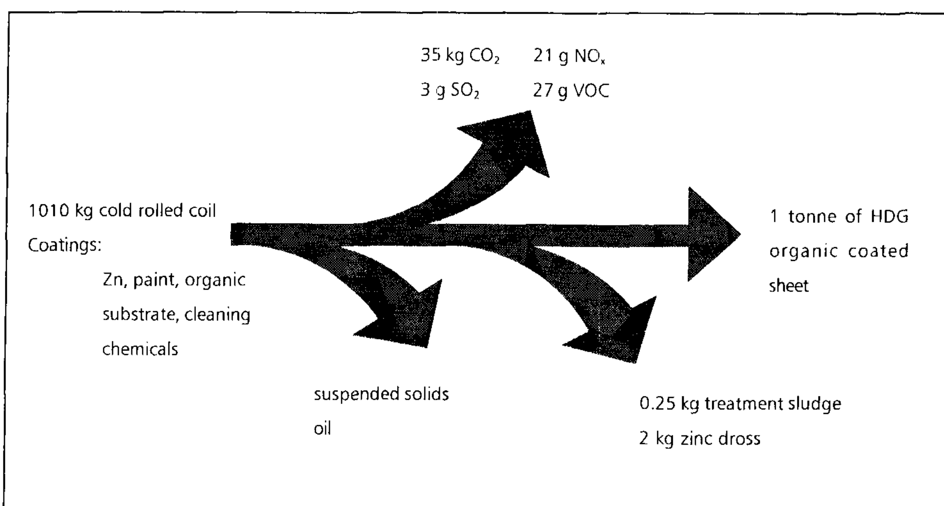
Processes for the direct reduction of iron ore were first introduced on an industrial scale in the late 1950s and at the time were considered a real alternative to the blast furnace route, with sponge iron production of 100 million tonnes per year predicted for the mid-1990s. In fact, annual production of DRI is now approximately 30 million tonnes per year. Unlike the blast furnace, direct reduction yields solid sponge iron from iron ore using reformed natural gas or coal as the reducing agent. This iron sponge is then melted in the EAF.

While the blast furnace will operate without sinter, it cannot operate without coke and one appeal of the DRI processes was the possibility that they offered to make iron without the need for coke production. However, the expected growth failed to take place due to the economics of the processes, which demanded an abundant low price energy source (e.g. natural gas or coal), and the development of the international scrap trade, which reduced the demand for sponge iron. DRI is no longer seen as an alternative to blast furnace iron, but as a competitor or supplemental iron source to scrap for the EAF.

The leading gas reduction processes are marketed by the companies Midrex and HyL and the SL/RN process, although only a few examples, is the leading technique using a solid reductant. **Figure 2.12** shows that in 1992 gas reduction processes accounted for 91.8 percent of global sponge iron production.

DRI processes may be classified both according to the reducing agent used and process configuration as indicated in **Table 1.1**.

Gas based DRI processes normally require natural gas as the feed material for making the reducing gas. In the Midrex and HyL III processes iron ore is reduced to sponge iron in a shaft furnace by passing a reducing gas mixture, produced by cracking CH_4, countercurrent to the ore. The resulting sponge iron is discharged and either cooled or hot briquetted. The Fior Process uses a fluid bed reactor to produce up to 400,000 tonnes per year of DRI and involves the multi-step reduction of fine ore at below 750°C with a hydrogen rich reducing gas made from the 'shift reaction' with



Minor emissions of concern:	Metals (Zn, Ni, Cr ^{VI}) VOC
Waste water constituents of concern:	Suspended solids, oil, pH, metals
Inputted energy breakdown:	0.8 GJ by-product gas; 0.8 GJ electrical (88 kWh) ; 0.2 GJ steam

Figure 2.11 Energy/materials balance for one example of a coating line

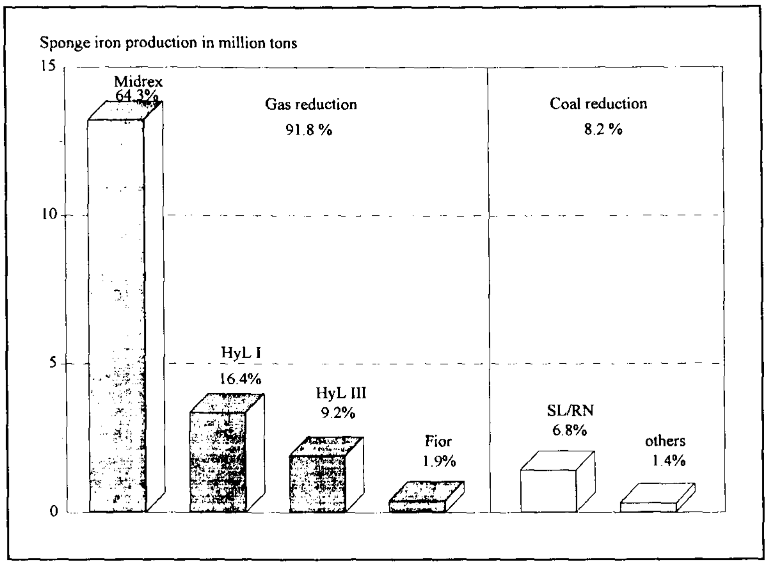


Figure 2.12 **Share of different DR processes for 1992 sponge iron production**

Table 1.1 **Processes for the direct reduction of iron ore**

Gas reduction		**Solids reduction**	
Shaft furnace:	Midrex#	Rotary kiln:	SL/RN#
	HyL III#		Krupp Codir
			DRC
Fluidised bed:	Fior#	Rotary hearth:	Inmetco#
	Iron carbide#		Fastmet
	Circofer *		

* — Generation of gas from coal gasification
# — Processes in commercial use or examples under construction

steam. Work by companies in Venezuela and Austria is underway to reduce the material and energy requirements of the process and a one million tonnes per year plant is planned. The Iron Carbide and Circofer processes also use fluidised beds and a plant to make 320,000 tonnes per year of iron carbide has been built. In Circofer, reducing gas is produced from the gasification of coal and is mixed with fine ores in a circulating fluidised bed. As the gas is circulated, no surplus gas is produced.

Solid reductant processes use coal to reduce the iron ore. In the SL/RN process iron ore, additives and coal are heated in a rotary kiln to produce sponge iron. Rotary kiln processes are much more flexible with regard to the physical properties of the iron ores and allow the charging of pellets, lump or fine ore. Fastmet and Inmetco are rotary hearth processes which are as yet unproven on a large scale although an order has been recently placed for the latter (500,000 tonnes per year). They have the advantage that green pellets containing carbon can be reduced with minimum mechanical abrasion.

2.7.2 Smelting Reduction

Currently, there are several new smelting reduction processes being developed: although the COREX is the only one to have reached industrial maturity (**Figure 2.13**) and two plants are now operational worldwide. The first 300kt/year commercial plant was commissioned in 1989 in South Africa, and the most recent installation, a 750kt/year plant, was commissioned in 1996 in Korea. Further installations of this higher production configuration are being planned, or undertaken, in Korea, India and South Africa. Other processes under development include the Cyclone Converter Furnace (CCF), the Direct Iron Ore Smelting Reduction Process (DIOS), Hismelt and Romelt.

The main advantages of these alternative ironmaking technologies are lower investment costs, greater environmental compatibility (i.e. SO_x, NO_x and waterborne contaminants are lower for the COREX process compared to the blast furnace route), coke is not required, as coal is main reduction feedstock, and, for all but the COREX process, fine ore can be processed directly without the need for sinter or pellet production. Such processes are, therefore, particularly suited to regions such as Southern Africa where steam coal is widely available and scrap is scarce.

It is likely that the blast furnace integrated route, incorporating coke, sinter and/or pellet production, will remain the dominant route for steelmaking into the future as this provides the lowest cost option for production capacities in excess of 3Mt/year. However, the new smelting reduction processes may be considered where additional hot metal capacity is required, both for BOF steelmaking or as a virgin iron source in the EAF, in areas where there are plentiful supplies of non-coking coals, where scrap is scarce or where other local conditions (e.g. lack of investment capital, environmental regulations, high electricity costs, weak power grid etc.) favour the installation.

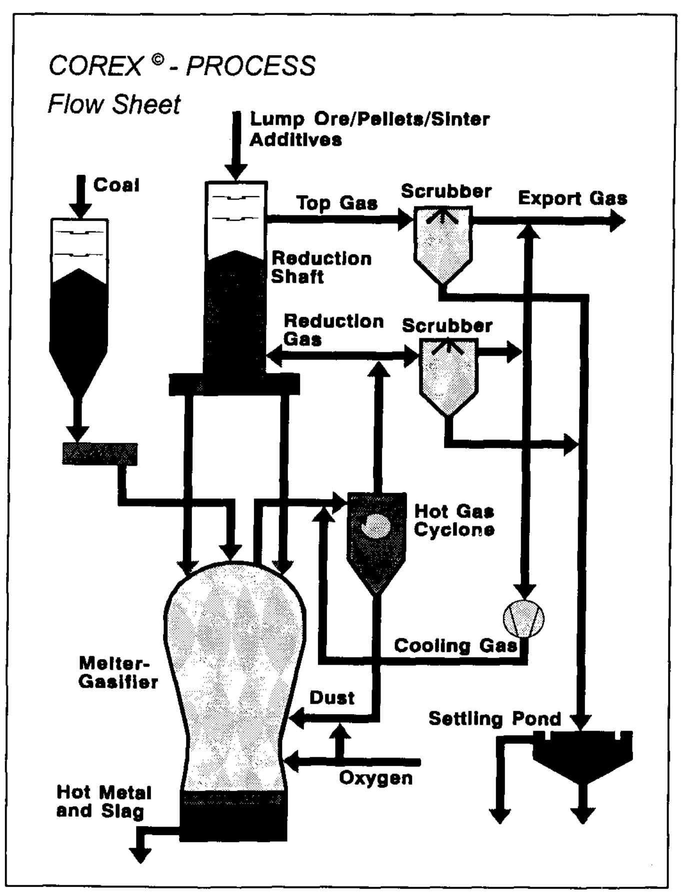


Figure 2.13 The COREX process

Chapter 3
Environmental Impacts

3.1 INTRODUCTION

Iron- and steelmaking operations have the potential to lead to a variety of impacts on the environment. These impacts depend on the process stage, the size and type of operation, the technology employed, the nature and sensitivity of the surrounding environment, and the effectiveness of planning, pollution prevention, mitigation and control techniques adopted. The perceived severity of impacts will be based on value judgements made by society and will be linked to the current status of scientific debate.

Chapter 2 clearly identified the sources and types of pollutants, and resources consumed. In this chapter, potential impacts of the release of these pollutants are discussed, as well as the problems associated with over-consumption of resources. Health impacts are included in this discussion, but only as they pertain to the health of a surrounding community. Health and safety issues in the steelworks is covered in detail in Chapter 4.

For the purposes of clarity only, this chapter has been subdivided into sections on atmospheric, aquatic, terrestrial and other impacts. This structure is not intended as, and should not be interpreted as, an encouragement to companies or governments to seek environmental solutions in a media-specific manner, as it is now well recognised that an integrated approach (i.e. the collective consideration of releases to air, water and land from all process stages combined) provides the most effective means for dealing with environmental issues.

Table 3.1 Pollutant releases and potential environmental impacts of steel manufacture

Process Stage	Potential Pollutant Release	Potential Environmental Impact
Raw Materials Handling	Dust.	Localised deposition.
Sinter/Pellet Production	Dust (inc. PM_{10}), CO, CO_2, SO_2, NO_x, VOCs, methane, dioxins, metals, radioactive isotopes, HCl/HF, solid waste	Air and soil contamination, ground-level ozone, acid rain, global warming, noise.
Coke Production	Dust (inc. PM_{10}), PAHs, benzene, NO_x, VOCs, methane, dioxins, metals, radioactive isotopes, HCl/HF, solid waste	Air, soil and water contamination, acid rain, ground-level ozone, global warming, odour.
Scrap Storage/Processing	Oil, heavy metals.	Soil and water contamination, noise.
Blast Furnace	Dust (inc. PM_{10}), H_2S, CO, CO_2, SO_2, NO_x, radioactive isotopes, cyanide, solid waste.	Air, soil and water contamination, acid rain, ground-level ozone, global warming, odour.
Basic Oxygen Furnace	Dust (inc. PM_{10}), metals (e.g. zinc), CO, dioxins, VOCs, solid waste.	Air, soil and water contamination, ground-level ozone.
Electric Arc Furnace	Dust (inc. PM_{10}), metals (e.g. zinc, lead, mercury), dioxins, solid waste.	Air and soil contamination, noise.
Secondary Refining	Dust (inc. PM_{10}), metals, solid waste.	Air and soil contamination, noise.
Casting	Dust (inc. PM_{10}), metals, oil, solid waste.	Air and soil contamination, noise.
Hot Rolling	Dust (inc. PM_{10}), oil, CO, CO_2, SO_2, NO_x, VOCs, solid waste.	Air, soil and water contamination, ground-level ozone, acid rain.
Cold Rolling	Oil, oil mist, CO, CO_2, SO_2, NO_x, VOCs, acids, solid waste.	Air, soil and water contamination, ground-level ozone.
Coating	Dust (inc. PM_{10}), VOCs, metals (e.g. zinc, C(VI)), oil.	Air, soil and water contamination, ground-level ozone, odour.
Waste Water Treatment	Suspended solids, metals, pH, oil, ammonia, solid waste.	Water/groundwater and sediment contamination.
Gas Cleaning	Dust/sludge, metals.	Soil and water contamination.
Chemical storage	Different chemicals.	Water/groundwater contamination.

The relevance of the integrated approach is highlighted by the range of potential environmental impacts arising from steel manufacture, presented in **Table 3.1** (page 29) and based on the discussions in Chapter 2. Obviously, the reduction of one of these pollutant releases, by the adoption of some environmental measure, may not be considered appropriate if this merely shifts the release from one process stage to another, or the impact from one environmental compartment to another. Thus, the entire manufacturing route, as well as the environment as a whole, need to be considered if the overall environmental impact is to be minimised.

The development of analytical environmental tools, such as life-cycle assessment (LCA), can facilitate the integrated approach to environmental decisionmaking by providing a framework for assessing the environmental impacts throughout the life cycle (manufacture, use and end-of-life) of a product. Some of the environmental impacts that might be considered by an LCA, and are therefore relevant here, are outlined in **Table 3.2** and specific emissions and their impacts are discussed below.

Table 3.2 **Environmental Impacts that might be considered as part of an LCA**

Environmental Impact	Source Pollutant/Resource Consumed
Acid rain and soil and water acidification	SO_2 and NO_x from fossil fuel burning
Resource/energy depletion	Iron ore, coal, limestone, natural gas
Global warming*	CO_2 and NO_x from fossil fuel burning and methane
Photochemical oxidation	NO_x and hydrocarbons (inc. VOCs) from fossil fuel burning
Terrestrial, aquatic, human toxicity	Heavy metals, organic compounds, ammonical nitrogen, other chemicals
Eutrophication	Nitrate in rain from fossil fuel burning
Reduction of biodiversity	Land usage
Stratospheric ozone depletion	Use of CFCs for cooling, halons for fire extinguishers. methyl chloroform and carbon tetrachloride solvents

* See Chapter 8, Section 8.4.1 for discussion of this issue.

3.2 ATMOSPHERIC IMPACTS

Local, regional and global atmospheric impacts remain the most significant environmental issues for steelmaking. Global warming, acid rain, ground-level or troposheric ozone, which can all lead to the disruption of aquatic and terrestrial ecosystems, are of primary concern. Of particular interest is the emission of particulate matter (PM), including PM_{10}, as well as CO_2, SO_2, NO_x and VOC.

In addition, trace quantities of other substances present in raw materials such as iron ore, coal or scrap may later appear in the gaseous waste streams depending on their chemical and physical characteristics and the processes involved. For example, zinc, cadmium, lead, mercury and other heavy metals from iron ores, fluxes and scrap, chlorides occurring naturally in coal or as organochlorides in coatings on scrap steel and in greases, fluorine from fluorspar, organic species in coal, as solvents or formed during the process, and naturally occurring radioactive isotopes in iron ore or coal, and discarded radioactive sources included in scrap for the steelworks.

As a recycler of used steel, the steelmaker, and in particular the EAF meltshop operator, has to deal with tramp materials that accompany returned steel scrap. These tramp materials include nonferrous metals and mineral and organic compounds used for coating steel (e.g. plastics, paints, metals etc.), associated with the steel during its useful life (e.g. copper armatures etc.) or are present as contaminants in the scrap (e.g. batteries, glass, concrete, radioactive sources etc.). These substances may end up in the metal, in the slag, in the gas cleaning residue or in the fume emitted by the plant.

3.2.1 Particulate Matter

Particulate matter (PM) is the most visible form of pollution, both when airborne and following deposition, particularly on clean washing, cars and windows. Red iron ore, black coal and coke and white limestone can be blown from stockpiles or enter the air during loading and transport. Coarse materials generate dust as they rub together during handling or when crushed by the tyres of vehicles. Very fine fume particles are generated during sintering, smelting and melting processes, and particularly when liquid iron or steel come into contact with air, to form iron oxide. Cokemaking gives rise to fine coal, coke and tar emissions, while the heating of limestone in a kiln can produce a fine white emission.

Airborne PM may be a complex mixture of organic and inorganic substances, characterised by its physical attributes and chemical composition. Physical attributes include mass concentration, measured in micrograms (μg) or milligrams (mg) per normal cubic metre, and size distribution characteristics, most frequently measured by reference to the aerodynamic diameter. As a guide, PM exceeding 2.5 microns in aerodynamic diameter is generally referred to as 'course particulate', while PM smaller than 2.5 μm ($PM_{2.5}$) is termed 'fine particulate'.

The human health effects associated with PM (e.g. respiratory disease) arise primarily from the ability of the finer fractions (both PM_{10} and $PM_{2.5}$) to enter deep into the lung space, where they can remain for long periods, causing inflammation. In addition, this fraction provides a route for other pollutants, which tend to adsorb/condense preferentially onto the surface of the finer particulate (e.g. PAHs, condensed metal oxides etc.), to enter the body and exert their own effects. The combined effects of PM in the form of smoke particles and SO_2 (see below) on the respiratory tract can impact on those already susceptible to respiratory and heart disease.

Several studies have found statistically significant relationships between *short-* and *long-term* exposure to particulate matter and *morbidity* effects. A significant increase in emergency room visits was found among people under the age of 65, for daily average PM_{10} concentrations less than 70 percent of the U.S. air quality standard (Schwartz et al. 1993). Several studies carried out in the U.S., Germany, Canada and Switzerland have found an association between respiratory symptoms and exposure to long-term ambient particulate concentrations of about 30-35 $\mu g/m^3$, without any evidence of a threshold level below which health effects do not occur (Schwartz 1991/92).

The wet and dry deposition of coarse particulate onto leaf surfaces can reduce gas exchange and photosynthesis. Plant function may be further affected if these particulate are combined with other pollutants. For example, deposition onto soils of particulate contaminated with heavy metals can affect processes that convert nutrients into a form readily accessible to plants. This, combined with particulate leaf deposition, may contribute to the reduction of plant growth and yield.

Particulate contributes to the soiling and erosion of buildings, materials and paintwork resulting in increased cleaning and maintenance costs and loss of utility.

PM impacts mostly on terrestrial ecosystems in the vicinity of emission sources. Ecological alterations may result from the gross emission of benign or inert particulate (e.g. iron oxide), or from less significant emissions that include toxic components (e.g. surface adsorbed species). Further, the accumulation of atmospheric PM in urban areas and the regional transport of fine particulate frequently results in light scattering, or atmospheric haze, leading to reduced visibility and sunlight penetration. Thus, transportation safety, property values, aesthetics, quality of life as well as plant growth can be adversely affected.

3.2.2 Ground-Level Ozone

Ozone (O_3) is a colourless, reactive, oxidant gas and a major constituent of atmospheric smog near the surface of the earth (i.e., in the troposphere). Ground-level O_3 is a secondary pollutant formed in the air by the photochemical reaction of sunlight on nitrogen oxides (NO_x), facilitated to a varying degree, depending on structure and reactivity, by a range of volatile organic compounds (VOCs). The major source of these compounds in the urban environment is vehicle exhaust, but the contribution from industrial sources can be significant. Transboundary transportation phenomena mean that O_3 may be formed hundreds of kilometres from the emission source.

The main health concern of exposure to ambient O_3 is its effect on the respiratory system, especially on the function of the lungs. Several factors influence these health impacts including the concentration of ozone in the lower atmosphere, the duration of exposure, average volume of air breathed per minute (ventilation rate) and the length of intervals between short-term exposures.

Most of the evidence of the health impacts of O_3 comes from animal studies and controlled clinical studies of humans focusing on short-term or acute exposures. Clinical studies have documented an association between short-term O_3 exposure at concentrations of 200-500 $\mu g/m^3$ and mild temporary eye and respiratory irritation, indicated by symptoms such as coughs, throat dryness, eye and chest discomfort, thoracic pain and headache (WHO, 1979, 1987).

Elevated O_3 exposures affect agricultural crops and trees, especially long-growing varieties. O_3 damages the leaves and needles of sensitive plants, causing visible alterations such as defoliation and change of leaf colour. In North America, tropospheric O_3 is blamed for about 90 percent of plant damage. In addition to the physiological damage, O_3 may also cause reduced resistance to fungi, bacteria, viruses and insects, reduce growth and inhibit yield and reproduction. These impacts on sensitive species may result in the decline of agricultural crop quality and the reduction in biodiversity of natural ecosystems.

The impact of the exposure of plants to O_3 depends not only on the duration and concentration of exposure, but also on the frequency of exposure, the interval between exposures, the time of the day and the season, as well as site-specific conditions and the stage of development of the plants. Additionally, O_3 forms part of a complex relationship between several air pollutants, along with other factors such as meteorological conditions and nutrient balances. For example, according to some studies, the presence of sulphur dioxide may increase the sensitivity of plants to leaf injury by O_3 (WHO, 1987). Others (Reinert and Heck, 1982) point out that the presence of O_3 may increase the growth suppressive effects of nitrogen dioxide (see below).

3.2.3 Nitrogen Oxides

Nitrogen oxides (NO_X) in the ambient air consist primarily of gaseous nitrogen monoxide (NO) and nitrogen dioxide (NO_2). NOx is formed during the combustion of fuel (e.g. in vehicle engines, power stations, reheat furnaces etc.) and, depending on combustion conditions, such as flame temperature and fuel nitrogen content, is discharged primarily as NO, a colourless and tasteless gas. This form is readily converted to NO_2, a yellow/orange - red/brown gas with a pungent, irritating odour and a strong oxidant, by reaction with oxygen in the atmosphere, a reaction that is also a precursor to O_3 formation. A portion of the NO_2 thus formed is then converted to nitric acid (HNO_3) by reaction with water in the atmosphere and, following combination with ammonia (another common atmospheric pollutant), ammonium nitrate (NH_4NO_3). This latter substance (along with the equivalent sulphate compound, see below) forms a secondary atmospheric aerosol which can contribute significantly to ambient $PM_{10/2.5}$ in urban areas. The nitrate aerosols are removed from the atmosphere through wet or dry deposition.

NO_x plays an important role in atmospheric chemistry and can impact on human health in a variety of ways. Lung function can be affected both by direct exposure to NO_x and by indirect exposure through the formation of secondary pollutants such as O_3 and atmospheric aerosols, which contribute to photochemical smogs and atmospheric $PM_{10/2.5}$.

Available data from animal toxicological experiments rarely indicate effects of acute exposure to nitrogen dioxide (NO_2) concentrations of less than 1,880 $\mu g/m^3$ (WHO, 1987). Asthmatics are likely to be the most sensitive group and two laboratories have reported reversible effects on pulmonary function of asthmatics exercising intermittently after 30 minutes of exposure to nitrogen dioxide concentrations as low as 560 $\mu g/m^3$ (WHO, 1987). However, the health impact of the change in pulmonary function is unclear as the change of about 10 percent is within the range of physiological variation and is not necessarily adverse. At levels above 3,760 $\mu g/m^3$ normal subjects have demonstrated substantial changes in pulmonary function (WHO, 1987).

The available data suggest that physiological effects of NO_2 on humans and animals are due more to peak concentrations than to duration or to total dose.

NO_x is a precursor both to acid precipitation and to O_3 formation, each of which can impact on plant function. The effect of O_3 has already been described and the most evident damage due to acid depositions is to fresh water lake and stream ecosystems. Acid depositions can lower the pH of the water with potentially serious consequences for fish, animals and plants, thus leading to a decrease in the variety of species and abundance of life. Lakes in areas with little calcium or magnesium carbonate deposits, which can help neutralise and buffer the effects of acidified rain, are especially at risk. Few fish species can survive the shifts in pH and effects of substances solubilised under the acidic regime resulting from atmospheric depositions and runoff of contaminated water such that affected lakes may become completely devoid of fish life. For example, 'acid pulses' have been associated with fish kills, observed in sensitive watersheds, during the spring meltdown of the snowpack.

The atmospheric deposition of nitrate is also a substantial source of nutrients for algae which, in some circumstances, can bring about estuarine damage caused by algal blooms that restrict the penetration of sunlight and deplete oxygen levels (US Environmental Protection Agency, 1992).

3.2.4 Sulphur Dioxide

Sulphur dioxide (SO_2), a colourless gas with a suffocating smell, is formed primarily in combustion processes, the quantity emitted dependent only on the sulphur content of the fuel used. In the atmosphere SO_2 may react with O_3, oxygen radicals and water to form a sulphuric acid (H_2SO_4) aerosol and, following combination with ammonia, the secondary aerosol ammonium sulphate ($(NH_4)_2SO_4$). The sulphate aerosols are removed from the atmosphere through wet or dry deposition.

Exposure to SO_2 in the ambient air has been associated with reduced lung function, increased incidence of respiratory symptoms and diseases, irritation of the eyes, nose and throat and premature mortality. Children, the elderly and those already suffering from respiratory ailments such as asthmatics are especially at risk. Health impacts appear to be linked primarily to brief exposures at ambient concentrations above 1,000 $\mu g/m^3$ (acute exposures measured over ten minutes). Some epidemiological studies, however, have shown an association between relatively low annual mean levels and excess mortality. It is not clear whether long-term effects are related simply to annual mean values or to repeated exposures at peak values.

Health effects attributed to sulphur oxides are not all due to exposure to SO_2, but also to sulphate aerosols and SO_2 adsorbed onto particulate matter. Alone, SO_2 will dissolve in the watery fluids of the respiratory system and be absorbed into the blood stream. However, SO_2 reacts with other substances in the atmosphere to form sulphate aerosols which fall within the $PM_{2.5}$ size range and, therefore, have an important role in health impacts associated with fine particulates. These aerosols can also be transported long distances through the atmosphere before deposition occurs. Average sulphate aerosol concentrations are about 40 percent of average fine particulate levels in regions where fuels with high sulphur content are commonly used. SO_2 adsorbed onto particulate can be carried deep into the pulmonary system, therefore, reducing concentrations of particulate matter may also reduce the health impacts of SO_2. Acid aerosols affect respiratory and sensory functions.

SO_2 emissions are believed to cause adverse impacts on vegetation, including forest and agricultural crops. Studies in the United States and elsewhere have shown that plants exposed to high ambient concentrations of SO_2 may lose their foliage, become less productive or die prematurely. Some species are much more sensitive to exposure than others and plants in the immediate vicinity of emission sources are most vulnerable. The most sensitive species of plants begin to demonstrate visible signs of SO_2 exposure at concentrations of about 1,850 $\mu g/m^3$ for 1 hour, 500 $\mu g/m^3$ for 8 hours and 40 $\mu g/m^3$ over the growing season (Smith, 1981 cited in NAPAP, Report 18, Effects of Pollution on Vegetation, 1990). In studies carried out in Canada, chronic effects on pine forest growth were prominent where SO_2 air concentrations averaged 44 $\mu g/m^3$, the arithmetic mean for the total 10 year measurement period, and slight where SO_2 annual concentrations averaged 2 $\mu g/m^3$ (Federal-Provincial Advisory Committee on Air Quality, 1987).

Trees and other plants exposed to wet and dry acid depositions at some distance from the source of emissions may also be effected. Impacts on forest ecosystems vary greatly according to the soil type, plant species, atmospheric conditions, insect populations and other factors that are not well understood.

Agricultural crops may also be affected by exposure to deposition; alfalfa and rye grasses are especially sensitive. It appears that leaf damage must be extensive before exposure affects the yields of most crops, but it is possible that, over the long-term, sulphur input to soils will affect yields (OECD, 1981 and NAPAP, Report 18, Effects of Pollution on Vegetation, 1990). Having said this, SO_2 may not be the primary cause of plant injury and other pollutants, such as O_3, may have a greater impact.

As discussed previously, acid depositions can damage freshwater lake and stream ecosystems by lowering the pH of the water. Lakes with a low buffering capacity (i.e. in areas with little calcium or magnesium carbonate deposits) are especially at risk as few fish species can survive large shifts in pH.

SO_2 emissions may affect building stone and ferrous and nonferrous metals. Sulphurous acid, formed from the direct reaction of SO_2 with moisture, accelerates the corrosion of iron, steel and zinc, SO_2 reacts with copper to produce the green patina of copper sulphate and acids, in the form of gases, aerosols or precipitation may chemically erode building materials such as marble, limestone and dolomite. Of particular concern is the chemical erosion of historical monuments and works of art. Sulphurous and sulphuric acid may also damage paper and leather.

3.2.5 Heavy Metals

Metals such as zinc, cadmium, lead, mercury, manganese, nickel, chromium etc. can be emitted from the furnace as a dust, fume or vapour and, therefore, have the potential to enter the atmosphere unless properly controlled. Heavy metals such as these are associated with a wide range of impacts (if exposure is sufficiently high) including, in humans, irritation of the lungs, eyes, nose and throat, lung, kidney and liver damage, reproductive and fertility problems, lung and skin allergies, flu/pneumonia like symptoms, pulmonary edema, bronchitis, neurological disorders, brain damage, depression and cancer. In animals exposure may give rise to shortened lifespans, reproductive problems and lower fertility; toxicity toward aquatic organisms is variable depending on species and metal. Plants may be affected by reduced yield and photosynthetic capability.

3.2.6 Acid Emissions

Acid emissions, such as hydrochloric (HCl), hydrofluoric (HF) and sulphuric (H_2SO_4) acid can give rise to irritation of the lung, nose and throat in humans, leading to coughing, shortness of breath, bronchitis and emphysema, liver and kidney damage, pulmonary edema and, for HCl, respiratory cancer. In plants they may lead to low growth and death (again dependent on exposure levels).

3.2.7 Organic Emissions

Organic species emitted from steelmaking operations might include benzene, toluene, xylene, solvents, polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), dioxins, phenols, VOCs, etc. The effects of exposure to these compounds are, again, wide ranging and include liver, kidney, pancreatic and heart muscle damage, vomiting, diarrhoea, headaches, dizziness, mouth, nose and throat irritation, cancer, chloracne, reproductive problems and neurological damage. These compounds also have a range of toxicities towards animals and plants may be affected by membrane damage, low growth, decreased germination and death.

Attention has, in recent years, been given to the potential for the EAF to produce organic pollutants which are not captured by conventional gas cleaning systems. Such substances include potentially highly hazardous organic and chlor-organic compounds such as PAH, PCBs, dioxins and less hazardous compounds, which have an annoying pungent odour, including VOCs. As indicated above, the release of some of these compounds, for example PCBs, can have a variety of environmental and health effects.

3.2.8 Radioactivity

Since the 1970s there have been reports of incidents where radioactive sources, which have been unwillingly introduced into EAF together with steel scrap, have been melted. Radioactive contamination of scrap can have different origins:

- Activation levels acquired by steel during its useful life within nuclear installations. Although dismantling procedures of such facilities aim at channelling contaminated materials to proper processing or disposal, the possibility that steel scrap from such origins can enter the common scrap market cannot be excluded.
- Presence within the scrap of discreet radioactive sources used in industrial and medical applications. Generally such sources are contained within a protective lead shielding and external radiation levels may be very low, although the sources may have very high energies.
- Presence of natural radionuclide deposits accumulated during the useful life of steel parts used in mining, oil drilling and the chemical industry.
- Presence of radioactive coatings deposited on steel parts used in particular applications (static eliminators, smoke detectors).

The physicochemical properties of the nuclides, such as boiling temperatures and affinity for oxygen, will affect their distribution between the process phases (e.g. the metal bath, the slag and the flue dust) and the melting of radioactive material can result in the contamination of steel products, by-products and wastes requiring costly cleanup and disposal. Added to this are the potential dangers of contamination of steelmill equipment and the exposure of steelmill personnel.

3.2.9 Others

Carbon dioxide: Although carbon dioxide (CO_2), at current atmospheric levels, has no direct adverse impact on human health or ecosystems it is increasingly viewed as an air pollutant because of its importance as a "greenhouse gas' (i.e. a gas that is suspected to contribute to global warming). The sources of CO_2 include animal and plant respiration, anoxic decomposition processes and the combustion of fossil fuels. The main sink is plant photosynthesis, although there is a significant amount of CO_2 contained in the oceans, in the form of bicarbonate (HCO_3^-), in equilibrium with atmospheric CO_2. The source drawing most attention, fossil fuel combustion, is a relatively minor one, but the resulting small imbalance in the CO_2 cycle is thought to be leading to a steady increase in atmospheric temperatures. The potential environmental effects, resulting from a rise in the earth's temperature, range from shifting weather patterns to a rise in sea level that could impact on biodiversity, agriculture, water quality and many other environmental parameters.

The steel industry is a significant generator of CO_2, however, this is due to the unavoidable use of carbon as a reducing agent in the production of iron from iron ore, rather than from the use of carbon as an energy source.

CFCs: Chemicals such as chlorofluorocarbons (CFCs), halons, methyl chloroform and carbon tetrachloride, are implicated in the depletion of the stratospheric ozone layer, that segment of the earth's upper atmosphere which protects animal and plant life from the damaging effects of ultraviolet radiation. The use of CFCs in cooling units, including industrial uses and air conditioning, halons in fire protection equipment and methyl chloroform and carbon tetrachloride for solvent uses may still be carried out at steelworks, but these applications should be phased out in line with the Montreal Protocol and national regulations.

Odour: Odour can be a nuisance even when the concentration of a gaseous pollutant is well below the level at which serious harm can result. SO_2 and hydrogen sulphide (H_2S), released during slag quenching, are especially pungent. Ammonia (NH_3), mercaptans (organic sulphur compounds) and phenolic odours arise from the coke oven and gas processing plants. Organic and acidic mists may be generated during rolling, while paint and solvent odours can be emitted at the coating lines. Often these emissions can have a far bigger psychological impact on the local community than other, potentially more hazardous, emissions and, therefore, should be reduced to a minimum.

Noise: Many steelmaking operations are noisy and, despite the many precautions taken to reduce the propagation of noise outside the plant, can cause a nuisance to local communities. Sources of noise include traffic movements both on and off-site, noisy equipment, such as the EAF, pollution control fans etc., noisy operations, such as scrap processing and product handling, and non-normal operations such as the release of pressure on the blast furnace, slag explosions, etc. Depending on the frequency, duration and time of day of the different noises, these can have a detrimental effect on the wellbeing of the local community.

3.3 AQUATIC IMPACTS

3.3.1 Suspended Solids

Suspended solids are the main waterborne pollutants to be discharged during steel manufacture, particularly from integrated sites. Primarily, suspended solids are made up of iron oxides resulting from scale formation during processing, although other sources, such as raw material handling losses, carryover from the coke ovens biological treatment plant, pickling and coating line water treatment plants and wet gas cleaning systems may give rise to coal, biological sludge, metal hydroxides and other solids respectively. Suspended solids may also be associated with oils where they arise from rolling operations. These components are largely nontoxic in the aqueous environment at normal discharge levels, but elevated levels can lead to discolouration of water courses, de-oxygenation (if light is unable to penetrate) and silting.

3.3.2 Heavy Metals

The discharge of metals to the aquatic environment has been a major cause of concern and, consequently, the treatment of metal bearing wastes (solid and liquid) has attracted considerable attention. Increased awareness of pollution from metals and its effects has emphasised the importance of water quality management in maintaining our natural waters (surface, ground and marine) in a fit state for various purposes (e.g. for use as drinking water, for recreation or to assure the viability of native biota). It is important to realise that, with the exception of synthetic elements and nuclides, all pollutant metals are naturally present in the aquatic environment, but it is their presence at higher than usual concentrations that presents a threat to the biota and, ultimately, the human population. As indicated above, the toxicity of metals to aquatic organisms can vary significantly from moderate (e.g. Mn, Cr(III),) to high (e.g. Pb, Hg, Cd, Cr(VI), Ni, Zn).

Steelmaking process water may contain high levels of zinc and manganese, while the cold rolling mill and coatings area discharges can contain zinc, cadmium, aluminium, chromium and copper. Unlike many organic pollutants, which are susceptible to biodegradation, heavy metals do not degrade to harmless end products and can become concentrated in sediments and in the tissues of aquatic organisms.

Furthermore, metal wastes from iron and steel manufacturing may be combined with other toxic components, such as ammonia, organics, lubricants, cyanides, alkalis, solvents, acids, etc. that may interact and present a more significant toxic release to the environment. Therefore, it is necessary that chemical and physical treatments are used to minimise the impact on the receiving water course of effluent resulting from the direct discharge of wastewaters or the leaching of pollutants from landfilled waste.

3.3.3 Oils and Greases

Originally derived from vegetables, animal tissue, crude petroleum or its components, oils and greases may be present in waste water as a surface floating liquid, an emulsion or as a light petroleum fraction in solution. As most heavy oils and greasy materials are insoluble in water they can be removed relatively easily unless they become emulsified by contact with detergents, alkalis and following agitation. In the cold mill area, emulsified oils are routinely used as part of the process. In general terms, aliphatic oil compounds are relatively innocuous, although very small quantities can give rise to discolouration of the water surface and larger quantities can reduce oxygenation and lead to oiling of wildlife. Monohydric aromatic oil compounds are generally toxic, the degree of toxicity increasing with increasing unsaturation. Some oil components, such as PCBs and lead, will accumulate in the tissues and can have adverse effects, as described above. Emulsifers and dispersants, often used following oil spillages, are themselves often highly toxic (Harrison et al 1990).

3.3.4 Oxygen Demand

Chemical oxygen demand (COD) is the amount of oxygen consumed in the complete oxidation of carbonaeous matter in an effluent sample. The COD can be empirically related to biochemical oxygen demand (BOD) (i.e. the rate at which microbiological oxidation of organic matter reduces the level of dissolved oxygen in water), organic carbon or organic matter content and is a useful index for measuring the potential for effluent to render receiving waters unfit to support life. That is, the organic material content of an effluent begins to be degraded once discharged which can lead to a severe reduction in the levels of dissolved oxygen, thus affecting the viability of aquatic life. Organic components that may contribute to the COD/BOD of a steelworks effluent include phenols, light oils, oil, PAH etc., as well as NH_3 and thiocyanate (CNS).

3.3.5 Organic Compounds

These include natural and synthetic molecules containing carbon and hydrogen. They exhibit a wide range of physical and chemical properties depending on molecular size, molecular weight and polarity. Some organic compounds can cause serious physiological disorders and can effect aquatic and terrestrial ecosystems, even when present at very low concentrations. This may be due to their very high toxicity or their persistence in the environment, leading to bioconcentration in the tissues of aquatic life. The major source in the steelworks is the coke plant. The coal feed to the plant is a heterogeneous mixture of carbon and the coking process discharges a variety of organic species including benzene, toluene, xylene, naphthalene and other PAH and phenols.

3.4 TERRESTRIAL IMPACTS

In the early 1970s greater attention began to be paid to the phenomenon of soil and ground water contamination as an important environmental issue. Soil and groundwater are threatened by a wide range of activities within the steel sector, from gas cleaning water lagoons and soakaways, that can lead to the infiltration of contaminated water into the ground, to the disposal or storage of materials, wastes, slags and scrap on or in the ground, from which contaminants can leach. It is recognised that the current problems and issues cannot all be attributed to modern practices and production methods, as many steelmaking sites have a long history of industrial activity and contamination. In the past, environmental regulations and safeguards were less onerous and there was little understanding, and certainly less recognition, of the potential problems involved. Such long term damage has proved, in many instances, both expensive and difficult to remediate, owing to the insidious nature of the contamination, and many steel companies now seek solutions to reduce the potential for ongoing contamination, by improving current operating practices, and to remediate historical contamination, where significant harm to the environment is suspected.

The impacts of long term contamination can be far reaching. For example, the release of contamination from a single source, such as an underground benzene storage tank that has been leaking over a long period of time, will give rise to a very high level of localised contamination and, depending on soil and groundwater characteristics, this can be dispersed over a very wide area. The leak may only be detected after a long period, perhaps when a drinking water extraction borehole many miles from the source begins to show elevated levels of benzene. At that stage it is very difficult to remediate the problem because of the reservoir of contamination that exists in the ground that will continue to disperse long after the leaking tank has been repaired.

The pollutants that can be dispersed in this manner include light oils (e.g. benzene, toluene, xylene), oils, phenol compounds, cyanides, some metals, acids etc. The impact of each is dictated by the degree of attenuation, controlled by the pollutant source strength, pollutant chemical and physical characteristics and soil and groundwater characteristics, and the potential targets, which may include human populations (e.g. drinking water contamination), agriculture (e.g. irrigation water contamination), aquatic life (e.g. if groundwater breaks out to contaminate surface waters) and soil biota.

Soil contamination can result from the storage or disposal of materials on or in the ground, spills or deposition of pollutants from the atmosphere. Depending on the pollutants involved and the degree of contamination this may lead to groundwater contamination (see above), habitat loss, where plants and animals are unable to survive in the prevailing conditions, reduced amenity, where hazardous substances are present, or exposure of the local population owing to the lift off of contaminated material.

Once contamination is suspected, whether remediation is carried out or not will depend on many factors. If standards or guidelines exist there will be a need to define the degree of contamination (potentially requiring a comprehensive sampling and analysis exercise) and potential targets, to determine if remediation is required and, if this is the case, the most appropriate techniques to employ (e.g. remove and dispose, isolate/control/check, biological/chemical/physical treatments etc..).

3.5 OTHER IMPACTS

The construction and operation of a steel works may lead to other direct or indirect impacts on the environment all of which should be addressed prior to construction of a new works or major modification at an existing site. Some of these impacts include changes in:

- Land-use patterns, such as agriculture, fishing and hunting as a direct consequence or as a secondary consequence of providing new access routes (by land and by sea/lakes)
- Socio-economic systems due to new employment opportunities, income differentials, inflation, difference in per capita income when different members of the local groups benefit unevenly from induced changes
- Availability of and access to goods and services such as housing, education, medical, water, fuel, electricity, sewage and waste disposal
- Planning strategies, where conflicts arise between development and protection, natural resource use, recreation use, tourism, historical, archaeological and cultural resources
- Aesthetic impacts due to the presence of facilities, for example visual and noise impacts
- Transportation systems, due to the increased road, rail and sea infrastructure and associated effects, such as noise pollution, increased accident risk, increased maintenance requirements or deterioration of existing services.
- Impact on the biodiversity of the local environment. For example, the interruption of migrating species and the disturbance of wetlands.

Steelworks have come a long way from the traditionally dirty, polluting, dangerous industry of years gone by. Technology changes have greatly changed this reality, but not completely. The industry, especially if poorly located, built or managed may still give rise to serious ecological and health impacts. Conversely, where environmental factors are 'designed in' and 'managed', the impact can be reduced to levels compatible with contemporary notions of environmental quality, always realising that a massive conversion plant that is a modern steelworks will never be pollution-free.

Chapter 4
Occupational Health and Safety Issues

4.1 INTRODUCTION

There are clear relationships between the inplant environment and those external environmental issues, which arise from steelmaking operations, addressed in Chapter 3. This chapter is concerned primarily with these relationships and does not attempt to address occupational safety problems which are essentially plant based (related to machinery safety or works access, for example) except insofar as it is useful by way of illustrating the industry's overall efforts in the occupational environment. These relationships are apparent in many areas, including:

- Taking adequate precautions to protect employees will often have beneficial implications for the environment generally and for the people who may live, work, or travel in the vicinity of a steelworks.
- The experiences gained in protecting employees and protecting the environment can frequently be applied to both problem areas or, at least, are helpful in determining the approach to finding solutions.
- The standards established for the occupational environment, and the methods of establishing them, are made use of in the process of establishing general environmental standards and vice versa, although other factors frequently need to be taken into account.

The steel industry recognises that many of its operations are potentially dangerous for its employees, because of the nature of the materials being processed and the processes themselves. Molten metal and slag at temperatures up to 1,800°C are frequently present, toxic or corrosive substances and flammable gases are used and produced, while steel industry machinery is among the most powerful and, in some instances, the noisiest in the world.

In the field of occupational health and safety the industry as a whole has recognised its responsibilities to ensure that its operations are carried out in such a way as to avoid damage to its employees. Records show, for example, that there have been significant improvements in safety performance associated with iron- and steelmaking in such areas as fatal accidents and lost time injuries, and it is now generally appreciated that steel plants should and can be accident free. Similarly, in recent years health problems have become more generally recognised and the industry has introduced ever more stringent controls over the use and introduction of chemical substances and exposure to physical agents. One of the problems in this area, of course, is that results take much longer to filter through, for example, the incidence of occupational deafness being observed today is largely the result of working conditions twenty or more years ago.

It must be understood that the potential dangers which are intrinsic to iron- and steelmaking cannot always be designed out by new plant and technology and, therefore, the importance of everyday control is crucial. Similarly, the industry is constantly changing both in technology and in its use of manpower. Whole processes have disappeared in some plants, for example, as a result of the introduction of continuous casting. While this may result in the elimination of some potential hazards, the industry has to be alert to the introduction of new problems arising from technological change, for example the growth of coatings for steel strip. Finally, the industry has to be constantly alert to the identification of new problems arising from improved knowledge or changes in accepted standards.

It must also be remembered that employees are not the only people facing potential health risks from a steel plant. The size and scale of these plants means that impacts to the surrounding community should be carefully monitored, particularly the health effects from air pollution. Chapter 3 outlined some of the environmental impacts and this chapter considers, in greater detail, some of these same pollutants as they pertain to occupational health. The remaining sections of the chapter deal with other key issues such as the control of chemical agents, the control of physical agents, fire explosion and major hazards, ergonomics and health surveillance.

4.2 POLLUTANTS OF CONCERN

The fact that steelworkers can, potentially, be exposed to a wide range of pollutants as part of normal operations has long been recognised and this has led to the development of processes, operating practices and training programmes that obviate the possibility, or minimise the risk, of exposure. Thus, under present practices employees are unlikely to be exposed to levels of pollutants that will give rise to health problems. However, despite the advances made, exposure to some pollutants still occurs, and therefores monitoring and continued surveillance is carried out to ensure that maximum limits are not exceeded. Some pollutants of concern, emitted from the steelmaking processes, are discussed below with regard to emission sources and health impacts. However, whether a pollutant is toxic or not depends on the level of exposure, duration of exposure, accumulation potential and individual sensitivity. The limits for exposure within the workplace are well defined and these should be considered initially when deciding whether an exposure is significant and health threatening. The list is not exhaustive, but it reflects some of the priorities for monitoring and control within the industry. Obviously, some processes, not covered here, may give rise to very specific emissions that are hazardous and these should be dealt with as described elsewhere in this chapter to minimise the risk to personnel.

4.2.1 Particulate Matter

The major sources of particulate matter, that may result in exposure of personnel within the steelworks, include emissions during cokemaking, blast furnace tapping, BOF charging, blowing and tapping, hot metal pretreatments and EAF charging, melting and tapping. The operating conditions of these processes are such that the emitted particulate has a size distribution conducive to deep penetration of the lung (i.e. the bulk of the particulate is <10 um in size) allowing direct entry into the body. Other processes, that may lead to the exposure of personnel to particulate with different size characteristics, include equipment maintenance, duct cleaning and refractory wrecking operations.

The health effects from particulate exposure can arise as a result of the physical size of the particulate (i.e. iron oxide is nontoxic, but exposure to fine iron oxide dust may lead to health problems) as well as the presence of other potentially hazardous components adsorbed onto the particulate surface (such as PAH, benzene or metals). The health effects of these latter species are discussed more fully in the relevant sections below.

Exposure to particulate matter can lead to eye, nose and throat irritation, phlegm production, coughing, wheezing and other breathing and respiratory problems, associated with inflammation of lung tissue, and can aggravate existing respiratory and cardiovascular disease. Particulate matter may also affect the body's immune system and reduce the capacity to remove foreign matter from the lungs. Long term exposure may lead to permanent lung damage, carcinogenesis and premature death.

The health effects of particulate matter may be enhanced in the presence of SO_2 which can be found in the blast furnace cast house and at high level within the BOF and EAF melting shops when sulphur casts are processed.

4.2.2 Heavy Metals (Pb, Cr, Ni, Mn, Cr (VI))

Heavy metals may be present in a variety of emissions into the working environment including dust and fume, particularly that generated during processing in the BOF and EAF, in emissions from alloying and casting operations, when leaded steels are produced, in acidic and other aerosols, generated on the pickle line, and in the fume emitted during hot dip coating. Metals that are often present include lead (Pb), zinc (Zn), chromium (Cr), nickel (Ni) and manganese (Mn).

Pb is present in many scrap streams and is easily volatilised during charging and melting. Leaded steels are also produced at some sites giving rise to emissions during alloying, casting, grinding, scarfing and rolling and subsequent machining operations. Maintenance of gas cleaning plant etc. may also give rise to exposure when collected dust is disturbed. Exposure to high levels of Pb may result in damage to the central nervous system, the brain, the kidney and the male reproductive system. Other symptoms include increased blood pressure, weakness in joints, memory loss and anaemia.

Case Study — Precautions for Handling Lead in the Steelworks

Lead for Leaded steels — *In the manufacture and subsequent processing of steels alloyed with lead (freecutting steel), measures must be taken to limit the exposure to lead as far as possible, primarily by providing adequate means of extraction.*

Steelmaking — *Lead is alloyed in an argon rinsing stand after tapping the crude steel into a ladle. This treatment should be performed under a canopy with adequate extraction to remove emissions.*

Casting — *The lead-containing steel is then continuously cast into a mould from a tundish. The tundish should be equipped with an extractor system to protect employees. In addition, sequential casting minimises the frequency with which the tundish must be changed (and therefore handled by the employees). When the tundish is changed, personal protection equipment must be worn by the operating personnel.*

In both the above areas, control stands with filter systems for the incoming air are provided for the operating personnel. The same provision is made for crane drivers. The time spent by operators outside the control stands should be limited to the essential minimum and, when it is necessary to leave the stands, personal protection equipment should be made available as necessary.

To limit exposure further, high air change rates should be maintained in the factory bays and the quantity of settled dust around the plant minimised by cleaning the floor and other surfaces with vacuum cleaners.

Hot rolling — *Exposure to lead during hot rolling can be limited by maintaining high ventilation rates in the rolling shop. As in the case of steelmaking and casting, operating personnel should be provided with ventilated control stands equipped with filters and time spent outside the control stands kept to a minimum.*

Further processing — *Operators can be protected during subsequent processes, such as grinding, by fitting appropriate extraction hoods to the work areas. More generally, all employees working in zones involving exposure to lead should undergo precautionary medical examinations. (see Section 4.7.)*

Zn is present in many scrap streams and is easily volatilised during charging and melting. Zn is also used as a coating to impart corrosion resistance to steel. Maintenance of gas cleaning plant may also present a hazard. Short term exposure to high levels of zinc, and other volatilised metals, may give rise to 'metal fume fever', characterised by symptoms such as fever, chills, nausea, breathing difficulties and fatigue. The condition is reversible and individuals may develop a tolerance. Other health effects resulting from short term exposure include inflammation of the lung tissue and immunological reactions. Long term exposure to low levels may cause occupational asthma. The long term effects of exposure to high levels of zinc are unknown.

Cr may be found in three distinct forms within the steelworks environment. Cr metal is present in ferrochromium alloys, used for the manufacture of stainless steel, Cr (III) is present in emissions from the EAF and secondary steelmaking facilities, during stainless steel production, and in emissions generated during the downstream processing of stainless steel, for example welding, and Cr (VI) can be found in the emissions generated during the electrolytic pickling of stainless steels and passivation of coated steels. Cr containing refractories and dust collected in gas cleaning plant may also be a source of both Cr (III) and Cr (VI), with exposure occurring during lining wrecking operations and gas cleaning plant maintenance operations respectively.

The potential health effects of Cr metal are not well characterised, but it is thought to have a low toxicity and is unreactive in the body. Exposure to Cr metal dust, however, may cause short term coughing and irritation of the airway and eyes. In the body Cr metal may be partially oxidised to Cr (III) (an essential nutrient), but this form also has a low toxicity and is poorly absorbed. Cr (VI) is by far the most hazardous form and short term high level exposure may lead to irritation of the nasal mucosa and gastrointestinal tract, perforation of the nasal septum and ulceration of the skin. Longer term exposure to moderate levels may cause damage to the nose and lungs and increase the risk of lung disease. Exposure may also lead to adverse effects in the liver and kidneys and there is limited evidence that Cr (VI) is also a carcinogen. Individuals who are allergic to Cr may suffer an asthma attack after breathing high levels of Cr (III) or Cr (VI).

Within the steelworks Ni may be present as nickel metal, used as a raw material for stainless steel manufacture, as an oxide, in the fume emitted and collected from the EAF and secondary steelmaking processes during stainless steel manufacture, and in the fume generated during the downstream processing of these steels. Long term exposure to high levels of nickel may lead to lung disease, lung and nasal cancer and premature death. Other effects include heart problems, blood disorders, kidney damage and, most commonly, allergic reactions such as skin allergies and asthma attacks.

Mn may be present in the steelworks as a metal, in the form of ferromanganese, and as an oxide, in the fume emitted and collected during blast furnace tapping, processing in the BOF and EAF and during downstream processing of manganese steels. The potential health impacts of Mn have not been fully investigated, but short term exposure may lead to irritation and long term exposure may lead to reproductive disorders and nervous system disturbances, such as sleepiness, weakness, emotional disturbances and walking difficulties. Exposure to Mn may also lead to pneumonia.

4.2.3 Asbestos

Asbestos is not used directly as part of the steelmaking process, but historically it was used as thermal and noise insulation. Exposure only occurs during maintenance or construction activities when existing asbestos products are disturbed, generating airborne fibres. There are several types of asbestos fibre with inherently different physical characteristics (e.g. chrysotile, crocidolite, amosite, etc.) and which show a range of health effects. However, long term exposure to asbestos may result in lung cancer, asbestosis (scarring of the lung tissue), mesothelioma (i.e. cancer of the chest lining or abdominal cavity), cancer of the larynx and of the gastrointestinal tract and scarring and thickening of the pleural membranes, leading to breathing difficulties. Smoking in combination with long term exposure may also increase the risk of lung cancer. There is a latency period for many of these conditions, and therefore the effects may only become obvious many years after the initial exposure. Minor, short term, effects of asbestos exposure include irritation of the nose and throat.

4.2.4 Cyanide

Cyanides may be present in electroplating and steel cleaning solutions where brass plating of wire is carried out. Both sources can give rise to an airborne hydrogen cyanide (HCN) under the right conditions. Exposure to HCN reduces the ability of the body to use oxygen. High level exposure over a short time period may lead to respiratory, cardiovascular and central nervous system damage, breathing difficulties, convulsions, coma and possibly death. Short term exposure to smaller quantities can lead to breathing difficulties, convulsions and loss of consciousness. Long term exposure to lower levels of cyanide may lead to central nervous system problems, such as deafness, vision and coordination problems, and thyroid enlargement.

4.2.5 Hydrogen Sulphide (H_2S)

The predominant source of H_2S on the steelworks is blast furnace slag. The odour of H_2S is unpleasant and the short term effects of exposure are highly variable depending on concentration. These range from dryness and irritation of the nose and throat, coughing, hoarseness, shortness of breath and pneumonia at 50 ppm. At ~150 ppm there is a temporary loss of smell and higher levels (<250 ppm) lead to headaches, nausea, vomiting and dizziness and, if exposure is prolonged, lung damage, increased production of lung fluids and death. At concentrations of 300-500 ppm the same effects are observed much sooner and death can occur in under 4 hours. Exposure above 500 ppm may lead to respiratory failure and death in less than 1 hour. Prolonged exposure to lower levels (<10 ppm) leads to inflammation and irritation of the eyes and higher levels (>50 ppm) may lead to permanent eye damage. Long term exposure to low levels may cause fatigue, headaches, dizziness, coughing and irritability.

4.2.6 Oil Mist

Oil mists are generated during the cold rolling of steel. Short term exposure can result in irritation to the skin, eyes, mucous membranes and upper respiratory tract, nausea, vomiting and headache.

4.2.7 Benzene

Benzene, along with toluene and xylene, is one of the components removed from coke oven gas in the byproducts plant. Therefore, the major sources of benzene exposure within the steelworks are on the battery during cokemaking and within the byproducts area during the handling of the benzene mixture. Short term exposure to elevated levels of benzene can cause irritation to the nose and throat, lung inflammation, headaches, tiredness, depression, nausea, loss of coordination, confusion and unconsciousness. Long term exposure may lead to serious blood disorders, such as reduced numbers of red, white and clotting cells, the effects of which are reversible, although continued exposure will lead to bone marrow damage, aplastic anaemia and leukemia. Long term exposure to elevated levels of benzene may also affect the central nervous system leading to increased incidences of headaches, fatigue, difficulty sleeping and memory loss.

4.2.8 Carbon Monoxide (CO)

Carbon monoxide (CO) is a colourless, tasteless, odourless gas that is produced by the incomplete combustion of carbon based fuels, such as coal, oil, blast furnace gas etc. Thus, CO is released as part of any combustion process, but emission levels can be increased by poor combustion control and maintenance. Other sources within the steelworks include the coke battery, blast furnace and BOF offgas systems and secondary degassing treatments, that may release the generated CO directly to atmosphere. CO enters the body through the lungs and binds preferentially to blood haemoglobin, displacing oxygen and affecting oxyhaemoglobin dissociation, resulting in tissue hypoxia. Health effects associated with CO poisoning include headaches, irritability, dizziness, nausea, vomiting, weakness, difficulty concentrating, difficulty breathing and, in cases of elevated exposure, death.

4.2.9 Polycyclic Aromatic Hydrocarbons (PAH)

Most combustion processes give rise to PAH, depending on the fuel type and combustion conditions, but the most significant exposure sources on the steelworks are the cokemaking process and blast furnace tapping operation. The PAH emitted may be present as vapours or as adsorbed species on the surface of fine particulate. There are many PAH compounds that display a wide range of properties and toxicities of which one, benzo (a) pyrene, which is considered the most toxic, is routinely monitored to determine the exposure of workers. Short term exposure to PAH may cause irritation of the skin, nose, throat and upper respiratory tract, dizziness, nausea, headaches and weakness. Very high doses may lead to respiratory collapse and damage to the liver, lungs, kidneys and blood system. Long term exposure may also cause cancer and damage to the liver, kidneys, lungs and blood and lymph systems.

4.3 THE CONTROL OF CHEMICAL AGENTS

Worldwide concern for occupational health, safety, fire prevention and occupational environmental issues has led industry and governments to reconsider the controls over the supply and use of chemical substances in the workplace and elsewhere. The use of these substances continues to grow apace in the world generally and the steel industry is no exception to that growth.

An integrated steelworks will typically use more than 1,000 different chemicals in many diverse applications:

Materials used:	Examples of application:
• Raw materials for direct use in the manufacturing process	as additives in steelmaking, continuous casting
• Fuels to enable the manufacturing process to be carried out	coke, coal and gas in ironmaking
• Specialised materials peculiar to the end product itself	for the manufacture of stainless steel, tinplate or coated products
• Materials essential to the operation of the plant	hydraulic fluids; refractories
• Materials essential to the maintenance of the plant	for cleaning purposes; as a solvent
• Specialised material used for research or quality control	laboratory usage

Steel industry byproducts such as tar, benzene and ammonia from the coke oven byproduct plant and the fuel gases generated during iron- and steelmaking are useful yet potentially hazardous. Other byproducts such as sludges and slurries, which are less recyclable at the present time, also present handling and disposal problems.

To protect employees from potential hazards, it is necessary to implement comprehensive control programmes which include:

- Controls on the ordering and purchase of such materials
- Arrangements for the elimination of the most dangerous substances and the search for alternatives
- Controls on their introduction and use within the works
- Arrangements for the handling of information about the substances and appropriate dissemination to management and other employees
- Arrangements for the storage and retrieval of the considerable data involved
- Procedures for monitoring and checking.

The industry's own controls are often required to operate within a legislated control system which embraces the supplier through to the end user of the product and typically includes reference to the use of:

- Engineering systems to control exposure such as the enclosure of plant, exhaust and ventilation systems
- Personal protective equipment, such as eye protection, respiratory protection, foot and body protection
- Personal occupational environmental monitoring and ambient air monitoring
- Biological monitoring and other health surveillance techniques.

These programmes are based on practical steel industry experience and should be seen as operating alongside the more detailed precautions which are necessary, as part of the wider effort by management and employees generally and by specialist doctors, hygienists and safety staff, to ensure a healthy and safe working environment.

4.3.1 Controls for Introducing Chemicals into Steelworks

Companies must develop their own systems to meet legal and internal policy needs. The first stage is to develop a procedure to ensure the user and/or employer obtains all relevant information about each chemical substance. Information may be supplied automatically or on request from the supplier, from another source of reference or from internally held records based on previous experience. If information is considered commercially sensitive, the supplier may agree to it being given to the medical doctor or hygienist on a confidential basis. Typical information about the chemical would be:

- The product name, reference number and supplier's details
- A description of its physical state and its chemical and physical properties
- Health hazards and precautions (personal protection/first aid)
- Toxicity
- Fire and explosion hazards, including flashpoint and extinguishing media
- Storage and transport specifications
- Packaging arrangements
- Waste disposal procedures and any other relevant information.

4.3.2 Company Risk Assessment

Risk is related to the conditions under which the substance is to be used, making the company's risk assessment an important process in determining the conditions of use and the precautions to be observed. A procedure for risk assessment must be established and made known to all those concerned.

In essence, risk assessment allows a valid decision to be made about measures necessary to control substances which may give rise to a risk. It enables the employer to demonstrate, both to himself and other persons, that all the factors pertinent to the work have been considered and that an informed and valid judgement has been reached. Elements of this judgement will include:

- An understanding and identification of the risks
- A decision on whether the substance may be used or should be prohibited
- The precautions which need to be taken to achieve and maintain adequate control
- The need for monitoring of ambient air and personnel exposure at the workplace
- The need for health surveillance
- The availability of alternative substances.

4.3.3 Information Handling

Information in readily usable form is often kept on Material Safety Data Sheets (MSDS) or Hazardous Substances Data Sheets (HSDS). This information should generally be made available to all management and employees or, in the case of commercially sensitive information, retained by the information coordinator/assessor (normally a doctor).

4.4 CONTROL OF PHYSICAL AGENTS

The main physical agents of concern in the steelworks environment may be divided into two categories, although the boundaries are not always clear. These are:

- Those agents and phenomena which could have an impact outside the steelworks as well as a potential impact within the steelworks. The principal examples are noise and particulate matter. (Particulate matter is covered in Chapter 3.)
- Those agents whose impact lies almost entirely within the plant, yet which may in some cases affect the external environment. Among these are heat, vibration, lasers, radiation and electromagnetic fields.

4.4.1 Noise

Noise is typical of an environmental issue where concern for the working environment is also directly relevant to the general environment. In addition, much of the occupational deafness steelworks employees or ex-employees experience today is, at least in part, related to the long term exposure to the noise conditions prevalent 30 or 40 years ago, when the effect of noise on hearing was not fully understood.

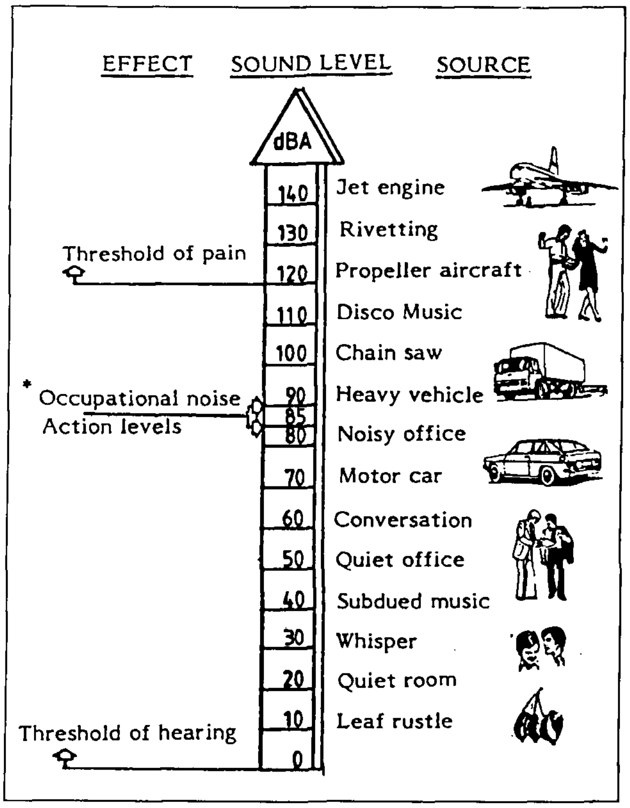


Figure 4.1: Typical examples of noise levels from nonsteelworks sources

Typical major sources of noise include fume extraction systems, vacuum systems using steam ejectors, rolling and forging mills, the EAF as well as general factors such as transport movements. The EAF generates noise from its electrical transformers and the arcing process, in addition to that from the gas extraction system. Many noise sources are only a problem inside the plant, where suitable protection for the workforce can be provided. For example, noise levels in areas close to large fans, in rolling mills and in the vicinity of the EAF can reach as high as 100 or 110 dB (A). However, it is important to distinguish between different types of noise, requiring that both intensity and frequency details are studied before deciding upon the most appropriate noise reduction or protection measures. **Figure 4.1** gives an indication of noise levels to be found in the general environment for comparison.

As for other types of environmental pollution, noise reduction should be considered at the design stage of the plant, influencing the choice of process and equipment as the modification of existing plant and retrofitting of noise reduction equipment is an expensive alternative. Two diverse examples, where the approach has been successfully applied, are in the design of the DC EAF and the design of saw blades for finishing operations. It may be necessary to involve acoustic experts using specialised sound and vibration analysis techniques to derive a sound 'picture' of the interior of a plant or the surrounding environment, where multiple noise sources may be present which can then be used to determine the best position for insulation or sound barriers.

Hearing conservation programmes have been introduced by most companies to combat the possible effects of noise on employees' hearing. Known as 'Hearing Conservation Programmes', they address aspects of noise assessment, noise control engineering, personal protection, health surveillance, education, training and information dissemination.

A noise assessment will include a survey to identify specific work areas and/or individual employees who are likely to be exposed to potentially dangerous noise levels and to provide information about both the level and the nature of noise in specific situations. For example, the contribution of individual noise sources and the frequency characteristics. Competent staff should then prepare conclusions, recommendations and proposals for follow up monitoring and action.

Noise control engineering efforts, implemented as part of a Noise Control Programme, aim primarily to reduce employee exposure to noise, which will also automatically lead to a reduction in external environmental pollution. Engineering effort should be directed towards the design of new plant to minimise noise, or the modification and maintenance of existing plant.

Personal protection will, on occasion, be necessary no matter how much the industry attempts to control exposure to noise by engineering and other methods. The nature and pattern of noise exposure in the steel industry requires that, in conjunction with other remedial measures, such protection is made available as necessary. For the working environment there is no identifiable risk of hearing damage in noise levels of <75 dB (A) Leq (8h). For higher levels, there is an increasing predictable risk and this must be taken into account when setting occupational noise standards.

Within the European Community, personal protective equipment in use in industry must be capable of attenuating noise so that the perceived noise levels do not exceed the daily limit laid down by the Directive 86/188/EEC on the protection of workers from the risks relating to noise at work. This Directive is implemented in different ways by the Community members, for example, in the UK the appropriate legislative instrument is the Noise at Work Regulations (SI 1989/1790) which came into force on January 1, 1990 and under which employers have a legal duty to prevent damage to hearing. Noise levels in excess of 85 dB (A) require the employer to take action, for example by:

- The use of antivibration mountings, sound deadened steels, damping material, rubber or cork gaskets and flexible connections to reduce vibration.
- The use of absorptive silencers (in combustion air fan intakes and some compressors, for example), reactive silencers (on some types of blowers) and porous plastic diffusion silencers for pneumatic exhausts (on shears, clamps, etc.)
- Reducing drop height on stacking, fall heights on conveyors, use of cushioning materials on chutes, conveyors, looping tables, etc.
- The use of noise transmission barriers (the construction of complete or partial enclosures for noisy machinery or plant, ranging from water pumps to EAF).
- Maintenance of plant in good working order (adequate lubrication, balance and alignment of rotating parts, repairs/replacement of worn parts, secure closure of doors and access panels, and so on).

Health surveillance based on clinical examination and audiometry are used throughout the industry as a means of establishing and monitoring personal status. In addition, education, training and information dissemination are key elements of many companies' Hearing Conservation Programmes and may involve special courses and seminars for new employees and updating sessions for existing employees.

4.4.2 Other Physical Agents

Issues which are of importance to works based employees but less so to the general environment include:

- Vibration caused by oscillating mechanical movements, often created by machines whose movements have not been balanced and mainly found when handling portable tools (pneumatic drills, saws, grindstones, chipping hammers) and in shop floor machinery. Reduction of exposure is important to avoid long term medical problems. Antivibration supports (mobile crane cabins, for example) and the use of flexible couplings can help, as can preventive maintenance to optimise machine balance.
- Heat exposure which, particularly in already hot climates, can place stress on the employee and impair safe working, efficiency and quality. In addition to the use of heat shields and adequate ventilation, the work programme for individuals should ideally be organised so that they periodically conduct other duties away from the heat.
- Lasers have a wide range of applications in steelmaking and metallurgy, for example to measure distances (telemetry) and to apply energy very precisely in welding, cutting, machining and surface treatments. They may also be used in certain measurement applications such as interferometry and spectroscopy and analyses such as remote analysis, trace analysis and microsampling. Its effect on the eyes presents a particular risk of retinal lesions which may occur at power levels well below those which the unfocused beam would require to produce effects on the skin. By way of precautions working lasers should normally be fixed, ideally with the beam confined and above eye level, reflections should be avoided and the area of use should be confined or restricted using suitable sign posting. Appropriate goggles should be available for personal protection as necessary.

- Radioactive sources are employed in measurement devices in many operations in the steelworks and, provided they are correctly marked and monitored, are not hazardous. The potential for accidentally charging radioactive scrap into steelmaking vessels is more serious and stringent precautions in the purchase, sorting and charging of scrap must be observed to prevent this occurring. Many steel plants now routinely monitor all scrap entering the works using sensitive radiation detectors and, for maximum safety, some also monitor the liquid steel and products leaving the plant.

4.5 FIRE, EXPLOSION AND MAJOR HAZARDS IN THE STEELWORKS

4.5.1 Fire and Explosion

Many steelworks operations provide the prerequisites for fire: a combustible material, oxygen and an ignition source. Flammable gases are used, produced and transported during cokemaking, ironmaking and steelmaking. Solid fuel, in lump, pulverised or granulated form is present at the blast furnace and coke ovens, while large quantities of ammonia and hydrogen are used and stored. Flammable liquids in the form of hydraulic fluids, solvents and cleaning materials are extensively used and produced as byproducts. Other combustibles such as electric cables, timber, rubber and plastics are also present. These combustibles are often unavoidably sited near to ignition sources such as molten metal, slag, hot solids, electrical sources of ignition and frictional heat.

Explosions can occur if molten metal or slag come into contact with water. To reduce the possibility of fire and explosion it is advisable to:

- Reduce the risks at the design stage of new plants, structures and processes. The use of noncombustible materials or the repositioning of combustible materials away from ignition sources may be possible. This is particularly important in vulnerable situations such as control rooms and cable tunnels
- Survey existing plants and processes to identify and evaluate potential fire and explosion hazards
- Establish standard working procedures for normal plant operations and maintenance
- Install fire alarm systems and means of escape.

If a fire does start, its spread can be reduced if:

- High water content fluids are used in place of traditional hydraulic oils
- Nonfire propagating belt conveyors are fitted
- Fire barriers and compartments are used in cable runs, mill cellars, etc.
- Automatic fire detection and fire suppression systems are installed, including water sprinklers or inert gas extinguishers for high risk areas which are not manned
- Firefighting equipment appropriate to the type of fire likely to be experienced is available
- High standards of housekeeping and effective maintenance practised to prevent leaks of flammable liquids
- Proper education and training is provided for all employees.

4.5.2 Major Hazards

If a hazard extends beyond the works boundary it may affect persons living, working or travelling in the vicinity. Hazards may also result in damage to property and the general environment. Such incidents not only include fires and explosions, but also damage from toxic releases. Most industries globally are required under national legislation to consider the potential for their operations to give rise to a major hazard scenario. In the steel industry, particular attention should be paid to the substantial quantities of toxic and flammable gases which arise as both byproducts and feedstocks. While most gas is reused, some is stored to maintain balance and pressure. Oxygen and liquefied petroleum gases (LPG) may also be bulk stored on site.

4.5.3 Emergency Plans

The major hazard concept has been addressed by developing emergency plans to deal with wider incidents should they occur. Within a hazard scenario, the company has the major responsibility for onsite activity, while other authorities control external arrangements, making it imperative that each fully understands the measures to be taken by the other. A typical emergency plan in a steelworks should address the following issues:

- Immediate action at plant or departmental level including sounding an incident alert, establishing a control point, plant shutdown, isolation and immobilisation, roll call, search and rescue and evacuation
- Action plan for the whole works including organising technical support (such as gas and works rescue teams), traffic control, security and communications, provision of mobile plant and heavy lifting and rescue equipment, emergency lighting and medical services and organisation of administrative services (such as accident prevention personnel, photography and information services)
- Liaison with external agencies including the fire, police and ambulance services, medical aid, hospital services, public alert systems, press and other media and other industries in the area.

4.6 ERGONOMICS IN THE INDUSTRY

Ergonomics seeks to optimise the human factor in the design of technical systems by integrating knowledge from different disciplines (e.g. engineering, psychology, physiology, organisation science) to arrive at design solutions for total system effectiveness. It has relevance to safe operations of the steelworks and, therefore, its environmental impact. Poor operating systems lead to poor working practices, compromised safety, absenteeism and the poor health of employees.

To optimise the overall performance of a system we often need to make compromises with regard to its individual parts. Thus, the cost of job aids, auxiliary equipment and tools needs to be weighed against the contribution to the value of the system. Also, as system design is an iterative process,

Case Study — Ergonomic Design of a New Quench Car Cabin

This ergonomic activity was part of a coking plant renovation programme. In designing the new cabin, the following criteria were established for the design:

- *Clear sight lines during receiving of coke, driving and discharge of coke*
- *Avoidance of the necessity for the driver's torso to be twisted or his head to be turned during operation*
- *Improving the controllability of the operator devices by redesign*

As the operators had difficulties in getting the feel of the situation from the drawings, it was decided to make a wooden model. To improve the basic design of the cabin and arrive at a good layout of the operator devices, an operating situation was 'played out'. It was surprising how well the drivers could identify with the situation even though the coking plant could not be seen and was not simulated.

Discussion of all the operating procedures made it possible to specify the required improvements in the control of the locomotives. This enabled the spreading of the coke in the quench car to be improved, the more uniform quenching resulting in improved coke quality. A new model was made to help incorporate the improvements by aiding decisions on where subsidiary equipment could be placed and by providing a three dimensional guide to assist the cabin builder in a final design.

The systematic approach and end user involvement resulted in a cab which met all expectations and was commissioned without problems. For example, by paying attention to details, it was possible to relocate a diesel motor exhaust, which had previously hindered the view, behind a window frame.

final solutions will only appear during the design process and will be consistent with the prevailing constraints of time, cost and performance expectations.

4.6.1 Applying Ergonomics

As an example, ergonomic principles were applied in the redesign of a crane driver's chair, by incorporating anthropometric data along with information concerning the working posture required by the job. The new chair design was accompanied by a new layout of the levers, knobs and dials of the crane. The rethink in cab design which the work triggered made a significant contribution to steelworks safety. The example is typical of ergonomic activity in the engineering area which focuses on the design of technical solutions to problems of work station layouts and man machine interfaces.

Ergonomic activities in the personnel area by contrast focus more on issues such as task allocation between man and machine, job and organisation design, required physical and mental personnel qualifications and training and organisational change processes as brought about by technological change. Recently, job rotation and team working have become widespread in the steel industry, requiring a comprehensive review of personnel skill and qualification requirements and the suitability of existing management systems.

4.6.2 The Future of Ergonomics in the Steel Industry

A major trend is from designing for users to designing with users, requiring them to invest time and effort into a product which is ultimately of higher quality and easier to accept. When it is understood that success depends upon a multidisciplinary input a climate of mutual respect for the different kinds of expertise present will develop. Difficult ideas can be articulated to the user through the use of models or simulations.

4.7 HEALTH SURVEILLANCE

4.7.1 Company Organisation and Policy

Given the potential for occupational health and safety problems in the industry, commitment, awareness and attention to detail must be established as key principles. Senior management play an important role, although all employees must recognise their individual responsibility in applying and developing company guidelines. Management and the workforce should plan their efforts in the same way that plans are developed for production, maintenance, financial control, quality control, delivery performance and other functions. Senior management must clearly define company policy and establish the organisational arrangements and practices by which that policy can be put into effect. Such a policy would typically state its approach and role, and affirm its duties. Similarly, the practices by which the company policy will be put into effect must be established (see **Table 4.1**).

Table 4.1 Company policies and practices for health and safety

Statements included in policy	Duties affirmed in policy	Company policy practices
- The overall approach taken to occupational health and safety and its relationship to other company policies and objective; - The special role and responsibilities of executive management; - The role and responsibilities of all employees; - The role of joint consultation.	- Establish a functional advisory service; - Provide adequate information for all employees; - Establish standards; Identify problem areas; - Comply with legal requirements.	- Agreement of annual objectives with individuals; - Establishment of audit systems; - Paying particular attention to new developments including the use of hazard analyses where appropriate; - Development of data storage and retrieval systems on accidents, medical treatment, health surveillance, ambient and personnel monitoring, etc. (proper provision being made for medical confidentiality); - Establishment of a process for joint consultation; - Making arrangements for the operation of a functional advisory service.

4.7.2 Occupational Health Programmes

The definition of health embodied in the constitution of the World Health Organisation:

'Health is a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity'

is an excellent foundation for any occupational health programme. Such programmes typically include the following elements:

- Health education or health promotion of the worker
- Provision of good information about adverse health life style factors: cigarette smoking, excessive alcohol consumption, leading a sedentary life, etc. and about adverse health working conditions: noise, toxic substances or gases, heat stress, etc.
- Primary prevention to avert the occurrence of disease or infirmity by good industrial hygiene, e.g. engineering controls, working practices, signs and labels, training of the workers, etc. Individual skin and respiratory protection are a prerequisite.
- Secondary prevention or health surveillance to avert the start, or detect the early stages, of disease.
- Tertiary prevention to avert the progression or deterioration of an established disease.

4.7.3 Health Surveillance

Health surveillance is an essential part of the occupational health programme and comprises:

- Detection of early adverse effects including effects which involve or are predictive of an impairment of functional capacity, a decreased ability to compensate for an additional stress or to maintain homeostasis or an enhanced susceptibility to other environmental influences.
- Medical testing of workers to detect organ dysfunction or disease before an individual would normally seek medical care (preclinical stage) and while intervention is still beneficial. Ideally, the intervention should not only be beneficial, but sufficiently early to allow any health effects to be reversed.
- Screening to detect adverse health effects by the application of tests or other procedures. The problem comes in defining exactly what adverse health is as the distinction between physiological and pathological effects, between reversible and irreversible effects is not obvious.
- Employees should be questioned about medical complaints and minor ailments and biologically monitored for adverse health effects using clinical examinations and other relevant methods such as radiography, haematology and audiometry. Where there is a risk of chemical exposure, two further methods of surveillance are complementary, ambient and biological monitoring of exposure:

Ambient monitoring provides an estimate of the external air dose. Toxic and/or hazardous substances can be sampled at any point in time and semicontinuously. Available techniques are the absorption of the substance on to a badge (passive method) or aspiration by a pump (active method). Personal sampling involves air sampling of hazardous chemicals in the breathing zone of the worker, which gives a good estimation of the personal external dose, while static sampling, at a fixed point in the workplace, can provide a good estimate of overall exposure. Ambient monitoring is also possible for physical factors such as noise, vibrations and ionising radiation, in which case the personal sampling apparatus must be fixed at the appropriate part of the body.

Biological monitoring of exposure involves measurement and assessment of workplace agents and the related biochemical changes in tissues, secreta, excreta, expired air or any combination of these, to evaluate absorption by all routes (i.e. inhalation, percutaneous absorption or ingestion). This method takes into account the absorption by the skin of the toxic substance and individual physiological characteristics of the employee (e.g. pulmonary status). The data reflects the internal (absorbed) dose or the biological effective dose of the agent. Ambient monitoring, when combined with biomonitoring of exposure, is referred to as 'exposure monitoring', whereas

Table 4.2 **Indicative test for routine surveillance**

Chemical/Location	Ambient monitoring	Biological monitoring	
		Type	**Indicator**
Lead/Steel plant	Lead in air	Blood Urine	Lead Zinc protoporphyrin Free erythrocyte d-aminolevulinic acid
Benzene/Coke ovens	Benzene in air	Blood Urine Enumeration and cell morphology	Benzene t-t-muron acid
Polycyclic aromatic Hydrocarbons/ Blast furnace taphole clays	PAH in air Benzo-a- pyrene in air	Urine	l-hydroxypyrene

biomonitoring of exposure combined with biomonitoring of effects and the diagnosis of occupational diseases are considered to be a part of 'medical surveillance' (**Table 4.2**).

It is important when conducting a health surveillance programme that:

- The surveillance is completely oriented toward action for the benefit of the employee
- An excellent knowledge about the information content of the methods of investigation in a particular case is attained
- The cost/benefit aspects of the exercise are understood. The benefit being the information content of the results of each monitoring method alone or in combination and the cost being the amount of money and/or time required
- Extensive questions about lifestyle factors, e.g. smoking, alcohol consumption, housing, hobbies, car driving, etc. are asked
- The predictive value of the test or procedure has been estimated in advance
- Health surveillance records are kept and updated and include details of medical surveillance and biological and ambient monitoring data, occupational injuries, illnesses, sickness, absence data and professional data (working history).

Photo 1: Aerial view of large coastal integrated steelworks

Photo 2: Reclamation of iron ore from iron ore beds at the steelworks

Photo 3: A sinter strand

Photo 4: Two large modern blast furnaces with raw material stockpiles in foreground

Photo 5: A coke oven battery

Photo 6: Aerial view of blast furnaces with slag pits and gas holders in foreground

Photo 7: Blast furnace slag becomes a useful building product

Photos 8 and 9: Case study of improving emissions from a hot metal torpedo ladle with CO_2 blanketing

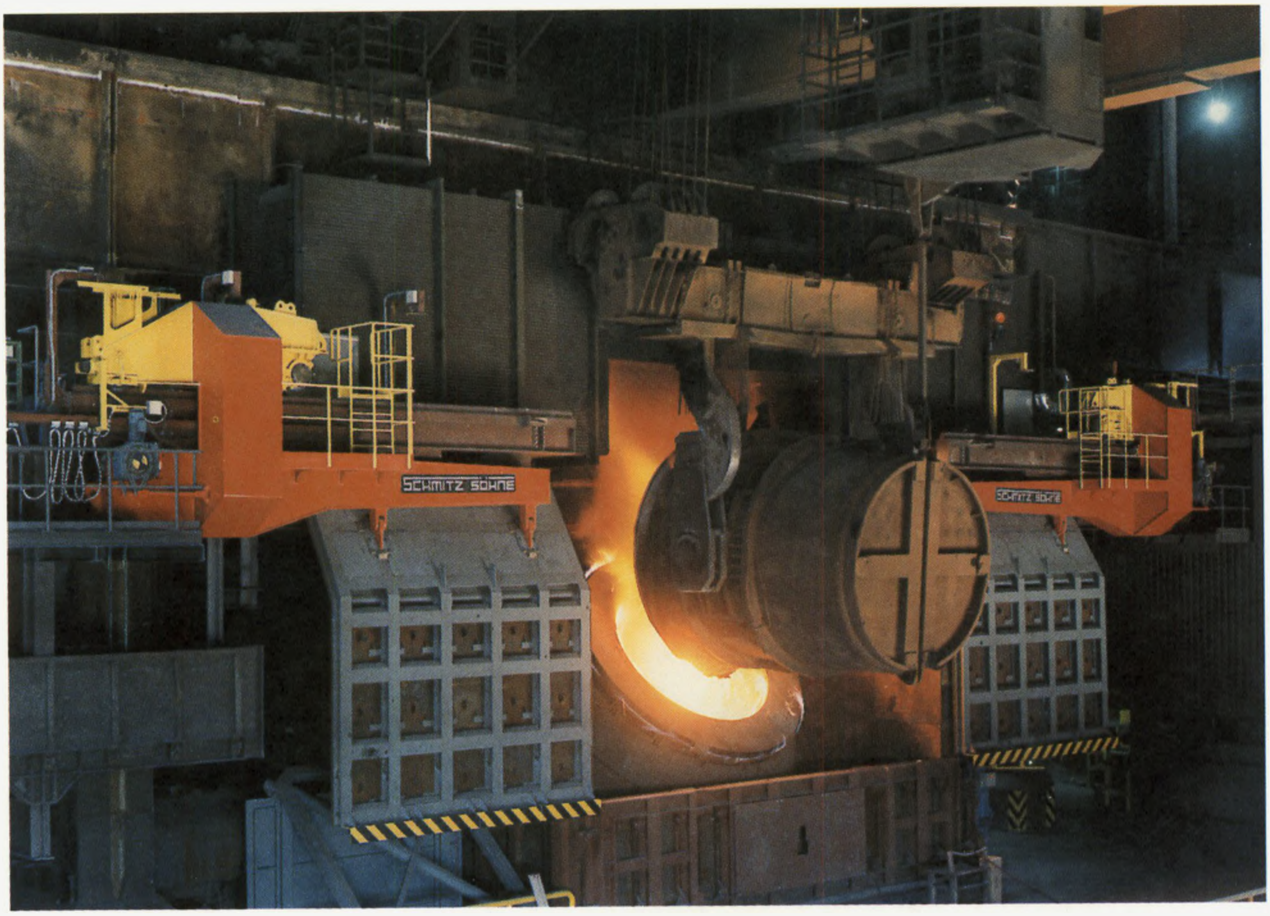


Photo 10: Charging hot metal into a BOS vessel

Photo 11: Charging recycled steel into a BOS vessel

Photo 12: Pelletisation of steel plant dust

Photo 13: Gas recovery plant at a BOS plant

Photo 14: **Electric arc steelmaking — example of a twin shaft furnace**

Photo 15: **Bag filter dust collection at electric arc steel plant (producing stainless steel)**

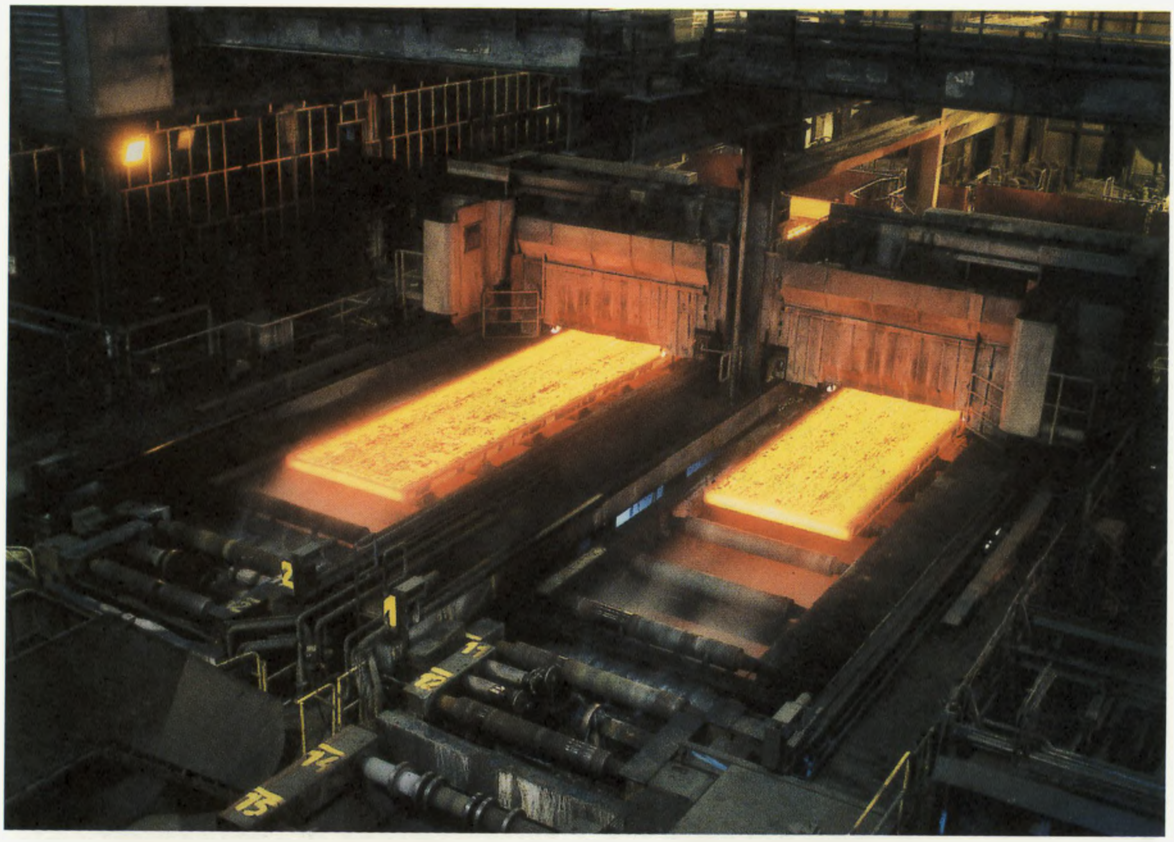


Photo 16: The continuous casting of slabs

Photo 17: The continuous casting of beam blanks

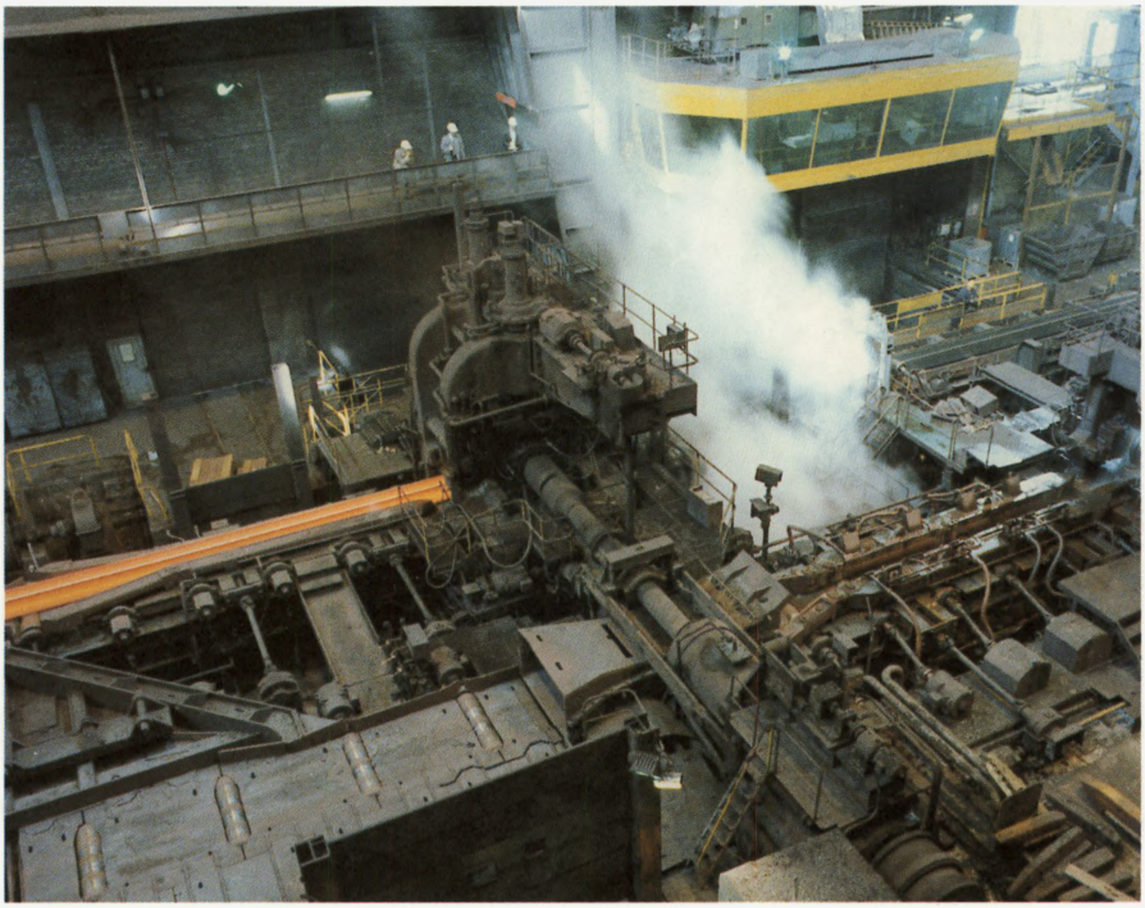


Photo 18: Hot rolling of steel sections

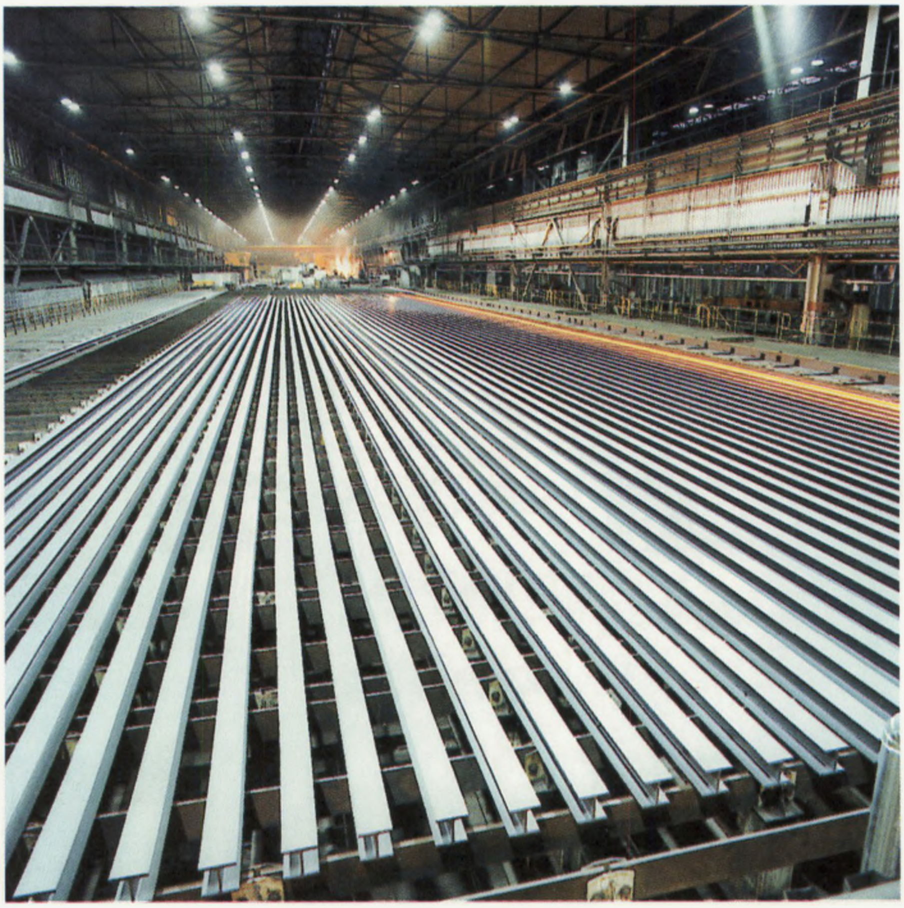


Photo 19: Finished steel — steel beams on the cooling bed

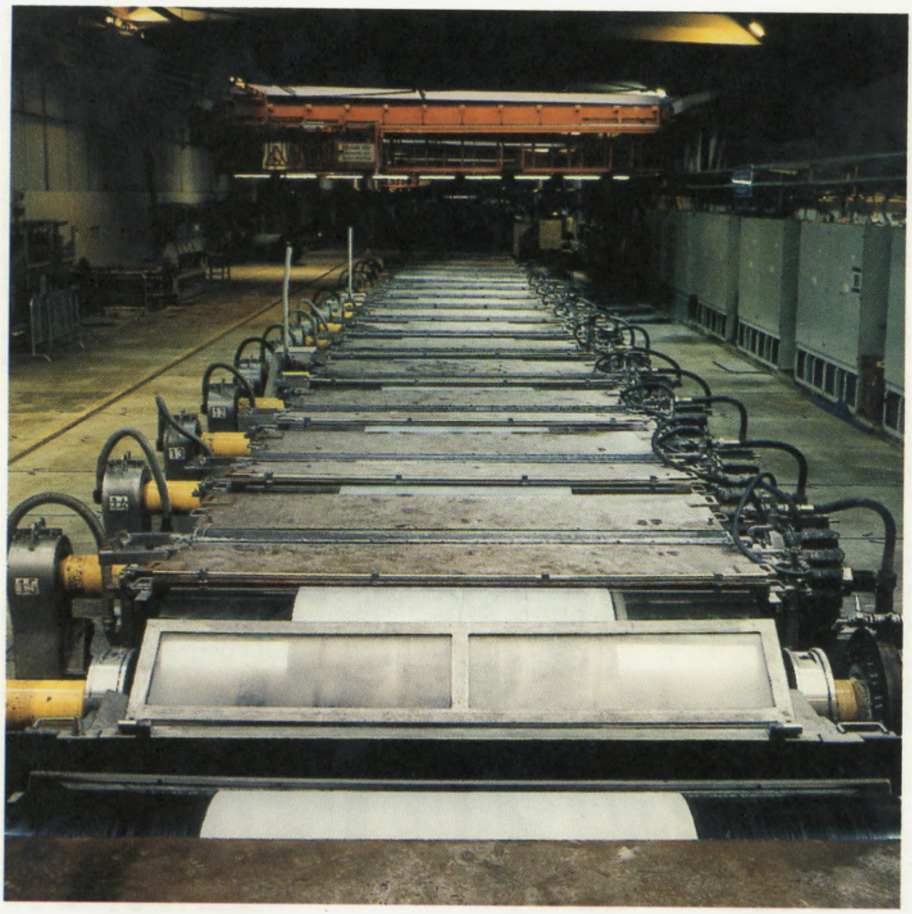


Photo 20: Electroplated galvanised steel sheet

Photo 21: A continuous annealing line for steel sheet

Photo 22: Closed loop water recycling

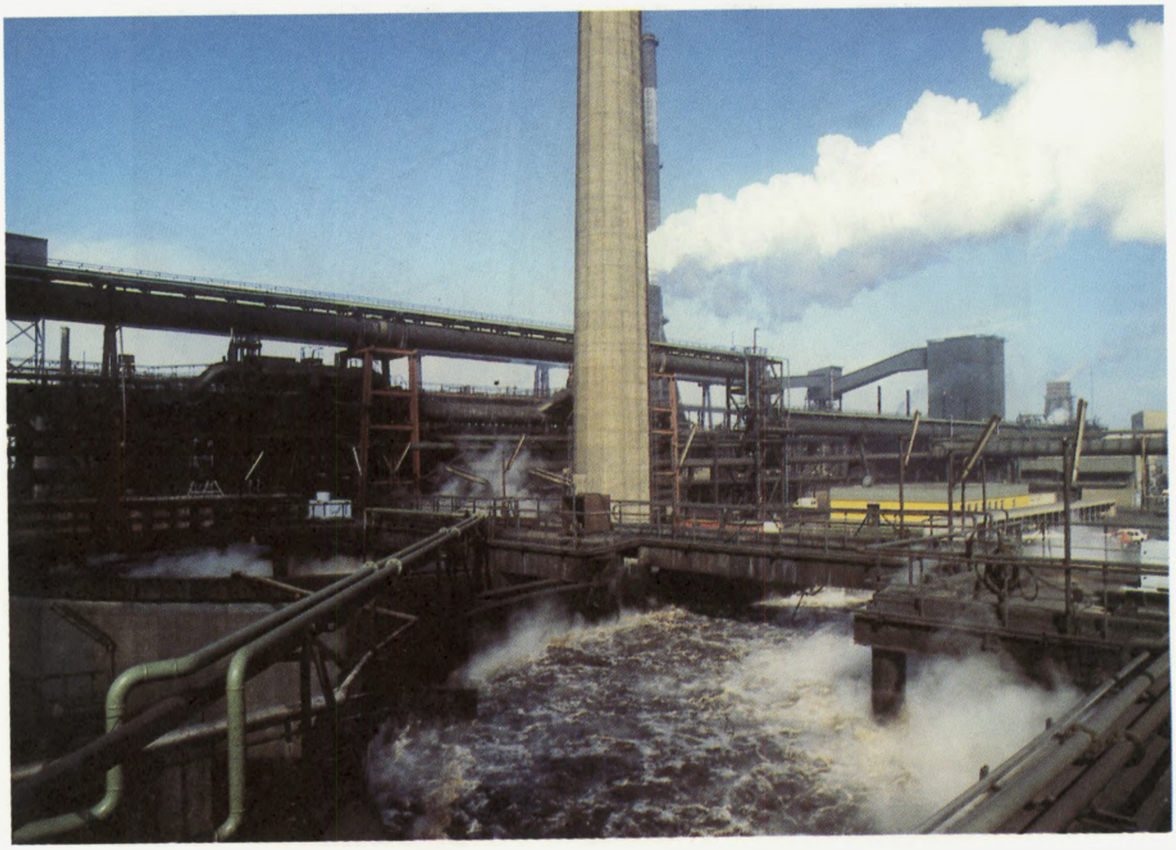


Photo 23: Water treatment facilities

Chapter 5
Cleaner Production

5.1 INTRODUCTION

As mentioned in Chapter 1, cleaner production is good business, good for government, industry and society at large. The lesson from the past is simple: it is less costly to prevent pollution at source than to clean it up after it has been produced.

Cleaner production may not solve all of the environmental problems at a facility, but it will decrease the reliance on end-of-pipe solutions and will create smaller quantities of less toxic waste requiring treatment and disposal. Cleaner production will reduce workers' exposure to hazardous chemicals and the potential for accidents that can lead to harm of surrounding areas. Products that are designed and produced with cleaner production in mind are less harmful to the environment and their residuals are less of a burden to waste streams.

As a guide, the application of cleaner production can be subdivided into the following areas:

- change of process or manufacturing technology
- change of input materials
- change to the final product
- reuse of materials on-site, preferably within the process. Off-site recycling is not considered part of cleaner production, although it may bring substantial environmental benefits
- improved housekeeping
- training

The steel industry of the 1950s and early 1960s was a major source of pollution, particularly air pollution, in the densely populated areas where production has traditionally been concentrated. Initially, the problem was tackled with the retrofitting of gas and dust collection facilities to existing plant, but this approach was superseded by the replacement of obsolete plant, with newer facilities designed with cleaner production in mind, and the training of personnel to raise awareness of environmental issues. Thus, the improved design, operation and maintenance of steelworks processes has resulted in a reduction of emissions to air of 50 to 80 percent over the last 15 years.

This chapter has been subdivided into sections on air pollution prevention, water and waste water management, energy conservation and raw material conservation, within which clean production techniques are described. This structure is intended to bring clarity to the discussion and is not intended to be used as a framework for implementing cleaner production, which should be an integrated process. True cleaner production options are those that reduce the overall environmental impact, taking into account all media. Therefore, in the following cleaner production case studies, improvements in one media - such as the air - often result in corresponding benefits in terms of energy conservation, water management, etc.

5.2 AIR POLLUTION PREVENTION

Air pollution remains the most significant environmental issue for steelmaking, but the reduction or prevention of atmospheric emissions is closely linked to energy and resource conservation, as well as waste water management. For example, by-product gases are a valuable fuel source which form an integral part of a steelworks energy balance. However, cleaning systems are required to treat these gases before they can be used and the resulting waste water may contain particulate matter and some heavy metals (int the case of blast furnace and BOF gas cleaning, for example) or organic pollutants, cyanide, ammonia and other species (in the case of COG cleaning).· In addition, iron containing dusts and sludges may also be collected. Thus, by reducing emissions to air of by-product gases a steelworks can benefit from the flexibility of a captive energy resource, reducing energy consumption, and the availability of iron containing materials that might be returned to the process, reducing resource consumption. Recirculating systems can be employed ensuring that water is used effectively within the process and, with careful management of the necessary system bleeds, process water might be downgraded to less critical applications, thus minimising the overall water demand of the steelworks. Examples such as these are discussed below with regard to the individual processes operated within a steelworks.

5.2.1 Ironmaking

Raw Materials Handling/Preparation — Most often the raw materials for iron- and steelmaking by the integrated route arrive by ship to a port close to the works. The fine ore and coals must be unloaded and stored in stockpiles prior to blending, all processes that can give rise to dust emissions. The reduction of emissions during unloading can be achieved by employing self discharging vessels, incorporating conveyors and water sprays to dampen the finer fraction, that limit the number transfer operations at the docks, thus reducing the potential for loss of material to the wind. In addition, materials that are known to cause particular problems can be shipped in a dampened condition, by arrangement with the suppliers, thereby minimising dust release during unloading. Once the raw materials are stockpiled, automated water or surface crusting agent spray systems can be employed, dependent on the prevailing weather conditions, to reduce the potential for dust liftoff during high wind conditions. Careful positioning and contouring of stockpiles, as well as the use of natural or man-made windbreaks, can also reduce overall emissions.

Covered belt systems, designed to prevent spillage and incorporating belt cleaning devices and exhaust systems at all points where material falls, should be used for the movement of materials in preference to vehicles.

Careful blending optimises the characteristics and consistency of the raw material feed allowing for the efficient and stable operation of downstream processes, which will ultimately lead to improved environmental performance. Blending also provides a route for returning wastes, arising on a site, back to the process route.

Sintering / Pelletising — Dust is generated from both the sinter feed and sinter product as it travels along conveyors, through screens and at the many feeding and transfer points. These areas should be enclosed, to reduce the potential for dust emissions, exhausted and the extracted air cleaned. Collected material can normally be recycled directly to the sinter plant leading to reduced resource consumption and associated financial savings.

The sinter machine itself gives rise to a large volume of waste gas which must be cleaned prior to emission to atmosphere, primarily to remove particulate, but potentially SO_x, NO_x and other components. Equipment for de-dusting, desulphurisation and denitrification requires a substantial amount of space, energy and financial capital, therefore, some producers are looking to new processes which consume less energy, generate much lower waste gas volumes and reduced emissions (for example, the EOS system: see **Section 5.4.1**). The blending of waste and other materials into the sinter feed can also have an impact on emissions. For example, oily materials and highly volatile coals can increase VOC and, potentially, toxic organic emissions and halide and mineral components are not easily collected in the precipitators and, therefore, lead to elevated dust emissions.

Emission problems associated with the thermal hardening of pellets can be avoided if cold bonding agents are used, although the low strength of such pellets means they can only make up 15 percent of the blast furnace feed.

Cokemaking — The principal method of pollution prevention on the coke works is containment. For example, leaks during charging can be reduced by improved alignment of the charge car using lasers and/or increasing the suction on the charge hole by connecting the oven being charged to an adjacent oven using a 'jumper pipe'. 'Square charging' is the rapid charging of a pre-measured quantity of coal such that the operation is over before emissions have had a chance to build up. Where emissions do arise these can be treated by ignition or by wet or dry cleaning systems mounted on the charge car or at ground level. If bag filters are used, they should be automated to prevent the accidental filtration of tarry fumes which can cause clogging.

The oven chambers are sealed by mechanically sophisticated door systems, designed to operate under the extremes of temperature and pressure prevalent during carbonisation. Effective operation can be assured only by continued maintenance and cleaning of both doors and associated door frames following each push, operations that are automated on modern coke batteries. Where significant gas emissions do occur these can often be reduced by manually sealing the leak with glass wool or some other material. Gas leakage from damaged refractory chambers, ascension pipes and other sources can be reduced by continued inspection and maintenance (e.g. the hot repair of refractory walls by silica welding).

Pushing emissions are minimised by ensuring complete carbonisation of the coal by careful heating control. This is facilitated by stable operation of the coke battery which is brought about by a consistent raw material feed and combustion control; the latter often aided by computer control models.

Most contemporary coke works employ wet quench systems to cool hot coke immediately following pushing. A recirculating water supply is used, but the process gives rise to a steam plume that may be laden with particulate matter and various quantities of other pollutants associated with coke production and makes no use of the significant quantities of heat energy contained within the hot coke. Alternatively, the coke dry quench (CDQ) system is sealed, thereby reducing emissions and allowing energy recovery. Hot coke is lifted and passed down a cooling shaft countercurrent to a circulating nitrogen gas stream which is heated, cleaned and passed to a waste heat boiler to produce steam. This steam can then be used to generate electricity or to preheat coal for charging to the battery. Thus, the huge steam plume, traditionally associated with cokemaking, is absent when CDQ is applied reducing the visual impact of operations.

The by-products plant - for the recovery of valuable by-products from carbonisation, such as tar, benzene and sulphuric acid - has significant potential for the release of volatile compounds including benzene. These emissions can be reduced by operating closed circuit gas cooling systems, ensuring pumps, joints, valves etc. are properly maintained and by collecting tank emissions during storage and transfer.

Alternative coke processes which have the potential to reduce overall emissions and/or energy consumption, but which are not yet widely applied include:

- The 'jumbo coke reactor', which is based on the conventional slot type oven, but which incorporates fewer large ovens, has fewer emission sources, less frequent oven opening and improved thermal efficiency.
- The 'indirect quenching process' includes a cassette, adjacent to the oven chamber, into which hot coke is pushed. The cassette is then cooled by external water sprays.
- The 'formed coke process' makes coke briquettes from a wider range of coal types, but is at an early stage of development.
- 'Non-recovery coke ovens' either flare excess gas or combust all by-products within the oven chamber. However, while the type of emission is changed, the ovens are wasteful of energy and yield poor quality coke.

Blast Furnace — The sources of emissions to air from the blast furnace process include the stoves used to preheat the blast, slag and iron tapping operations, slag processing operations, charging and non-normal operations such as iron plating and the opening of furnace pressure release valves.

Emissions from the stoves can be minimised by combustion control, aided by computer systems, that optimise the use and combustion of different fuels for a given heating pattern.

Case Study — Emissions Abatement in Coking Works in Poland

Background

The five coking plants in the Zabrze Coking Works are of varying technological conditions. The Knurow Coking Plant has one M63 cokeoven battery consisting of 50 coking chambers. The cokeoven battery has a mechanical cleaning system for the frame doors and hydro-injection to reduce pollution emissions.

Cleaner Production

A cleaner production assessment was carried out on the entire coke production process, to establish the sources of emitted pollution. The benzene recovery plant, responsible for 71 percent of total plant emissions, was chosen as the field of study. The coke gas open cooling system was the main source of emitted pollution from the benzene recovery plant. The cooling water contained pollutants such as benzene and its homologues, ammonia, hydrogen sulphide (H_2S), phenol and hydrogen cyanide (HCN), which were emitted to the atmosphere when the water was evaporated in the cooling tower.

Improved housekeeping led to the reduction of energy and water consumption, as well as an improvement of the technical process. A feasibility study was carried out for three variants of the same solution to reduce emissions, with the selected variant based on closing the coke gas cooling system by applying a spray cooler.

Enabling Technology

The dirty water closed cycle contains water at 40°C which flows through the pipes of a spray cooler. The pipes are sprayed with clean water, which cools the dirty water to a temperature of 25°C prior to being recirculated to the gas aftercooler to remove the pollutants. After leaving the spray cooler, the clean water is cooled in a cooling tower forming its own recycle circuit.

In this way, two independent systems are created:

- *a closed system of dirty water and*
- *an open system of clean water.*

Advantages

Implementation of cleaner production technology resulted in an emission reduction of the following pollutants relative to the coking plant as a whole:

Pollutant	**Before** (tonnes/year)	**After** (tonnes/year)	**% change**
Hydrogen cyanide	10.65	0.99	91
Benzene	40.62	4.68	88
Toluene	10.92	1.26	89
Xylene	2.73	0.31	88
Hydrogen sulphide	27.80	4.74	85

Economic benefits included

Capital investment (gas aftercooler system)	US $ 20 000
Net savings	US $ 166 000
Payback period	1 month

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The furnace is tapped by drilling a taphole from which the iron flows until the hole is re-plugged. Drilling can be difficult if iron has solidified in or behind the taphole, and it has been conventional practice under these circumstances to open the hole by burning with an oxygen lance, a process which generates large quantities of red fume which must be collected. In response to this, more sophisticated drilling machines have been developed which can drill, impact and reverse, thereby performing all the actions necessary to drill the taphole and keep it open without using oxygen.

Several slag processing operations are available which give rise to different co-products for use in road construction and the cement industry. Slag processed by the open pit practice is tapped from the furnace and diverted to an open pit where it is left to air dry for a period of time and then water quenched. Depending on the chemical characteristics of the slag and the air drying period various quantities of H_2S and SO_2 may be released. The addition of an oxidising compound, such as potassium permanganate, to the quench water has been shown to reduce the emission of H_2S and the overall sulphur emission. A prequench with water containing lime may also be applied to reduce the level of H_2S and overall sulphur emissions. Slag can also be pelletised, where the molten material is impinged on a rotating drum under a water stream, or granulated, where the molten material is rapidly cooled under the action of water, both processes that can give rise to overall lower emissions and which provide greater potential to collect and control emissions compared to the open pit practice. There is also potential to further reduce the emissions from the granulation processes by applying the same techniques described above for the open pit practice. A dry pelletising process has also been proposed that may give rise to even lower overall emissions.

Where a blast furnace is fitted with a bell charging system a small quantity of crude BF gas is lost every time the furnace is charged. This gas can be recovered or, preferably, a bell-less charging system is adopted.

Iron plating is carried out when there is an excess of iron, most probably due to unscheduled delays in the BOF plant, when the hot metal specification is below that required for steelmaking or for sale. The process can give rise to large quantities of iron oxide fume which are uncontrolled and, therefore, are released directly to atmosphere. The need for iron plating can be reduced by minimising the number and severity of unscheduled delays downstream of the blast furnace and improving the consistency of hot metal quality by process control and stable operation. Emissions may be reduced by adopting inert gas blanketing.

The need to release pressure within the furnace occurs as a result of burden slippage. The procedure is both very noisy and releases crude blast furnace gas, primarily containing CO and particulate. The need to release pressure can be reduced by ensuring stable operation of the furnace which is a function of raw material quality and consistency and effective control of furnace parameters; the latter often aided by knowledge based or neural network type computer systems.

The by-product gas from the furnace top is collected, but must be dedusted to prevent clogging of pipework, improve combustion and reduce emissions when used in the stoves, reheat furnaces or power plant. Modern multi-stage dust collection systems can reduce the dust content to less than 10 mg/Nm^3.

5.2.2 Steelmaking, Secondary Refining and Casting

BOF Steelmaking — Air emissions from the BOF plant include those resulting from the flaring of by-product gas, fugitive emissions from the melting shop, scarfing emissions and cleaned gas from the secondary extraction system. The by-product gas from the BOF can be collected and used as a fuel, thus reducing the need to flare, although a proportion will always need to be flared at the beginning and end of each heat when the CO concentration is low. Thus, both the effectiveness of the gas cleaning plant and the efficiency of gas collection will have a significant effect on the overall quantity of emissions to air. Computer control systems can be applied to improve the efficiency of gas collection, which is aided by consistent plant operation.

Fugitive emissions arise primarily from hot metal transfer and pretreatment operations and BOF charging, blowing and tapping operations. Secondary refining and continuous casting plant are

Case Study — Control of Dust Emissions with Carbon Dioxide Blanketing (CO_2)

*See **Photos 8** and **9**.*

Background

Emissions of iron oxide fume occur when hot iron from the hot iron mixer or torpedo car is poured into the charging ladle. Around 0.5-1 kg/t iron of red/ brown iron oxide fume is generated by oxidation. The Luxembourg steel producer, ProfilARBED, in collaboration with Air Liquide, researched measures to prevent this fume from arising.

Existing abatement equipment captures the dust in filters after generation. Such equipment is very expensive, both in terms of investment and operating costs and, due to the significant air flow generated by the extraction system, the quantity of fume produced can be increased by a factor of 1.6. Also, the dust collected by the abatement system is generally not suitable for recycling, without costly conditioning, and disposal of this waste can be difficult and expensive. ProfilARBED, therefore, looked at preventative measures in preference to improving the handling and processing of the waste.

Enabling Technology

The technology creates an inert atmosphere by pouring solid carbon dioxide into the receiving ladle, in order to limit oxide dust formation. By vaporising the 'dry ice', continuous liberation of CO_2 gas occurs. Since this gas is heavier than air it forms an oxygen free layer (or blanket) on the bath surface, preventing iron oxidation. As the CO_2 is heated it will lift by thermal effect and shroud the liquid iron being poured.

The optimum procedure for producing an inert atmosphere at the hot iron transfer station is as follows:

- *render the inside of the empty ladle inert by injecting a maximum supply of CO_2 for about 30 seconds*
- *maintain the inert conditions throughout the metal transfer using the minimum CO_2 flow*

Although CO_2 is not a toxic gas, a CO_2 enriched atmosphere is a potential workplace safety problem because it can cause asphyxiation. Maximum allowable workplace concentration values have been established for CO_2 to limit the exposure of the personnel, and an appropriate ventilation and monitoring system has been installed in order to ensure no excessive exposure occurs.

Advantages

With a specific CO_2 consumption of 2.4 kg/t, the following results have been achieved:

- *87 percent reduction of dust emissions*
- *Workplace limits for CO and CO_2 far from being exceeded*

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less important sources of air emissions. Inert gas can be applied to reduce the formation of iron oxide fume during hot metal transfer and BOF charging operations and charging fume can often be reduced by optimising the charging practice and scrap characteristics (such as scrap quality or distribution within the vessel). Secondary emissions during blowing can be better controlled by ensuring a close fit between the vessel mouth and primary offgas system skirt, but this can often be hampered by slag and metal splashes resulting from the blowing operation.

EAF Steelmaking — A typical EAF melting shop would incorporate a primary extraction system to collect directly the fume generated in the furnace during the melting process and a secondary system to collect fugitive releases into the melting shop during charging, melting and tapping. The primary gas is filtered, primarily to remove particulate, prior to discharge to atmosphere, but these systems may not be as effective at reducing the level of VOCs, oil fume, trace organic compounds, volatile metals such as mercury etc. The level of these compounds can be controlled to a certain degree by improved scrap selection, scrap preparation and post combustion. Secondary emissions can again be reduced by careful attention to scrap quality and preparation, although charging practice, furnace practice and furnace configuration can be important. For example, a second basket charge may not be required for operations incorporating shaft furnace or continuous charging technology and the distribution of scrap within the basket charge may affect overall emissions.

Casting — Ingot casting gives rise to higher fume emissions than continuous casting plant owing to the increased exposure of molten steel to the air. Scarfing can also give rise to copious quantities of fume which must be contained, collected and cleaned. Operation of the steelmaking facility and caster should, therefore, be optimised to reduce the need to perform scarfing operations.

5.2.3 Hot Rolling

Emissions from the various hot rolling mills arise primarily from the combustion of fuel in the reheat furnace which gives rise to particulate, NO_x, SO_x and CO. The level of particulate and CO will be dependent on fuel type, but emissions can be minimised by careful control of combustion conditions, such as excess oxygen levels, aided by computer control systems. To a varying degree all fuels generate nitrogen oxides at the high combustion temperatures employed in the reheat furnace, but the problem can be countered by employing low NO_x burners or by using fuels such as BF gas or natural gas. Emissions of SO_x are a function of fuel sulphur content only and, therefore, can be reduced by switching to low sulphur fuels such as BF gas, natural gas and desulphurised COG and oil.

Theoretically, these emissions can be reduced still further by adopting the practices of hot charging or hot direct rolling combined with a stabilising furnace. These practices make use of the sensible heat in cast steel thereby reducing, or, in some circumstances obviating, the need for reheating. Unfortunately, hot charging / direct rolling is not easy to apply in practice owing to limitations associated with slab quality requirements, steel quality specifications and equipment capability.

Specific emission rates will also be reduced by optimising productivity, brought about by improved maintenance, scheduling and operating and engineering practices.

5.2.4 Pickling, Cold Rolling, Annealing and Tempering

The main emissions from pickling, cold rolling, annealing and tempering are acid aerosols from pickle tanks and combustion products from annealing and tempering furnaces. Acid emissions can be reduced by operating at the lower pickle bath temperatures associated with shallow bath spray pickle systems and, for some steels, dry pickling processes can be used (i.e. shot blasting). Combustion product emissions can be minimised by choice of fuel and close control of combustion conditions and the use of hydrogen as the annealing gas instead of nitrogen, which requires much longer heating times.

5.2.5 Coating

Emissions from the coating process include combustion products from associated furnaces, acid/alkaline aerosols from the various cleaning processes, metal fume from the hot dip bath, chromium (VI) aerosols from passivating washes and VOCs and particulate from the solvent based paints, lacquers and other coatings. Cleaner production techniques include the application of furnace combustion control, covered tanks for the various washes and passivating treatments (often in conjunction with local exhaust ventilation), VOC incinerators on large coating lines and particulate control. Water based coatings may be applied for some steel applications, reducing the emission of VOCs.

5.2.6 Others

A typical integrated site includes many process operations linked by road, rail and conveyor systems. The road system is integral to plant operations for the movement of steel products, intermediate products, slags, dusts, sludges etc. and this can entail many truck movements per day. In addition, for older sites where the road system has developed over many years, movements may be longer than necessary and can often include public highways. These movements give rise to dust emissions due to friable materials crushed under wheels and wind losses. Therefore, some consideration should be given to reducing the distance and number of in-works vehicle movements, as well as the design of a road system conducive to efficient spraying, sweeping and solids collection. All in-works movements of dry material should be covered, loading procedures should prevent spillage and vehicle washing stations should be available.

Smelting reduction processes are currently being developed as an alternative to the blast furnace in order to overcome the high capital cost associated with blast furnace ironmaking, the need for coke and coking quality coals and the environmental concerns over both cokemaking and sintering. Of the smelting reduction technologies only the COREX process has reached industrial maturity, but other commercial scale processes are being considered (e.g. the cyclone converter furnace or CCF). The advantages of these processes is that the air emissions associated with cokemaking, sintering and ironmaking are either partially or completely eradicated and a wider range of raw materials can be used.

The smooth operation of plant is critical to maximise productivity and reduce the specific emissions associated with steel production. In addition, the start-up and shutdown of processes may give rise to proportionally higher emissions than during normal operations. Thus, the consistency of the raw material feeds, maintenance and operating practices all contribute to overall lower air emissions.

5.3 WATER AND WASTE WATER MANAGEMENT

The total water requirement of the iron- and steelmaking processes is of the order 100-200m^3/tonne of product which is supplied, primarily, by integrated recycling systems. From the viewpoint of pollutant control a high recycling ratio is preferred, however, factors such as buildup of hardness and conductivity require that an optimum recycling ratio is determined from a total water system analysis. **Table 5.1** illustrates a comparison between the intake water requirements of a once-through system and a system involving extensive recirculation in a typical integrated works. The extensive recirculation in indirect and direct cooling systems reduces the total water intake to 2.4 percent of the requirement of the once through system. (See **Photo 23**.)

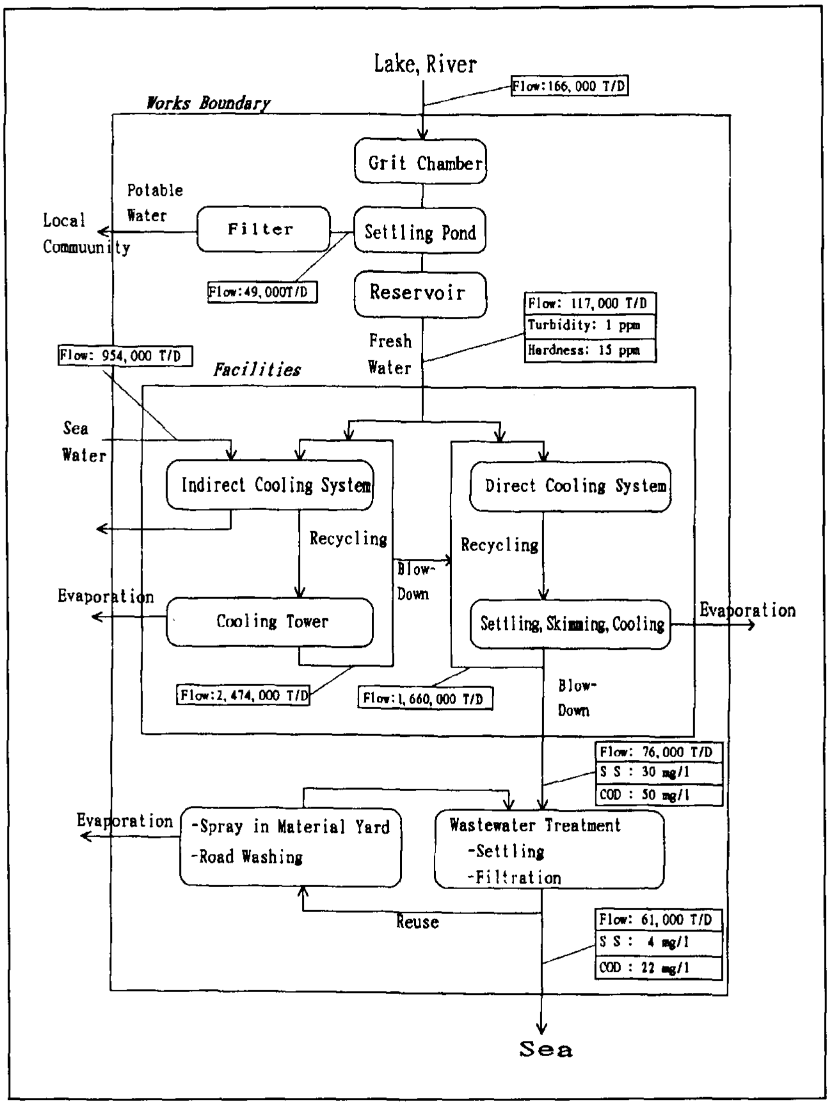
Sources of waste water include that resulting from direct and indirect cooling, gas cleaning, scale breaking, pickling, washing and rinsing operations and rainfall runoff from raw material stockpiles, roads, roofs etc.

Table 5.1 **Intake water requirement for a 4 Mt/annum crude steel integrated works**

Water use	Quality	Water intake m^3/min (% of total)			
		Once through		Extensive recirculation	
Indirect cooling	General	675	(70.7)	7.4	(32.0)
Direct cooling	General	265	(27.8)	6.2	(26.8)
Process water	Low grade	7.7	(0.8)	5.1	(22.1)
Potable	High	1.5	(0.2)	1.5	(6.5)
Total	-	954	(100)	23.1	(100)

Case Study — Water Balance at POSCO's Pohang Works

The figure below shows a simplified water balance for POSCO's integrated Pohang Works in Korea, which produces 10 Mt steel/year. The combination of recycling and reuse systems cuts the water intake down to only 117,000 m³/day and the waste water discharge volume to only 61,000 m³/day.



Water balance in Pohang Works, Posco, Korea

Direct cooling involves the open spraying of water onto steel or equipment and is most commonly used for cooling hot steel leading to contamination with millscale and equipment oil. Water used for indirect cooling is contained in a closed system and is far less prone to contamination, however, some water must be removed from the circuit to prevent excessive water hardness and build up of suspended solids. When direct and indirect cooling systems are used together, the water removed from the indirect circuit can often be used as make up water for the direct cooling system, although some intermediate cooling may be required. Similarly, although a waste water treatment plant and pumping system can render waste water reusable the use of poor quality water in critical areas may cause product degradation and equipment deterioration. As such, waste water may be best suited for quality insensitive applications such as the dampening of raw material stockpiles or road washing.

Typical clean production techniques are discussed below with regard to the individual processes operated within a steelworks.

5.3.1 Ironmaking

Raw Materials Handling / Preparation — Water is used to dampen fine particulate to reduce wind losses during unloading and transportation and storage of raw materials. Water sprays and crusting agents may also be applied to stockpiles to limit liftoff during high wind conditions. Low grade water from other operations can be used for these applications, although the potential impact on downstream processes should always be considered (e.g. water containing chloride may promote dioxin formation in the sinter plant) as well as the impact on runoff.

Water runoff from the raw materials handling areas should be collected and settlement traps installed to remove solids. The collected solids can normally be recycled directly to the sinter plant and the water recirculated.

Sintering / Pelletising — Water is added to the sinter plant feed prior to the sintering process in order to agglomerate the fine particles thereby improving the permeability of the bed. Optimisation of the water content improves combustion air flow through the sinter bed, reducing the energy requirement of the process, and promotes more consistent operation and sinter production. Low grade water can be used for this process, but as explained above some thought should be given to the potential impact of contaminants in water on the sinter quality and emissions.

Wet gas cleaning systems should incorporate recirculating water systems with a bleed to maintain scrubbing efficiency. Thus, the central and monitoring of scrubbing water can minimise the quality of bleed requiring treatment and ultimate discharge.

Cokemaking — Water is used at the coke battery for pushing emission control, coke quenching and door and frame cleaning and on the by-products plant for COG cooling and cleaning. Water spray pushing emission control hoods may incorporate once through or recirculating water systems, but the latter may offer benefits in terms of both water consumption and operational effectiveness. That is, water from the once through system ultimately falls on the hot coke generating a steam plume which may re-entrain particulate and reduce the effectiveness of the cleaning system. The coke quenching station normally operates a water recirculating system incorporating solids removal for which low grade water may be employed, although the impact on emissions, coke quality and thus downstream operations should be considered. Door and frame cleaning operations are critical to the environmental performance of the coke battery therefore clean water is normally employed to ensure trouble free operation. Recirculation or collection of the used water is not normally possible.

The coke oven by-products plant uses water for a variety of cooling and gas cleaning operations. The primary and secondary coolers should, ideally, be closed, recirculating systems (see case study in 5.2.1) in order to reduce emissions to atmosphere. Prior to being stripped in the ammonia still, water leaving the ammonia scrubber can be reused to cool the COG leaving the battery. However, once stripped the resulting weak ammonia liquor should be treated in a biological treatment plant (BETP) before discharge. The smooth operation of the BETP, which is sensitive to large variations in pollutant load, can only be guaranteed by ensuring reliable and consistent operation of the ammonia scrubbers and coking operations. Thus, the control of water use in the by-products plant is critical to the cleanliness of the COG fuel distributed to the rest of the works (e.g. ammonia content leading to NO_x formation), the quality and consistency of discharge water and the effective recovery of useful by-products (e.g. tar, sulphur, sulphuric acid, benzene).

Blast Furnace — Water is used on the blast furnace for cooling, gas cleaning and slag processing. The blast furnace requires large quantities of cooling water to ensure safe operation and recirculating systems have largely replaced the 'once through' approach leading to substantial savings in water consumption. **Figure 5.1** shows a typical water system, embodying the latest technical standards. This system is suitable for cooling the hearth and the shaft of the furnace, including the tuyeres and hot blast valves.

The gas cleaning system removes dust from the blast furnace offgas prior to distribution around the works as a fuel. Thus, gas cleaning water becomes highly laden with particulate requiring

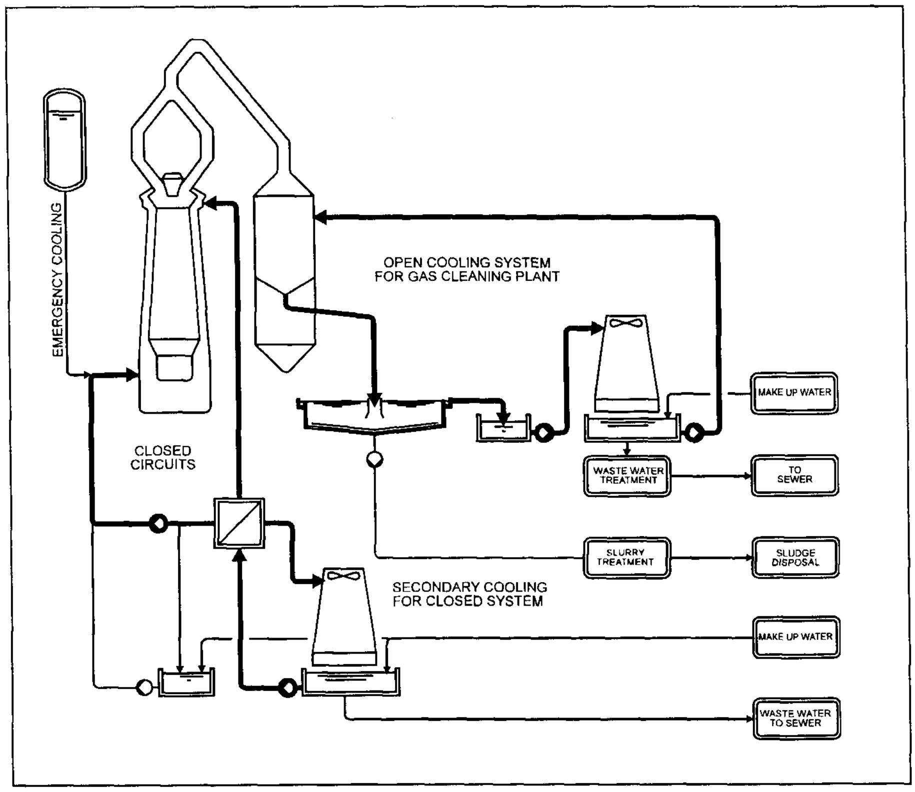


Figure 5.1 **Typical water system for the blast furnace**

treatment before reuse. Treatment normally incorporates settlement only, giving rise to a cleaned water for recirculation and a sludge, which is normally landfilled or subject to size classification before partial reuse.

The slag processing operations include open pit practice, pelletising and granulating (see Section 5.2.1). Low grade water can be used for each operation, but the overall quantities consumed can vary significantly. The open pit practice may incorporate full to no recycling of water depending on pit construction, and can result in significant infiltration of water into the ground. Pelletising requires less water and the opportunities for recycling are much greater, as is also true for the granulation process. Obviously, a dry pelletising process would require no water.

5.3.2 Steelmaking, Secondary Refining and Casting

BOF / EAF Steelmaking — Water is used on BOF and EAF plant for cooling and gas cleaning. The cooling systems for the BOF vessel, EAF, water cooled ducts, secondary refining ladles etc. should be closed. Gas cleaning may incorporate dry or wet systems for dust removal; the latter requiring subsequent settlement giving rise to a cleaned water for recirculation and a grit and/or sludge which may be landfilled, recycled or treated. The continuous casting plant requires large volumes of water to cool the cast steel as it exits the mould. As above, recirculating systems, incorporating scale and oil removal, can be employed.

5.3.3 Hot Rolling

The hot rolling mills require water for cooling on the furnace and scale breaking. Cooling systems on the furnace should be closed and indirect and scale breaking/ rolling water should be recirculated. Where water quality is critical, the recirculation system may incorporate settlement, to remove solids and bulk oil, with subsequent filtration to ensure that pipelines and spray nozzles remain clear. Water from the indirect furnace cooling system may be downgraded to the scale breaking system as necessary.

5.3.4 Pickling, Cold Rolling, Annealing and Tempering

Waste water from pickling operations can include waste acids and rinse waters from steel rinsing and gas cleaning operations which can contain toxic substances that should be prevented or controlled. In order to reduce the burden both on water treatment plants and following discharge into water courses the pickle bath wastes can be treated to regenerate the acid. Techniques employed include ion exchange media and spray roasting, applied to HCl, and cooling to precipitate $FeSO_4$ and regenerate H_2SO_4. These methods may give rise to a solid by-product (e.g. fine α-Fe_2O_3 or $FeSO_4$) as well as an effluent requiring neutralisation and precipitation prior to discharge, but the overall loads to water are lower.

Rinse water arises from rinsing operations following pickling etc. and gas cleaning. Recirculating systems should be employed, but these need to be monitored carefully to maintain the efficiency of the operations. All waste waters from the process must be treated by neutralisation and precipitation prior to discharge, although some rinse water may be sufficiently dilute to be used as a make-up for the hot rolling mill water circuit.

Cold rolling involves the use of an oil emulsion as a coolant and to ensure surface quality of the rolled steel. It may be possible to install filter systems that allow a degree of recirculation, but the oil is critical to product final quality and, therefore, recirculation must be closely monitored. The resulting large quantities of effluent must be properly treated before discharge.

Case Study — Recovery and Regeneration of Waste Pickle Liquor

Enabling Technology

Hydrochloric acid (HCl) pickling baths are regenerated and recycled for pickling of steel plates. The spent pickle liquor is treated in a roasting oven where the HCl is recovered, along with ferric oxide powder which is sold. Residual acid losses are neutralised and settled.

Materials/Energy Balance and Substitution

FEEDSTOCK: HCl - 20 kg/tonne steel, lime - 10 kg/tonne steel, wash water - 0.3m³/tonne steel, energy (gas) - 0.125 GJ/tonne steel.

WASTES: Waste pickle liquor and wash water

Advantages

- *FEEDSTOCK REDUCTION: HCl requirement is reduced by 18 kg/tonne steel, lime by 8.5 kg/tonne steel, water by 0.2 m³/tonne steel.*
- *WASTE PRODUCTION: The technique generates 0.2 m³/tonne steel of wastewater containing 0.25 kg chloride ions, compared to 0.3 m³/tonne steel of wastewater containing 1.3 kg chloride ions with conventional technology. Ferric oxide mud is reduced from 7 to 0.6 kg/tonne steel.*
- *IMPACT: Wastewater generation is reduced by 33 percent, with a high recovery rate of chlorides and ferric oxide..*

Economics

CAPITAL COST: FF25 M (1979)

OPERATION/MAINTENANCE: FF4.9/tonne steel

DISPOSAL & FEEDSTOCK: Capital investment is increased by FF25 M, but operating costs are decreased by FF5.1/tonne steel. Recovered ferric oxide is sold for FF1.1/tonne.

5.3.4 Coating

Depending on the coating being applied the water requirement of the process will vary. Of particular concern is the use of Cr (VI) solutions for surface passivation of galvanised strip, although the various cleaning solutions (e.g. caustic) must also be considered. The process solutions are recirculated until spent and may be batch treated or sent off-site for treatment. Rinse waters from local exhaust ventilation systems should be treated by neutralisation and precipitation prior to discharge, although some may be reused as described above.

5.3.5 Others

An assessment of the various effluents arising from the many operations operated on a steelworks should be made to optimise the effluent treatment system which, ideally, should be operated as an integrated system. For example, dilution of a heavily contaminated effluent with relatively clean water may increase the required size of treatment facilities unnecessarily, reduce treatment efficiency and require additional treatment chemicals to cope with the much greater flow. Contrarily, the combination of some effluents may be beneficial, such as the use of waste HCl pickle liquor, containing the Fe (II) species, for the reduction of Cr (VI) to the much less toxic Cr (III) or the use of BOF gas cleaning water to neutralise more acid solutions. The use of continuous bleeds from pickle tanks, recirculating systems etc. can reduce the need to batch treat strong solutions allowing more efficient and consistent treatment, thus reducing peak loads on receiving water streams. Further on, assessment of the water needs of different process stages, in conjunction with the application of non-traditional effluent treatment technologies, such as reverse osmosis, ultrafiltration etc., may provide opportunities for recycling water normally discharged to local water courses.

5.4 ENERGY CONSERVATION

The steel industry is a major user of energy. In Japan, steel accounts for 10 percent of total energy consumption and in Germany for 5.7 percent, equivalent to 27 Mtonnes of coal. However, indicative of many national industries, the energy consumed by the German industry to make one tonne of steel has fallen significantly from 29 GJ, in 1960, to about 22 GJ in 1989 (**Figure 5.2**). This has been achieved by concentrating production at a smaller number of sites and increasing the capacity of the process units, made possible by the introduction of technologies such as the back pressure blast furnace and oxygen steelmaking. Thus, the number of blast furnaces and steel plants have been reduced over that time to one quarter and one fifth of their previous number respectively.

About 95 percent of an integrated works' energy input comes from solid fuel (mainly coal), 3-4 percent from gaseous fuels and 1-2 percent from liquid fuels. However, approximately three

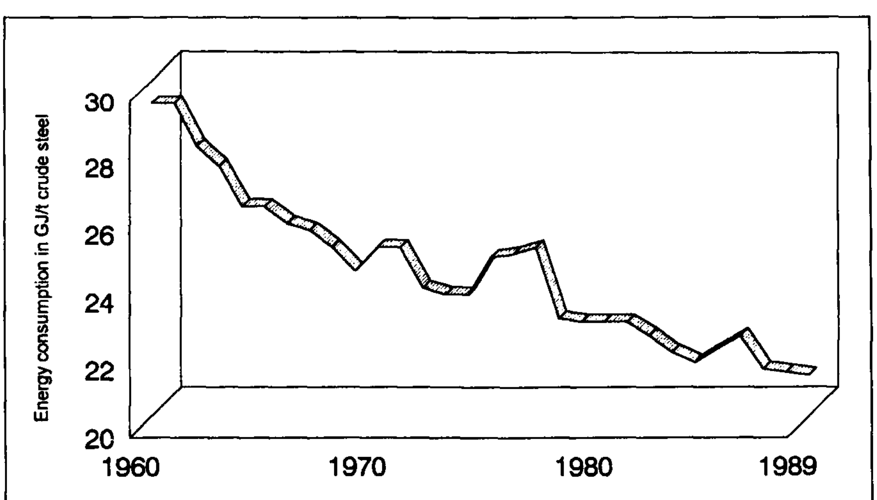


Figure 5.2 **Energy consumption in the German steel industry**

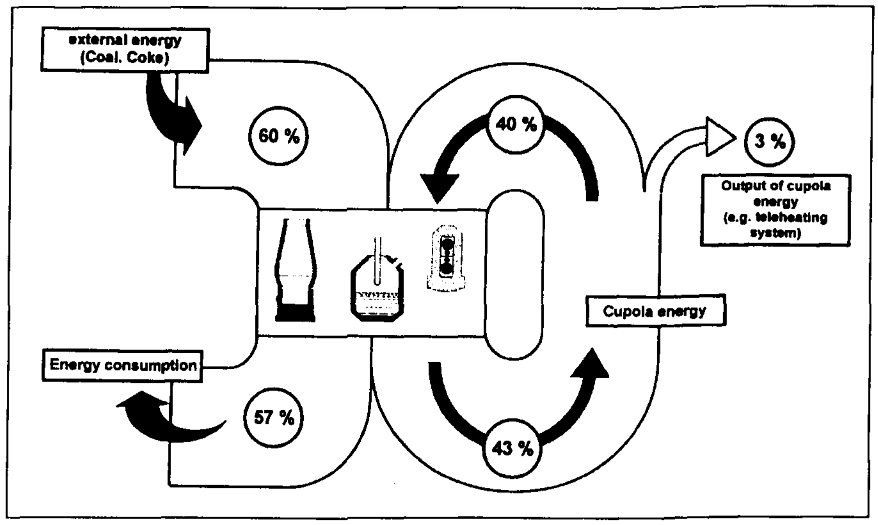


Figure 5.3 **Reuse of internally generated fuel gases**

quarters of the energy content of the coal is consumed in the reduction reaction which converts iron ore to iron in the blast furnace. The remainder provides heat at the sinter and coking plants and, in the form of by-product gas to the various downstream process stages. The quantities of liquid and gaseous fuels used alongside the by-product gases in the downstream process stages depends on the overall works energy balance. Thus, by-product gases from the coke oven, blast furnace and steelmaking furnace typically contribute 40 percent to total energy and are used either as a direct fuel substitute or for the internal generation of electricity (**Figure 5.3**). The efficient utilisation of these internally generated energy sources is critical to the overall energy efficiency of a works, requiring that the complex relationships between the different generating and consuming facilities are understood (**Figure 5.4**).

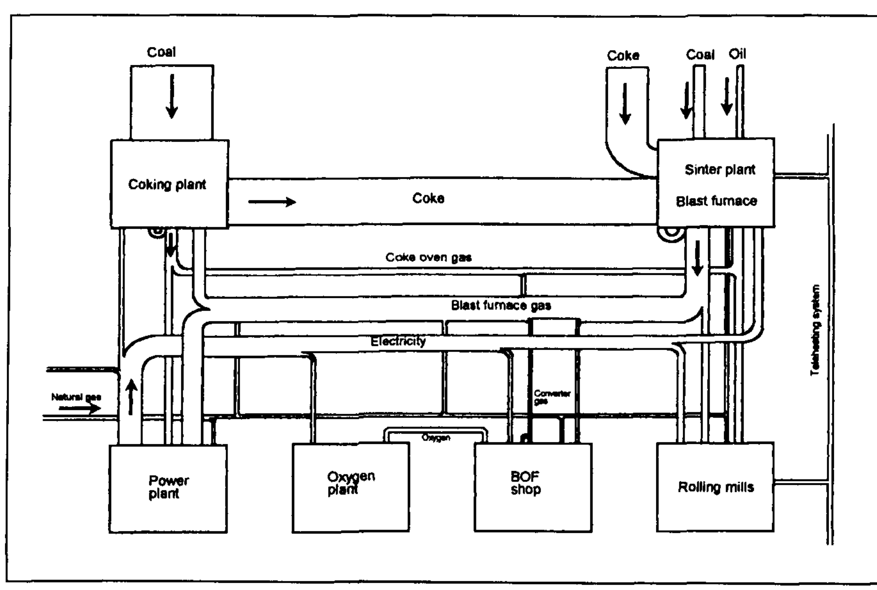


Figure 5.4 **Relationships between internal energy sources**

A selection of those technologies that can contribute to a reduction in energy consumption is discussed below. Some of the technologies are limited in application, for reasons of economic payback, plant configuration, process limitations etc., and their use is not widespread (e.g. CDQ), whereas others are more generally applicable, offer significant savings (e.g. coal injection) and, therefore, have been applied more widely.

5.4.1 Ironmaking

Raw Materials Handling / Preparation — The operation of an integrated works requires the transport of large quantities of raw materials over great distances. Sea transport can only be economical in very high capacity (up to 320,000 tonnes) ore transporters and the use of road, rail and fluvial transport should be minimised to reduce the energy burden. There are no specific energy saving technologies relating to ore preparation, but as discussed previously, the quality and consistency of the raw materials delivered to the coke works, the sinter plant and the blast furnace are critical to smooth, efficient operations. Thus, the raw materials can affect the energy consumption of these processes directly, by altering process conditions, and indirectly, by reducing the occurrence of unscheduled delays and downtime, as well as product quality.

Sintering — The energy consumed at the sinter plant includes coke breeze and coal on the sinter bed and electricity for the combustion air fans. Substantial reductions in coke breeze consumption have been achieved in some countries in recent years. **Figure 5.5** shows how a decline in breeze consumption in Germany from 80 kg/t sinter to as low as 38 kg/t sinter, has resulted in energy consumption being halved. The improvement was achieved by operating with burnt lime additions, an increased sinter bed height, olivine instead of dolomite, a lower FeO content and heat recovery from the sinter coolers. Other methods include waste gas recirculation, which has been applied successfully to reduce both emissions to air and coke consumption (see case study below), ignition furnace combustion control and material segregation charging, to improve air flow through the bed.

The electricity consumption of the combustion air fans can be minimised by careful control of the sinter feed water content, to optimise permeability, reducing leaks in the main duct and by incorporating fan speed control.

As discussed above, the consistency of the raw material feed can ensure the stable operation of the sinter plant, thus maximising productivity and sinter quality, which itself will reduce the specific energy consumption of the process as well as impact on BF operation.

Cokemaking — Within the coke works the primary consumers of energy include the underfiring system, which may operate on COG or BF gas, and the exhausters, which may be steam or electrically driven. The specific energy consumption of the underfiring system can be minimised by the application of a computer controlled heating system and coal preheating/moisture control utilising waste heat recovered from the hot coke (CDQ), the hot COG leaving the battery and/or the combustion waste gas. Coal moisture control both reduces directly the energy requirement for underfiring and provides a more consistent feedstock allowing closer control

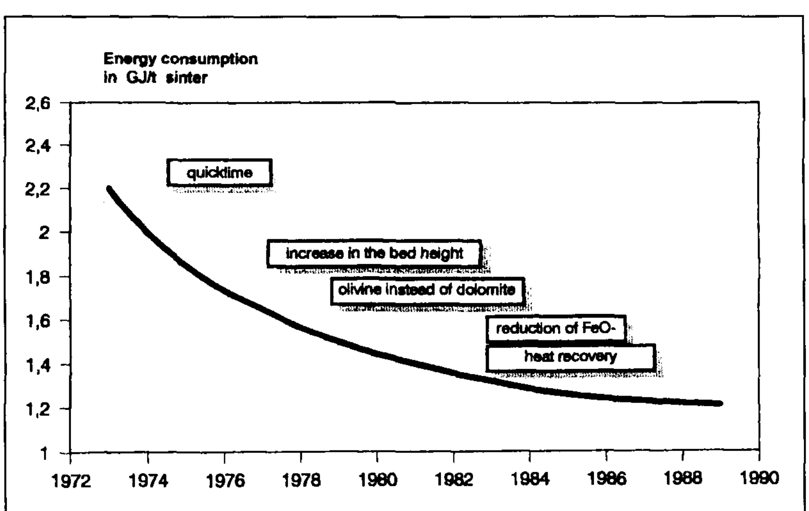


Figure 5.5 **Declining use of coke breeze for sintering in Germany**

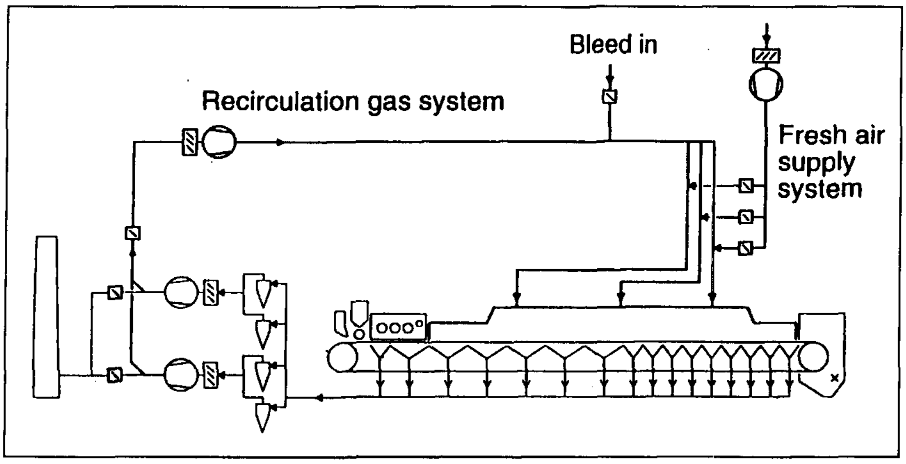
Case Study — Emission Optimised Sintering at Hoogovens Steel

Background

The transition towards Emission Optimised Sintering (EOS) is the first step in the 'Action Plan Ore Preparation' at Hoogovens Steel in Ijmuiden. The total plan comprises the EOS and a high-pressure scrubbing system plus additional water treatment plant to reduce the emissions to air at the sinter plant and a water treatment plant to reduce the emissions to water at the pellet plant.

Enabling Technology

In the EOS process, a controlled mixture of fresh air and recycled flue gas is fed to the ore mix on the sinter strand, which is covered by a gas-tight hood. Three separate mixing zones within the hood allow the fresh air/flue gas ratio and therefore the oxygen concentration, to be varied over the whole length of the sinter strand. The system layout is shown schematically below.



Advantages

The change from conventional sintering to EOS at Hoogovens has led to significant reductions in flue gas volume, coke breeze rate and emissions. The results are shown in the table below.

		Reduction (%)
Flue gas volume emitted		45
Coke breeze rate		10-20
Emissions:	Dust	50
	SO_2	25
	Dioxins	65
	NO_2	35
	CO	35
	Hydrocarbons	30
	CO_2	10

Although process has reduced the total dust load, the emission loads of heavy metals have remained virtually unchanged due to the fact that, in general, the heavy metal contents within the dust have significantly increased. Further reduction of dust emissions, including heavy metals, will be achieved when a new high pressure scrubber becomes operational.

The capital and maintenance costs are offset by the savings resulting from the reduced coke breeze rate.

over the heating cycle, thus increasing productivity and reducing both the specific energy consumption of the process and the potential for pushing emissions.

Coke dry quenching (CDQ) allows the sensible heat of coke to be recovered, with 85 percent of the 2 GJ/t coke of energy supplied to the boiler being converted to steam for use on the works or for electricity production. The process is illustrated in **Figure 5.6**.

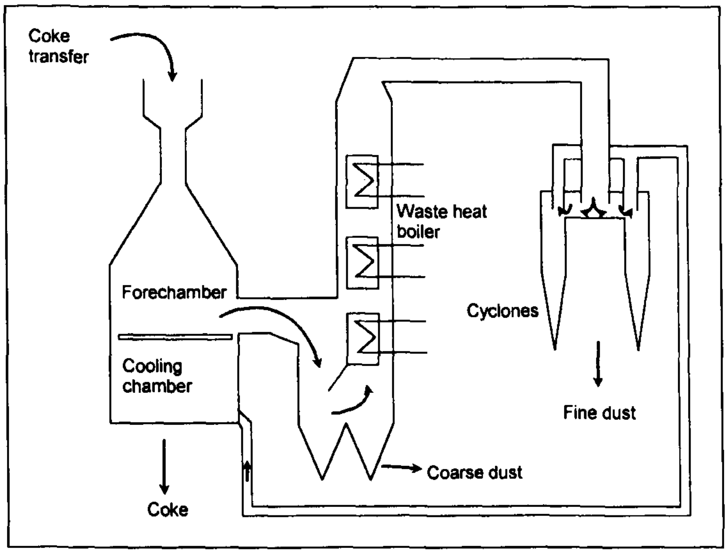


Figure 5.6 **Coke dry quenching (CDQ)**

The choice of steam or electrical exhausters must be made based on the expected steam requirement of the by-products plant. Although both types show equivalent efficiencies the back pressure steam from steam exhausters would be wasted if no other use could be found for it. In this case electrical exhausters would be more appropriate.

As described previously, coke characteristics are critical to efficient BF operation and can impact directly on the overall energy efficiency of the works. Thus, the consistency of the coal feed, the carbonisation process and coke handling are all important parameters. In addition, with the advent of coal injection into the blast furnace the demands on coke have increased still further, requiring greater control over coke strength, reactivity and size distribution to ensure optimum gas flow within the BF at injection rates of 150kg/tonne and over.

Blast Furnace — The main input of energy to the BF is in the form of coke, the consumption of which, in Germany, has fallen from 750 kg/tonne of iron produced in 1948 to 470 kg/t in 1995 (**Figure 5.7**). This drastic reduction has been brought about by the use of higher iron content ores, reduced slag volumes, the development of sintering technology, the introduction of wide hearths and bell-less furnaces operating under high internal pressures and leading to improved burden distribution, gas flow, offgas recovery and thermal efficiency. Substantial further energy savings are possible if coke is partially replaced with injected coal, oil, gas or waste plastic, primarily related to the reduced energy requirement for coke production, but benefits are limited by the amount of coke that can be replaced whilst retaining stable furnace operation (currently approximately 150kg/t).

The higher top gas pressures have allowed for the installation of top recovery turbines which can generate between 20 and 40 kWh/tonne iron, dependent on inlet temperature and pressure. This is equivalent to 25 to 40 percent of the electricity needed for blast generation. The operation of a dry gas cleaning system may yield ~30 percent more power recovery, as the top gas is not cooled on leaving the furnace, and has the additional benefit that the increased sensible heat of the gas leaving the turbine can be recovered if burnt directly in the stoves or boilers.

Case Study — Coal Injection to the Blast Furnace

Background

VSZ Steel Ltd. operates an integrated site in the Slovak Republic producing ~4 Mtonnes of steel per year. In 1991 work began on a project to decrease the consumption of coke in the two operational blast furnaces by replacement with injected pulverized coal, allowing the closure of coke oven battery No. 2.

Enabling Technology

The two blast furnaces at the Kosice site were fitted with pulverised coal injection facilities over a two year period, which lead to a significant decrease in the quantity of coke required for ironmaking from 1993 onwards. As indicated below the coke consumption fell from 510-388 kg/thm and 514-415 kg/thm for BF2 and BF3 respectively over the first three year period that coal injection was installed. In addition, the total energy requirement, calculated as the equivalent coke consumption, fell from ~537-510 kg/thm in both cases, resulting from the use of higher iron content ores and improved process control.

Operational Data - BF2/BF3

	1991	1994	1995	1996
Burden Fe content (%)	54.1/ 54.8	57.3/ 56.9	57.6/ 57.5	57.3/ 57.3
Coke consumption (kg/thm)	510.0/ 513.9	403.3/ 433.8	385.9/ 417.2	388.0/ 414.6
Oil consumption (kg/thm)	16.6/ 17.0	-/ -	-/ -	-/ -
Coal consumption (kg/thm)	-/ -	122.8/ 89.7	138.1/ 103.5	136.0/ 106.0
Natural gas (Nm^3/thm)	7.2/ -	-/ -	-/ -	-/ -
Total energy (kg/thm)	**536.6/ 536.6**	**512.2/ 515.1**	**510.2/ 510.3**	**510.4/ 510.0**

Advantages

The advantages of coal injection were that coke oven No. 2 battery could be closed down, without jeopardizing the coke supply to the blast furnaces, resulting in reduced emissions to air and water. Thus, the volume of phenol/ammonia laden waste water requiring treatment was reduced by 96200 m^3/y, and specific air emissions were reduced as indicated below.

Emission Data - Battery No.2 (tonnes)

	1991	1992
Particulate	213.4	108.8
SO_2	188.9	96.3
NO_x	150.3	76.6
CO	415.9	212.1
Benzo-a-pyrene	2.0	1.0
Benzene	44.3	22.5
H_2S, HCN, phenol, pyridine	174.9	89.2
Naphthalene, toluene, xylene, byphenyl, NH_3	85.5	43.6
Total	**1275.2**	650.1

Economics

The total investment cost for the project was US$ 35k and direct economic savings resulted from the reduced cost of waste water treatment and fees for air emissions, which amounted to US$ 13.5k/y and US$ 17.4k/y respectively.

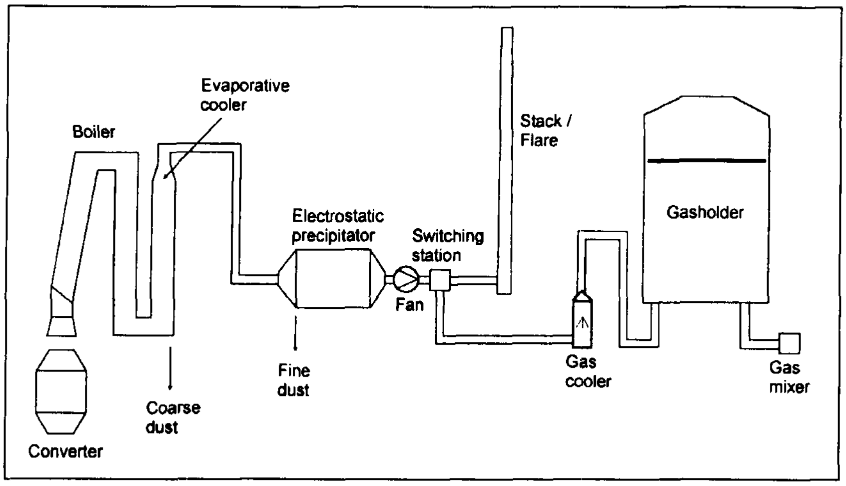


Figure 5.8 **BOF gas cleaning and recovery system (see Photo 13)**

Other energy saving measures include programmed ladle heating control, vessel bottom stirring, to enhance process metallurgy and improve productivity, and variable speed drives for fans, pumps etc. to reduce overall energy consumption during stoppages and delays.

EAF Steelmaking — A typical EAF works consumes about 600-650 kWh/ tonne of steel of which ~500 kWh is accounted for by the furnace itself. The principal energy saving measures have been the introduction of ultra high power (UHP) furnaces, to maximise the power input to the furnace, the injection of alternative fuels, to improve scrap heating, oxygen injection, to maximise post-combustion and the release of energy within the furnace shell, and the use of ladle furnaces to carry out secondary metallurgy operations external to the main melting unit. These improvements reduce the overall energy demand of the EAF both by improving the efficiency of energy use in the furnace and by maximising productivity, which reduces the time dependent energy losses. Several plants have also achieved substantial energy savings by preheating scrap using waste furnace gas, in either a shaft above the furnace or in a tunnel. However, care should be taken that potentially harmful organic and other emissions are not generated in the process.

Other energy saving measures include the use of fan speed control and computer systems to control the operation of the offgas system, particularly in a multi-furnace melting shop.

Casting — Continuous casting has largely replaced ingot casting both reducing the specific energy consumption of steel production, by increasing the yield to cast product, and, by reducing the energy demand associated with soaking pit furnaces, giving a saving of between 0.5 and 0.8

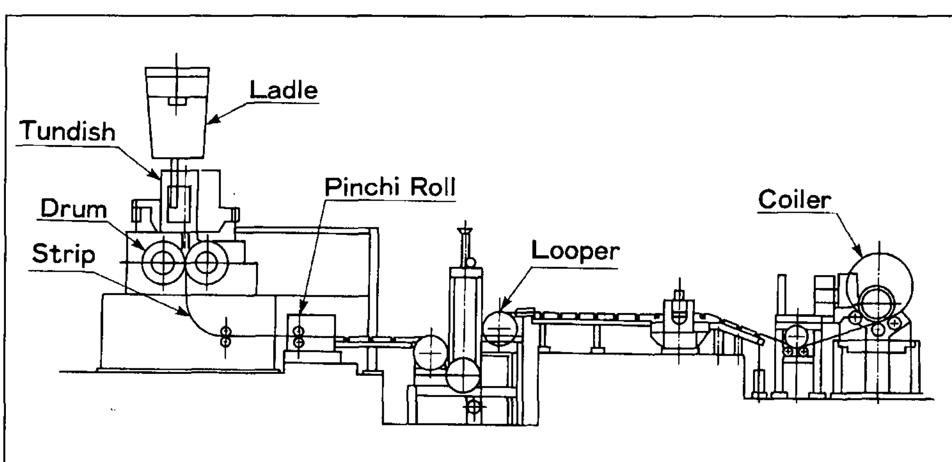


Figure 5.9 **Layout of a strip casting plant**

GJ/t crude steel. In circumstances where ingots were hot charged these latter savings were not necessarily realised as continuous casting introduced a cooling step, to allow for surface quality inspections etc., resulting in the loss of the cast slab sensible heat and requiring reheating. Savings in the reheating of slabs prior to rolling have been achieved, however, where the hot slab is 'direct linked' to the rolling process without allowing it to cool. Plants where this practice has been adopted tend to be those casting thin slabs, a relatively new technology which in its own right provides energy savings by obviating the need for a rough rolling stage.

Strip casting involves the direct production of thin strip from molten steel. The process is technically proven and commercialised for the production of stainless steels, although technical difficulties and limited capacities make it unlikely that the technique will quickly replace the conventional route for carbon steels. Strip casting is attractive from an energy and capital investment viewpoint as it removes the need for both the conventional reheating furnace and rolling mill, which are normally needed to reduce the cast slab into strip. A variety of methods have been tested and one of the most successful has been the twin-roll approach illustrated in **Figures 5.9** and **5.10**

5.4.3 Hot Rolling

The main consumption of energy in the hot rolling mills can be broken down into the fuels used to reheat the cast steel, fuels used for heat treatment and the electricity used to drive the rolls. The proportion of each will vary according to the mill type (e.g. strip, light, medium and heavy section, plate, wire etc.) and other process parameters.

In terms of furnace design there are several techniques that can be applied to reduce overall energy consumption by maximising heat transfer to the cast material, minimising unnecessary losses and by recovering energy that would otherwise be lost. These techniques include the incorporation of a long unfired preheat zone, to maximise the transfer of heat from the waste gases to the cast material, isolated firing zones, to allow flexibility for firing of individual zones, the use of computer combustion control models, to optimise furnace firing based on cast material temperature, mill status, offgas analysis etc. and improved burner designs to maximise efficiency whilst minimising emissions to air of, for example, NO_x. The proper installation and continued maintenance of insulation is vital to ensure the on-going thermal efficiency of the furnace and thermal boxes before the furnace can help retain the sensible heat of cast material, where hot charging is employed. The adoption of these and other measures over the past ten years, has reduced the fuel consumption of a typical walking beam furnace from 2.4 to 1.6 GJ/t.

The energy consumption of the furnace can also be reduced by taking advantage of the cast material sensible heat by maximising the use of hot charge direct rolling, where the furnace is fed directly from the caster at a temperature of ~900°C, and hot charge rolling, where there is some

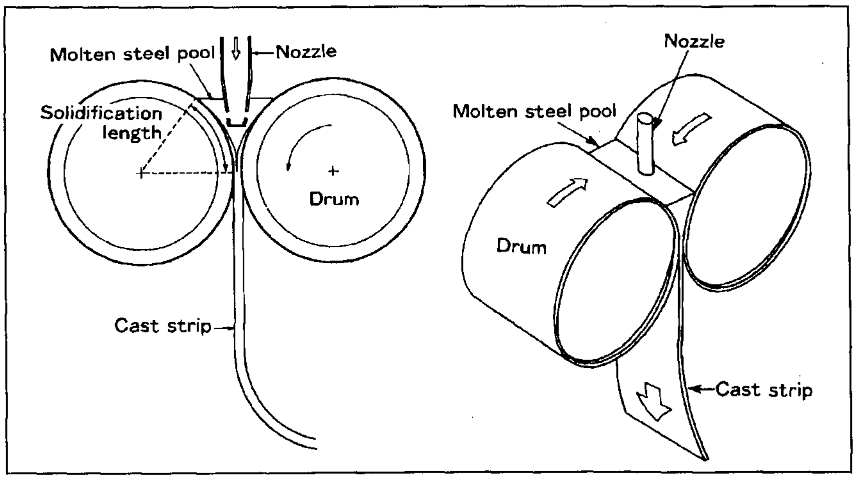


Figure 5.10 Metal feed for twin-roll strip casting

Case Study — Strip Casting

Background

A new system for the production of stainless steel strip in one cycle by means of an innovative process named ISP (In-line Strip Production) yields a number of environmental and economic benefits.

ISP - which incorporates a narrow mould - allows the utilisation of the sensible heat of the strip and a drastic reduction in plant size, alleviating the principle problems in the traditional process including high costs, due to the discontinuous nature of the conventional process, high energy consumption, high labour costs and a lack of flexibility to produce a range of commercial goods.

The new technology permits:

- *use of the heat contained in liquid steel*
- *a greater production yield compared with conventional plants, thereby producing more steel strip from the same quantity of liquid steel*
- *a consistent thickness of steel strip*
- *the elimination of the need for intermediate storage of the slabs for subsequent rolling*

Enabling Technology

The new process eliminates the intermediate step between casting steel slabs and subsequent hot rolling. The system consists of a machine that continuously casts thin strip, combined with a first line of heated rolls, an induction oven for temperature normalisation, a coil box and the finishing stands.

The principle stages of the process include the curvilinear mould in which the strip solidifies, soft reduction in thickness to 40 mm, an induction oven for normalisation and reduction to 15-20 mm. This system, compared with the conventional system, is more compact in size, has an increased processing speed (approximately 15 minutes compared with several hours), incorporates a rational utilisation of the heat of the product, as a consequence of the high velocity of production and reduced thickness, and allows increased flexibility in production (e.g. it is possible to produce small lots of specialised products).

The plant produces 500,000 tonnes/year of steel strip and is considered a novel technology because it enables the production of quality hot strip that passes directly from liquid steel, without interruption, to the casting and rolling phases.

Advantages

The smaller dimensions of the plant reduce environmental impacts. Furthermore, the new process has eliminated the need for acid pickling.

The investment and maintenance costs per tonne are reduced compared to conventional plants because of the speed of the process, the reduced dimension of the plant, the energy savings, the elimination of intermediate storage and the reduction in waste and primary materials.

ECONOMICS: *Investment costs are 2/3 less than that of the traditional process. The production of 25 tonnes of rolled steel strip with the new continuous process requires a layout of 150m versus 1,400m required by the traditional technology. Running costs are reduced by 40 percent as a result of the reduction in energy consumed and the reduction of waste scraps.*

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Case Study — The Quenching and Self Tempering Process

*See **Photos 18** and **19**.*

Background

In an effort to provide better performing rolled sections, ProfilARBED of Luxembourg, in cooperation with the Centre de Recherches Metallurgiques in Liege (Belgium), developed a process of 'in line' heat treatment of steel sections. The process allows the use of the in-line hot rolling 'waste' energy instead of fossil energy from natural gas or LPG for an off-line heat treatment.

Enabling Technology

The heat contained in the section at the last stage of hot rolling (T>950°C) is used to perform a 'Quench' and subsequent 'Tempering' of the steel, hence the designation QST which stands for 'Quenching and Self Tempering'.

- *Quenching is performed by the massive, but controlled, cooling of the steel with water sprays.*
- *The heat contained in the core of the material subsequently warms the outer layer to an adequate temperature to perform a tempering treatment.*

As a result a product is obtained which displays a fine grained structure with a higher yield strength, an excellent toughness at low temperatures and an outstanding weldability, compared to the conventional rolled section. Since the early nineties this process has been in common use at the heavy section mill of Differdange where parallel flanged H and I beams are produced. The process has also been successfully adapted to the rolling of special sections for the mining industry.

Advantages

The advantages are as follows:

- *material savings of up to 30 percent.*
- *energy savings range between 2.7 and 5.4 GJ/tonne*
- *avoids the use of alloying elements (e.g. manganese, niobium and vanadium).*
- *improved weldability does not require preheating prior to welding. This leads to energy savings depending on the required preheating temperature for conventional steel which can range between 50°C and 250°C.*
- *avoids the need for off-line 'normalisation' heat treatment requiring an energy input of approximately 0.8 GJ/tonne.*

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delay between the caster and the furnace, but mean charging temperatures are of the order 300-600°C. The obvious extension of the above is the practice of hot direct rolling in which the caster is linked directly to the mill. The potential to apply these procedures will, obviously, be dependent on mill type and configuration, the proximity of the caster, steel specifications etc. and is reliant on the installation of equipment to allow a higher furnace throughput, temperature normalisation (e.g. edge heaters), schedule free rolling, schedule matching, high quality slabs etc. In practice, hot charge rolling and the other variants described above can be difficult to operate because of the need to match the output of the caster with the output of the rolling mill, both of which can be subject to delays, stoppages etc.

The use of fuel for heat treatment of rolled plate can be reduced by adopting a thermo-mechanical control process (TMCP) in the plate mill. TMCP introduces a delay between the roughing and finishing mills in order that the plate is rolled at a reduced temperature, giving rise to the correct crystal structure, without the need for additional heat treatment. TMCP may also incorporate accelerated cooling to improve the weldability and other properties of the plate.

The electrical requirement of the hot strip mill can be reduced by installing a coil box, which reverses the transfer bar between the roughing and finishing mills, ensuring greater temperature uniformity throughout the rolling process. This reduces the amount of additional power required to roll the strip as the temperature drops during rolling and can allow greater control over the steel final properties. Thermal covers between the roughing and finishing mills can also reduce the electrical requirement of the mill by retaining the heat of the transfer bar, allowing for higher temperatures on the inlet to the finishing stand. This latter method may also allow for lower furnace drop out temperatures leading to savings in fuel consumption and yield loss.

The specific energy consumption of the furnace and the mill are both sensitive to the level of productivity. That is, during periods of low productivity the overall specific energy consumption is high, and visa versa, due the need to maintain furnace set points, water pumping requirements, cooling fans etc. Thus, the productivity of the mill should be maximised and the number and length of unscheduled delays minimised. Where unscheduled delays do occur the impact on energy use should be minimised by ensuring continued dialogue between the maintenance and mill personnel so that furnace setpoints can be ramped down and mill equipment powered down accordingly. The application of computer control equipment can automate the process allowing optimum temperature profiles to be followed in the furnace based on the expected time of delay, which may be updated periodically by plant personnel. Continuous hot strip rolling has also been implemented at one plant in Japan by welding consecutive transfer bars prior to the finishing stand. The process has the potential to increase the overall productivity of the mill, reduce yield losses and improve steel quality leading to overall reductions in specific energy use.

5.4.4 Pickling, Cold Rolling, Annealing and Tempering

Energy consumed for pickling, cold rolling, annealing and tempering includes steam for acid bath and cleaning tank heating, fuel or steam for acid recovery, electricity to drive the rolls and various roll coolant pumps, fans etc. and fuel used for annealing.

The use of a steam/acid heat exchanger in place of a steam sparging system on the pickle line can reduce the overall steam requirement and the amount of liquor requiring treatment in the acid recovery plant (ARP). To obtain maximum benefit the steam condensate from the heat exchanger should be used for strip preheating. In addition, shallow bath pickling, in which acid is sprayed onto the strip surface and continuously drained from the tank for reheating, allows a lower acid temperature to be used for the same productivity, compared to deep bath technology, reducing evaporation losses and steam usage. The choice of acid can also affect the energy consumed by the ARP as HCl gives rise to about one quarter the quantity of spent acid compared to H_2SO_4, the most common, and cheaper, alternative. Some of the heat contained in the spent acid can be recovered in a heat exchanger and used to reheat the cold, recovered acid. The process of ultrasonic pickling, which is still under development, may also provide energy savings by allowing productivity to be maintained at lower acid bath temperatures, or increased productivity, where the acid bath temperature is maintained.

Electricity consumption of the cold mill roll drives is dictated by the initial and final gauge of the rolled steel, thus, there are limited possibilities for saving energy. However, the use of control devices, such as soft starts, on the roll coolant pumps can minimise electricity consumption during delays. Further savings may be made by linking the pickle line directly with the cold mill by welding consecutive coils together. This process can increase the productivity of the mill and savings in energy use of 10 percent have been claimed.

Cold rolled coil may be batch or continuously annealed under an inert atmosphere. Continuous annealing provides for faster heat transfer and greater control over annealing temperatures allowing a wider range of steel qualities to be produced. However, a single stack batch annealing furnace operating with a hydrogen atmosphere (nitrogen has a lower capacity for transferring heat) can have a lower overall energy use owing to the greatly reduced cycle times (compared to the nitrogen furnace), greater potential for waste gas heat recovery and lower gas requirement. Combustion control systems may also be installed on the single stack furnace to optimise gas firing rates and excess air levels throughout the annealing cycle, reducing losses associated with the waste gas.

Where cold rolled steel is to be used for tinplate production there may be a rigorous cleaning step before annealing is carried out. The use of energy can be reduced by minimising the quantity of water used in the scrubbers between cleaning tanks, consistent with satisfactory cleanliness, and by ensuring good temperature control of cleaning baths and flow control of steam.

5.4.5 Coating

Energy used for coating will be dependent on the coating process (e.g. galvanising, tinplate, organic substrate etc.). The energy consumption of electrolytic processes will be dependent on a variety of factors including bath temperature, coating thickness, solution concentration, bath geometry, cathode/ anode distances etc. and these should be optimised for a particular process, product and application. Hot dip galvanising requires less energy than the equivalent electrolytic process and this material is suitable for most current applications. Other savings may be made by waste gas heat recovery from the preheat and radiant tube furnaces to preheat combustion air for the non-oxidising and radiant tube furnaces respectively.

5.4.5 Others

As indicated earlier a typical integrated works has a complex energy management system linking the energy producers (e.g. coke ovens, blast furnace, BOF plant) with the energy consumers (e.g. coke ovens, blast furnace, rolling mills, power plant). In order to ensure that maximum use is made of the available fuels the distribution and management system has to take into account, and react quickly to, many factors relating to the demand for by-product gases and electricity. Where proper consideration is not given this may lead to situations where excess gas is flared or situations where additional fuel must be purchased. The smooth operation of all plant, brought about by high levels of maintenance, effective operational and engineering practices and the application of computer control and other information technology systems for schedule matching etc., allows predictions of energy supply and demand to be made accurately, based on production requirements, ensuring optimum use of all fuels. Additionally, smooth operation maximises productivity and specific energy consumption.

Most integrated works use excess by-product gas to generate a secure supply of steam and electricity on-site, for use by the works and for sale. Typical power generation facilities include steam generating boilers and steam turbines with an overall efficiency of between 25-32 percent, depending on the amount of steam used on plant. The by-product gases could be more efficiently used to generate electricity using a combined cycle combustion turbine / waste heat boiler configuration which may operate with an efficiency of between 38-45 percent, depending on the quantity of steam used on plant. Several examples of the combined cycle unit have been installed and are running successfully on a blend of by-product gases and further units are planned.

5.5 RAW MATERIAL CONSERVATION

When iron ore is converted into finished steel products, some iron units are 'lost' in the processes which are inevitably less than 100 percent efficient. Thus, the production of one tonne of steel in an integrated plant requires several times that quantity of raw materials. A measure of the efficiency of individual or groups of processes is the yield, defined as the quantity of material leaving a process expressed as a fraction of the material entering, or the mass of product divided by the crude steel necessary to make that product. While the phrase 'yield loss' is widely used, its literal translation is misleading because the majority of the material comprising the 'loss' can often be recycled as feed to an earlier process stage.

Table 5.2 **Range of yields for processes and products**

Process	Range of yields (%)
BOF steelmaking	86.0 - 95.0
EAF steelmaking	85.0 - 92.5
Slab concast	84.9 - 98.0
Bloom concast	82.3 - 97.6
Billet concast	76.6 - 99.0
Hot rolled coil	84.5 - 98.8
Cold rolled coil	82.4 - 93.8
Tinplate	83.4 - 97.3
Plate	74.1 - 94.8
Sections	78.4 - 97.5
Wire rod	88.0 - 98.6
Straight bar	85.5 - 97.3

Yield losses occur at all the main process stages, from material handling through iron- and steelmaking to the subsequent operations of casting, rolling and coating. Some loss is inevitable, although studies revealing the wide variation in yield performance between countries suggest that not all producers have implemented the best technology and methods. For example, an IISI global survey showed that between 1961 and 1987 yields for hot rolled products in Japan rose from 77 to over 85 percent, while yields for the same process during this period in the former USSR remained static at around 70 percent. **Table 5.2** shows the range of yields being achieved by steelmakers for the major processes in 1991.

As indicated above, scrap steel can be 100 percent recycled back into the process route and in tonnage terms is the world's most recycled material. Actual scrap recycling rates of over 80 percent are achieved on a world basis and over 40 percent of all steel is manufactured using processes that consume scrap as the primary input material (e.g. the EAF and open hearth). Scrap use is also an essential aspect of steelmaking in the BOF process which requires about 10-30 percent of scrap as a feed material to operate correctly. As such, steel scrap is a valuable and necessary raw material, and one that is returned to the steelmaker through a sophisticated, and often independent recycling infrastructure. The technology for steel recycling is well proven and based on the magnetic properties of iron and steel for its separation from nonmetallic / nonferrous contaminants. In addition, scrap processing technologies involving the shredding and subsequent separation of scrap components have resulted in an increase in the recyclability of products as diverse as automobiles and beverage cans. Obviously, the EAF producers have always sourced the majority of their scrap feed from external sources, but increasingly the integrated producer is having to do the same as the quantity of internally generated scrap is falling as yields improve. For example, in Germany the introduction of continuous casting has cut the quantity of in-plant generated scrap by two thirds (**Figure 5.11**).

By recycling nearly 300 million tonnes of scrap each year (i.e. not including internally generated scrap), the steel industry:

- Does not have to extract 475 million tonnes of natural iron bearing ores
- Saves energy equivalent to 160 million tonnes of hard coal, and
- Avoids the emission of 470 million tonnes of carbon dioxide.

The following is a general discussion of some of the techniques available to improve the yield of each process stage. Not all techniques will be applicable at all plant as product requirements will have a significant impact on final yield.

5.5.1 Ironmaking

Raw Materials Handling / Preparation — The control of the yield of the steelmaking process begins with the selection, handling and blending of raw materials. A range of ore and coal types are available on the open market and these must be selected not only with reference to the current market price, but in anticipation of current and future process requirements. Ores can contain variable quantities of iron and gangue and may be in the form of fines, rubble or pellet. The range of coals available is also large and these must be selected based on coking and blast furnace injection requirements.

The handling and storage of raw materials in stockpiles can give rise to a small yield loss associated with dust liftoff which should be reduced by minimising the number of transfer operations (e.g.

from ship to shore, to rail, to boat etc.) and by using water sprays and crusting agents to dampen the finer fractions. The increased use of rubble or pellet can reduce losses from this source.

Different ores are blended, along with much smaller quantities of grits, dusts and sludges from the steelmaking process in order to keep the chemical and physical characteristics the sinter plant feedstock uniform over a long period of time. This promotes stable sinter plant operation and allows close control over sinter quality and yield. Coals are also blended, with reference to coke battery limitations and blast furnace requirements, to promote stable operation, to optimise final coke characteristics and to improve yield.

Sintering — Yield losses during the sintering process are associated with loss of fine material, that becomes entrained in the combustion air as it is drawn through the bed, and the sinter product undersize fraction, that is too small for use in the blast furnace and is, therefore, returned to the process. Losses to the combustion air can be minimised by proper selection of raw materials and losses to the undersize fraction can be minimised by careful blending of the sinter plant feedstock, improved control over operational parameters and improved sinter handling (e.g. the overall distance that sinter falls during conveying can have a significant influence on final product dimensions). Typical yield losses associated with the handling and transport of graded sinter to the blast furnace range between 4-12 percent.

Cokemaking — Coke production is focused on producing coke with the correct physical and chemical resistance characteristics for effective blast furnace operation. However, in order to prolong battery life it is often necessary to compromise between the optimum coal blend for blast furnace coke and a blend that provides some protection for the battery walls. For example, highly volatile coals will lead to smaller size coke lumps, but will give rise to overall lower wall pressures during cokemaking. These smaller size coke lumps may not be appropriate for use in the blast furnace, particularly if coal injection is practised, and, therefore, may need to be downgraded to breeze or sold. Obviously, the poorer the quality of the coke the lower the overall yield of coke to the blast furnace. This yield loss can be minimised by careful blending of coals, improved control over the heating cycle and improved handling of coke (e.g. as for sinter the overall distance that coke falls during conveying can have a significant influence on the final physical dimensions).

Blast Furnace — Losses of iron, in the form of metallic iron and iron oxide, during blast furnace processing are associated with the slag and the dust emitted with the top gas respectively. The slag may be subject to some form of iron recovery, allowing much of this material to be recycled, and the top gas dust may be partially recycled to the sinter plant. Iron carry over into slag can be reduced by control of the tapping operation and top gas dust levels may be minimised by maintaining stable furnace operation and appropriate raw materials selection.

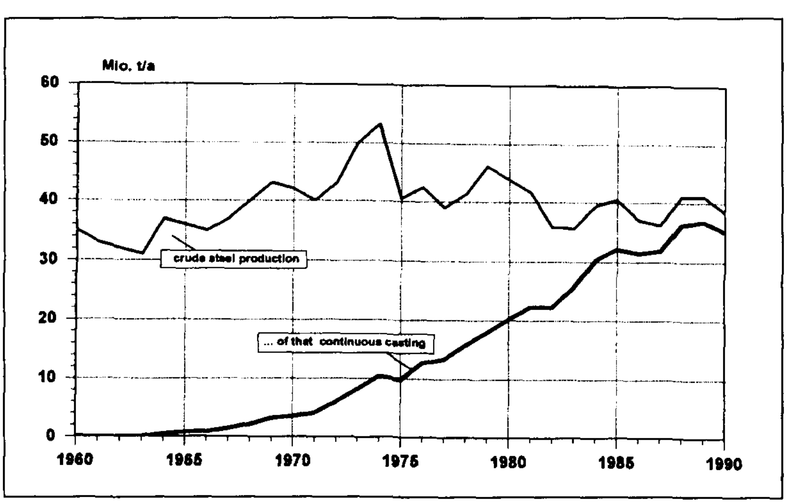


Figure 5.11 Increase in steel produced by continuous casting in Germany

5.5.2 Steelmaking, Secondary Refining and Casting

BOF Steelmaking — The mean molten yield of the BOF process, defined as the quantity of liquid steel delivered to the caster/ total metallic charge, will be affected by vessel size, the amount of reblows, the hot metal silicon content and degree of hot metal pretreatment. For smaller vessels (<200 tonnes), parameters such as sparkling and slopping and operations such as deslagging are more difficult to control than for larger vessels (>200 tonnes), leading to higher specific liquid steel losses. The need to reblow a heat, in order to achieve the correct sulphur or phosphorous end-point or correct temperature for downstream processing, will lead to a lower yield due to losses as described above. The amount of reblows can be reduced by installing process control computers, using accurate control instrumentation (e.g. sub-lance sampling system) and by maintaining a stable hot metal composition (e.g. temperature and silicon content). The increased lime requirement for hot metal with a high silicon content leads to increased iron losses to the slag, but these can be reduced by performing hot metal pretreatment. Pretreatment also promotes a more consistent hot metal quality, resulting in less reblows.

EAF Steelmaking — The molten yield of the EAF process is affected primarily by the oxygen activity and carbon content of the bath and slag practice. Increasing the amount of oxygen injected into the bath can be expected to reduce the yield, although the effect can be balanced by increased carbon injection into the slag. The prevalence of secondary metallurgy units in modern EAF melting shops has reduced the need to operate with a double slag practice, however, where this practice is still carried out iron losses to the slag are higher.

Casting — The continuous casting yield may be affected by parameters such as the number of heats or throughput per tundish, tundish size, number of heats per sequence, tundish draining practice, caster reliability, product mix and the rate of steel grade change-overs. As the number of heats or throughput per tundish increases the quantity of tundish skull and change-over semi scrap decreases. Smaller tundishes reduce the quantity of tundish skull losses, but steel quality is more difficult to control and this may lead to additional yield losses associated with the cast semi. Thus, where a larger tundish is used, for steel quality reasons, the quantity of tundish skull losses can be minimised by increasing the number of heats per tundish. In addition, as the number of heats per sequence increases the losses associated with head and tail scrap decrease. At the end of a sequence the tundish may be completely drained to reduce tundish skull losses, but again this may impact on steel quality and downstream yield losses. Caster reliability and frequent steel grade change-overs can increase the quantity of scrapped material and the final product mix may require substantial subdividing of the cast semi leading to further losses (e.g. plate production) or have more or less stringent quality requirements leading to more (e.g. strip or wire production) or less (e.g. section, bar production) rejection scrap.

5.5.3 Hot Rolling

Yield losses during hot rolling can be broken down into scarfing and grinding losses, furnace scale losses, crop and cutting losses, cobble losses and finished steel losses associated with rolling defects, metallurgical defects and geometric defects. Scarfing and grinding is carried out to ensure the final quality of the rolled product and is related to the surface quality of material entering the mill, which in turn is related to the operating practices on the caster. Oxidation of the surface of the cast material in the furnace is a time and temperature dependent factor which can be reduced by controlling the oxygen level in the furnace, by careful scheduling and improved mill availability to avoid over-soaking. Crop and cutting losses might be reduced by optimising the rolling procedure, to improve the geometric or, in the case of plate, mechanical properties of the rolled product, by introducing improved or automated control of the cropping process, to increase accuracy, and the use of edging facilities for dimensional control. Cobble losses can be reduced by ensuring a more uniformly heated semi, resulting from good maintenance practices and furnace control, improved cropping (e.g. in the section mill), mill availability and scheduling. Finished steel losses can be minimised by controlling steel metallurgical quality in the steel plant, improving the rolling procedure, to minimise the quantity of out of specification product, and improved scheduling within the mill to ensure compatibility between rolled product and ordered lengths. Rejections of material can be significant and costly, particularly for demanding applications, and these can only be reduced by attention to detail in every aspect of the rolling process.

5.5.4 Pickling, Cold Rolling, Annealing and Tempering

Pickling losses may arise from operations such as coil handling, leading to damage and ultimately rejection of the rolled material, end losses, side trim losses, pickle losses and downgrades. Product handling procedures and equipment should be designed to reduce the occurrence of losses due to coil damage. Downgrading, end and side trimming losses are function of hot rolled coil quality, which can be improved by paying attention to those factors discussed above and pickle losses might be reduced by improving the surface quality of the hot rolled coil, also a factor dependent on processing in the hot mill.

Effective process control of the cold mill, temper mill and annealing furnaces is necessary to ensure uniformity of gauge and properties, leading to reduced losses, and other factors, such as strip cleanness prior to tempering and the prevention of rusting, can have an impact.

5.5.5 Coating

Yield losses during coating include entry and finishing scrap and quality losses. Entry and finishing scrap arises as a result of non-uniform geometric properties at either end of the rolled product and differences between the rolled product and customer order. End cuts are carried out prior to coating to minimise the potential for problems during the coating process and product dimensional requirements are satisfied after coating. These losses can be minimised by improving the quality of the incoming material with regard to width, gauge and degree of damage through rolling, handling etc.

5.5.6 Others

Many of the losses associated with the production of the finished product are non-systematic in nature and result from equipment or operating failures and, therefore, should be avoidable. Systematic losses, such as losses to slag during steelmaking, generation of scale during reheating or the cutting and trimming of rolled products, are less easy to avoid, but they can be reduced by following good operating practices. Best performance will be achieved by understanding the limitations and capability of individual plant and operating within these limits as far as possible. Thus, in general, the highest yields are achieved by those plants that pay attention to equipment maintenance, so that high levels of plant reliability and consistency are achieved, that operate plant within its capabilities and develop standard operational and engineering practices. In addition, and as detailed above, the interface between process stages must also be considered as improvements in one area can, potentially, be offset by losses in another. Thus, any efforts to improve the yield associated with steel manufacturing must encompass the whole process route if real benefits are to be realised.

The best technology for a particular application will be dependent on the type of emission to be abated and local circumstances. For example, electrostatic precipitation uses less energy than the other methods, but is unsuited to highly resistive dusts. Wet scrubbers are suitable for treating saturated gases but require water pollution control facilities to clean the water. Fabric filters provide high cleaning efficiency, but can operate over only a limited range of temperature and moisture conditions. Thus, while ESPs are less sensitive to high temperatures, bag filters require strict compliance to operating conditions. For example:

- The gas temperature should not exceed 130°C and 300°C when using polyester fabric and glass fibre fabric respectively (glass fibres gives lower performance).
- The type of bag filter fabric should be compatible with the system, suitable either for a gentle counterflow of fresh air or a sudden counterflow of compressed air, and particulate to be collected, to reduce the effects of abrasion, blinding etc.
- The pressure drop over the filter should remain within the design conditions to maximise performance.
- Incandescent particles should be prevented from entering the filter since holes can be burned into the fabric resulting in a dramatic decrease in filtration efficiency. Spark arrestors need to be installed ahead of the filter to assure sound operation
- Short lived temperature surges due to high temperature and high volume secondary emissions, or generated by sudden metallurgical reactions involving carbonaceous materials, may ignite polyester fabric filters. Design and operational conditions should be adequate to prevent such surges

The technologies that may be applied at each stage of the steel manufacturing route are discussed in the following pages.

6.2.1 Ironmaking

Raw Materials Handling / Preparation — When lime is produced in a lime kiln an airborne emission, containing fine limestone and lime dust, is generated. The quantity of dust generated will be dependent on the characteristics of the raw material feed, kiln design and firing conditions, but the levels can be controlled easily by the incorporation of a scrubbing tower on the kiln stack. The water used in the scrubbing tower can be recirculated via a settling pit to remove collected solids.

The movement of raw materials from the handling yard to plant is most often accomplished by conveyors, however, those points where conveyors are exposed to the prevailing wind and/or where material drops often give rise to airborne emissions. These can be reduced by covering conveyors, installing belt cleaning devices, minimising the number and height of drop zones and using water sprays to dampen the finer fraction. Where emissions do arise these can be abated by installing extraction systems to remove and clean the dust laden air, most often in a bag filter plant.

Sintering / Pelletising — Sinter plant waste gas contains combustion products such as dust, sulphur oxides, nitrogen oxides, CO as well as other pollutants such as heavy metals, acid vapors, naturally occurring radioactive isotopes and organic compounds such as dioxins, PAH, VOCs and methane. The most efficient and widely used cleaning technology is the dry electrostatic precipitator (ESP). Gas entering the ESP typically contains 1000 mg/Nm^3 dust, 300 to 900 mg/Nm^3 SO_2, 400 to 600 mg/Nm^3 NO_x and 10 to 40 mg/Nm^3 acidic aerosols such as HCl and HF. The best precipitators are characterised by high or variably pulsed voltages, rapid reaction voltage and current control and are able to achieve exit dust concentrations of 50 mg/Nm^3 or less, but have little impact on the gaseous pollutants mentioned above. Bag filters and high pressure wet scrubbers are also used, but there are disadvantages in that both technologies consume more energy, the bag filter may suffer from blockage by moisture and, potentially, oily deposits, particularly during start-up, and the wet scrubbers produce an effluent requiring treatment. They are, however, well suited for the removal of ultra-fine materials such as alkali chlorides and, when additives such as limestone or activated carbon are injected upstream of the collector, can remove trace organic compounds such as dioxins from the gas stream.

Sulphur in the waste gas is less of a problem for sinter plants which operate with low sulphur ore and coke breeze. When they are present, over 95 percent of the sulphur oxides can be removed by scrubbing with an aqueous slurry of pulverised lime, magnesium hydroxide or ammonia solution to produce gypsum, magnesium sulphate and ammonium sulphate respectively. An equally effective dry process, incorporating activated carbon on a moving bed, may also be applied to produce a sulphuric acid by-product. When combined with ammonia injection, this latter technology also has the capacity to the reduce the level of NO_x by up to 20 percent.

Approximately 90 percent of the NO_x can be removed from the gas stream by application of selective catalytic reduction. Following de-dusting and desulphurisation, ammonia injected into the gas stream reacts with NO_x on the surface the catalyst to produce nitrogen. Following this, the CO in the exhaust gas may be oxidised on an oxidising catalyst and the excess heat generated by the reaction recovered prior to discharge.

A departure from the traditional methods of gas cleaning at the sinter plant is the proposed combination of Emission Optimised Sintering (EOS), to reduce the overall gas volume requiring treatment, and high pressure wet scrubbing. This system will allow the removal of dust, SO_x, metals, acid vapors and aerosols as well as some organics from the gas stream.

The sinter feed and sinter product both give rise to dust emissions during handling, crushing, screening etc. Most sinter plants operate a de-dusting system with many extraction points around the plant served by a common dry ESP or bag filter.

Cokemaking — As already discussed there are many sources of airborne pollution in and around the coke works. The preparation and handling of coals, including crushing, briquetting, transport etc., generates dust which should be contained, as described in the section above on *Raw Materials Handling*, and any emissions collected and cleaned, most probably in a bag filter. Charging emissions may be controlled by extraction directly from the oven during charging followed by bag filter cleaning and/or ignition. Pushing emissions on the coke side may be reduced by the use of spray hoods or entirely collected by the use of a mobile dust collection hood served by a bag filter or wet gas scrubbing system (Minister Stein system). Emissions on the pusher side may be adequately controlled by the installation of a pusher mounted collection hood and bag filter, although this is less common.

The installation of a plastic chip filtering media within the wet quench tower can reduce emissions from this source. This passive device (i.e. there is no extraction system involved) can be cleaned between quenches using a water spray. The quantity of fume cleaned by this system can be maximised by operating with water curtains across the face of the quench tower coke car openings, thus reducing emissions at ground level and protecting the coke car operator from exposure to hot steam.

The coke wharf can be covered to reduce overall dust emissions from this source and water curtains applied at the charge and discharge points to prevent the dispersal of generated dust.

Where CDQ is installed dust collection and cleaning devices may be installed on the hoisting tower and on the facilities for charging to the cooling vessel.

In order to reduce emissions from the by-product plant the various vents and openings associated with the benzene recovery operation, including transfer and loading operations, can be subject to gas recovery to minimise the quantity of vapours emitted to atmosphere. However, the large number of collection points often makes such a system expensive to install.

Blast Furnace — The raw material feed to the blast furnace, including coal for injection, can give rise to dust emissions during handling, conveying etc. As indicated above, conveyors should be covered and transfer points enclosed to allow rising emissions to be collected and cleaned. Water sprays can be used to dampen the finer fraction.

Case Study — Coke Oven By-Product Recovery Operations

Background

In February 1991 the Administrator of the US Environmental Protection Agency launched the 33/50 Program as part of the agency's broad pollution prevention initiative, asking more than 600 companies (including Bethlehem Steel) to voluntarily reduce their emissions of 17 high-priority chemicals targeted by EPA. The program name '33/50' was derived from EPA's goals to reduce the emissions of 17 chemicals by 33% by 1992 and 50% by 1995, using 1988 as the baseline. Bethlehem's operations collectively generate 10 of the chemicals. For more information on 33/50 see Chapter 8.

Much of Bethlehem's success in the 33/50 Program has come from controlling emissions at its four coke oven by-product recovery operations. During the coking process, called destructive thermal distillation, volatile materials are driven off as coke oven gas and cooled with a liquor spray system as the gases leave the oven. The gases then go through a by-product recovery process to separate and recover the various components, one of which is light oil, which consists primarily of benzene, toluene and xylene (BTX). Prior to their control, BTX emissions were released to the atmosphere through process vessels, vents, sumps, storage tanks, lines etc.

Enabling Technology

In 1990 the installation of a new control technology called 'gas blanketing' was begun by Bethlehem. A gas blanketing system involves the capping or enclosure of process vents, sumps, process vessels, storage tanks, piping systems etc which are open to the atmosphere and 'blanketing' them with a positive pressure gas (such as nitrogen or coke oven gas). This prevents volatile light oil vapours, including BTX, from escaping to the atmosphere. Instead, these chemicals are captured and returned to the process system.

Advantages

As a result of the installation of gas blanketing technology, Bethlehem reduced its annual emissions of benzene, toluene, and xylene to the atmosphere from its coke oven by-product recovery operations by 95% (1988 baseline). Bethlehem also received favourable publicity as one of 20 companies recognised nationwide by EPA and McGraw-Hill's Chemical Engineering *and* Environmental Engineering World *magazines as an 'Environmental Champion' in 1995.*

Economics

During the period 1990 to 1994, Bethlehem Steel spent approximately $75 million to reduce its releases of benzene, toluene and xylene vapours from the coke oven by-product recovery operations at four business unit locations. The recovered light oil vapours are captured, extracted from the coke oven gas system and sold commercially as a product. Although an economic analysis has not been done on the various projects undertaken to reduce BTX emissions, the costs to operate and maintain gas blanketing systems in a dirty and corrosive environment are likely to far exceed the added value derived from the light oil product which is recovered and sold rather than released as pollution.

For furnaces operating a double bell system, emissions during charging can either be collected and treated as part of the blast furnace gas system or a secondary filtering system installed. Where a bell-less top is operated emissions are not sufficiently large to justify collection and cleaning.

The large volumes of dust and fume which are released into the casthouse during tapping will, if not captured, enter the environment as a highly visible cloud. On large modern furnaces the tapping and tap-free periods are almost equal, while smaller furnaces tap for shorter periods at slightly lower rates. Collection of hot fume using hoods is standard in Europe and Japan with extraction points at the taphole, the skimmer, the spout and the runner. Runners may be covered and the fume extracted or, as in the USA, a blanket of inert gas may be used to prevent fume from forming, although such systems used alone are not recommended as an alternative to fume extraction. The cast house itself may also have a general roof evacuation system to capture fume generated from all sources. In most cases bag filter gas cleaning systems are employed, although ESPs are also routinely used.

6.2.2 Steelmaking, Secondary Refining and Casting

BOF Steelmaking — Emissions from the BOF plant include primary emissions (i.e. those generated during the blow and which are collected directly by the primary system) and secondary emissions, which include all other emissions arising from hot metal transfer, charging and tapping operations and fugitive releases from the vessel.

The primary emissions cleaning system includes:

- A movable 'skirt', which can be retracted to allow the vessel to rotate for charging and tapping, but which seals the vessel during blowing to restrict air ingress, thus limiting the post combustion of carbon monoxide to carbon dioxide.
- A heat exchanger to cool the gases to an appropriate temperature for further processing and to recover heat for steam generation.
- A dust abatement system, which may include a wet scrubber or dry ESP (**Figure 6.1**).
- An extraction fan
- A gas holder to store collected gas prior to use on the works or sale.
- A flare stack to combust gas containing insufficient carbon monoxide.
- A gate to switch gas between the holder and the flare stack (only in systems with gas recovery equipment).

Dust concentrations of 30-60 mg/m^3 can be achieved with both wet scrubbers and dry electrostatic precipitators, although the latter generally provides the best performance.

Residual dust in the recovered gas settles in the gas holder, such that atmospheric emissions only occur at the start and finish of the process, when carbon monoxide levels are too low to make recovery worthwhile and off-gas is flared. The main pollutant leaving the works is particulate. Sulphur oxides are not a problem provided that the hot metal de-sulphurisation stage has been

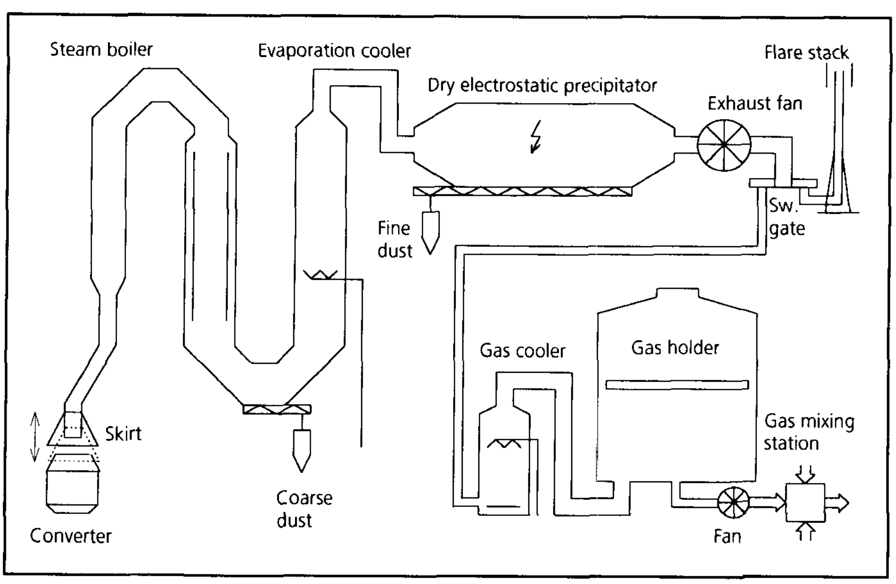


Figure 6.1 **Primary gas cleaning system with dry ESP and gas recovery**

effective and, despite the high temperatures involved, the use of very pure oxygen makes the formation of nitrogen oxides unlikely.

Secondary emissions can be collected in local hoods installed as close as possible to the emission source, in roof mounted hoods or in the roof itself if sealed to reduce fume escape. The presence of large movable pieces of equipment, such as charging cranes, can make the installation of local hoods difficult, thus the trend for new plants is towards roof hoods and sealed roofs.

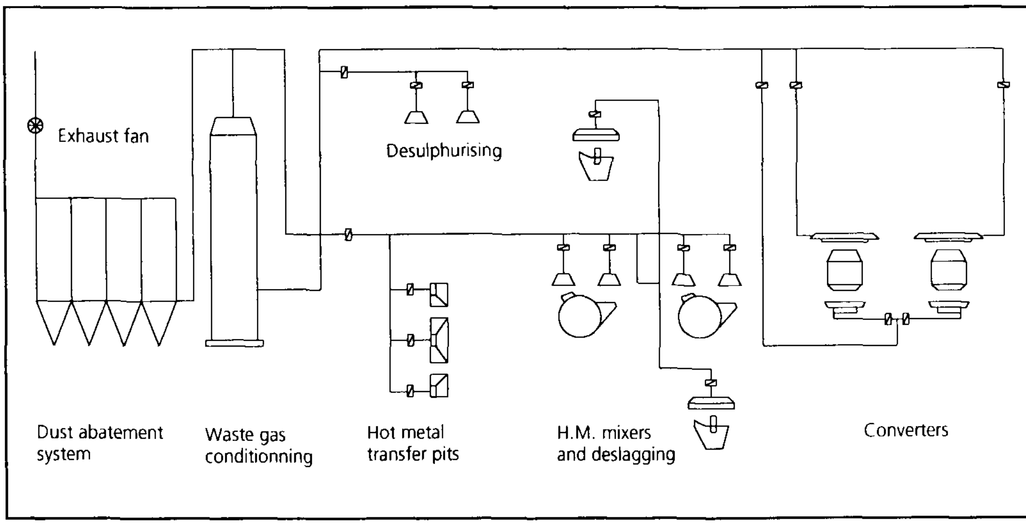


Figure 6.2 **Secondary dust cleaning system**

Figure 6.2 shows a secondary emissions control system with local hoods installed at various locations and connected by complex ductwork. Dampers allow the air flow at each hood to be controlled, as required at each station, with extraction rates from about 100,000 m^3/hour for local hoods to more than 1 million m^3/hour for roof hoods. Bag filters or electrostatic precipitators can be used to clean secondary emissions and both are able to reduce dust loadings to below 30 mg/m^3, although bag filters generally give better performance.

EAF Steelmaking — *As above, emissions from EAF steelmaking can be broken down into primary* and secondary emissions. Primary emissions are extracted directly from the furnace during steelmaking and secondary emissions include all other sources, such as charging, tapping and fugitive releases from the EAF and which are collected in a general roof hood. Bag filters and ESPs are suitable for the capture of EAF dust, whether primary and secondary emissions are treated separately or in a common filtration system and both systems can reduce the level of dust leaving the plant to less than 20 mg/Nm^3, in accordance with the more stringent legislated limits.

Figure 6.3 (page 100) shows a schematic of an EAF gas cleaning system with combined primary and secondary dust abatement. (See **Photo 15**.)

It is also possible to totally enclose the EAF and connect the enclosure to the primary exhaust duct. Such 'doghouse' systems are popular for new installations and, in some situations, these can be retrofitted. The advantages of the 'doghouse' system are that up to 98 percent of total emissions can be captured, extraction volumes are much lower than for building extraction systems and noise emissions are also reduced. Enclosure design is critical however, as it must be compatible with the scrap charging operation, the need to continuously feed materials into the furnace and the operation of the injection lance.

Attention has, in recent years, been given to the potential for the EAF to produce organic pollutants which are not captured by conventional gas cleaning systems. These include hazardous organic

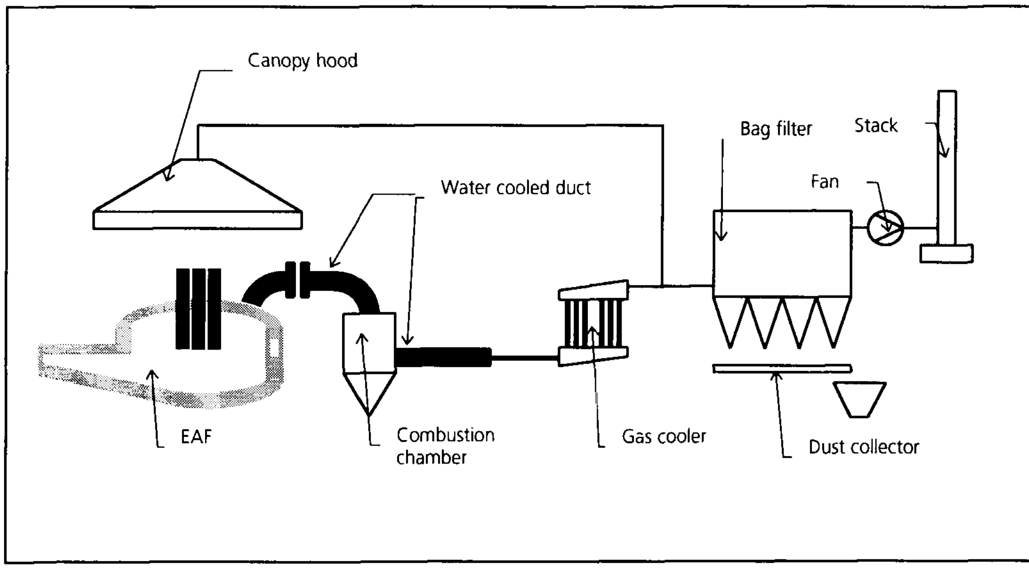


Figure 6.3 **Schematic of a gas cleaning system of a EAF shop with combined primary and secondary dust abatement**

and chlor-organic substances like polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCBs) and dioxins and less hazardous substances which have an annoying pungent odour, including volatile organic compounds (VOCs). To control these emissions it may be necessary to modify the operation of the gas cleaning system to ensure the total combustion of all organic compounds. The reformation of dioxins and furans during the slow cooling of offgas can also be reduced by rapid quenching with water and/or air.

Casting — Continuous casting machines can give rise to low levels of dust emissions that may be collected and cleaned using local hoods served by a bag filter or, possibly, a wet scrubbing system.

6.2.3 Hot Rolling

Prior to hot rolling, cast steel may be scarfed, to remove surface and subsurface defects, a process that gives rise to copious quantities of oxide fume and combustion products. Fume from scarfers is normally extracted through a suction hood and recovered in a bag filter.

6.2.4 Pickling, Cold Rolling, Annealing and Tempering

The pickling process gives rise to acid vapours and aerosols, depending on the temperature and degree of agitation in the pickle bath. Pickle tanks should be covered and the atmosphere above the tank extracted and cleaned in a wet scrubbing system.

Cold rolling gives rise to an oil mist that is generated as the strip passes between the rolls. The cold mill should, therefore, be equipped with a local exhaust ventilation system served by a mist eliminator which may be mechanical (such as plastic media, filtering fibres, meshes) or electrostatic in nature.

6.2.5 Coating

Emissions from the coating line include vapours and aerosols from the various pickling, cleaning and passivating washes and VOCs, particulate and metal fume from the coating operations. Pickling, washing and passivating tanks should be covered and the atmosphere extracted and cleaned in a wet scrubbing system. On large organic coating lines it may be appropriate to install a VOC incinerator, although other systems of control such as catalytic oxidisers, carbon absorption etc.

may also be suitable. Paint lines give rise to particulate that may be filtered in a bed of ceramic media, but hot dip coating lines tend to give rise to low levels of fume which may not require extraction and cleaning.

6.2.6 Others

The above has discussed the proven possibilities for collecting and cleaning air emissions arising from the steelmaking processes. However, one factor that underpins the performance of all the systems mentioned is the mode of operation once installed. All air pollution control equipment will have been designed and installed based on a given set of conditions and requirements and these must be adhered to if the expected performance is to be maintained. Thus, significant changes in operating practices (e.g. the installation of carbon/oxygen lances on the EAF), increased production levels, poor maintenance etc. can all be expected to reduce performance and may require redesign of the system. Therefore, the effectiveness of all pollution control plant must be assessed on an on-going basis, relative to current and future operational and legislative requirements.

6.3 WASTE WATER MANAGEMENT

Waste water treatment involves a combination of physical, chemical and biological processes. Each waste water stream normally undergoes an initial treatment close to its source, perhaps to remove gross solids and oil, before being sent to a secondary treatment system. Some sites also use municipal waste water treatment systems to complement internal secondary systems.

There are several basic treatments, applied at most steelworks, that are capable of removing the great majority (by mass) of waterborne pollutants prior to discharge and others, applied as necessary, to remove trace pollutants. These include:

For the removal of solids:

- *Settling basins*, which are a simple, low maintenance means of removing solid particles from liquid by gravity. After a preliminary stage of chemical coagulation and precipitation using alum or a polymeric flocculant, the velocity of the waste water stream is reduced as it passes into a large volume basin where settling occurs. Sufficient retention time and regular sludge removal are important factors which determine the success of this method.

- *Clarifiers,* which are more effective than settling basins for the removal of suspended solids, require less space and provide for centralised sludge collection. Conventional clarifiers consist of a circular or rectangular tank with either a mechanical sludge collection device or a sloping funnel shaped bottom into which sludge collects. Advanced clarifier designs using slanted tubes or inclined plates may be used for pre-screening coarse materials that could clog the system. Chemical aids can be used to enhance solids removal, although chemical pretreatment and sludge removal systems both require regular maintenance.

- *Filtration* is a highly reliable method of waste water treatment, capable of removing suspended solids and unwanted odours and colour. The advantages of filtration are the low solids concentration which can be achieved, low investment and operating costs, modest land requirements and low levels of chemical discharge. Some pretreatment may be necessary if the solids level is greater than 100 mg/l. Several types of filter and filter media are used, such as the pressure type or gravity types, operating with single, dual or mixed filter media. The most important variable in filter design is the width and depth of the media, although particle density, size distribution and chemical composition are also important in terms of media selection. The media selected depends on the filtration rate and may consist of sand, diatomaceous earth, walnut shells or, for concentrations below 5 mg/l solids, anthracite. All filters require regular back washing to prevent accumulation of solids in the filter bed.

For the removal of oil:

- *Skimming, which* can be used to remove floating oil and grease from the water surface. Skimming efficiency depends on the density of the floated material and the retention time for phase separation, which varies from 1 to 15 minutes. Dispersed or emulsified oil cannot be removed by skimming. Skimming is often used as a pretreatment to improve the performance of subsequent downstream treatments.

- *Filtration* is an effective means of removing oil from water. Problems are only encountered when high oil concentrations contact the filter bed directly, although this can be avoided if appropriate pre-treatments are applied.

- *Flotation*, in which air bubbles attach to the oil particles which then rise to the surface and can be skimmed off. The principal advantage of flotation over sedimentation is that very small particles can be removed more completely and in a shorter time. Various types of flotation are possible. For example, air may be injected while the liquid is under pressure, the bubbles being released when the pressure is reduced (dissolved air flotation), aeration may take place at atmospheric pressure (air flotation) or the water may be saturated with air at atmospheric pressure and a vacuum applied to release the bubbles (vacuum flotation). In all cases, chemicals for flocculation and coagulation are usually added before flotation.

- *Coalescing filters*, which agglomerate small oil particles thus enhancing the rate at which oil rises to the surface of waste water. The filter media is made up of plastic chips which have the correct surface properties to attract oil particles from the waste water stream allowing agglomeration and release.

For the removal of metals and inorganics:

- *Chemical precipitation* is a process by which metals in solution can be removed using alkaline compounds, such as lime or sodium hydroxide, followed by sedimentation, clarification or filtration. Lime also precipitates phosphates as insoluble calcium phosphate and fluorides as calcium fluoride. Sodium sulphide allows for the removal of metals by the precipitation of insoluble metal sulphides and calcium carbonate and carbon dioxide can remove metals as carbonates. Lime is widely used in the steel industry, as this technique operates under ambient conditions, has relatively cheap and available raw materials and is easily automated. Although the process produces clean water, it also generates a metal bearing sludge which should be recycled, where opportunities exist, or disposed of in a safe manner, such as in a well designed landfill.

For the removal of organics:

- *Biological treatment* is used to coagulate and remove soluble organics and may be based on the activated sludge system or, less frequently, other systems such as rotating biological discs, which are under test by the steel industry. The activated sludge process works by stabilising waste water using microorganisms in an aerobic environment, achieved by diffused or mechanical aeration of the waste water in an aeration tank. There is a constant bleed from the aeration tank to the settling tank which allows for the separation of the biological mass from the waste water, after which the waste water is sufficiently clean for discharge. Some systems may also incorporate an anaerobic stage to enhance the removal of nitrogen from the system. Following separation, the majority of the biological mass is returned to the aeration tank, but a small portion is removed and disposed of or recycled to the coking plant. The system is generally insensitive to normal fluctuations in hydraulic and pollutant loading, although certain pollutants, for example ammonia at high concentrations and heavy metals, can be extremely toxic to the microorganisms in the system. Temperature will also influence the metabolic activity of the microbiological population, gas transfer rates and the settling characteristics of the biological solids. The method incurs relatively low capital and operating costs and is widely used in the industry for coke plant waste water treatment.

- *Carbon adsorption* with activated carbon is an extremely efficient method for removing organics from waste water. In general, less soluble and relatively small organic molecules are most easily adsorbed by carbon, including most aromatic compounds, chlorinated non-aromatics, phenol, pesticides and high molecular weight hydrocarbons. The adsorption process is reversible, allowing the used carbon to be regenerated by the application of steam or a solvent. Activated carbon is produced by heating materials such as almond, coconut, walnut husks and coal. The process relies on the large internal surface area of activated carbon for efficient adsorption (500 to 1,500 m^2/g). The major benefits of carbon treatment are its applicability to a wide variety of organics and its high removal efficiency. The system is compact and insensitive to wide variations in concentration and flow rate, but due to the relatively high capital and operating costs it's use is restricted to the final treatment of coke plant effluents, where particularly stringent legislation applies.

For the removal of trace pollutants:

- Technologies such as ion exchange and membrane separation have been developed and applied when fresh water is in particular short supply. The ion exchange process removes contaminant cations and anions using synthetic resins or by adsorption on to activated alumina. Since most ion exchange reactions are reversible, the medium can be reused many times before it must ultimately be replaced due to irreversible fouling. The main application area for the ion exchange process in the steel works is in the preparation of indirect cooling water for use in boilers. There are many alternative membrane processes such as reverse osmosis, electro dialysis, ultra filtration and nano filtration. Membrane processes are usually used for desalination and for removal of specific ions that are difficult to remove by other means. Many attempts have also been made to apply membrane processes to the reuse of waste water. (See **Photo 23**.)

6.3.1 Ironmaking

Raw Materials Handling / Preparation — Raw materials handling yards should have facilities for the collection and treatment of water runoff. The runoff will contain solids primarily, although smaller quantities of oil from vehicles will also be present. The collection and treatment system may incorporate interceptor pits to allow solids to settle and oil to float. The water arising from this source could be reused for the spraying of stockpiles, roadways and raw material transfer operations.

Sintering / Pelletising — Only a small proportion of sinter production globally gives rise to an effluent as dry gas cleaning systems are used on most plant. Where wet systems are used, for example for the removal of dust, SO_2, acid vapours as well as some organic materials, the effluent must be treated to neutralise the acid components, allowing precipitation of dissolved metals, and allowed to settle to remove solids and organic matter. A portion of the effluent may be recirculated, but the degree of recirculation must be controlled to maintain separating efficiency.

Cokemaking — Water used for pushing emission control should be collected, allowed to settle and recirculated to the gas cleaning system.

Process waters from the gas cleaning operations contain ammonia, cyanide, phenols and thiocyanates. These can be removed by microbiological oxidation in a single or two stage process, followed by absorption onto activated carbon (and sometimes ozonisation or chlorination) to ensure that all organics are removed. Coke plants should be designed so that all leaks, spills and rainwater are collected and returned for treatment. The biological treatment system should be designed with some buffering capacity to compensate for fluctuations in waste water flow (due to variable coal moisture) and waste water concentrations, which may arise from insufficient control of by-product operations, such as ammonia stripping.

Blast Furnace — The blast furnace cooling water system is essentially closed and gives rise to no effluent. However, when water is removed from the system, to maintain specific quality requirements, this may be downgraded for use in the gas cleaning system. Most wet gas cleaning systems are also closed although bleeds from these systems must be treated to remove suspended solids, dissolved metals, such as zinc, lead and cadmium, and cyanide, which is formed in the blast furnace.

Slag processing operations are also significant consumers of water, but not all processes allow for efficient collection and treatment. Water used to quench slag in an open pit may simply infiltrate to the ground if effective collection measures are not present. The pelletising and granulating processes provide much greater scope for the collection of used quench water and, where steam condensation is carried out, condensate. Effluent from these processes must be treated to adjust pH, remove suspended solids as well as dissolved sulphurous substances such as hydrogen sulphide.

6.3.2 Steelmaking, Secondary Refining and Casting

BOF Steelmaking — Wet or dry systems may be applied to clean gases collected by the primary offgas system. Where wet systems are employed the water is generally recirculated although there will be a bleed to maintain water quality requirements. The bleed will require treatment to adjust pH, which may be high due to the lime content, and to remove suspended solids and dissolved metals such as zinc.

EAF Steelmaking — The electric arc furnace plant effectively operates with closed circuit cooling and, therefore, does not give rise to an significant effluents.

Casting — The continuous casting plant requires significant amounts of water for direct cooling of the cast material, but again, this is generally recirculated. The system bleed, however, must be allowed to settle to remove suspended solids, primarily scale from the surface of the cast steel, and oil, used as a roll lubricant.

6.3.3 Hot Rolling

Rolling mill water is treated in two circuits depending upon whether it has been used for direct or indirect cooling. Indirect cooling water is used for the electric motors, the reheating furnace, control rooms and power systems, instruments and process control. Direct cooling water is used to break scale, flush scale away, cool the rolls, quench cropped ends, assist scarfing, cool hot runout tables and downcoilers and for saw cooling. The quantities of water required for hot rolling dictate that closed circuits are used wherever possible, although all the problems of contaminant build up, clogging as well as the problem of excessive temperature build up and the need for cooling towers need to be addressed.

In order to maintain the water quality required for the hot rolling operation suspended solids and bulk oil are removed in settling tanks or clarifiers, often with coagulants added to accelerate the separation process. Trace oil, grease and smaller particulate can then be filtered under pressure or by gravity, paying careful attention to the selection of the correct filter media. Oil skimming is widely practised, although the application of inclined plate separator modules, developed for the petrochemicals industry, can be more effective in some situations. The clean water is then recirculated to the hot mill for reuse and a small quantity is extracted as a system bleed. Flotation may be applied to the bleed to ensure adequate cleaning prior to discharge. The efficiency of all the technologies described above can be optimised if high and low oil streams are kept separate through the use of segregated sumps.

6.3.4 Pickling, Cold Rolling, Annealing and Tempering

Acid mists generated during pickling are generally removed and washed in a wet scrubbing system. The water used is generally recirculated, but a bleed is necessary to ensure separating efficiency. Steel is then rinsed, following pickling, to remove traces of acid, a process that also gives rise to an acidic effluent. Although these systems are separate, the effluents arising may be combined with other acidic discharges, overflows or spills for treatment. Used pickle liquors can often be regenerated, dependent on the type of acid used, reducing the quantity of acidic effluent requiring treatment. Treatment of these effluents normally involves neutralisation and precipitation of dissolved metals with lime, followed by settlement and discharge.

After pickling and prior to rolling the strip is coated with an oil emulsion. The emulsion circulates in a closed circuit and suspended solids are removed by a combination of filtration, skimming, settling, centrifuging or magnetic separation operations. A bleed from this system is maintained, to ensure the surface quality of rolled steel, and this must be treated by emulsion breaking, with alumina and acid, followed by skimming. The arising waste water may then undergo further treatments in an inclined plate module or by flotation, to remove trace oil, followed by a final lime and flocculation treatment.

Fumes from degreasing lines operating with alkaline solutions are washed with water. The water can be reused after treatments such as flotation, for the elimination of solid particles, and neutralisation with hydrochloric acid.

6.3.5 Coating

Waste waters from coating operations may contain tin oxide, iron oxide, coating residues as well as acid, alkaline and organic components, including oil, from the various pretreatment and coating operations. Surface preparation solutions may contain chromium or other heavy metals which should not be released without being rendered nontoxic or insoluble. The different effluents are best dealt with separately, but treatment typically involves the recovery of tin oxide and/or the removal of fluoride from waste electrolyte solutions and the neutralisation of acidic wastes with lime to precipitate out dissolved metals, followed by settlement and discharge. Alkaline rinse waters and hot rinse effluent is normally clean enough to act as a make up to the hot strip mill water circuit.

Rinse waters from the chromate treatment scrubber contain hexavalent chromium which should be converted to the trivalent state before release. The trivalent form is both significantly less toxic than the hexavalent form and can be removed from solution by neutralisation and precipitation. The effluent can be treated with acid along with iron sulphate, sulphur dioxide or recycled pickle liquor to reduce the Cr (VI) to Cr (III) and then combined with the acid rinse waters for treatment at the neutralisation plant.

6.3.6 Others

The steelmaking operation gives rise to many effluents that must be treated for a variety of parameters prior to discharge. Therefore, in order to ensure that each is effectively treated an optimised combination of treatments should be designed by systematically studying the existing and expected effluents and considering how each will react to the available cleaning processes. Consideration should be given to the possibilities of combining effluents, where benefits can be gained, and keeping effluents separate, where this can improve the overall treatment potential. Ideally, the site will be designed such that the major waste streams are kept separate, for example rainwater runoff, industrial water and human waste water, ensuring that operation of treatment facilities can be optimised with regard to volume flow, chemicals usage etc. The possibilities for reusing treated water should also be investigated thoroughly, in order to minimise the overall works discharge and to reduce the works requirement for clean water.

6.4 BY-PRODUCT MANAGEMENT

While the large quantities of by-products and wastes associated with the production of iron and steel have been progressively declining over the past 30 years, responsible management of both types of material remains an important and challenging task. If internally generated scrap is

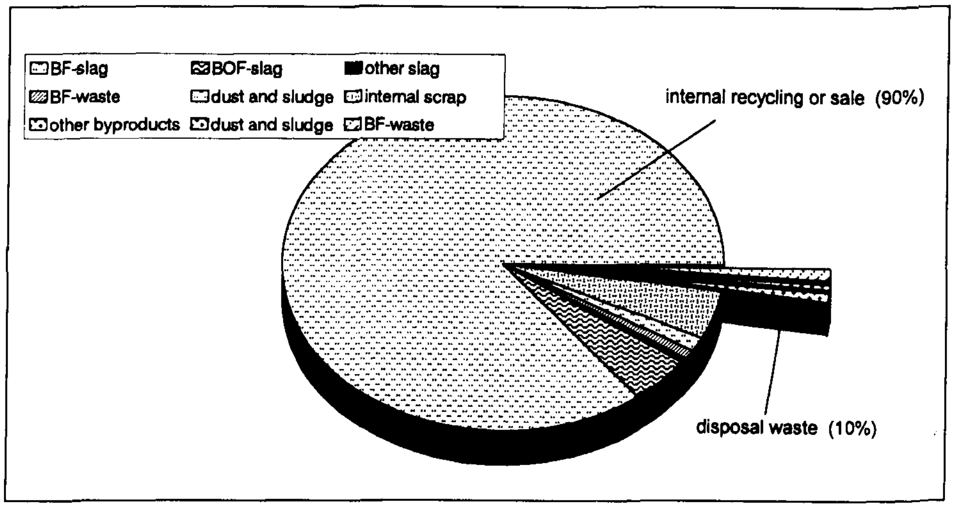
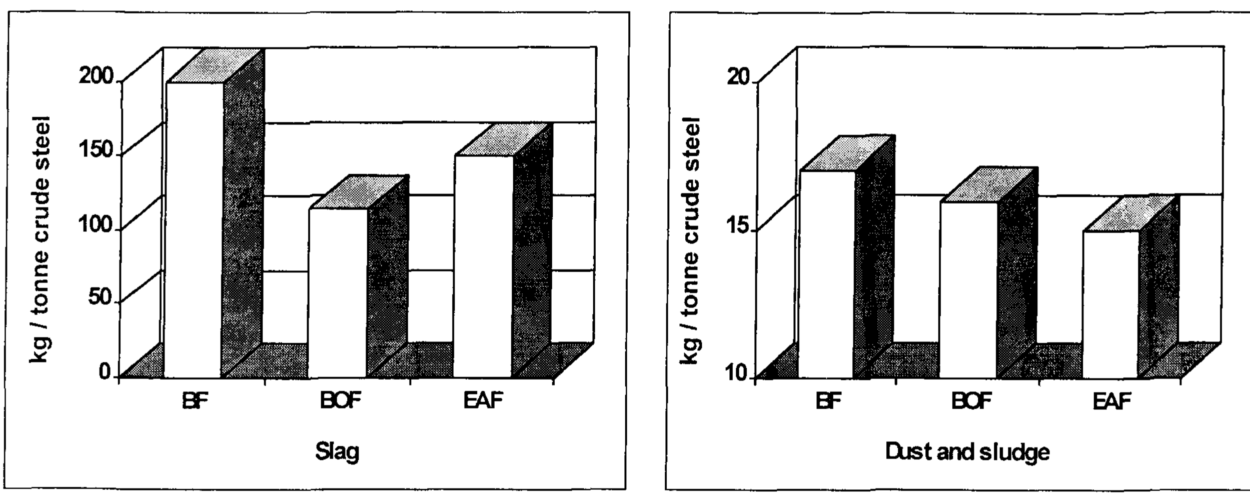


Figure 6.4 **Composition of by-products and waste in an integrated steel plant**



Figures 6.5 and 6.6 **Slag *(left)* and dust and sludge *(right)* generated from iron- and steelmaking**

counted as a by-product, the industry currently recycles about 90 percent of all its by-products and wastes. Blast furnace slag accounts for 54 percent by volume of all integrated site by-products. The remainder made up of steelmaking slag (21 percent), special slags from pre-treatments (6 percent) and construction and refractory wastes such as used furnace lining bricks (7 percent). Particulate matter and sludge from operations such as gas scrubbing have increased over the last 10 years and account for 7 percent of the total. Other materials include coarse scale (the oxidised skin on hot steel surfaces) and millscale which, together, account for about 5 percent of total by-products and wastes.

Although the industry successfully recycles or reuses a large proportion of the wastes and by-products arising from the steelmaking process there are still major efforts to valorise the more difficult materials. This effort, it is felt, will bring both environmental and financial benefits. The main types of by-product and waste from the integrated plant are summarised in **Figure 6.4** and typical quantities of slags, dusts and sludges from gas cleaning are shown in **Figure 6.5** and **6.6**. By-product management is discussed below with regard to the individual process stages, although it should be recognised that this report cannot hope to cover all of the relevant issues.

6.4.1 Ironmaking

Raw Materials Handling / Preparation — All dust, spillages and solid material collected from water runoff may be recycled directly back to the process via the blending yard.

Sintering / Pelletising — The sinter plant is routinely used to recycle waste materials that arise from the sintering operation itself, as well as the many other processes operated on an integrated site. However, this recycling must be carried out considering the requirements of the process and the process route, including the impact of sinter chemistry on the operation of the blast furnace and steelmaking plant, and the operation of the sinter plant pollution control equipment. For example, some of the chemical parameters that may affect the iron- and steelmaking operation include alkali, lead and zinc loadings to the blast furnace and hot metal sulphur and phosphorous levels. Parameters that may affect ESP performance include the level of alkali metal chlorides, leading to elevated emissions, and the presence organic material in collected dust that can lead to glow fires and subsequent buckling of collector plates. In addition, the water content of the sinter feed can affect fuel usage, progression of the flame front through the bed and sinter formation, therefore, the water content of returned materials must also be closely monitored to ensure consistent operation.

The treatment and reuse of dust and sludges generated on the sinter plant will be dependent on the type of gas cleaning system installed. Most plants operate a dry gas cleaning system in which particulate material in the main waste gas is collected in a dry ESP. ESPs are generally divided into three or four zones which are controlled individually to optimise gas cleaning. However, the chemical characteristics of the dusts collected can vary quite significantly both between and within zones. Thus, sinter and ferrous materials are preferentially deposited in the fields closer to the inlet, in contrast to the alkali metal chlorides which tend to deposit in fields closer to the outlet. As alkali metal chlorides are difficult to collect in the ESP, as well as being detrimental to blast furnace performance, recycling of material from the later fields may result in increased emissions, therefore, it may be prudent to recycle only those dusts collected in the earlier fields. Treatment of these dusts to remove the alkali metal chlorides is possible, but this is only feasible for a plant incorporating a complementary wet gas system and associated water treatment plant (see below).

Dust generated by the handling of both sinter feed and sinter product, and collected by the dedusting system or deposited on the ground at conveyor transfer points, can be recycled entirely to the process via the blending yard.

A wet gas cleaning system incorporating a dry ESP, gas quench and wet scrubbers will give rise to various effluent streams requiring treatment. Process waters may be treated by staged neutralisation to bring about the preferential precipitation of iron compounds, which can be returned directly to the sinter bed in the form of a sludge for moisture control. Further treatment of the waste water then brings about the precipitation of other dissolved metals which can be settled, collected and disposed of. Organic matter, collected as a scum on the surface of sedimentation basins, may be skimmed and collected for injection into the blast furnace and treated water may be used to remove alkali metal chloride contaminants in dust collected in the dry ESP, allowing recycling to the sinter bed.

Cokemaking — In addition to coke oven gas, which is a valuable fuel source for the steelworks, the coke works produces a variety of other by-products in the approximate quantities shown below. All by-products are either recycled, for example coal dust, breeze, biological sludge etc., or sold and very little solid waste arises.

Blast Furnace — Ironmaking by-products have considerably reduced in volume over the last 40 years, from 700 kg/t in the 1950s, to about 255 kg/t today, due to the use of higher grade ores and improved burden preparation. Further substantial reductions are unlikely, however, given the chemical composition of the charge materials and the effect reductions would have on the blast furnace process and the quality of the by-products generated. The main by-products and wastes from the process include slag, gas cleaning sludge and cast house fume.

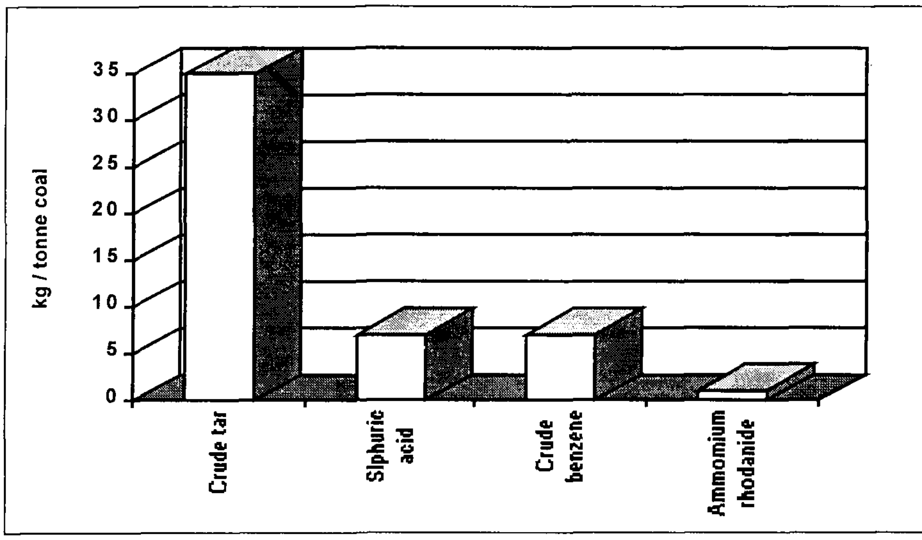


Figure 6.7 **Coke plant by-products**

Blast furnace slag is virtually 100 percent recycled. Currently, most slag is treated by the open pit practice and is used in lump form as a high grade aggregate for road construction. However, other slag processing options, such as water granulation and pelletising, are being adopted to provide a much sought after and high value material for cement manufacture. **Figure 6.8** shows the proportion of slag used as granulate, which is currently growing to displace that used in lump form for road and track construction.

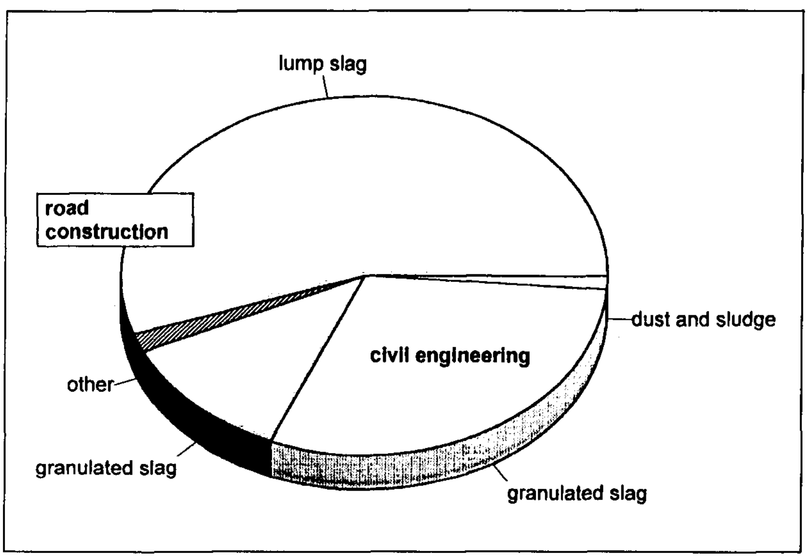


Figure 6.8 **Trends in blast furnace slag utilisation**

Blast furnace sludges from the gas washing system can contain elevated levels of tramp materials, such as zinc and lead, that preclude recycling to the process route because of the potential impact on blast furnace operations. However, the sludge may be processed in a hydro-cyclone to produce a fine fraction (<10 mm), rich in the undesirable metals, and a coarse fraction, which can be recycled to the sinter plant. The lead/zinc fraction requires further enrichment in a fluidised bed before it can be sold and is mostly disposed to landfill.

Cast house fume can be recycled to the sinter plant via the blending yard, although handling may cause a problem.

6.4.2 Steelmaking, Secondary Refining and Casting

BOF Steelmaking — Steelmaking by-products and wastes include pretreatment, steelmaking and secondary steelmaking slags, primary gas cleaning grit and slurry, secondary gas cleaning dust and refractories. The slag is by far the biggest component of the wastes produced at the BOF plant, but reuse can often be hampered by the prevailing chemical and physical characteristics, as discussed below.

Depending on the treatment process adopted, hot metal desulphurisation pretreatment slags may be used for cement manufacture, as a fertiliser or land reclamation. For example desulphurisation based on soda ash can give rise to a slag containing high levels of Na_2O, which requires dilution with low alkali slags for use in cement manufacture, whereas a process based on magnesium injection does not. However, the high sulphur content of all the slags may preclude their use in some applications, requiring disposal.

The use of steelmaking slags in road building applications has declined, owing to problems associated with expansion and pavement cracking, whereas applications in building construction have grown (**Figure 6.9**). In addition, less of the slag is now used as a fertiliser, due to a decline in the use of high phosphorous ores, although slag enriched with other phosphate sources is popular. At the same time, internal recycling has declined as a consequence of higher metallurgical specifications. Thus, there are continued efforts by the industry to both develop existing markets and to find new applications, to limit the quantity of this material requiring landfill.

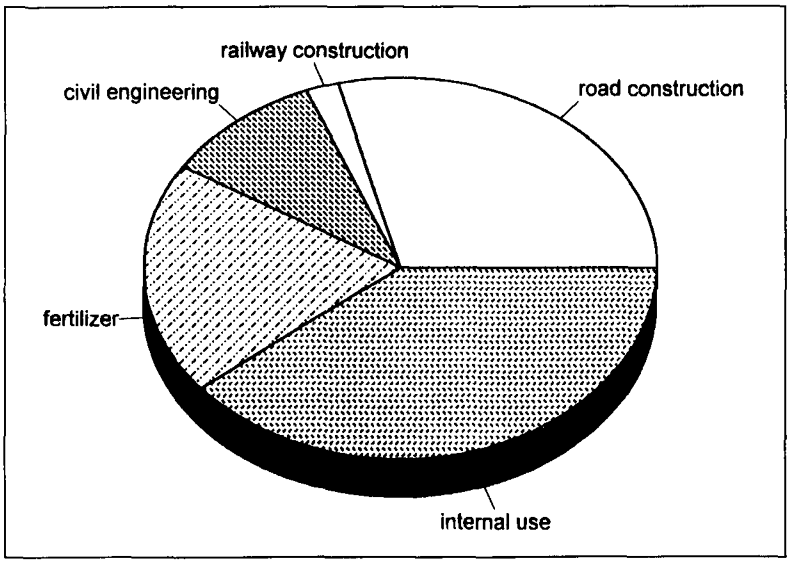


Figure 6.9 Steelmaking slag utilisation

In order to maximise the potential for reuse of steelmaking slags it is necessary to optimise the production process so as to limit the level of free lime. The sources of free lime may include unreacted lump lime added to the vessel as part of normal steelmaking activities, late additions of lime and the mixing of ladle slags with the steelmaking slag prior to processing. Thus, improved practices that limit the quantity of unreacted lime and reduce the need for late additions, as well as segregation of the different slag streams, stabilisation by sand injection or accelarated weathering should allow a greater proportion of the slag to be reused. Steelmaking slag may also be recycled to the sinter plant, although this is limited by phosphorous levels.

Steelmaking slag is also routinely processed to remove metal, which can be recycled as a scrap or ore substitute.

The use of secondary steelmaking slags is less predominant owing to the smaller quantities produced and inconsistent volume, chemistry and mechanical characteristics.

The potential to recycle the primary gas cleaning grit and sludge to the sinter plant depends primarily on the found zinc concentrations, although moisture content is also important. Generally, grit contains lower quantities of zinc and has the greatest potential for recycling, although the zinc content of both materials is dependent on the quality and quantity of scrap used in the BOF. Therefore, those works that use clean inplant scrap, as opposed to galvanised scrap from external or internal sources, have the greatest potential for recycling. Alternative methods include briquetting of the sludge for direct recycling in the BOF, high temperature treatment of the sludge, to remove the zinc component, prior to recycling in the sinter plant or sale for use in cement and brick manufacture.

Secondary dust generally contains lower levels of zinc and can normally be recycled to the sinter plant via the blending yard.

Case Study — Hydrogen Treatment of Blast Furnace Slurry at British Steel

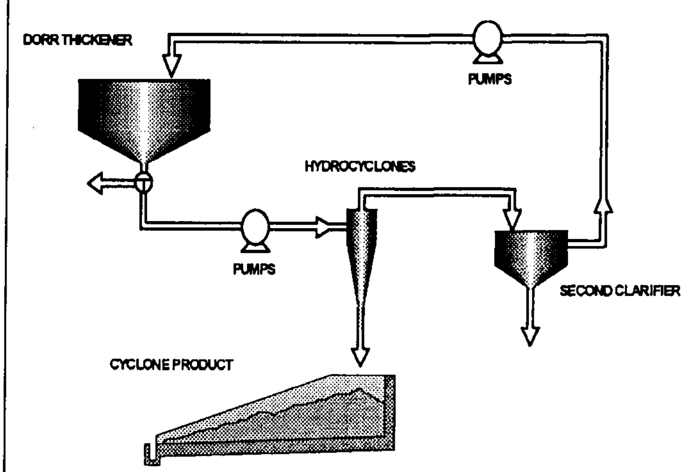
Background

The high levels of iron and carbon present in blast furnace slurry would make it an attractive material to recycle if it were not for the levels of tramp elements which it also contains. It is because of the levels of these 'tramp' elements that until fairly recently British Steel has always transferred this material to internal landfill sites.

Being aware that several other steelmakers were using hydrocyclones to affect a degree of dezincification of the slurry, British Steel carried out investigations to determine the applicability of the technique to slurry arising at its integrated steelworks. Laboratory testwork was quickly followed by a confirmatory pilot scale trial at Scunthorpe Works, the results of which led to the construction, commissioning and operation of full scale hydrocyclone plants at Llanwern and Teesside Works designed to treat all of the arising by-product.

Enabling Technology

The system developed by British Steel (shown schematically below) employs a single stage treatment (unlike several other systems currently available). The use of costly slurry drying equipment has also been avoided resulting in overall lower capital, operating and energy costs.



Schematic of a Hydrocyclone Plant

Advantages

Results indicated that the ZnO in the slurry could be reduced from 2.7% to 0.4%. The fraction of material recovered for recycling was found to range between 70% - 80% of the solids arising. The results also demonstrated that approximately 88% of the ZnO could be removed in only 28% of the solid material.

Benefits to be gained from the introduction of hydrocyclones include, the intrinsic value of the recovered material, a considerable reduction in landfill quantities with associated reductions in costs and taxes, and an overall benefit to the environment.

Economics

Capital cost estimates of such plants can differ depending on the availability of existing 'redundant' buildings which may be utilised, the necessity for thickening the overflow in a clarifier and any other ancillary work which may be required. The capital cost of a plant to treat approximately 20000 tonnes of slurry per annum is in the order of £250K.

The value in use of the recovered material will vary (depending on local conditions), but based on an analysis of around 34% total iron, 34% carbon and also taking into account the offset of landfill tax the net value of the material can be up to £20 per tonne.

Assuming 70% of the material is recovered and recycled the capital payback time can be calculated to be less than 12 months.

Scrap generated inside the works, for example as material trimmed from intermediate products during rolling, as metal cut from sheets which have been shaped to customers' requirements before despatch and from used ingot moulds and ingot butts, is easily recycled to the steelmaking vessel and forms an integral part of the steelmaking process.

Waste refractories, generated from vessel relines, may be recycled and used as gunning materials depending on refractory type.

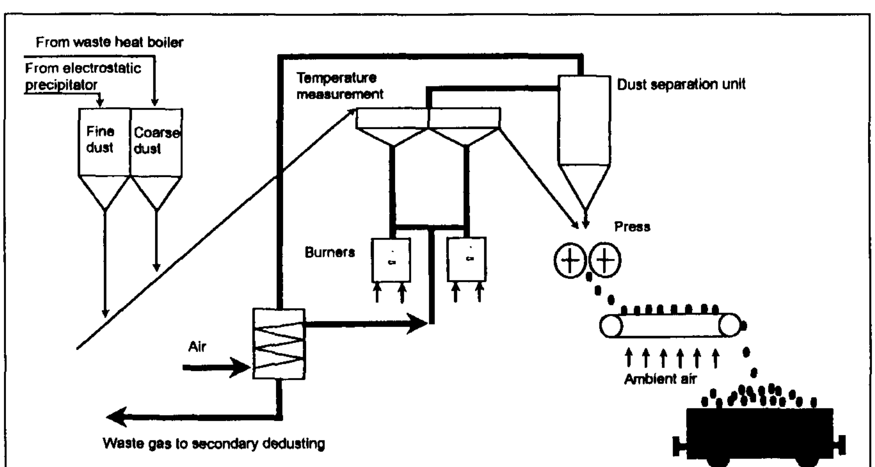
EAF Steelmaking — By-products and wastes from EAF steelmaking include EAF and secondary steelmaking slags and dust. Depending on the specific properties, EAF slag may be suitable for similar applications to BOF steelmaking slag such as in road surfaces, as a rail fill or in specific marine and civil engineering applications.

EAF dust is normally a combined material from the primary and secondary EAF dust extraction systems, with smaller quantities of dust generated by secondary steelmaking facilities. The dust can contain high levels of zinc and lead, along with other metals, such as cadmium, which render it hazardous (**Table 6.1**, page 98). Historically, the dust was disposed to landfill, although more recently there have been greater efforts to recycle or reuse this material.

In order to increase the value of the material to zinc manufacturers it is possible to enhance the zinc concentration of the dust by intentionally adding greater quantities of zinc coated scrap to the EAF. Additionally, the dust can be pelletised or briquetted allowing direct recycle in the EAF, again with the objective of enhancing the overall zinc concentration. Other options for treating the dust include pyrometallurgical and hydrometallurgical processes for recovering the zinc as a concentrated oxide or in metallic form, leaving an inert iron oxide/gangue waste that can be disposed of safely, reduced to produce a low grade DRI pellet or smelted to a liquid product. Although several

Case Study — Hot Briquetting BOF Filter Dust at Thyssen Stahl (See **Photo 12**.)

Highly metallised dry dust from the oxygen steelworks is pyrophoric and by partial oxidation can be heated and formed into briquettes for recycling to the steel plant as a scrap or ore substitute. The central component of Thyssen Stahl's 70,000 t/annum hot briquetting facility is the reaction drum (see figure below). The fine dust is fluidised and heated to a temperature of 750°C, most of the heat being self generated by the oxidation of metallic iron in the dust. The briquetted dust is returned to the steelmaking process or used to make special pig iron, while the briquetted coarse dust is used as a substitute for cooling scrap.



Facility for briquetting dust from basic oxygen steel plants

Element	Low alloy steel (%)	Stainless steel (%)	Element	Low alloy steel (%)	Stainless steel (%)
Fe_2O_3	25-40	41.0	Pb	2-6	1.9
SiO_2	2.5-4	10.4	Cd	0.1	0.03
CaO	6-10	0.7	Cu	0.2	0.3
Al_2O_3	0.5-1.5	4.4	Ni	0.1	3.75
MgO	0.8-1.2	4.8	Na	1.5	n.a.
P_2O_5	0.3-0.8	0.09	K	1.2	n.a.
MnO	2-4	5.8	Cl	1.5-2.5	n.a.
Cr_2O_3	0.4-0.6	20.0	S	0.5-1	n.a.
Zn	15-30	1.9	C	1-1.5	n.a.

Table 6.1 **EAF dust composition**

processes of this sort have been proposed, and are in some cases operational, there are drawbacks that can affect the overall feasibility of treatment. These drawbacks relate to the economics of the processes, the value of the products and the impact on energy use of the EAF process associated with the recycling of dusts and low grade DRI.

Casting — Caster scale may be recycled to the sinter plant depending on the oil content, which is normally limited to less than 0.5 percent. Caster scale, as with millscale below, provides both iron units and heat to the sintering process, but the increasing risk of glow fires must be considered.

6.4.3 Hot Rolling

Millscale sludge can be used directly in the sinter plant, if oil levels are sufficiently low, can be treated to reduce the oil content prior to use, sold for external applications, such as cement manufacture, or processed by an external company. Another technique that may allow the use of high oil content scale in the sinter plant is a two layer sintering process that uses the high temperature flame front within the sinter bed to combust volatilised oils.

Waste oils from the rolling mills can be sold to be recycled as a waste oil fuel, injected into the blast furnace, used to control coal bulk density at the coke works or used as a dust suppressant on coal stockpiles.

6.4.4 Pickling, Cold Rolling, Annealing and Tempering

Pickling line by-products include ferrous sulphate and ferrite, produced when sulphuric and hydrochloric acid are regenerated respectively. Heptahydrate ferrous sulphate crystallises out of the pickle liquor, strengthening the acid which is further strengthened with new acid before reuse, and is sold for cement manufacture, as a fertiliser, for water purification or as a pigment base. Modern 'cascade flushing' systems reduce the amount of ferrous sulphate contaminated rinsing water which leaves the process, although that which remains must be neutralised. Ferrite is high grade raw material used for magnet manufacture and in audio and video tape applications.

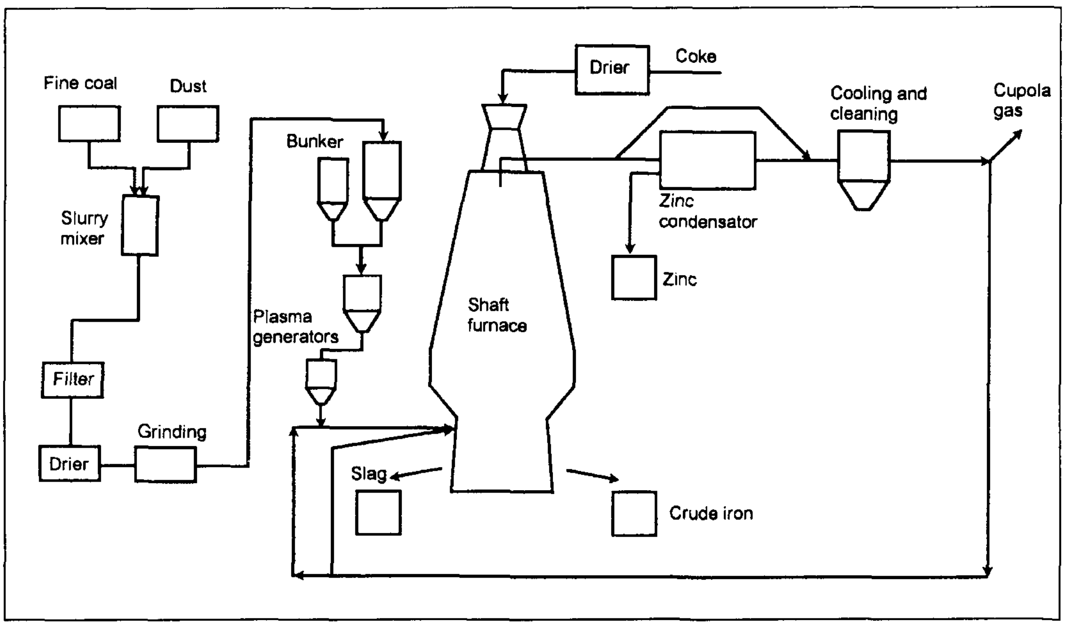
Other wastes include alkaline wash sludges, essentially iron oxide, which can be used at the neutralisation plant, waste oil from the cold rolling process, which may be treated as for oil generated in the hot rolling process and electrolytic pickle sludge, which can be returned to the steelmaking process, sold for cement, pigment or ferrite manufacture or disposed to landfill.

The iron hydroxide sludge, containing gypsum when sulphuric acid is the pickling medium, formed at the neutralisation plant cannot normally be reused. This material is landfilled although it may need to mixed with other wastes to stabilise the tip site.

Case Study — Processing Stainless Steelmaking Dusts in Sweden

Primary and secondary dusts from stainless steelmaking are reprocessed in Sweden using plasma technology (see figure below). A metal alloy is produced containing iron, chromium, nickel and molybdenum, which can be reused by the steelworks. The process can also be used to treat dusts rich in lead and zinc. Energy can be recovered from the flue gas at the rate of 300 kWh/t dust and is suitable for heating local habitations or for other purposes.

The metals are reduced from their oxides using a mixture of coal, coal fines, coke breeze or charcoal. Typically, the processing of one tonne of dust requires 150 kg coal fines, 50 kg coke and 1,500 kWh of electricity. The charge materials are mixed and transferred to the shaft furnace using compressed air. The furnace is charged with coke, forming a reduction chamber which remains permeable to gases and fluids. The oxides are immediately reduced, liberating metals in the liquid and gaseous states. The vaporised metals are carried with the waste gas to the condenser where they are precipitated out, while the molten metals collect in the base of the shaft furnace from where they can be tapped off. The smelting energy is produced in a plasma generator developed by SKF Steel. Operating at a plasma temperature of 3,000°C, this supplies the heat for smelting and volatilisation of the charge materials.



Stainless steel dust treatment in a plasma dust facility

6.4.5 Coating

Wastes from coating operations include waste water treatment sludges and coating residues, such as zinc dross, tin oxide, waste paint and solvent. Water treatment sludges cannot generally be reused and these are normally disposed to landfill. Coating residues may be sold to the supplier for regeneration or, in the case of paints and solvent, incinerated.

6.4.6 Others

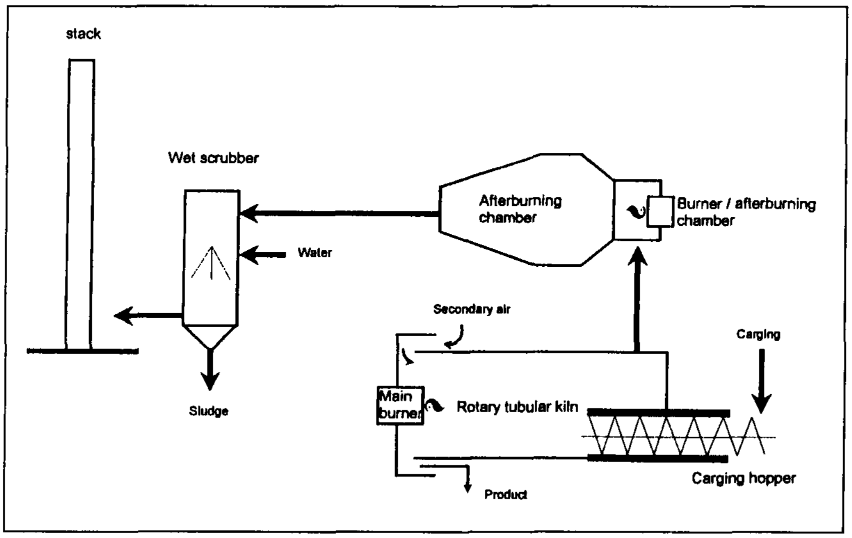
Other by-products include pig iron skulls, steel and slag skulls, mouth and tail skulls, slag iron from pig iron ladles, pouring losses, off-cuts and trimmings which, following processing for some materials, can all be recycled to the BOF.

Refractory materials can normally be returned to the manufacturer for reuse, however, each grade must be collected separately for this purpose.

Case Study — Thermal Treatment of Millscale Sludge

At the steelworks in question millscale sludge had traditionally been recycled to the sinter plant. When electrostatic precipitators were introduced however, the oil in some sludges caused blockage of the filters and in some cases fire.

In the first stage of tackling the problem, the quantity of millscale produced was reduced, and a 70% reduction in oil content was achieved by intensive servicing and maintenance work on the relevant rolling mill facilities. Further reduction in oil content was achieved by thermal de-oiling in a rotary kiln (see figure below). The sludge is transferred by screw conveyor into the rotary kiln where it is carried by conveyor vanes past the burner flame to the discharge side where it cools in air. The counter current flow of hot gas first dries the sludge before the combustible component is ignited in the flame. The process gases are treated in an after burning chamber and cleaned by cyclone dedusting; the cyclone dust subsequently being combined with the material discharged from the kiln. The technique enables the treatment of millscale containing approximately 4% oil and 20% water such that dry scale with an oil content of <0.1% is produced at between 450 and 570°C.



Thermal treatment of millscale in a rotary tubular kiln

In some cases, regardless of the technology which is applied, there is no option other than to dispose of waste materials. This should be treated as a last resort and undertaken in a controlled and responsible manner. In some countries, quality criteria have been developed for the disposal of inert metallurgical plant by-products. To ensure compliance with the guide values, special hydro-geological characteristics must be respected before these materials can be landfilled. For example, there must be no groundwater run off from the landfill or, if this is allowed, it must be treated and be incapable of entering drinking water sources. Provided that these conditions are satisfied, disposal is possible. It should be borne in mind, however, that contemporary legislation normally stipulates fairly onerous post closure requirements. Thus, when the landfill is closed, a surface seal must be built over the site to limit the seepage water into the landfill and long term monitoring and leachate treatment may need to be carried out. Therefore, the disposal of waste will carry a long term liability to ensure that no lasting damage results from the diposed materials.

Chapter 7
Environmental Management

Environmental issues are now so numerous, complex, interconnected and continuously evolving that an ad hoc approach to problem solving is no longer considered effective. A systematic approach to management is required.

Environmental problems have too often been dealt with after they have arisen, and then usually individually. It has gradually become clear that environmental impacts (including effects on human health) are frequently related. Many traditional pollution reduction programmes simply propose moving pollutants from one environmental compartment to another, as when a waste water treatment plant produces sludge which then presents a further disposal problem. The *ad hoc*, one-problem-at-a-time approach has proved inefficient and unnecessarily costly.

Incentives to deal systematically with environmental management can be divided into:

- Economic gains realised through more efficient use of resources, lower compliance costs, and workplace productivity
- Easier compliance with legislation
- Favourable publicity

A formal environmental management system (EMS) provides a decision-making structure and action programme to support continuous improvements in environmental performance. As with any management system, the EMS, itself should be assessed and evaluated on an ongoing basis with improvements being made as required. While the specific needs and circumstances of individual companies and countries will influence the nature of the system, every EMS should be consistent with, and complementary to, other decisionmaking processes in the areas of finance, health and safety, operations and quality.

UNEP, together with the International Chamber of Commerce and the International Federation of Consulting Engineers, has published an *Environmental Management System Training Resource Kit*; a training manual to assist companies in adopting an EMS.

As EMS has evolved, a need has arisen to standardise its application. ISO 14000 is an evolving series of generic standards developed by the International Organisation for Standardisation (ISO), that provides company management with the structure for managing environmental impacts. The standards are basically of two types: guidance and specification. All the standards except ISO 14001 are guidance standards. Companies do not register to ISO 14000 as a series: they register to 14001, the specification standard that is a model for an environmental management system. The standards include a broad range of environmental disciplines, including the basic management system (ISO 14001); auditing (ISO 14010, 14011/1 and 14012); performance evaluation (ISO 4031); labelling (ISO 14020 and 14024): life-cycle analysis (14040, 14041, 14042, 14043); and product standards (ISO 14060). It is expected that the list of standards under the ISO 14000 series will expand as new documents are developed and adapted when the need arises.

7.1 MANAGEMENT POLICIES

Policy and commitment alone cannot provide assurance that environmental performance is meeting - and will continue to meet - legislative and corporate requirements or best industry practice. To be effective they need to be integrated with the overall management activity and address aspects of desired environmental performance.

Some Elements of a Company Environmental Programme

1. *Top management commitment*
2. *Clear identification of all environmental issues, and company goals in regard to each issue*
3. *Clearly defined line responsibility and accountability for environmental issues*
4. *Adequate budget and resources for the programme in the company accounts*
5. *Clear, written company targets for resource consumption, discharges and site safety, above those required by law*
6. *Regular monitoring of environmental performance, e.g. CP Assessment, audits*
7. *Striving for continuous improvement in environmental performance with appropriate corrective action*
8. *Programmes on environmental training and awareness of environmental risks*
9. *Effective incident reporting and investigation*
10. *Effective contingency planning for potential accidents, spills and fires*
11. *Communication procedure within the company and with the public*

7.1.1 Environmental Principles

Environmental management in the company should be based on a set of values that are common to all employees and reflect a commitment to preserving the environment. Guiding environmental principles will typically state the company's values and ethical positions, and should form the foundation on which environmental policy and objectives within the company are built. Such principles have been proposed by a number of organisations including the International Iron and Steel Institute (the complete set of principles is reproduced later in this Chapter) and the International Chamber of Commerce.

7.1.2 Environmental Policy and Objectives

The environmental principles define a company's level of commitment to the environment. They are the foundation of policy which in turn dictates the level of environmental performance, goals, and expected objectives.

In developing policy, companies should consider issues such as continual improvement, local conditions, environmental regulations, pollution prevention, stakeholder needs, resource management, and mitigating adverse environmental impacts. The policy should be clearly communicated to internal and external stakeholders, and should be understood by them so that it may be incorporated into their activities.

Environmental objectives should be consistent with the environmental policy, and targets should be periodically reviewed to confirm that they are consistent with the overall direction in which the company is moving. Objectives may address broad corporate issues such as waste minimisation, energy conservation, or pollution prevention; or they can address specific issues, possibly relating to individual product lines. Quantified objectives are best in order for a company to measure its progress. This can be achieved by establishing performance indicators.

Environmental performance indicators that could be considered include:

- Tonnes of raw materials consumed
- Energy consumption per tonne of steel
- Number of incidents, such as spills
- Quantity of pollutants released to the environment

- Financial investment in environmental protection
- Elimination of toxic substances from products
- Percentage of material recycled
- Rate of waste generation
- Percentage of time that internal and external set limits are complied with
- Cost per tonne of product
- Annual environmental costs (including operating as well as capital costs)

Indicators which can be meaningfully compared over time should be selected, and which allow the assessment of company performance in terms of the environmental policy and objectives.

7.2 ORGANISING ENVIRONMENTAL PROTECTION

An effective management system requires that management clearly define the environmental responsibilities of all employees. To fulfil these responsibilities, management should provide the necessary decisionmaking authority and access to adequate labour and financial resources.

7.2.1 Organisational Structure

While organisational structures will vary between companies, as will the responsibilities assigned to individuals, the environmental responsibilities common to all situations will include:

- Compliance with regulations
- Developing environmental management plans
- Implementing environmental management plans
- Training
- Monitoring
- Auditing
- Pollution prevention
- Community relations concerning environmental effects
- Government interactions and interpretation of regulations
- Spill prevention
- Development of job procedures
- Assessing environmental trends
- Establishing overall direction

Structures which allow these responsibilities to be fulfilled and environmental objectives to be met include:

- A corporate environmental control department reporting to senior management
- Environmental responsibilities within each operating department or business unit
- Environmental committees to control environmental planning, waste management, and air and water pollution control
- Participation in industry associations and associated environmental committees, such as those of the International Iron and Steel Institute

7.2.2 Job Procedures

Job procedures for environmental control may be written or verbal. Employees should be provided with instructions describing the environmental aspects and requirements of their jobs so that they maintain an awareness of their responsibilities. These instructions can be provided in the form of written procedures, discussions, and training sessions. Instructions may be integrated with job descriptions, task design, instruction manuals for pollution prevention and bulletin board postings.

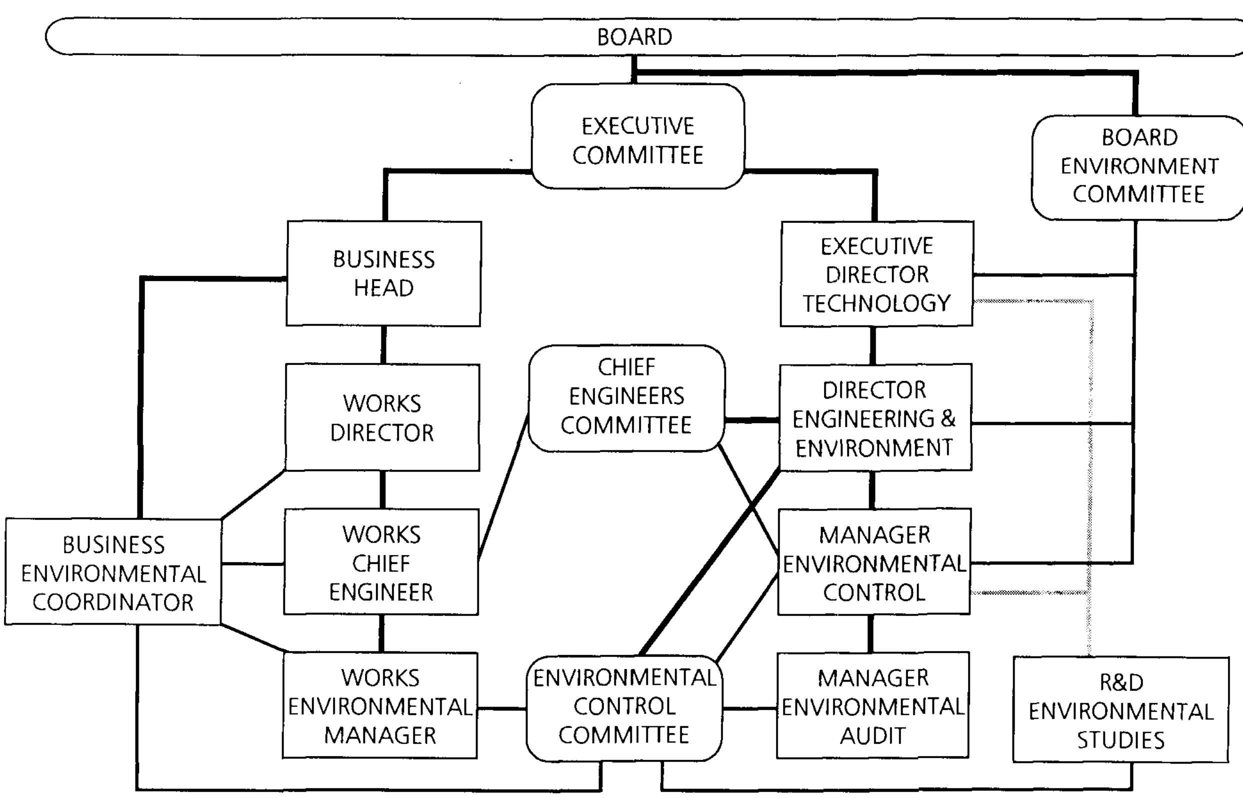
British Steel Environmental Policy Statement

British Steel plc is committed to the protection of the environment by minimising the impact of its operations through adoption of sustainable practices and continuous improvement in environmental performance and control.

We shall:

- *meet requirements of all relevant legislation;*
- *implement effective environmental management systems and ensure the environmental awareness of our workforce;*
- *reduce emissions, minimise waste arisings and control noise;*
- *promote the recovery, recycling and reuse of our products;*
- *use energy and raw materials more efficiently;*
- *research and develop new cleaner techniques for the manufacture and use of our products and by-products;*
- *cooperate with government and regulatory authorities in the development of cost effective legislation;*
- *help customers understand the environmental effects of our products;*
- *encourage suppliers and contractors to maintain sound environmental practices;*
- *maintain communication with local communities on environmental issues;*
- *respect the general environment and wildlife habitats local to sites and, where appropriate, progressively improve the visual amenity of sites;*
- *audit environmental performance and report progress on policy objectives.*

British Steel environmental management structure



A typical pollution prevention manual would contain the following sections:

Pollution prevention sections	**Key Information**
Pollution control equipment	• Equipment name and specification • Flowsheet • Factors causing environmental pollution
Equipment inspection standards	• Key points of inspection • Inspection frequency
Equipment operating standards	• Pollutant control standards • Operating procedures • Cautions for operation • Methods for detecting abnormalities
Measures to be taken when pollution occurs	• Operating measures to be taken at the time • Conceivable causes of the trouble • Measures to stop the problem spreading
Production restricting measures	• Where to make contact • Persons available
Matters requiring production restrictions	• Educational items • Training items

7.3 ENVIRONMENTAL MANAGEMENT TOOLS

Environmental management tools are often used within an environmental management system to measure aspects of a company's operation. Information generated from the use of these tools can improve decision-making and effect positive change in the behaviour of those within and outside the company.

Many tools are interrelated and overlap. Most include requirements for documentation and communication of environmental emissions, wastes and resource consumption.

7.3.1 Evaluation and Risk Management

The techniques of environmental risk assessment and risk management are in their early stages of development, however, the concepts are well founded in terms of safety. Evaluation and analysis of risk should form an important component of all developments and should be an integral element in all stages of the planning process, in particular Environmental Impact Assessment (EIA) and contingency planning.

Risk assessment is considered by many inside and outside the industry as a fundamental requirement in addressing the concept of sustainable development. Decisions should be based on the best possible scientific information and analysis of risks. The concept and perception of risk and value must also form part of the assessment because different groups will regard risk and value from varying viewpoints.

Risk Estimation and Management

- Description of project
- Hazard identification
- Identification of consequences
- Magnitude of consequences
- Probability of consequences
- Risk Management

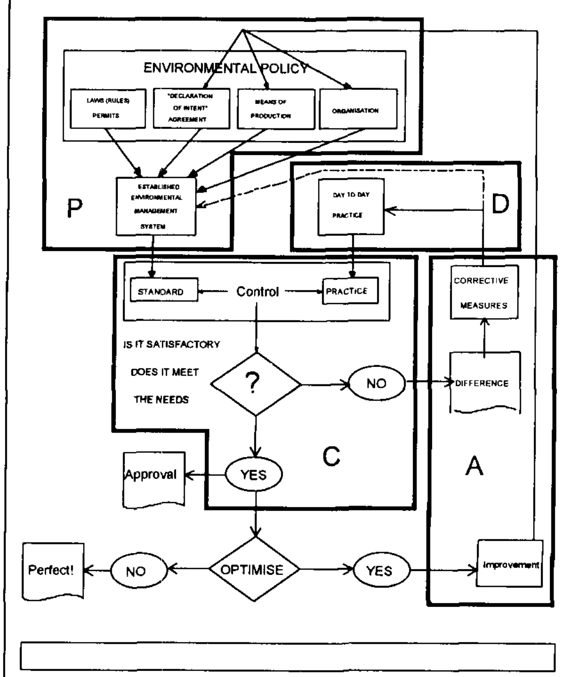
A company should maintain procedures to systematically identify the hazards and effects which may affect or arise from its activities and from materials employed in them. The scope of the identification should encompass all activities from inception through to decommissioning. One of the basic methods of assessing the implications is an environmental assessment.

Case Study — Environmental Management at Hoogovens Steel

Hoogovens Steel is a Dutch steelmaker producing approximately six million tonnes of steel each year. The company considers that care for the environment is its own responsibility and compliance with permits is an important objective. In working to establish a reduction in environmental pollution the company aims to influence employees' behaviour towards the environment.

In 1995, Hoogovens Steel established an Environmental Management System (EMS). The EMS was based on principles described in government and other sources including the documents 'EMS in companies' *by the Organisation of Dutch Companies, and* 'Environmental Management' *by the Dutch Minister of Environment. Care was taken that the system was consistent with the ISO 9000 series of standards so that the system may later be integrated with other management systems. The EMS is based on the Deming PDCA method illustrated in the figure below (top). According to the note of the Dutch Minister of Environment, an EMS should contain the following elements:*

- *Environmental statement - The established objectives and targets of the company should concern the environment in the short term as well as in the long term;*
- *Environmental programme - A programme, which has to be established yearly, of concrete activities concerning the environment;*
- *Integration of environmental management in the company operation - The necessary adaptations of procedures and organisation in order to make it possible to reach the objectives;*
- *Measurements and registrations - The establishment of the physical environmental effects related to the company operation;*
- *Internal control - Internal inspection of the environmental provisions and compliance with the relevant regulations;*
- *Internal information and education - Improvement of knowledge and motivation within the organisation;*
- *Internal and external reporting - Feedback within the company and reporting/giving account with regard to the environmental performance to government and civilians;*
- *Screening of the EMS/audits - The periodic evaluation of the EMS.*



The environmental management system at Hoogovens Steel

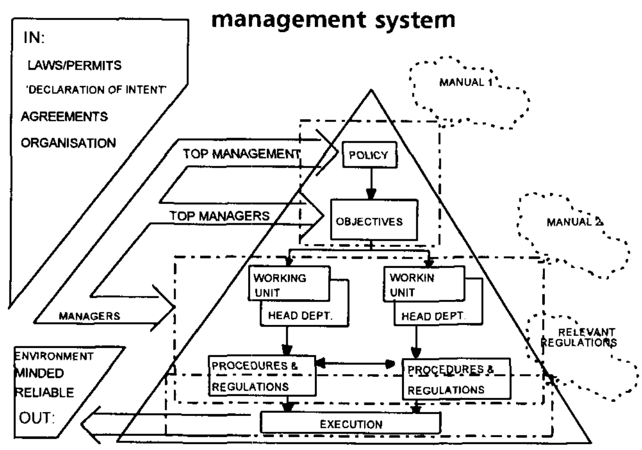
The EMS is organised in three levels:

Level 1: The EMS of the General Director of each Business Unit 'Board of Directors' (the top management) put down in the so-called manual 1

Level 2: The EMS for every working unit is put down in the so called manual 2. In some cases there is an extra manual on the product or service group level

Level 3: The EMS on the shop floor, put down in work and operation instructions.

The three levels of the environmental management system



The three levels in which the EMS is organised are also shown (right).

By following this approach, Hoogovens Steel was able to fully integrate environmental management into the other activities of the company.

7.3.2 Environmental Impact Assessment (EIA)

Some environmental impact will always result from the operation of a new site or expansion of an existing facility. The type and magnitude of the impact will depend on factors such as the proximity to residential and commercial areas, meteorological conditions, and topography. To identify potential impacts and avoid unnecessary problems, environmental assessments can be conducted at the planning stage with the aim of identifying potential problems and the formulation of cost-effective solutions which address the concerns of governments and the community.

The environmental assessment process should begin during the early stages of pre-project planning, and continue as an iterative process with the project feasibility and specification, detailed design, construction and operations. The findings of the assessment can at each stage be incorporated into the next phase of the project design. Any changes in project specification must be re-evaluated in terms of impact assessment. The importance of integrating the findings of the assessment process into engineering design is stressed and many potential impacts can be mitigated or removed with proper design consideration.

Impacts can be positive as well as negative, and relate to economic, aesthetic, and social issues in the region. Current and likely future land use, and the demands that the facility will make on the infrastructure of the area should be considered. Also important are the effects on the atmosphere and meteorology, on water supply and use, on fauna and flora; and the implications for solid waste disposal. Disaster precautions, major hazards, and emergency response plans should also be developed should a catastrophic spill or accident occur, including provision for employee and community evacuation, communication, and procedures to mitigate damage.

Management should also consider and plan for the ultimate closure of the facility. Planning for remediation during operations allows waste management and operating practices to be designed so that the remediation task is minimised. When a site or parts of a site close, management should evaluate and make decisions which will ensure that the decommissioned site is:

- Not a risk to human health and safety
- Not the cause of unacceptable risks to the environment

Steps to an EIA

- *Identify legislation*
- *Describe environmental baseline*
- *Identity sensitive environments*
- *Implement risk assessment*
    - *Identify project effects*
    - *Determine impacts*
    - *Evaluate alternatives*
    - *Select Best Practicable Environmental Options (BPEO)*
    - *Investigate mitigation*
    - *Evaluate residual impact*
    - *Establish basis for standards, targets and operational procedures and other plans*
    - *Develop basis for contingency planning*
    - *Recommend management plan - consultation, monitoring, review and audit*
    - *Recommend basis for documentation and training*

Note: Legislation in many cases will prescribe EIA requirements.

Case Study — EIA in South Africa

Background

In early 1992, South Africa's largest steel producer, Iscor and the Industrial Development Corporation of South Africa (IDC) decided to investigate the establishment of an export driven steel plant using the recently developed technologies of Corex, direct reduction, arc furnace melting and thin slab casting. A feasibility and environmental impact assessment (EIA) were commissioned.

The EIA addressed the predicted effects on the ecology, air and water pollution, the infrastructure needed for the plant, impacts on aesthetics and sense of place and the social, economic and cultural effects of the proposed plant. In order to provide a thorough coverage of the affected environment, eleven specialist studies were commissioned.

Key issues

The key issues identified were:

- *concerns that the proposed site was chosen according to economic criteria only, that alternative sites were not considered and that the proposed site could have a negative long term impact on tourism by changing the 'sense of place' of the area*
- *concerns that air and dust pollution from the plant and proposed solid waste disposal sites could affect the nearby mariculture industry in the Saldanha Bay*
- *environmental impacts on the Langebaan Lagoon and Wetlands, which is a registered Ramsar site of international importance*
- *the potential economic benefits which may be realised if labour and materials are sourced locally*
- *the potential social impacts (both positive and negative)*

Although the proposed property on which the plant was to be erected had been earmarked for industrial development, it was in fact still zoned as 'farm land' and, therefore, needed to be re-zoned. The re-zoning application was, however, opposed by various factions mainly on environmental grounds and this led ultimately to an interdiction and the appointment of a Supreme Court Judge by the Minister of Environmental Affairs and Tourism to hear evidence and advise on the environmental issues.

Results

The recommendation of this commission was that although no detrimental effects could be proved, the plant would have to be moved further inland. In addition, the company agreed to:

- *establish of a sound and proven environmental monitoring system which would involve an Environmental Working Committee advised by selected technical specialists*
- *develop an environmental management plan*
- *report to an environmental monitoring committee on which local interested groups would be represented.*

Case study — Sample EIA Table of Contents

The following page shows the table of contents of an EIA presented with the permit application for an EAF operation in Germany (1993).

- 1. Table of contents
- 2. General data (18 pages)
  - 2.1. Structure of the documents for the environmental impact assessment
  - 2.2. Difficulties encountered while working out the EIA documents
  - 2.3. Information on operation
    - 2.3.1 . Data about the applicant
    - 2.3.2. Type and size of the planned installation
    - 2.3.3. Proof of the necessity of the project
    - 2.3.4. Time schedule
    - 2.3.5. Overview on the project cost
- 3. General data on the EAF steelmaking plant (26 pages, 22 appendices)
  - 3.1. Choice of the site
  - 3.2. Concept of the installation
    - 3.2.1. Installation and production capacity
    - 3.2.2. Short installation and process description
      - 3.2.2.1. Process description
      - 3.2.2.2. Description of the plant constituents
    - 3.2.3. Description of design and construction
- 4. Description of the environment (30 pages)
  - 4.1. Location and particularities of the business site of NN
  - 4.2. Previous use of the site, extent of construction and tendency of development
  - 4.3. Description of the actual condition of protected goods
    - 4.3.1. State and pollution of the soil
    - 4.3.2. State and pollution of the atmosphere
    - 4.3.3. State and pollution through noise
    - 4.3.4. State and pollution of the water
    - 4.3.5. Climatic conditions
    - 4.3.6. Fauna, flora and biotops
    - 4.3.7. Utilisation and landscape
    - 4.3.8. Traffic
    - 4.3.9. Cultural goods
  - 4.4. Site assessment
    - 4.4.1. Initial situation
    - 4.4.2. Surface request
    - 4.4.3. Future construction concept
- 5. Environmental impact assessment/consideration of effects (45 pages, 8 appendices)
  - 5.1. Content of examinations / Generalities
  - 5.2. Site consideration
  - 5.3. Project alternatives
  - 5.4. Assessment of the plant technology
    - 5.4.1. Description and evaluation of the plant components
  - 5.5. Considerations to the effect of the planned EAF meltshop on the protected goods
    - 5.5.1. Environmental effects of the construction activities
    - 5.5.2. Operation in accordance with regulations
      - 5.5.2.1. Climate
      - 5.5.2.2. Emission of waste gas
      - 5.5.2.3. Emissions - air
      - 5.5.2.4. Odour
      - 5.5.2.5. Noise
      - 5.5.2.6. Soil
      - 5.5.2.7. Water
      - 5.5.2.8. Flora/fauna
      - 5.5.2.9. Inherited contamination and soil excavations
      - 5.5.2.10. Water protection
      - 5.5.2.11. Utilisation of waste heat
      - 5.5.2.12. Traffic
      - 5.5.2.13. Land utilisation and landscape
  - 5.6. Non conform operation
  - 5.7. Closure of the operation
  - 5.8. Evaluation of global effect
- 6. Description of substitute measures (3 pages, 1 appendix)
- 7. Regional development and planning (5 pages)
  - 7.1. Advantages and disadvantages of rail and road transportation
  - 7.2. Project state of 220 kV supply
  - 7.3. Project state of oxygen supply
  - 7.4. Integration of NN into the general development of the industrial site XX
- 8. Appendices and enclosures

- In compliance with applicable laws and regulations
- Suitable for a proposed new use
- Not a liability to current and future owners
- Aesthetically acceptable.

To achieve these objectives, decommissioning and site remediation plans should identify possible contamination and environmental impacts, establish cleanup plans and follow-up monitoring to confirm the property is acceptable. Elements of a decommissioning plan would include:

- Site information assessments: This involves gathering and reviewing all information available about the site, such as historic waste disposal practices and site inspections
- Preliminary testing to characterise the nature and extent of the contamination
- Detailed testing of subsurface soils, areas not tested in the preliminary tests, and establishment of the boundaries of contamination
- Decommissioning and site remediation plan including alternative technologies, costs, health and environmental concerns and review and approval by regulatory agencies
- Implementation of the plan
- Monitoring and sampling when the remediation work is completed to confirm that cleanup standards are met for the property, groundwater, remaining structures, and surface water.

7.3.3 Cleaner Production (CP) Assessment

A CP Assessment is a procedure which companies or consultants, for example, can use to identify sources of environmental concern and catalyse corporate effort to achieve continuous environmental improvement through an on-going programme.

A central element of a CP assessment is analysis of the material and energy flows entering and leaving a process. Cleaner production options, e.g. substitution of raw materials, or use of more energy efficient equipment, can be identified after quantifying inputs and outputs from a process. Of equal importance is analysing the economic costs of new options.

Sources of information needed to analyse material and energy flows are:

- purchase records
- material inventories
- batch composition records
- product specifications
- other product information from supplier
- operating logs
- standard operating procedures and operating manuals
- samples, analyses and measurements of raw materials, input materials, products and waste and emissions
- energy bills
- emission inventories
- equipment cleaning and validation procedure
- waste and emission forms
- literature, consultants
- interviews with employees to verify whether operations are carried out according to prescribed procedures

A CP Assessment is, however, only a starting point for a CP programme in companies. By assessing its energy and material flows a company should be able to identify key environment, health and quality issues, decide on further tools to be used (waste, energy, health and safety and audits) and to compile benchmarks figures.

7.3.4 Life Cycle Assessment

Life Cycle Assessment (LCA) is used to consider the environmental issues associated with the production, use, disposal and recycling of products, including the materials from which they are made. An LCA is generally recognised to consist of four phases: the establishment of the goals and scope of the assessment, the drawing up of an inventory of the input of materials and energy and

IISI'S Practical Guidelines for those Undertaking or Using Life Cycle Assessment

1. *Maintain the highest standards in both the undertaking of LCA studies and their disclosure to both internal and external audiences.*
2. *Seek to place LCA within its broader context of Sustainable Development recognising that this requires that due weight must also be given to the impact on human health, safety and welfare, bio-diversity, the impact on individual ecosystems, the length of a product's life and its recyclabilty, and the sustainable use of natural resources.*
3. *Support efforts to develop a consistent rigorous and transparent methodology for LCA to enable society to make informed choices on the environmental impact of products and processes.*
4. *Support the collection and dissemination of data on the use and reuse of materials and the environmental effects resulting from their production.*
5. *Publish data clearly in a form that allows the user to clearly identify the key assumptions made and the sensitivity to those assumptions.*
6. *Avoid the selective disclosure of results or the use of data out of its original context.*
7. *Avoid the mixing of product comparisons based on actual current practice with those based on optimal performance at some future date.*
8. *Avoid claims of superior impact on the environment where the differences between materials are likely to be within the margin of error of the key assumptions .*
9. *Support the development of standards for LCA including the work of the International Organization for Standardization (ISO).*

the output of emissions for each stage of the product life cycle, an assessment of the impact on the environment, and the identification of actions for improvement.

The techniques of life cycle assessment are still being developed as a science. The results are often sensitive to the exact assumptions made. Environmental priorities and issues differ in different societies and therefore the analysis is specific in both location and time. There is a danger in reducing complex issues to simplistic and partial analysis.

Working alongside customers, a LCA can be used to identify priorities for improvements in process operations and product design and development. The present state of the art and the sensitivity of results to subjective assumptions demand extreme caution when using LCA to compare the impact on the environment of alternative materials.

To assist companies in using this tool, UNEP has published *Life Cycle Assessment: What it is and How to do it.*

7.3.5 Monitoring

Monitoring allows environmental performance to be evaluated, a comparison to be made between actual performance and objectives, and indicates where corrective action should be taken and modifications made. Internal items which should be monitored include air and waste discharges, and water quality. External factors include government policy and initiatives, the activities of environmental groups and community concerns.

Internal Monitoring — A data collection and information management system can be established to aid the measurement of environmental performance and assessment against government requirements and corporate standards and objectives. Data analysis should allow successful initiatives as well as areas requiring improvement to be identified. Data types to be monitored include:

- Pollutant releases to air, water and land
- Energy consumption
- Spills
- Purchase of chemicals
- Water consumption
- Operating efficiency of pollution control equipment

Monitoring may be automatic, with on-line opacity meters on stacks for example; or by visual observation. The systems should be regularly tested, calibrated and audited to ensure data reliability.

External Monitoring — Management should monitor the activities of external stakeholders such as governments, customers, suppliers and the surrounding community, the collected information being used to assess current performance and guide future direction. For example, government policies relating to toxic reductions may have long term impact on the types of products used, thereby affecting the production process. Advance knowledge through external monitoring enables the company to gradually change to meet future regulatory requirements. External monitoring may include:

- Improvements in environmental control technology
- Environmental impact assessment
- Community groups and expectations
- Government policies and international agreements
- Customer expectations
- Advocacy groups
- Local air quality

For more information, readers should consult UNEP/UNIDO's publication *Monitoring Industrial Emissions and Wastes.*

Case Study — Environmental Control at Nippon Steel Corporation

Nippon Steel has for several decades regarded the need for environmental control as one of its highest management priorities, tackling the issues in a step by step fashion on a company-wide basis. In 1968, the 'Committee on Environmental Control Measures' was created to provide guidelines and enforce company-wide environmental protection measures. The committee was chaired by an executive vice-president with steelworks managers as committee members.

Five subcommittees comprising experts from the steelworks were formed to pursue forward-looking improvement programmes, and specifically to 'establish equipment design standards and equipment control standards for the treatment of pollutants, and to formulate easy-to-understand manuals'. *The five topics assigned to the committees were soot and dust, noise, SO_x, waste water, and NO_x. The manuals were prepared in collaboration with production personnel, who identified the most appropriate treatment and control techniques for each site. A four stage process was adopted:*

1. *A quantitative understanding of the process control was gained by examining the properties of the pollutants, where they were generated, and the quantities involved.*
2. *Examination of the generation mechanism.*
3. *Consideration of appropriate techniques to control the pollution. For example by collection, cleaning, reducing generation at source, or control of concentrations.*
4. *Compilation of equipment planning manuals specifying design and control standards.*

In a short time the existing pollution control procedures for air, water, waste and other materials had been amended. In addition, a series of projects was started on the development and standardisation of methods to collect and analyse pollutant data.

7.3.6 Communication and Reporting

Results from monitoring exercises should be made available to all employees with environmental responsibilities so that they can judge their performance against standards and identify areas for improvement. Communicating environmental performance also demonstrates management commitment, addresses questions and concerns, and raises awareness.

Management should communicate performance to external stakeholders. The degree of communication will depend on corporate culture, legislation, and the nature of the impacts being reported. Stakeholder information should be understandable, verifiable through audit, provide a complete picture of positive and negative aspects of performance over time. Performance may be communicated by:

- Internal reports to employees, management and the Board of Directors
- Bulletin board posting or e-mail

Case Study — Environmental Declaration of Det Danske Stalvalsevaerk A/S*

Net impact of 1 tonne of steel produced at Det Danske Stalvalsevaerk A/S

Type	Unit	Plates			Bars		
		1995	1994	1993	1995	1994	1993
Energy							
Electricity	kWh	811	800	829	770	744	749
Natural gas	Nm^3	77	78	84	46	47	49
Oxygen	Nm^3	35	38	41	22	20	16
Other gasses	kg	0.8	0.6	0.7	0	0	0
Metalluric carbon (C)	kg	15	13	15	14	12	14
Recycled heat (50-60% of total consumption of Frederiksvaerk)	kWh	102	116	132	83	87	86
Air							
Dust emission	gram	145	142	153	123	138	152
Heavy metal emission (Ni, Pb, Cd, Zn and Hg)	gram	13	18	25	11	16	22
CO_2	kg	223	220	238	150	145	156
Water							
Tap water, consumption	m^3	0.13	0.13	0.17	0.12	0.12	0.17
Cooling water, consumption	m^3	3.3	3.2	3.8	1.8	1.6	1.5
Heavy metals discharged (Ni, Cr, Cu, Pb, Zn and Cd)	gram	1.3	0.9	1.5	0.6	0.2	0.5
Waste products							
Deposited waste products	kg	26	23	45	24	20	40
Recycled waste products	kg	251	223	186	228	199	161

	Unit	1995	1994	1993
Number of industrial accidents	number /tonne	0.00012	0.00009	0.00012
Hours of absence due to industrial accidents	h/tonne	0.0108	0.0072	0.0097
Maximum emission, dust	$\mu g/m^3$	80	145	149
Maximum emissions heavy metals (Ni, Pb, Cd, Zn and Hg)	$\mu g/m^3$	7	25	39
Recycling of waste products (recycled/produced)	%	117	99	82

* from the 1995 company environmental report

- Yearly corporate environmental reports
- Advertising
- Government filings
- Customer information
- Community meetings
- Videos
- Local newspapers
- Verbal communications

Case Study — Environmental Auditing at Dofasco Inc.

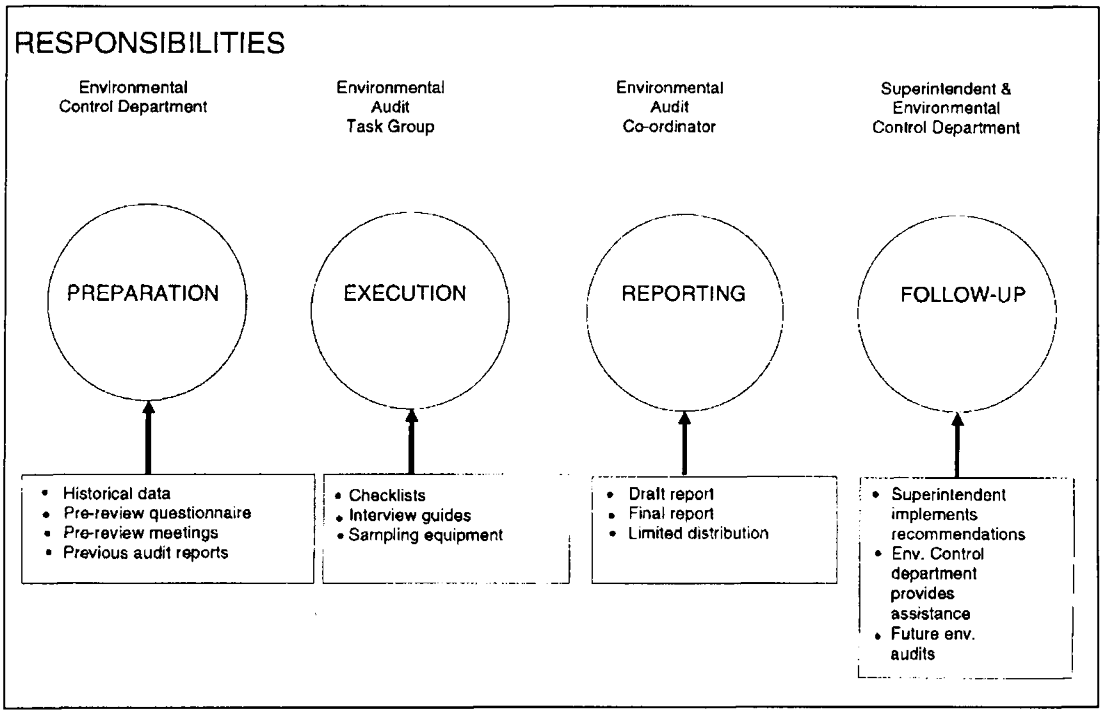
At the 3 Mt./annum Canadian steelmaker Dofasco, environmental audits are an important part of the overall management system, and include audits to:

- *Confirm that the management system is working properly*
- *Confirm that the company is complying with regulations*
- *Identify opportunities for improvement*

The audits are carried out by environmental professionals from the company's Environmental Health and Safety Department.

There are four stages to the audit process, as shown below: ***information gathering, execution, reporting of results,*** *and* ***follow-up*** *to the recommendations. Step one involves a study of previous audits, reports which identify past deficiencies, process diagrams, accidental spill reports, and documents listing complaints from community and government officials. Detailed questionnaires are developed for management and operating personnel and a first meeting of the audit team is held. Step two is the audit itself, during which interviews are held, site inspections take place, and samples are collected and analysed. Detailed notes are taken all the time. Step three, the reporting process, involves preparation and review of a report with all parties involved so that any errors can be corrected. A final draft with recommendations is sent to the business team management. Step four involves follow-up meetings held every quarter to monitor progress in the resolution of outstanding issues.*

The environmental auditing process at Dofasco



7.3.7 Environmental Auditing

Environmental audits are a systematic and objective evaluation of performance relating to the environment. There are many different types of audit and reasons for auditing. Companies may audit their activities to develop an understanding of current activities, to confirm that the management system is operating as planned, to identify cost reduction opportunities, to check compliance with regulations, or to meet requests from government or customers. Examples of audits currently undertaken within the steel industry include:

Statement of Policy

The member companies of the International Iron and Steel Institute are committed to providing leadership in achieving a high standard of environmental care while contributing to the needs and prosperity of society through the production of steel.

IISI Statement of Environmental Principles

Environmental excellence can be furthered by following these principles:

1. *Sustainable Development*

'Apply the principles of sustainable development to the steel industry'

This involves working together to take a long term global view of environment, economy and social integration. These principles should be incorporated into business decisionmaking at all levels and throughout the life cycle of the process and products. Sustainable development should be seen as an opportunity as well as a challenge. IISI recognises that different countries and steel firms are evolving towards these goals in different ways.

2. *Decisionmaking*

'Incorporate sound science, risk assessment and cost/benefit analysis to establish priorities and standards for continuous and fundamental improvement that are equitable and reasonable and to identify the most cost effective application of resources'

These principles apply to internal decisionmaking as well as public policy and legislation.

3. *Environmental Protection*

'Support efforts to conserve and to improve the quality of the environment by recognising environmental management as among the highest corporate priorities and a key element in sustainable development'

This includes safe and responsible life cycle management of chemicals and processes, environmental impact assessment and planning for new processes, best management practices, assessment of environmental performance, emergency response planning and product stewardship.

4. *Environmental Management Systems*

'Incorporate innovative and progressive environmental management systems to minimise environmental impact'

Examples include safe and reasonable life cycle management of chemicals and processes, environmental impact assessment and planning for new processes, best management practices, assessment of environmental performance, emergency response planning and product stewardship.

5. *Environmental Technologies*

'Design, operate and maintain facilities and equipment to minimise environmental impact'

This includes incorporating reasonable measures for pollution prevention at source through process or raw material changes, incorporating cleaner technologies, and using all reasonable care to control discharges. Environmental considerations should be an integral part of the research, development and design stages through to the recycling of used products and ultimately decommissioning of facilities.

- Regulatory compliance
- Complete material balances
- Identify waste flows
- Test integrity of management system
- Test procedures and accuracy of laboratory systems and results
- Identify potential environmental hazards

International organisations such as the United Nations Environment Programme and the International Standards Organisation are active in preparing standards and guidelines, such as the ISO 14000 series on environmental management which includes environmental auditing. UNEP/UNIDO have published the technical report 'Audit and Reduction manual for Industrial Emissions and Waste'.

IISI Statement of Environmental Principles *(cont'd from page 130)*

6. Resource Management

'Incorporate the fundamentals of efficient resource conservation and waste reduction, reuse, recycle and recovery into all elements of operations and products'

Examples include scrap recycling, slag and oxide reuse and recycle, coke by-product reuse and material and energy conservation through yield improvements.

7. Energy Management

'Conserve and make the most efficient use of energy to reduce the production of greenhouse and acid gases and thereby improve the environment'

Although the mechanism and impacts of global warming are not yet confirmed or clear, prudent and reasonable conservation measures can be taken now based upon cost reductions and resource conservation.

8. Education, Training, and Information

'Develop and promote mutual understanding through education, training and information for stakeholders, including directors, management, supervisors, employees, contractors, shareholders, suppliers, customers, government and the community'

These measures should be appropriate to the needs and responsibilities of the stakeholders. This should be open, positive and incorporate a long term global view.

9. Research, Innovation and Technical Cooperation

'Support research, innovation and technical cooperation that will result in continuous improvement, technical breakthroughs and cleaner technologies'

This development should be seen as an opportunity to transfer technology to other firms and countries to further educational and economic improvements on a global basis.

10. Government Requirements

'Cooperate with government in a responsible manner and contribute to the development of cost effective legislation and regulations that are based upon sound science, technical possibilities and the true environmental and economic priorities of the global community'

Environmental regulations require a balancing of social, economic and environmental goals. The health and environmental risks addressed by proposed regulations must be carefully quantified and then properly evaluated by comparison with other natural and man-made risks. The resolution of economic and social conditions among nations including the use of economic instruments should be consistent with equity and harmonisation of their environmental requirements. International cooperation and consensus is important and necessary for successful implementation.

7.4 TRAINING AND DEVELOPMENT

The capabilities needed by employees to achieve the environmental objectives should be identified and the training and development programme adjusted as necessary. The type of training will vary according to the degree of environmental responsibility. For example, all employees should be offered awareness training on the company's environmental policy and objectives. Those involved in activities which could affect the company's compliance with regulations should be trained on these issues. Training and development should be an on-going activity to retain awareness of recent trends and issues.

A typical training programme will contain the elements of:

- Needs identification
- Development of a plan to meet needs
- Training of targeted employee groups
- Documentation of training
- Verification of training to regulatory requirements

7.5 COOPERATIVE INDUSTRY INITIATIVES

Environmental issues can have national and international dimensions and require concerted cooperative action.

At the global level, major companies have formed a number of international environmental business associations. Some, such as the World Business Council for Sustainable Development (WBCSD) arose through the need to take concerted action at the time of the 1992 Rio summit.

The International Chamber of Commerce has developed a Business Charter for Sustainable Development, which has been signed by over 1,200 companies, including the International Iron and Steel Institute and many of its steel company members.

7.5.1 Steel Industry's 'Statement on the Environment'

As a guiding philosophy, the steel industry believes that operations should be conducted in a manner that protects the environment while contributing towards the objectives of sustainable development. This is reflected in the Statement of Policy and set of Principles prepared by the International Iron and Steel Institute, whose membership represents the majority of world steel production (see pages 130-131).

Chapter 8

Government Approaches and International Conventions

8.1 ENVIRONMENTAL REGULATIONS

Minimising the environmental impact of industrial operations is clearly a company responsibility. However, the government retains the vital role of determining the environmental standards which must be complied with. Authorities are beginning to also rely on other control instruments such as obligatory public disclosure of emissions data, agreed environmental improvement plans, fiscal incentives and tradable permits, as well as bans on certain products. This section briefly outlines some of the main elements of the regulatory instruments as they are applied today, recognising that they vary from place to place, and are subject to further evolution everywhere.

8.1.1 An Integrated Approach

Until recently, industries and governments took environmental action on a media-specific basis to resolve air, water, and waste disposal problems, and in many countries this is still the most common way in which environmental controls are addressed. While some improvements in environmental performance have resulted from this approach, it also had its limitations. One observed consequence was the appearance of 'cross media pollution' whereby industrial contaminants were merely transferred from one environmental 'compartment' to another. For example, following costly treatment of waste water, the subsequent disposal of treatment sludge can cause serious groundwater pollution which requires a further clean-up programme.

In recognition of this fact, the new environmental objective became Integrated Pollution Control (IPC) which was further developed into Total Environmental Risk Management. Whatever the term used, the notion of looking at all impacts simultaneously and addressing the priority areas in a systematic way has now become universally accepted. A second principle, equally important, has been that of preventive rather than remedial action.

Several countries are enacting laws that support integrated pollution control. Examples include laws that require environmental impact assessment; laws that provide for issuing a single permit for releases to all media from major facilities; laws that require notification of new chemicals before manufacturing or marketing; laws that integrate other environmental laws, or procedural aspects of such laws.

A direct relationship often exists between the structure of an organisation and the legislation it administers. Reorganisation within an environmental authority, for example replacing media-based units with units that focus on resource management, product use, economic sectors, waste prevention or waste clean-up, may be a pre-condition for integrated pollution control.

8.1.2 Plant Siting and Approval

Correct siting is one of the most important environmental decisions to be made. Major new projects commonly require an environmental impact assessment (EIA) in order to identify and then minimise any external impacts that may occur. The content of an EIA (see Chapter 7) should be determined by national level environmental legislation. The planning permit or site license for the plant should reflect the findings of the EIA, which identify areas where modifications to the original proposal can further reduce the expected impacts. Such a license will specify a number of

Case Study — European Union Directive on Integrated Pollution Prevention and Control

The Directive on Integrated Pollution Prevention and Control's (IPPC) aims to avoid the danger - which can result from traditional pollution control systems - of transferring pollution problems from one part of the environment to another. The new integrated system should also reduce the administrative burden on industry in the long run by streamlining approval procedures.

Some relevant points of the Directive are:

- *It regulates as close to the end user as possible while encouraging upstream preventive solutions*
- *It sets strict values based on the Best Available Techniques (BAT), to protect the environment and stimulate innovation.*
- *It allows industry the opportunity to innovate to meet standards. The long transitional period to IPPC can provide an opportunity to stimulate innovation, not an excuse to do nothing.*
- *It promotes partnership - an atmosphere of mutual trust between industry, the regulator and the public.*
- *It provides one-stop-shopping for permitting, minimising the time and resources taken up by the regulatory process itself.*

The key to implementation of IPPC is the exchange of information on BAT. Member States, together with industrial and environmental NGOs will get together to discuss for each sector what techniques are available, what performance they deliver, and how the definition 'Best' applies in each particular case. The aim is to achieve consensus on a set of techniques to serve as a benchmark for the implementation of IPPC, which the Commission will publish as reference documents. Under previous Directives, BATs on air emissions in iron and steel production have already been published.

The involvement of industry at all stages of the process is essential to ensure the robustness and credibility of the reference documents. The role of the public and of the environmental NGOs is equally crucial. Both the permit application and the permit decisions are available for public comment. The benchmark reference values from the exchange of information will inform the public broadly what level of control they have the right to expect. A permit should satisfy the key aim of the Directive, to prevent or minimise pollution. And the role of the local environment authority is clear - to guide environmental optimisation and not to justify lax standards.

The public will also have before them a register compiled by the Commission giving the location and the emissions of the most polluting installations remaining in Europe. Besides those values, benchmark values for the installations will also be available. The Commission will give the very highest public profile possible to this list.

With this transparency the public can challenge lax values in permits and campaign for the proper implementation of the spirit of IPPC.

Case Study — IPC Permit

The following page shows the table of contents of an IPC Permit for an EAF operation in Luxembourg (1996)

1

I) List of authorised plant components

II) General application conditions

III) Specific conditions

- Specific conditions related to scrap management and acceptance
  - Acceptance of scrap ~ information ~ control procedures

IV) Air protection

- General requirements
- Definition of specific parameters
  - Reference for emission concentration measurements
  - Interpretation of limit values
- General emission conditions
  - Capture of emissions generated inside buildings
  - Requirements for evacuation equipment

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- Requirements on production, transformation and transport of energy
  - General conditions
  - Emissions by diesel engines for emergency pumps
  - Production of electric power by diesel operated emergency power stations
  - Air conditioning equipment
- Utilisation of halogenated products and substances
- Specific limitations for the emission of pollutants from different production units
  - Restrictions related to the EAF and directly related installations

    Dust emissions

    Emissions of heavy metals

    Emissions of inorganic fluorine and chlo-

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rine compounds

Emissions of dioxins/furans, PCBs and PAHs

Emissions of organic substances

Emissions of gaseous pollutants

  - Specific restrictions related to the ladle furnace
- Atmospheric pollutant emissions-mass flow
  - EAF
  - Ladle furnace
- Pollution abatement installations - furnace operation
- Conditioning of filter dust
- Access roads and manoeuvring areas

V) Water protection

- Evacuation of used water in general
- Treatment of used water
  - General requirements
  - Treatment of surface water from the scrap yard

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  - Treatment of water from the open air electric transformer station
- Utilisation of detergents
- Cooling waters

VI) Soil and underground protection

- Prevention of accidental pollution
  - Storage and handling of flammable, toxic, corrosive and dangerous products

    General requirements

    Storage of oil for heating purposes

    General conditions

    Open air reservoirs

    Filling operations for reservoirs

    Reservoir equipment
  - Retention of cooling fluids of transformers
  - Soil decontamination

VII) Noise abatement

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- noise from the EAF hall
- noise from the scrap yard
- noise from diesel engines for emergency power supply

VIII) Prevention and management of wastes from normal operation

- General conditions for waste management
- Conditions for waste prevention and reduction
- Conditions for waste collection and storage
- Conditions for waste transfers
- Conditions for waste recycling
- General conditions for waste elimination
- Conditions regarding specific waste fractions

IX) Construction phase

- Air protection

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- Protection of soil and subsoil
- Noise abatement
- Waste management
- Specific conditions in relation with demolition and excavations
  - Non-contaminated wastes
  - Contaminated or potentially contaminated wastes

X) Particular requirements

- General rules
- Rational utilisation of energy
- Specific requirements regarding accidental fires
- Insurance coverage requirements

XI) Reception, controls and reporting

- General requirements

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- Reception of equipment and installations
- Reporting of annual production
- Reporting on scrap management
- Measuring points and sampling ports
- Monitoring related to air protection
  - Monitoring of the emission of pollutants into the atmosphere
    Checking of equipment used for continuous measurements
    Checking of non-continuously monitored emissions of pollutants
    Measuring conditions for emission measurements
    Monthly reporting on pollutant emissions
    Annual reporting on pollutant emissions
    Other annual reports
- Monitoring related to water protection

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- Checking related to soil and subsoil protection
- Checking related to noise control
- Checking related to waste prevention and management
- Energy audit
- Analyses required in case of abnormal operation (blaze)
  - Plant reception
  - Periodic checks
- Controls related to the closure of site activities

XII) Requirements for information in the event of a severe incident or accident

XIII) Designation of a contact person in charge of environmental matters

conditions concerning site preparation, layout and equipment. Day to day management requirements are more likely to be specified in an operating permit. Effective enforcement of environmental regulations requires adequate staff and resources. The industrial licence and permit fees in many countries are set so as to recoup some of the associated expenses.

8.1.3 Regulation of Environmental Releases

Environmental releases are normally regulated by media-specific standards under environmental or health laws. The industry is expected to comply with general or sector specific standards for release to water (surface or ground water) and to air.

Land discharge conditions are commonly applied to the landfill facilities rather than the source of the waste. Nevertheless, these conditions will be reflected in what wastes the facilities will accept from their clients. Toxic slags, for example, must first be stabilised. Liquids are becoming less and less acceptable for landfilling.

Case Study — Air Discharge Standards in Korea

An Environmental Impact Assessment study (EIA) at the Kwangyang works concluded that air emissions level would be problematic since the works were located near a petrochemical site. Bearing this in mind, the Kwangyang Steel Works imposed its own emission standards which are more stringent than the national standards, and have installed an environment monitoring system to ensure proper control.

Parameter	National Standard	Company Standard	Units
Dust	30-200	20	mg/Nm^3
NH_3	200	200	ppm
CO	600-700	400	ppm
SO_2	300-1200	300	ppm
NO_x	200-400	200	ppm
HCl	80	80	ppm
Cl_2	80	80	ppm

Table 8.1 Reference Standards and Guidelines of Average Ambient Particulate Concentration ($\mu g/Nm^3$)

	Long-term (annual)			Short-term (24 hours)		
	PM_{10}	BS(1)	TSP	PM_{10}	BS(1)	TSP
EU limit values	-	80(2)	150(3)	-	250(4)	300(5)
EU guide values	-	40-60(2)	-	-	100-150(6)	-
US EPA primary and secondary standards	50(7)	-	-	150(8)	-	-
WHO guidelines(9)	-	40-60	60-90		100-150	150-230
WHO guidelines for Europe (8)	-	50	-	70(10)	125	120

(1) Converted to $\mu g/Nm^3$ measure
(2) Median of daily mean values
(3) Arithmetic mean of daily mean values
(4) 98th percentile of all daily mean values throughout the year
(5) 95th percentile of all daily mean values throughout the year
(6) Daily mean values
(7) Arithmetic mean
(8) Not to be exceeded for more than one day/year
(9) Guideline values for combined exposure to SO_2 and particulates
(10) Guideline for thoracic particles. According to International Organization for Standardization (ISO) standard (ISO-TP), thoracic particle measurements are roughly equivalent to the sampling characteristics for particulate matter with a 50 percent cut-off point at 10μm diameter.

Table 8.2 Reference Standards and Guidelines for Ambient Sulphur Dioxide Concentration ($\mu g/m^3$)

	Annual average	Associated particulate levels	Winter	Associated particulate levels	24-hour	Associated particulate levels	1-hour
EU limit values	80(1)	>40(4)	130(2)	>60(4)	250(3)	<150(4)	-
	120(1)	<40(4)	180(2)	<60(4)	350(3)	<150(4)	-
	80(1)	>150(5)	130(2)	>200(5)	250(3)	>350(5)	-
	120(1)	<150(5)	180(2)	<200(5)	350(3)	<350(5)	-
US standards	80(6)	-	-	-	365(7)	-	-
WHO guidelines	40-60(6)	-	-	-	100-150(3)	-	-
WHO guidelines for Europe	50(6)	-	-	-	125(3)	-	350

(1) Median of daily values taken throughout year
(2) Median of daily values taken throughout the winter
(3) 98th percentile of all daily values taken throughout the year. Should not exceed more than 7 days/year.
(4) Black smoke method
(5) Geometric method
(6) Arithmetic mean
(7) Should not be exceeded more than once/year

Sources: WHO(1979,1987); US Environmental Protection Agency, (1990); European Community Directive 80/779 (July 5, 1980) and amending Directive 89/427 (July 14, 1989)

Table 8.3 Reference Standards and Guidelines for Ambient Levels of Nitrogen Dioxide ($\mu g/m^3$)

	Annual Average	24-Hour Average	1-Hour Average
EU Limit Values (1985)	200(1)	-	-
U.S. Standards (1992)	100(2)	-	-
WHO Guidelines (1977)	-	-	190-320(3)
WHO Guidelines for Europe (1987)	-	150	400

(1) 98th percentile calculated from the mean values per hour or per period of less than an hour taken throughout the year
(2) Arithmetic mean
(3) Not to be exceeded more than once a month. Only a short-term exposure has been suggested.

Sources: WHO (1977, 1987); US Government Printing Office (1992); European Communities (1985)

Table 8.4 **Reference Guidelines and Standards for Ambient Atmospheric Ozone Concentrations (µg/m³)**

	Short-term (1 hour) Average	Medium-term (8 hours) Average
U.S. EPA	235(1)	-
U.S. California State	180(1)	-
WHO (1979)	100-200	-
WHO Guidelines for Europe (1987)	150-200	100-120

(1) Value not to be exceeded more than once in a year.

Sources: U.S. EPA (1986); WHO (1976, 1987)

Table 8.5 **National Air Emission Standards (mg/Nm³ unless otherwise stated)**

Parameter	Belgium	Denmark	France	Pakistan	Thailand
Particulate Matter/Dust	50-100	20-40	50-100	200-500	300-500
Nitrogen Oxides (NO_x)	500	500	500	400	1000
Sulphur Oxides (SO_x)	500	500(SO2)	300	400	500-700 ppm
Carbon Monoxide (CO)	-	-	-	800	1000
Hydrogen Sulphide (H_2S)	-	-	5	10	100 ppm
Hydrogen Chloride (HCl)	30	-	50	400	-

In addition to regulating actual discharges, some countries also apply ambient environmental standards; that is to say the quality of the environment which must not be diminished by industrial discharges. In such cases, some calculation will be required to determine the dilution that occurs at discharge points, and hence the allowed concentration in the discharges. The permissible quantity (or 'load') of pollutant, generally air pollutant, may also be specified in a plant permit. In certain countries, notably the USA, companies may sometimes trade their unused allocation to another plant that has difficulty in meeting the standards.

Tables 8.1 to 8.4 are examples of some of the ambient standards for air pollutants.

Air emission standards are also used to control specific air pollutants at iron and steel plants. Table 8.5 illustrates some examples of these emission standards. Comparison of these national standards, however, is difficult as they will differ according to such factors as the individual unit process, definition of the pollutant, mass flow/gas volume, stack height, pollution control technology, and so on.

Concentrations are expressed either in mass per volume (mg/Nm³) or in volume mixing ration (1 ppm = 10^{-6}). Much confusion arises in the interconversion of mg/Nm³ and ppm. Whilst the volume mixing ratio is independent of temperature and pressure for an ideal gas (and the air pollutant behaviour is close to ideal), the mass per unit volume is dependent on T and P conditions, and hence these will be taken into account.

Regulatory authorities will also control waste water or effluent discharges. Both ambient quality and discharge standards are used. **Table 8.6** illustrates some standards in use today.

Table 8.6 National Effluent Discharge Standards

Parameter	Brazil	India [1]	Korea [2]	Nether'ds [3]	Malaysia[4]	Japan [5]
pH	5-9	5.5-9.0	5.8-8.6	6-9	6-9	5.8-8.6
Temperature (°C)	<40	<40	<40	-	40	-
TSS (mg/l)	-	100	80-100	20	50	200
Settleable matter (mg/l)	1	-	-	-	-	-
Oil and grease (mg/l)	-	10	-	-	ND	-
Mineral oil (mg/l)	20	-	5	1	-	5
Vegetable and animal oil (mg/l)	50	-	30	-	-	30
BOD (mg/l)	-	30	80-100	-	20	160
COD (mg/l)	-	250	80-100	25	50	10-40
Ammonia (mg/l)	5.0	1.5	-	-	-	-
Ammoniacal N_2 (mg/l)	-	50	-	-	-	-
Cn (mg/l)	0.2	0.2	1	-	0.05	1
Fluorine (mg/l)	10.0	2.0	15	5	-	15
Organic phosphorous (mg/l)	-	-	1	-	-	1
Phenols (mg/l)	0.5	1.0	3	0.1	0.001	5
Sulphide (mg/l)	2.0	2.0	-	1	0.5	-
Trichloroethylene (mg/l)	-	-	0.3	-	-	0.3
Tetrachloroethylene (mg/l)	-	-	0.1	-	-	0.1
Arsenic (mg/l)	0.5	0.2	0.5	0.002	0.05	0.1
Cadmium (mg/l)	0.2	2.0	0.1	0.01	0.01	0.1
Copper (mg/l)	1.0	3.0	3	0.02	0.2	3
Chromium (total) (mg/l)	-	-	2	0.1	-	2
Chromium (VI) (mg/l)	0.5	0.1	0.5	0.05	0.05	0.5
Chromium (III) (mg/l)	2.0	-	-	-	0.2	-
Iron (mg/l)	15.0	-	10	2	1	10
Lead (mg/l)	0.5	0.1	1	0.1	0.1	0.1
Manganese (mg/l)	1.0	-	10	-	0.2	10
Mercury (mg/l)	-	0.01	0.05	0.0001	0.005	0.005
Alkyl mercury (mg/l)	-	-	-	-	-	ND
Nickle (mg/l)	-	3.0	-	0.05	0.2	-
Zinc (mg/l)	1.0	3.0	5.0	0.1	1	5

(1) Local standards stipulated by the State Pollution Control Board of Andhra Pradesh for Visakhapatnam steel project

(2) The effluent standards for all industries in Korea are classified into 4 grades mainly by the water bodies to which effluents are discharged. This standard is applied to Area II, second protected area for potable use after filtration. The standards will be revised from the start of 1996

(3) The required standards for the water to which the Hoogovens Group are discharging. This standard is equal to the so-called basic quality standard

(4) For all industries including iron and steel and for discharge to any inland waters within the catchment area

(5) pH value applies to the effluents discharged into public water bodies other than coastal seas. COD value applies to the effluents discharged into Tokyo Bay, Ise Bay and Seto Inland Sea areas, which are the most industrialised regions in Japan

8.1.4 Site Remediation and Liability

Many governments are now requiring by law that companies clean up their sites that have been contaminated by leakage of chemicals and on-site disposals. This is often dealt with under specific 'contaminated sites' legislation, or general environmental regulations. Although, there has been no agreement or guidelines on 'how clean is clean', a number of countries have attempted to prepare guidelines for soil standards expected from successful clean-up operations.

Case Study — The Assessment and Remediation of Soils and Groundwater at an Integrated Steel Plant

Introduction.

Inland Steel Company operates a steelmaking facility on the shores of Lake Michigan, which began operations at the turn of the century. Over that time, operations at the site have included all integrated activities, EAF and open hearth steelmaking, tinplating and the normal support facilities. The site currently covers 2,400 acres(~10km^2), of which ~70 percent comprises land reclaimed from Lake Michigan. The fill materials used to reclaim this land were primarily blast furnace slag, BOF slag and sand dredged from the lake itself. In addition, a number of waste materials generated in the plant have also been used, including coke plant wastes.

Formerly, the company operated a deep injection well for the on-site disposal of pickle liquor, defined as a hazardous waste under the US Resource Conservation and Recovery Act (RCRA). Therefore, the Environmental Protection Agency (USEPA) required that a comprehensive study of the entire facility be carried out to determine if hazardous constituents posed a threat to human health or the environment. In the US, this process is known formally as the Corrective Actions Program.

Assessment/Clean-up Approach

During the 4 year negotiations between Inland and the USEPA, concerning the assessment process, two departures from the traditional approach to Corrective Actions were agreed. The first was the requirement to assess Solid Waste Management Areas (SWMA), as opposed to Solid Waste Management Units (SWMU). There are 14 SWMA at the site, defined by their known history of operations, fill history and a limited survey of soil and groundwater characteristics. Potentially, there were thousands of SWMUs as these would include units such as individual underground storage tanks, spills, treatment lagoons and disposal areas.

The second departure was the agreement to adopt a phased approach to the assessment, whereby investigative boreholes are quickly and efficiently installed using a hollow auger from which water samples can be obtained. This Phase I, or screening step, allows the assessment process to progress quickly, whilst providing data for a more detailed, but focused, Phase II investigation. This second phase will include the installation of permanent monitoring wells, conforming to rigid QA/QC requirements, to confirm the data obtained in Phase I.

The validity of this approach is shown by the fact that the Phase I investigation has been able to highlight the presence of 'hot-spots' of contamination. For example, a layer of light oil(BTX) was found on the groundwater in the vicinity of the former by-products plant. A formal procedure to provide

8.1.5 Occupational Health and Safety

The protection of workers is normally controlled by occupational health regulations established by national health and safety administrators. Acceptable levels of worker exposure to airborne pollutants and to radiation, heat, noise and vibration is determined in schedules under regulations. International organisations such as the International Labour Office (ILO) and the World Health Organisation (WHO) publish guidelines which are often the basis of national schedules. The issue is further discussed in Chapter 4. It should be recognised that there is a vast literature on occupational exposure which is not reproduced here.

8.1.6 Regulation of Operations and Materials

Regulations concerning storage of hazardous and inflammable substances usually specify both physical location and design of storage sites, as well as safety provisions such as sprinklers or alarms. Handling requirements will cover identification and labelling of materials as well as worker protection.

Case Study — cont'd

interim or stabilisation measures in situations such as this, which were not unexpected, had already been agreed with the USEPA and Inland were able to respond quickly, with minimal regulatory oversight. Stabilisation costs have averaged between $50 - 100 K. The flexibility of this approach is considered essential for Inland to deal effectively with the issues raised during the assessment, whilst minimising the impact on current operations.

Clean-up Standards

As each SWMA is assessed, potential sources of contamination will be addressed as described above. However, the ultimate goal of the project is to determine if any contamination poses a threat to human health or the environment, based on the results of the Phase II investigation. In this particular case the site is bounded by the water on three sides therefore the contaminant pathways of most concern will be via groundwater into Lake Michigan. Thus, groundwater contaminant levels and volume flows will be quantified at the perimeter of the plant and this information used to determine the levels available to organisms in the vicinity of the plant. It is likely that surface water and sediment standards, which have been set taking into account acute and chronic effects, will form the benchmark for assessment. The pollutants of concern at the facility are mainly those generated from the coking operations. i.e. benzene, toluene, naphthalene and the numerous polyaromatic hydrocarbons (e.g. benzoapyrene). Metals appear to be 'locked up' in the soil/fill matrix because of the elevated fill pH's (>9) and have not been discovered in the dissolved state in groundwater at the site.

Conclusions

The assessment of a large operational steel site using a two stage approach is considered cost effective, by reducing the number of expensive boreholes required, whilst retaining the desired degree of accuracy. The ability to respond to found 'hot spots' of contamination and/or free product, without recourse to the regulatory authorities, allows flexibility that both ensures protection of the environment and minimises the impact on current operations.

The assessment phase is currently costing $5 million (US) dollars per year. Remediation costs are difficult to estimate at this stage but may reach $100 million dollars.

Given the size of the plant, it is likely that most contaminants will remain in place and be managed to minimise the risk to the environment. However, the eventual determination of contaminant loadings into Lake Michigan will be the primary factor driving any remediation. It is expected that the assessment procedure will take 10 years to complete, remediation may continue for 20-30 years after that time.

Similar considerations apply to transport. The Code of Practice prepared by the UN Committee on the Transport of Dangerous Goods is often the basic document used in preparing national legislation. Adherence to this code will in most cases ensure compliance with national regulations, but local additions and adaptations may well occur in some countries. The operation of machinery is generally covered by local factory legislation and safety regulations.

8.1.7 Environmental Auditing and Reporting

Plants are increasingly required to monitor discharges to air, water and land, and to report these to the authorities. A special example of this is the Toxic Release Inventory (TRI) in the USA. Companies are required by law to measure and report on the quantities of over 300 chemicals that were transferred or emitted during the year. Although TRI does not limit the release of pollutants (this is done under other regulations) the compilation and publication of the plant monitoring data strongly influences a company's attitude to its emissions as these data are in the public domain.

Case Study — USEPA Toxic Release Inventory for the Iron and Steel Industry

According to TRI data, the iron and steel industry released and transferred a total of approximately 695 million pounds (316,000 tonnes) of pollutants during calendar year 1993. These releases and transfers are dominated by large volumes of metal-bearing wastes. The majority of these wastes (70 percent or 488 million pounds (222,000 tonnes)) are transferred off-site for recycling, typically for recovery of the metal content. Metalbearing wastes account for approximately 80 percent of the industry's transfers and over fifty percent of the releases.

Releases from the industry continue to decrease, while transfers increased from 1992 to 1993. The increase in transfers is likely due to increased offsite shipments for recovery of metals from wastes. This shift may also have contributed to the decrease in releases. Another factor influencing an overall downward trend since 1988 in releases and transfers is the steel mill production decrease during the 1988 to 1993 period. In addition, pollution control equipment and a shift to new technologies, such as continuous casting, are responsible for significant changes in the amount and type of pollutants released during steelmaking. Finally, the industry's efforts in pollution prevention also played a role in driving pollutant release reductions.

Releases

The iron and steel industry releases just 14 percent of its TRI total weight. Of these releases, over half go to on-site land disposal, and one quarter of releases are fugitive or point source air emissions. Manganese, zinc, chromium, and lead account for over 90 percent of the on-site land disposal. The industry's air releases are associated with volatilisation, fume or aerosol formation in the high temperature furnaces and byproduct processing. Ammonia, lighter weight organics, such as methanol, acids and metal contaminants found in the iron ore are the principal types of chemicals released to the air. In addition to air releases of chemicals reported in TRI, the iron and steel industry is a significant source of particulates, carbon monoxide, nitrogen oxides and sulfur compounds due to combustion. Ammonia releases account for the largest part of the fugitive releases (approximately 42 percent) and 1,1,1-trichloroethane, hydrochloric acid, zinc compounds, and trichloroethylene each contribute another 4 - 5 percent. Underground injection (principally of hydrochloric acid) makes up about 14 percent of the releases reported by the industry.

Transfers

Eighty percent of transfers reported by SIC 331 industries are sent off-site for recycling. Zinc, manganese, chromium, copper, nickel, and lead are the six metals transferred by the greatest number of facilities.

Acids used during steel finishing, such as hydrochloric, sulfuric, nitric, and phosphoric acids, account for another 17 percent of transfers. These acids are most often sent off-site for recycling or for treatment. Hydrochloric acids are also managed by on-site underground injection. The next class of chemicals of significant volume in TRI are solvents and lightweight carbon byproducts, including: 1,1,1-trichloroethane, trichloroethylene, phenol, xylene, methanol, and toluene. These solvents are primarily released as fugitive air emissions, but also from point sources. A small percentage of these solvents are transferred off-site for recycling.

Chemicals sent off-site for disposal (primarily zinc, sulfuric acid, manganese, and ammonium sulfate) account for another 10 percent of transfers. Only approximately 7 percent of chemicals transferred off-site go to treatment These chemicals are primarily hydrochloric acid, sulfuric acid, and nitric acid. Only about one percent of transfers by weight are publicly owned treatment works' discharges (mainly sulfuric acid). Another one percent of transfers are sent for energy recovery (with hydrochloric acid as the most significant contributor).

Not only does TRI empower the public to become involved in environmental issues, it also provides a useful basis to encourage voluntary agreements. The '33/50 Program' is EPA's voluntary program to *reduce toxic chemical releases and transfers of seventeen TRI chemicals from manufacturing facilities. Participating companies pledge to reduce their toxic chemical releases and transfers by 33 percent as of 1992 and by 50 percent as of 1995 from the 1988 baseline year.*

Thirteen of the seventeen target chemicals are used in the iron and steel industry. Of all TRI chemicals released by the iron and steel industry, chromium and chromium compounds, a 33/50 target chemical, were released most frequently (from 347 facilities), and were the third greatest volume. Other target chemicals in the top ten TRI releases by volume were nickel and nickel compounds, lead and lead compounds, and 1,1,1-trichloroethane.

Auditing of the EMS is not usually required by law, as it is regarded as an internal tool. Nevertheless in Europe, companies are encouraged to subscribe to a voluntary environmental audit scheme which includes a reporting element.

8.2 ENVIRONMENTAL COMPLIANCE

Government compliance and enforcement programmes seek to create an atmosphere in which steel enterprises are stimulated to comply, both because the government has demonstrated a willingness to enforce when non-compliance is detected and because such actions bring to bear significant consequences. Many factors affect the extent to which compliance with environmental requirements is achieved. There are social, moral, and personal influences, as well as economic

	Factors that motivate compliance	Factors that encourage non-compliance
Economic	Desire to avoid a penalty Desire to avoid future liability Desire to save money by using more cost-efficient and environmentally sound practices	Lack of funds Competing demands for resources Greed or the desire to achieve unfair competitive advantage
Social and Moral	Moral and social values for environmental quality Society's respect for the law Clear government will to enforce environmental laws	Society's lack of respect for the law Lack of public support for environmental concerns Government's lack of willingness to enforce Lack of environmental awareness
Personal	Positive personal relationships between programmes Desire, on the part of the facility manager, to avoid a legal process Desire to avoid jail, the stigma of non-compliance and adverse publicity	Fear of change Inertia Ignorance about requirements Ignorance about the means of meeting requirements
Management	Jobs and training dedicated to compliance Bonuses or salary increases based on environmental compliance	Lack of internal accountability for compliance Lack of managment systems for compliance Lack of compliance training for personnel
Technological	Availability of affordable technologies	Inability to meet requirements because of lack of appropriate technology Technologies that are unreliable or difficult to operate

factors. The level of education and technical sophistication and familiarity with the requirements will also affect the rate of compliance. A successful compliance strategy should take into account all these factors. The underlying goal of a compliance and enforcement programme should be promotion and encouragement of compliance, rather than punishment.

Deterrence is a fundamental principle of all enforcement programmes. To create an atmosphere in which steel companies comply with the law, it is essential that there be:

- An effective educational programme.
- A system of incentives for those who comply.
- A credible likelihood of detection of violations.
- A swift and sure response.
- Appropriate consequences.
- Effective perception of each of these elements.

The key functions of an effective compliance and enforcement programme are as described in Sections 8.2.1 to 8.2.7:

Case Study — US Environmental Protection Agency (EPA):

Compliance of the Iron and Steel Industry

Background

To date, EPA has focused much of its attention on measuring compliance with specific environmental statutes. This approach allows the Agency to track compliance with the Clean Air Act, the Resource Conservation and Recovery Act, the Clean Water Act, and other environmental statutes. Within the last several years, the Agency has begun to supplement single media compliance indicators with facility-specific, multimedia indicators of compliance. In doing so, EPA is in a better position to track compliance with all statutes at the facility level, and within specific industrial sectors.

A major step in building the capacity to compile multimedia data for industrial sectors was the creation of EPA's Integrated Data for Enforcement Analysis (IDEA) system. IDEA has the capacity to 'read into' the Agency's single-media databases, extract compliance records, and match the records to individual facilities. The IDEA system can match Air, Water, Waste, Toxics/Pesticides/Emergency Planning and Community Right to Know, Toxic Release Inventory, and Enforcement Docket records for a given facility, and generate a list of historical permit, inspection, and enforcement activity. IDEA also has the capability to analyze data by geographic area and corporate holder. As the capacity to generate multimedia compliance data improves, EPA will make available more in-depth compliance and enforcement information. Additionally, sector-specific measures of success for compliance assistance efforts are under development.

Iron and Steel Industry Compliance History

An overview of the reported compliance and enforcement data for the iron and steel industry over the past five years (August 1990 to August 1995) show that:

- *Eighty-five percent of iron and steel facility inspections occurred in regions where most facilities are located.*
- *Within these regions where iron and steel mills are concentrated, the proportion of state-lead enforcement actions was significantly greater than federal action with the exception of one region where enforcement actions were fairly evenly split between state-lead and federal-lead.*
- *Of the 275 facilities inspected over the five-year period examined, 115 had one or more enforcement actions (42 percent), however, the aggregate Enforcement to Inspection Rate across all Regions was 0.14 (499 enforcement actions/3,555 inspections).*

8.2.1 Developing Laws and Regulations that Can be Enforced

Once an environmental need is identified, the legislation and regulation must be developed in a way that can be enforced when required. This may require interpreting broad environmental laws with specific regulations, or providing feedback to legislatures to revise laws that are unenforceable.

8.2.2 Identifying the Regulated Community

A clear understanding is needed of who should meet the requirements of environmental laws or regulation, and to establish priorities based upon the degree of environmental consequences of possible violations, past good or bad company environmental management practices, and any incentives or barriers to compliance. This will likely require an inventory and information management system to identify and keep track of those companies or installations to be regulated.

8.2.3 Promoting Compliance

No compliance and enforcement programme can expect to be able to monitor compliance everywhere or detect and respond to all violations. Compliance promotion includes:

- disseminating information about environmental requirements to companies, relevant government bodies and public
- providing cleaner production information, education and technical assistance to companies
- building public awareness and support
- publicising success stories
- providing economic incentives and facilitating access to financial resources

8.2.4 Permitting or Licensing of Facilities

Once a plant has been identified, a permitting system enables environmental requirements to be tailored to the specific circumstances. This will require developing permit application procedures, processing applications, and issuing permits in co-ordination with other relevant government bodies.

8.2.5 Monitoring Compliance

There are four primary ways of monitoring a plant's compliance with environmental laws and regulations:

- formal site inspections by government or certified inspectors
- self-monitoring, record-keeping and reporting by the steel company itself
- community monitoring and citizen complaints
- sampling of the environmental conditions (air, water, soil) in the vicinity of a facility.

8.2.6 Responding to Violations

When a violation is detected, every compliance and enforcement programme must follow a hierarchy of enforcement responses, consistent with its socio-economic and cultural situation. They may involve taking administrative, civil, and criminal actions, meant to do one or more of the following:

- return violators to compliance
- impose a sanction
- remove the economic benefit of non-compliance
- correct environmental damages
- correct internal facility management problems.

Enforcement responses depend on the severity of the violation, and may involve, for example:

- issuing administrative and legal notices of violation;
- permanently or temporarily closing a facility or a cycle of operation within a facility;

- revoking a permit or refusing to renew a permit;
- conducting emergency response plans and procedures;
- seeking compensation for damage caused by the violation or for the cost of the cleanup;
- imposing a monetary penalty; seeking imprisonment and punitive damages or fines;
- seizing property;
- requiring community service to improve the environment.

8.2.7 Role of Negotiation

Negotiation is part of a process to achieve compliance and enables both the steel plant and the concerned party or parties to consider the correctness of the facts, the circumstances of the case, and the variety of alternative responses. Negotiation provides an opportunity to obtain additional information and correct misinterpretations before legal action is pursued. In addition, negotiation provides an opportunity to reach a solution that satisfies all parties. Negotiation can result in a co-operative effort to develop a satisfactory solution that is not intended to alter basic requirements for compliance.

8.3 VOLUNTARY/NEGOTIATED AGREEMENTS

Voluntary/negotiated agreements between governments, industry, and other stakeholders can be an effective way to change behaviour and to work alongside existing regulations. Governments can seek an agreement with an industry sector, an industry chain - for example, packaging - or even a group of industries generating similar waste. There can be agreements on a range of aspects,

Case Study — Reduction of Benzene Emissions in Canada

Following a challenge by the Federal Minister of Environment, all the integrated steel mills in Canada have voluntarily agreed to reduce benzene emissions. One producer, Dofasco, has agreed to reduce emissions to air of benzene by 80 percent by the year 2000. Currently, Dofasco emits about 450 tonnes of benzene annually.

In the challenge the Federal Government recognised that the two main sources of benzene in Canada were gasoline and natural gas dehydrators, but that they were keen to include other emitters, such as the chemicals and iron and steel industries, in multi-stakeholder consultations. It was hoped this would allow the most effective strategic options to continuously improve the management of toxic releases to be applied.

In order to determine how best to reduce the emission of benzene Dofasco developed an Accelerated Reduction and Elimination of Toxics (ARET) Action Plan. This plan was the result of a comprehensive assessment, based on actual emission surveys, and carried out by an independent consultant.

Based on the conclusions of this plan the following projects have been put forward and are expected to be complete in late 1996:

- *The installation of two light oil bottom loading facilities and a fugitive emission recovery system. These projects which total, CAN$5M, are expected to bring about a 50 percent reduction in benzene emissions on their own*
- *Pollution prevention improvements through procedural and equipment upgrades.*
- *Enhanced waste water treatment through agreements with the municipal treatment facilities.*

It is expected that these projects, whilst concentrating on benzene, will also bring about a reduction of other VOCs resulting from cokemaking.

This approach, whilst not wholly voluntary, allows for open discussions between regulators and industry concerning the various issues at stake (for example, reduction potential, targets, cost, means). In this way, the most appropriate solutions can benefit the environment, and the various stakeholders.

Case Study — Reduction of Greenhouse Gas Emissions in France

The French Federation of Iron and Steel Companies (FFA) signed an agreement with the Ministry of the Environment in December 1996 to improve energy efficiency and reduce emissions of CO_2, thereby assisting the French Government to meet its suggested targets under the United Nations Framework Convention on Climate Change (FCCC).

The UNFCCC calls upon developed countries to stabilise greenhouse gas emissions to 1990 levels by 2000. To achieve this, the French iron and steel industry presented the following objectives:

	Reference value 1990	Objective by 2000
Consumption of reducing agents and fossil fuel combustion	0.399 tep/t crude steel *	reduce by 15.8%
Consumption of electricity	0.549 MWh/t of crude steel *	increase by 5.9%
Emission of CO_2	1.462 t/t of crude steel *	decrease by 14.6%

* from continuous or ingot casting

FFA companies will reduce their annual emissions of CO_2 by 2.5 million tonnes if this agreement is reached, which is a 10 percent decrease of 1990 emissions. To ensure that this agreement is attained, the FFA is responsible to produce yearly reports on the amount of CO_2 emissions.

including for example energy efficiency, waste/emission reduction targets, environmental reporting, or deposit-refund schemes.

In general, industry likes the flexibility, control, predictability associated with negotiated agreements. For governments, less administrative time is usually required to monitor results. However, entering into an environmental contract through this kind of agreement may also imply a binding legal obligation.

8.3.1 Demonstration Projects

Governments can further persuade companies to improve environmental performance by making them aware of cleaner technologies through demonstration projects.

In many countries, it appears that businesses are driven predominantly by legislation in deciding when and how to react to environmental pressures. Many firms still regard environmental pressures as more of a threat than an opportunity. A demonstration project can go a long way to sell the concept of cleaner production by showing them positive examples. There are various ways to finance a demonstration project. In some cases the government covers all costs (sometimes shared among several ministries), and in others the project is jointly financed by participating companies.

8.3.2 Legislative Trends

An article - reproduced overleaf - from the Economist Intelligence Unit's fortnightly report entitled Business Europe, September 11, 1996 illustrates some of the trends taking place in Europe.

8.4 INTERNATIONAL, NATIONAL OR REGIONAL CONVENTIONS

The use of multilateral environmental agreements is increasingly being used to bring governments together to solve transboundary and global environmental problems. Once a convention is signed and ratified by a national authority, it must then be implemented through national or regional legislation. The principal international agreements which affect the iron and steel industry concern energy use, pollution to water, the transport and disposal of industrial waste, and trade in chemicals.

'Clearing the air'

Confronted with significant air pollution problems, particularly in urban areas, the European Union is conducting a major overhaul of legislation on air quality. Two key directives are likely to be adopted before year-end, with others in the pipeline. And the Commission is considering the use of taxes and charges to help reduce emissions.

While keeping an eye on new pollution control proposals, companies should also be considering how climatic changes—in particular global warming affect their business operations.

A new framework directive

Existing European measures aimed at improving air quality have tended to focus on controlling major pollutants such as sulphur dioxide, suspended particulate matter and lead. The Commission believes that these measures are not achieving the desired results quickly enough.

Furthermore, information on air quality collected in the Member States is not always comparable or reliable. This makes it difficult for policymakers to know what action is needed. Hence, the Commission began an overhaul of the EU's approach to improving air quality by proposing a framework directive on the assessment and management of ambient air quality. Its proposal, tabled in 1994, is to be adopted soon.

The forthcoming directive will establish a framework for setting air quality targets for 13 priority pollutants. This will significantly extend the number of pollutants for which air quality targets are currently set at the EU level.

Member States will be obliged to introduce measures to ensure that emissions from industrial installations, power plants and other sources of pollution are reduced so that the overall quality targets for the specified substances can be met.

Under the framework, the Commission will propose so-called daughter directives setting quality standards for the priority pollutants, including sulphur dioxide, nitrogen oxide, suspended particulate matter, carbon monoxide and various heavy metals. These proposals are to be brought forward in accordance with a specified timetable over the next three years.

Air quality targets for sulphur dioxide, nitrogen oxide and lead, for example, are due to be proposed before the end of this year. Where appropriate, alert thresholds will also be established: when these thresholds are exceeded, the public will have to be informed.

The Directive will also establish a uniform system for the assessment and management of air quality throughout the EU. This is essential to enable regulators to determine what type of emissions controls are necessary and appropriate.

More controls on the way

The Union has recently taken a number of initiatives to tighten controls on emissions of substances which produce increased levels of groundlevel ozone (the cause of summer smog)—in particular, volatile organic compounds (VOCs).

A stage I directive on VOCs was adopted in 1994, to control the release of these invisible fumes during the storage of petrol. A possible stage 2 directive, currently being discussed within the Commission, would control emissions during petrol refuelling operations.

Also in the pipeline is a further directive concerning the use of organic solvents, which contain VOCs, in various industrial processes.

Source: Business Europe, 11 September 1996, The Economist Intelligence Unit Ltd.

8.4.1 Climate Change

After a long process of scientific research on the problem, and national consultations on policy options to address these, governments around the world agreed during the 1992 Rio summit on a UN Framework Convention on Climate Change (UNFCCC). This Convention entered into force in March 1994. In May 1997, the UNFCCC had over 130 signatory countries.

Further research into climate change mechanisms is ongoing, although the results in recent years seem to confirm the earlier conclusions that the accumulation of additional greenhouse gases will lead to potentially serious disturbance of our atmosphere. UNEP and the World Meteorological Organization (WMO) have been at the forefront of this work, and played a leading role in bringing the UNFCCC into being.

The Convention requires national administrations to provide a framework of regulations and policies to implement the various provisions of the Convention. Some reduction targets for countries have already been adopted. The recent tendency of many countries to rely more heavily on economic instruments to implement such policies has led to the option of CO_2, energy or carbon taxes being extensively debated. However, carbon dioxide is not the only greenhouse gas, and the various sources of greenhouse gases involve many industries and activities in society. Power generation and industries like steelmaking are clearly a major source of CO_2 emissions and options for reduction have to take into account the immediate and long-term economic impacts such measures would have, as well as their environmental objectives.

In any control programme, there will clearly be a differential effect on the competitiveness of various industry sectors and companies. This will provide both challenges and opportunities for companies, with a significant new market in energy-efficient technologies and products, and relative financial gains for those able to make in-house improvements in energy efficiency or substitution.

The policy position of various industry sectors reflects the complex situation described above. Although the Precautionary Principle adopted in the Rio Principles is acknowledged by industry at large, the level of scientific certainty needed before taking costly actions has been a divisive question between governments, non-governmental organisations, members of the scientific community, and industry. The iron and steel industry, through IISI, believes that further scientific work is needed to establish more clearly the causes and effects of any global warming and in particular the effects of proposed CO_2 reduction measures. In its position on the UNFCCC, the IISI (contrary to UNEP) suggests that other issues have higher priority today, and that the imposition of energy taxes could result in greater emissions through the resulting distortion in international trade. Instead, the industry proposes a greater use of voluntary programmes and incentives for energy efficiency.

8.4.2 Transboundary Movement of Hazardous Wastes

The Basel Convention was adopted on 22 March 1989 and came into force on 5 May 1992. The aim of the Convention is to reduce and strictly control the transboundary movement of hazardous wastes, and ensure that these wastes are disposed of in an environmentally sound manner. Transboundary movements of hazardous wastes carried out in contravention of the provisions of the Convention are to be considered illegal traffic and a criminal act.

At the Second Meeting of the Parties to the Convention a decision was adopted to immediately prohibit the export of all transboundary movements of hazardous wastes which are destined for final disposal from OECD to non-OECD states. It was also decided to prohibit the movement of hazardous wastes for recycling or recovery operations from OECD to non-OECD states after 31 December 1997.

The definition of what constitutes a hazardous waste under the Convention is subject to different interpretations but the definition is very broad and there was a high risk that trade in ferrous scrap would be included. This issue has been debated in the IISI Secretariat's Technical Working Group and it has been recommended that clean ferrous scrap should not be considered hazardous.

8.4.3 Others

In order to prevent the shipment of dangerous chemicals to countries not equipped to handle them safely, UNEP developed the London Guidelines on International Trade in Chemicals. The "prior informed consent" (PIC) procedures emphasise the pre-notification between exporting and importing countries before commencing the shipment of certain chemicals. Although these are largely pesticides for the moment, a number of industrial chemicals are listed, and the industry should remain aware of the procedure and the further listing of other chemicals in the future. The PIC procedure is expected to be transformed into a legally binding international agreement in 1997/1998.

Although not subject to legal procedures, the UN compilation "Consolidated List of Products whose Consumption and/or Sale Have Been Banned, Withdrawn, Severely Restricted or not Approved by Governments" is a useful guide to chemicals whose hazardous effects have given rise to concern in various parts of the world.

The Montreal Protocol on Substances that Deplete the Ozone Layer, and its subsequent amendments, limit the production and consumption of chemicals that deplete the stratospheric ozone layer. Developed countries have already stopped their production of halons (by January 1, 1996) and CFC, carbon tetrachloride and methyl chloroform (by January 1 1996). The lack of availability of these substances, coupled with the rapid development and commercialisation of alternative technologies and chemicals, has resulted in many companies having already made the successful transition away from ozone depleting substances. The remaining companies are encouraged to act now to identify, develop and introduce alternative products and technologies.

The Paris Convention for the Prevention of Marine Pollution has elaborated a general definition on Best Available Techniques (BAT) for limiting pollution. Although the jurisdiction of the Convention is restricted to countries bordering the North Sea, it has become a useful guide for other regions. The Paris Commission (PARCOM) is working on the definition of BAT for the steel industry. This includes the development of BAT guidelines and establishing emission limit values for iron and steel production.

While not yet subject to international conventions, the transfer of outdated and polluting production technologies or of hazardous technologies to developing countries is coming under increasing scrutiny by international organisations. Notification schemes similar to those applying to chemicals or wastes have often been proposed without however having been introduced to date.

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About the UNEP Industry and Environment Centre

Introduction

The Industry and Environment centre was established by UNEP in 1975 to bring industry and government together to promote environmentally sound industrial development. UNEP IE is located in Paris. Its goals are to:

1) Encourage the incorporation of environmental criteria in industrial development plans
2) Facilitate the implementation of procedures and principles for the protection of the environment
3) Promote the use of safe and clean technologies
4) Stimulate the exchange of information and experience throughout the world.

UNEP IE provides access to practical information and develops co-operative on-site action and information exchange backed by regular follow-up and assessment. To promote the transfer of information and the sharing of knowledge and experience, UNEP IE has developed three complementary tools: technical reviews and guidelines; *Industry and Environment;* - a quarterly review, and a technical query-response service. In keeping with its emphasis on technical co-operation, UNEP IE facilitates technology transfer and the implementation of practices to safeguard the environment through promoting awareness and interaction, training and diagnostic studies.

Some Recent UNEP IE Publications

Industry and Environment (quarterly) deals with issues relevant to industrial development, such as auditing, waste management industry-specific problems, environmental news.

Industry & Environment Emission Standards & Guidelines Information Clearinghouse (IE-ESGCGIC) Vol. IIIa Iron & Steel Air Emission Standards, Vol. IIIb Iron & Steel Industry Effluent Discharge Standards, UNEP IE, 1996

Life Cycle Assessment: What it is and How to do it, 92 p, 1996

Monitoring Industrial Emissions and Wastes (Technical Report Series No. 27), ISBN 92-807-1434-1, 131 p, 1996

Audit and Reduction Manual for Industrial Emissions and Wastes (Technical Report Series No.7), UNEP/UNIDO ISBN 92-807-1303-5, 127p., 1991.

Environmental Management System Training Resource Kit - a joint UNEP, ICC, FIDIC publication, 400 p, 1995

Company Environmental Reporting (Technical Report Series No.24), ISBN 92-807-1413-9, 118 p., 1994.

Health Aspects of Chemical Accidents. Guidance on Chemical Accident Awareness, Preparedness and Response for Health Professionals and Emergency Responders (Technical Report Series No.19) - a joint IPCS/OECD/UNEP/WHO publication: also published as OECD Environment Monograph No. 81), 147p., 1994.

APELL - Awareness and Preparedness for Emergencies at Local Level - A Process for Responding to Technological Accidents, 63p., 1988.

Hazard Identification in a Local Community (Technical Report Series No. 12), ISBN 92-807-1331-0, 86p., 1992.

Cleaner Production Worldwide Vol. II, ISBN 92-807-1444-9, 48p., 1995.

Government Strategies and Policies for Cleaner Production, ISBN 92-807-1442-2, 32p, 1994.

Industry Environmental Compliance Training Manual (Technical Report Series No. 36), ISBN 92-807-1565-8, 158 p, 1996

From Regulations to Industry Compliance: Building Institutional Capabilities (Technical Report Series No.11), ISBN 92-807-1342-X, 62p., 1992.

Companies Organization and Public Communication on Environmental Issues (Technical Report Series No. 6), ISBN 92-807-1304-3, 130p., 1991.

Case Studies Illustrating Environmental Practices in Mining and Metallurgical Processes, a joint UNEP/ICME publication, 61p., 1996.

Environmental Management of Nickel Production (Technical Report Series No. 15), 90p., 1993.

Environmental Aspects of Selected Non-Ferrous Metals (Cu, Ni, Pb, Zn, Au) Ore Mining (Technical Report Series No. 5), a joint UNEP/ILO publication, 116p., 1992.

Environmental Aspects of the Metal Finishing Industry (Technical Report Series No. 1), 91p., 1989.

Mineral Fertilizer Production and the Environment (Technical Report Series No. 26), a joint UNEP/UNIDO/IFA publication, 150p., *1996.*

UNEP IE Cleaner Production Programme

The Cleaner Production (CP) Programme was launched in response to a decision of the UNEP Governing Council on the need to reduce global industrial pollution and waste.

The objectives of the Programme are to:

- increase worldwide awareness of the CP concept;
- help governments and industry develop CP programmes;
- foster the adoption of CP; and
- facilitate the transfer of CP technologies

The Programme contains five main elements:

publications;

- training and technical assistance;
- working groups;
- the International Cleaner Production Information Clearinghouse (ICPIC) - E-mail icpic@unep.fr; and
- National Cleaner Production Centres.

Further Information

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About the International Iron and Steel Institute

Introduction

The International Iron and Steel Institute (IISI) was the first international industry association dealing solely with one industry. Founded in 1967 with headquarters in Brussels, Belgium, IISI is a non-profit research organisation which serves as a world forum on various aspects of the international steel industry.

IISI members are steel-producing companies and national and regional steel industry associations, federations and research institutes in 51 countries. The countries in which IISI steel-producing member companies are located produce over 70 percent of total world steel production. Membership has increased steadily since IISI's founding; nearly all the world's major steel producers are members of the Institute. Included are both publicly and privately owned enterprises using the basic oxygen or electric arc process routes.

IISI Committes and Policy Groups undertake initiatives to increase cooperative efforts within the international steel industry. Recent work related to the environment has focused notably on the development of a Life Cycle Assessment project to demonstrate steel's life cycle credentials. The Environment Policy Group publishes agreed common policy positions on environmental issues important to steel for members' guidance.

The International Iron and Steel Institute is recognised as an invaluable source of information concerning the steel industry worldwide, by industry analysts, international media, the United Nations, universities and research institutes and all others involved in following developments within the field of engineering materials. It provides the fastest and most comprehensive service on steel production and trade statistics and publishes authoritative reports on all aspects of the industry.

IISI Publications Related to the Environment, Health and Safety

IISI Position Statement on Wastes (1995); IISI Position Statement on the Basel Convention on the Trans-boundary Movements of Hazardous Wastes and their Disposal adopted by the IISI Board of Directors in October 1995.

IISI Policy Statement on Life Cycle Assessment (1995); Statement on LCA adopted by the IISI Board of Directors in April 1995. States the IISI position on life cycle assessment studies and includes a list of practical guidelines for those undertaking or using life cycle assessment.

IISI Statement of Environmental Principles (1992, Reprint 1996 in 5 languages); Statement on the Environment adopted by the IISI Board of Directors in April 1992. Sets out the principles that lead to environmental excellence in the operations of the steel industry. Text in English, French, Japanese, Spanish and Russian.

Environmental Control in the Steel Industry (1992); Over forty papers originally scheduled to be delivered at the first ENCOSTEEL Conference on Environmental Control in the Steel Industry, cancelled in 1991. 625 pages.

Preparing the Future: Towards a Better Environment (1993); A 20-page full colour brochure on the importance of steel in environment-friendly systems for air and water, and for energy and resource saving. Emphasises new steels, and recycling. Available in English, and from national steel associations in French, German, Japanese and Korean.

Health and Safety Series; A series addressing major health and safety issues in the steel industry:

- *Bringing Chemicals into Steelworks; A Good Practice Guide* (1993); Practical background information and advice on the potential hazards, precautions and standards associated with introducing chemicals into steelworks. Primarily addressed to works managers and supervisors, and occupational health and safety professionals.

- *Safeguarding Hearing in the Steel Industry* (1992); Gives an outline programme developed from the experience of many countries to assess the problem of noise in steelworks and the measures to be taken to control it.

IISI Publications Related to Technology and the Environment

IISI regularly publishes technical reports dealing with technology and environmental issues: some of these have been used in the production of this report. For a full list of publications available, contact IISI Library Services (see below).

Further Information

For further information on the activities of the International Iron and Steel Institute, please contact: Secretary General, International Iron and Steel Institute, 120 Rue Colonel Bourg, B-1140 Brussels, Belgium. Tel.: [32/2] 702 89 00. Fax: [32/2] 702 88 99. E-mail: steel@iisi.be.
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