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UNITED NATIONS
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(UNEP)

ENVIRONMENTAL MANAGEMENT IN THE IRON AND STEEL INDUSTRY

Sectoral Working Paper Series

No. 50

Prepared by the
Industry and Environment Office
United Nations Environment Programme (UNEP)

SECTORAL WORKING PAPERS

In the course of the work on major sectoral studies carried out by UNIDO, Studies and Research, several working papers are produced by the secretariat and by outside experts. Selected papers that are believed to be of interest to a wider audience are presented in the Sectoral Working Papers series. These papers are more exploratory and tentative than the sectoral studies. They are therefore subject to revision and modification before being incorporated into the sectoral studies.

Foreword

This document was prepared by the Industry and Environment Office of UNEP in co-operation with UNIDO. It forms part of the 1986/87 work programme of Sectoral Studies (programme element 3.14, environmental studies). The study presents: (a) a technical assessment of environmental problems in the iron and steel industry; and (b) guidance for developing countries in how to best manage those problems.

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The following annexes are not included in this document but are available from UNEP. Interested persons are invited to write to:

Industry and Environment Office
UNEP
17, rue Marguerittе
75017 Paris
France

Annex 1 Emission control technology on coke ovens, CDQ and others
Annex 2 Retrofitting of self sealing doors to 5 meter coke oven batteries
Annex 3 Casthouse dedusting system of the blast furnace number 3 of CSN
Annex 4 Retrofitting of an emission control system of a BOF-shop

GLOSSARY OF TERMS

Ascension pipe (p.22)		A curved pipe which connects the coking chamber with the dry main which collects the gas generated in the coking chamber and leads them to the COG refining equipment for further processing. It is usually installed at the side of the machine. (see Fig. 5 in ANNEX 1, p.11)
Ascension pipe ejector (p.21)		Ejector using high-pressure gas liquor sprayed from a nozzel which is installed in the ascension pipe and ejects the emissions generated in the coke chamber.
COG	(p.24)	Coke Oven Gas
FOSBEL CWP	(p.22)	FOSBEL : Name of a Belgian company CWP : Ceramic Welding Process
IISI	(p.33)	International Iron and Steel Institute
LAVA FLAME	(p.22)	Name of process developed by Kurosaki Yogyo in Japan
LPG	(p.22)	Liquified Petroleum Gas

RECOMMENDATIONS

1. Top management should have a sound policy regarding the protection of the environment and workers' health and safety. This policy should be integrated into the activities of the whole workforce with an appropriate allocation of resources and be monitored periodically.

2. A target or standard for environmental control should be developed jointly by the government or control authority with senior management of the company according to the characteristics of the iron and steel works and specific local environmental conditions of the plant site. These standards should be site specific.

3. In plant site selection, socio economic factors and environmental factors such as : assimilative capacity of the environment, buffer zones, land for solid waste disposal, etc. also need to be considered.

4. Environmental impact assessment is indispensable for the final selection between possible alternatives of the plant sites and the designs of plant facilities.

5. Technologies for environmental control have been well developed and are available. It only remains to select the right technology to suit the specific conditions. Pollution control facilities should be designed and operated as an integrated part of the production facilities.

6. Governments are encouraged to explore every possible means to encourage the iron and steel industry to use the best practicable pollution control technologies.

7. The environment should be monitored regularly to ensure the efficient operation of control methods.

8. Satisfactory environmental and health and safety control can only be achieved through the correct operation and good maintenance of production and pollution control facilities.

9. Disciplined behaviour on the part of the workforce is also an essential element in achieving good environmental and health and safety standards. Continuous education and training of staff and workers is therefore indispensable in order to establish and maintain these standards.

10. UNIDO and UNEP should ensure wider dissemination in developing countries of guidelines on ways of reducing adverse environmental impacts of the iron and steel industry. Information should include:

    (a) New technologies and their environmental implications.

    (b) New environmental control technology.

(c) Retro-fitting of pollution abatement equipment to older plants.

(d) Solid waste disposal

(e) Development of legal and regulatory measures. The management of iron and steel firms in developing countries should be reached through this information campaign.

1. Activities of the Industry and Environment Office of the United Nations Environment Programme (UNEP)

The Industry and Environment Office of UNEP was established in Paris in 1975 and has operated an on-going consultation, using the expertise of governments, industry and relevant international institutions, on the environmental aspects of specific industrial sectors including the agro-industry, aluminium, chemicals, iron and steel, motor vehicles, non-ferrous metals, petroleum, pulp and paper and tourism.

Within the context of this consultative process, a workshop was held in Geneva in October 1978 on the environmental aspects of the iron and steel industry. Proceedings of this workshop were published in 1980.[1]

With a view to making more widely known the environmentally related issues associated with steel making, and drawing on the material gathered for the workshop and using other information subsequently made available, the UNEP Secretariat has prepared two publications, namely an overview and a technical review. The overview, directed towards the environmental policy makers in governments and industry, summarises the decision and policy aspects regarding environmental impact of the iron and steel industry. The overview was published in March 1985.[2]

The technical review, prepared to support and supplement the overview, deals with the technical aspects of environmental management in steel making. It covers primarily the air and water pollution, solid waste and noise problems associated with new integrated steel works based on the classical production route. The technical review will be published by the end of this year.[3]

In April 1982, UNEP and UNIDO held a Meeting of experts on the Environmental and Resource Aspects of the Direct Reduction Route to Steel Making. The meeting took place in Puerto Ordaz, Venezuela, by kind invitation of the Venezuelan authorities. Thirty seven experts from six countries and three international institutions took part and discussed and exchanged information on environmental issues of the Direct Reduction Route to Steel Making. Environmental Guidelines for the Direct Reduction Route to Steel Making were also drafted. A Record of the meeting was distributed to all participants.

As follow-up activities to that meeting, a Technical Review document on Environmental Aspects of the Direct Reduction Route to Steel Making [4] and Environmental Guidelines for the Direct Reduction Route to Steel Making[5] were published by UNEP in 1983.

UNEP has devoted three issues of its "Industry and Environment" review to the Iron and Steel Industry since the last workshop in 1978, viz.:

"The Iron and Steel Industry and the Environment", published in 1978, [6];

"The Iron and Steel Industry and Resources Recycling", published in 1982, [7]; and

"Environmental Aspects of the Direct Reduction Route to Steel Making" published in 1985 [8].

In 1985, the first meeting of the UNEP Environmental Consultative Committee on the Iron and Steel Industry was held on 28 and 29 March at ILO Headquarters, Geneva [9].

The meeting benefited from the active participation of representatives from ten iron and steel companies, seven senior government officials from six countries, five United Nations bodies and the International Iron and Steel Institute.(IISI)

The issues discussed included retro-fitting of pollution abatement equipment to older plants, newly developed environment control technology, solid waste disposal, and development of legal and regulatory measures. An extensive background document, "Review of Emission Factors and Control Costs World-wide" was prepared and submitted by the secretariat [10].

One of UNEP's goals is to provide guidelines on ways of reducing adverse environmental impacts of industry. These are intended to assist policy makers and those involved in decisions on environmental issues. The first draft of the UNEP Guidelines for Environmental Management of Iron and Steel Works is now circulating among experts in Government, industry and related international organizations to seek comments and suggestions. The secretariat intends to finalize this document by the end of this year [11].

2. Environmental Management and Management Policy in General

Industrialization is mandatory for developing countries in order to create the economic growth necessary to increase the quality of life for the population as a whole. Developed countries also need growth to fulfill the basic needs of population. Industrial activities lead to a greater or lesser extent to an impact on the natural environment. At the same time, our spaceship, the earth, is unique and indispensable. Consequently, we need to protect and improve the human environment for present and future generations, because it is the resource base on which development depends.

The environment cannot and need not be totally shielded from change. However, that change should be limited within tolerable bounds. UNEP believes that industrialization can be made compatible with protection of the environment.

UNEP promotes "sustainable development", which it believes will only be achievable with proper environmental management.

Past experience has demonstrated that prevention is less costly than remedy where pollution is concerned. Ignoring environmental issues has caused several tragedies, with irremediable damage to human health in some countries. Nobody wants to see a repetition of such tragedies in any developing country.

At the World Industry Conference on Environmental Management (WICEM) held in Versailles, France, 14 - 16 November 1984, world industry endorsed the following principles.

(a) Sustainable economic development is an essential international goal. Environmental management should be an integral part of economic development. Environmental issues should be addressed in the earliest stages of the economic planning and development process. Special recognition should be given to the environmental problems created in urban areas by unchecked migration from rural areas.

(b) Economic growth can be made compatible with environmental protection.

(c) Cost/benefit analysis is, despite its limitations, an essential element of environmental decision making. The cost/benefit system should be improved to attempt to quantify the value of critical elements in our cultural heritage.

(d) There is not only the direct cost of environmental protection that has to be considered, but also the cost of damage to society as a whole.

(e) An anticipatory and preventive approach to the threat of environmental degradation is preferable to correcting environmental problems after they have occurred.

In principle, nobody denies the necessity of environmental control. However, as there are so many constraints, it is not easy to put into practice. But even limited consideration is better than none at all.

Pollution control technology is now well developed and only needs to be learned and selected by and transferred to those who need it.

However, the key to effective environmental management is "awareness" and "consciousness" of the issues, i.e. of "potential risks and problems" by top government officers and top management of industry.

Top management of industry should consider environmental protection as one of the company's most important social responsibilities and an important aspect of management.

Top management should have a sound policy and strong "conviction" to protect the environment and this "conviction" should be put into practice through the works manager and middle management into the daily activity of engineers, staff, foremen and workers in the plant. Only top management can provide the resources, such as money and manpower, for the protection of the environment. WICEM recommendation number 14 embodies this thinking: "To strengthen the anticipatory and preventive approach to environmental management within industry, each line manager from the chief executive down should also think of him or herself as an environmental manager. Clear accountability for environmental performance should accompany managerial responsibility in each case". The resources available can be utilized most effectively, and good environmental control can be achieved, only when all the employees in plant and works have the same understanding of environmental issues, and do their best under the management's basic policy to ensure effective environmental protection.

3. Outline of the Iron and Steel Industry

3.1 The Size of the Iron and Steel Industry

Throughout the world more than 700,000,000 tonnes of crude steel are produced annually. In industrialized societies ten to thirteen percent of the energy consumed is used in steelmaking. The pervasive nature of the steel industry is readily appreciated by looking at the figures for world steel production and consumption in recent years as summarized in Table 1, 2 and Figure 1.

3.2 Production Process and the Structure of the Iron and Steel Industry

The iron and steel industry involves a number of different industrial complexes and successive manufacturing stages, e.g.

3.2.1 Mining

Major mining operations for iron ore and coal; mining activities of some importance for silica, manganese, nickel and chromium ores, and other components for alloys; and the winning of limestone and industrial minerals for the manufacture of fluxes and refractories.

3.2.2 Preparation of raw materials

The operations of transportation; stockpiling; blending; coal washing; ore beneficiation; screening; coke making; the manufacture of pellets and sinter; the burning of limestone and the fabrication and firing of refractories; and the recovery of scrap.

3.2.3 Ironmaking and alloy manufacture

The production of liquid or solid iron and alloys, i.e. the manufacture of direct reduced iron by fluid bed, shaft or kiln processes;

Table 1. Apparent steel consumption, 1979-1984

	1979	1980	1981	1982	1983	1984
Japan	78.5	78.8	72.3	70.0	66.3	73.8
EEC	113.9	108.2	99.1	91.4	90.0	94.1
Other Western Europe	30.9	32.1	31.4	30.5	29.6	30.0
United States	142.6	118.4	128.2	92.1	96.0	114.3
Canada	14.9	13.8	14.4	10.5	11.3	13.1
Republic of South Africa	5.5	6.4	6.6	5.8	5.3	5.6
Oceania	7.3	7.2	7.4	6.8	5.8	6.9
Total industrialized countries	393.6	364.9	359.4	307.1	304.3	337.8
Latin America	32.5	36.8	34.3	29.3	23.3	28.1
Africa, except Republic of South Africa	9.4	10.7	11.1	11.1	12.2	12.3
Middle East	16.7	15.9	16.3	16.9	18.7	17.9
Asia, except Japan, PR of China and DPR of Korea	38.1	40.4	43.1	44.4	45.5	47.5
Total developing countries	96.7	103.8	104.8	101.6	99.7	105.8
USSR and Eastern Europe	211.3	209.6	205.9	204.6	211.0	215.0
PR of China and DPR of Korea	50.9	49.5	45.3	48.1	57.0	61.5
Total centrally planned economies	262.3	259.1	251.3	252.7	268.0	276.5
Total World	752.6	727.8	715.5	661.4	672.0	720.1
Unallocated	-6.1	-11.8	-7.9	-16.4	-8.8	-10.2
World crude steel production	746.5	716.0	707.6	645.0	663.2	709.9

Source: IISI (International Iron and Steel Institute).

Table 2. The major steel producing countries and areas, 1983 and 1984
(million metric tons crude steel production)

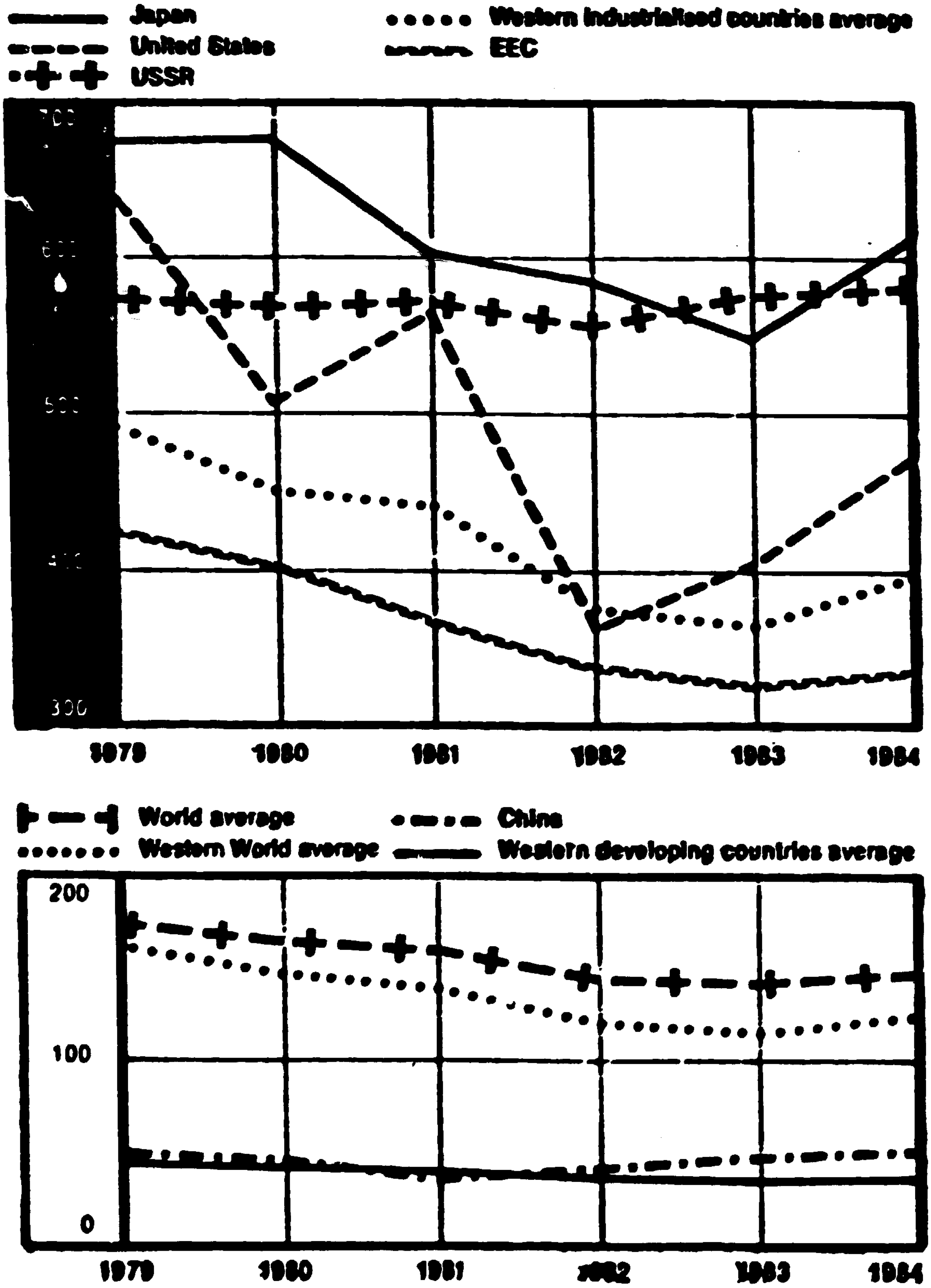
Country	1984 Rank	1984 Tonnage	1983 Rank	1983 Tonnage
USSR	1	154.3	1	152.5
Japan	2	105.6	2	97.2
United States	3	83.9	3	76.8
People's Republic of China	4	43.4	4	40.0
Federal Republic of Germany	5	39.4	5	35.7
Italy	6	24.0	6	21.8
France	7	19.0	7	17.6
Brazil	8	18.4	11	14.7
Poland	9	16.6	8	16.2
United Kingdom	10	15.1	10	15.0
Czechoslovakia	11	15.0	9	15.0
Canada	12	14.7	13	12.8
Romania	13	14.3	12	12.6
Spain	14	13.5	14	13.0
Republic of Korea	15	13.0	15	11.9
Belgium	16	11.3	17	10.2
India	17	10.5	16	10.2
Republic of South Africa	18	7.7	19	7.0
Democratic Republic of Germany	19	7.5	18	7.2
Mexico	20	7.5	20	6.9
Democratic People's Republic of Korea	21	6.5	21	6.1
Australia	22	6.2	22	5.6
Netherlands	23	5.7	24	4.5
Taiwan Province of China	24	5.0	23	5.0
Austria	25	4.9	25	4.4
Sweden	26	4.7	26	4.2
Turkey	27	4.3	28	3.8
Yugoslavia	28	4.2	27	4.1
Luxembourg	29	4.0	30	3.3
Hungary	30	3.8	29	3.6
Bulgaria	31	2.8	32	2.8
Venezuela	32	2.7	34	2.3
Finland	33	2.6	33	2.4
Argentina	34	2.6	31	2.9
Others		15.1		13.6
World total		709.9		663.2

Note: This table lists all countries producing more than two million metric tons of crude steel in 1984.

Source: IISI - International Iron and Steel Institute, 1984.

FIGURE 1

APPARENT STEEL CONSUMPTION PER CAPITA
1979 TO 1984
(kilograms crude steel equivalent)



Source: IISI (International Iron and Steel Institute) the use of the blast furnace to make pig iron (for foundry use) and liquid hot metal (for steelmaking); and the use of electric furnaces to smelt ferro-alloys.

3.2.4 Steelmaking

The manufacture of steel, usually in basic oxygen vessels (BOS) or in electric arc furnaces (EAF). In some countries flame combustion processes (e.g. the open hearth furnace) are used.

3.2.5 Making of semis

The transformation via solidification, casting (ingot casting or continuous casting), rolling or forging of steel products to make semis, which pass on to other manufacturing stages or are sold to other processing companies.

3.2.6 Hot rolling

The inspection of semis for internal and surface quality; their preparation, reheating and hot rolling or shaping to make heavy sections (e.g. plates, structurals, rails). Much steel is sold at this stage to final customers.

3.2.7 Cold forming and rolling

Fabrication of hot rolled products to make light angles or sections; cold drawing or twisting to make wire products; cutting or machining for engineering use; or cold rolling to bright sheet. Products largely are sold at this stage.

3.2.8 Coating

Covering with metallic or plastic materials certain hot or cold formed products for direct sale.

3.2.9 Manufacture of steel-based products

The forming, assembling, painting, enamelling or coating of cold rolled, drawn or shaped products to make goods which are sold.

3.2.10 Waste handling

The recycling, preparation for sale or disposal of residues.

Figure 2 illustrates the flow of materials and production processes involved in an Integrated Iron and Steel Works.

4. Environmental Problems and Pollutants and their Sources.

4.1 Emissions to atmosphere

4.1.1 Dust, fume and steam

Granular particulates are generated in mining, crushing and screening operations. They are spread during transportation, are released at points of belt transfer or are blown by winds from storage heaps and blending beds.

The high temperatures generated, for instance in high-intensity oxygen steel refining processes or in electric arc discharges in electric steel making, create very large quantities of fume which can only be controlled effectively by well engineered facilities.

The wet quenching of coke leads to high emissions of steam to atmosphere. Unless efficient grit arrestors are placed in the quench tower the operation is also accompanied by dispersal of relatively coarse dusts.

Presence of oil in scrap in electric arc furnaces and in mill scale returned in sinter plants can result in heavy visible emissions. Dust loadings in gases passing to the sinter plant exhaust stacks can also be appreciated.

4.1.2 Acid emissions

Substances such as oxides of nitrogen and sulphur (NOx, SOx), and fluorides and chlorides (F^-, Cl^-) may appear as air pollutants, since they are present in materials being heated or burnt, or in the air used in high temperature combustion. As indicated, the steel industry is a significant user of energy so considerable quantities of such substances can be emitted.

Given the concern in certain countries that acid rain may contribute to damage to inland water systems in cold climates and to forests these emissions are of current interest and the extent of control required is a matter of controversy.

4.1.3 Fugitive emissions

While primary collection systems handle about 99% or more of the total fume and dust generated in steelmaking small proportions escape as fugitive emissions particularly during intermittent operations such as charging and tapping, and these have to be controlled. Pouring and alloying operations for molten iron, steel and slags also lead to releases of fume mainly iron oxide but graphite (kish), soot and silica may also appear.

Another major source is the coke oven. In charging, dusts can escape, and on pushing coke coarse grit can be emitted to the atmosphere. If the charge is not fully coked high quantities of dense smoke may be generated.

Emissions from ovens being coked and certain emissions from coke ovens by-product plants may cause health problems. In particular, benzo-alpha-pyrene (BaP) is a polynuclear aromatic hydrocarbon representative of a group known to be carcinogenic. Analysis of these materials in the neighbourhood of coke ovens and monitoring of benzene emissions are advisable and should be a continuing concern of plant managements.

4.1.4 Toxic gases.

Large quantities of toxic carbon monoxide are produced in the processes of combusting carbon with oxygen to refine pig iron into steel. Carbon monoxide also comes from the blast furnace, and can sometimes in low concentration be found in gases from sinter plants. CO is recovered for its energy value (except from sintering) or is burnt to CO_2. By-product coke ovens gas contains CO and H_2. Care must be taken in its distribution and use.

Products of combustion can asphyxiate and must be vented. Similarly care is required in ventilation when N_2, Ar or natural gas are used.

4.2 Water pollution

For many operations within the steelmaking complex, waters are used in direct contact with toxic or foul materials, e.g. cooling and purification of coke oven gas can lead to pollutants such as tar oils, ammonia, phenols, cyanides, thiocyanates and thiosulphates entering the water system. The water requires extensive purification before it can be recycled or discharged to the environment or to local sewage treatment stations.

Cooling and cleaning waters in contact with gases from the blast furnace can become laden with cyanides, fluorides, lead and zinc compounds and dust particles. Waters from fume cooling and cleaning in steelmaking furnaces may carry particulates, fluorides and zinc compounds.

In continuous casting, scale and lubricating oil and hydraulic fluids can contaminate the water. Similar materials are problems in the effluents from rolling mills and from scarfing operations.

Indirect cooling waters require treatment to prevent fungal or baterial growths, and corrosion in water circuits. The chemicals used must be removed before the waters are released to the environment.

4.3 Solid wastes

These include materials rejected as waste from coal washeries, slag, dusts recovered from the cleaning of gaseous effluents, sludges from chemical treatment circuits, mill-scale, used refractories, oil and grease residues, waste by-products from coking and discarded tools and equipment.

Where these cannot be sold or recycled they must be dumped. Considerable quantities of material are involved and the establishment and maintenance of land disposal areas can create problems. There are also possible dangers of the dump leaching at a later stage to release effluents containing hydrocarbon residues, soluble salts, sulphur compounds and toxic heavy metals.

4.4 Noise and vibration

Noise within steel plants is not generally as high as in many other mechanical working operations. There are some sources of noise pollution e.g. sinter plant fans, the snort valve in the blast furnace, ultra high power (UHP) electric arc furnaces and certain burners. The noises of metal rubbing against metal in mills and on processing lines can be disturbing. Truck and rail movements can be quite loud.

4.5 Occupational health

Most environmental problems interlink with concerns for the health of the workforce. For example, noise in the workplace implies that personnel should undergo testing for hearing quality before commencing work in such areas, should be issued with protective equipment and should regularly be tested for the effects of exposure so damage, should it occur, can be limited. Means of reducing noise intensity should actively be sought. Similar provisions apply to hazards such as toxic gases, lead, asbestos, solvents, heat stress and equipment associated with repetitive strain injury. However, the most care should be taken to protect workers from coke oven fume which contains carcinogenic polycyclic organic matters.

Table 3 summarizes the environmental problems outlined above and indicates those sectors of the Industry in which they are of importance. Figure 2 also shows sources of each pollutant in the process of iron and steel production.

4.6 Control and Emission Factors

Most of the above problems can be solved. In certain cases, however, the complexity, size and the long depreciation time expected of steel plant make it difficult to achieve economic answers. As in other industries technology changes frequently lead to improvements in environmental control. Table 4 indicates semi-quantitatively (since the levels of emission and control differ from plant to plant) the amounts of pollutants emitted.

Although there might be many difficulties and limitations, it had been felt to be worthwhile making a study for the policy and decision-makers in Government and industry of emission factors from principal pollutants and nuisances, and the relevant control costs in the iron and steel industry. A study of this kind had been carried out by OECD in 1977 but had not been up-dated since then. UNEP consultant Mr. Raguin had written a 170-page report on this subject entitled "Review of emission factors and control cost worldwide"[10] and summarized that significant quantities of SO_2, NO, dust etc., are emitted from the integrated iron and steel mills.

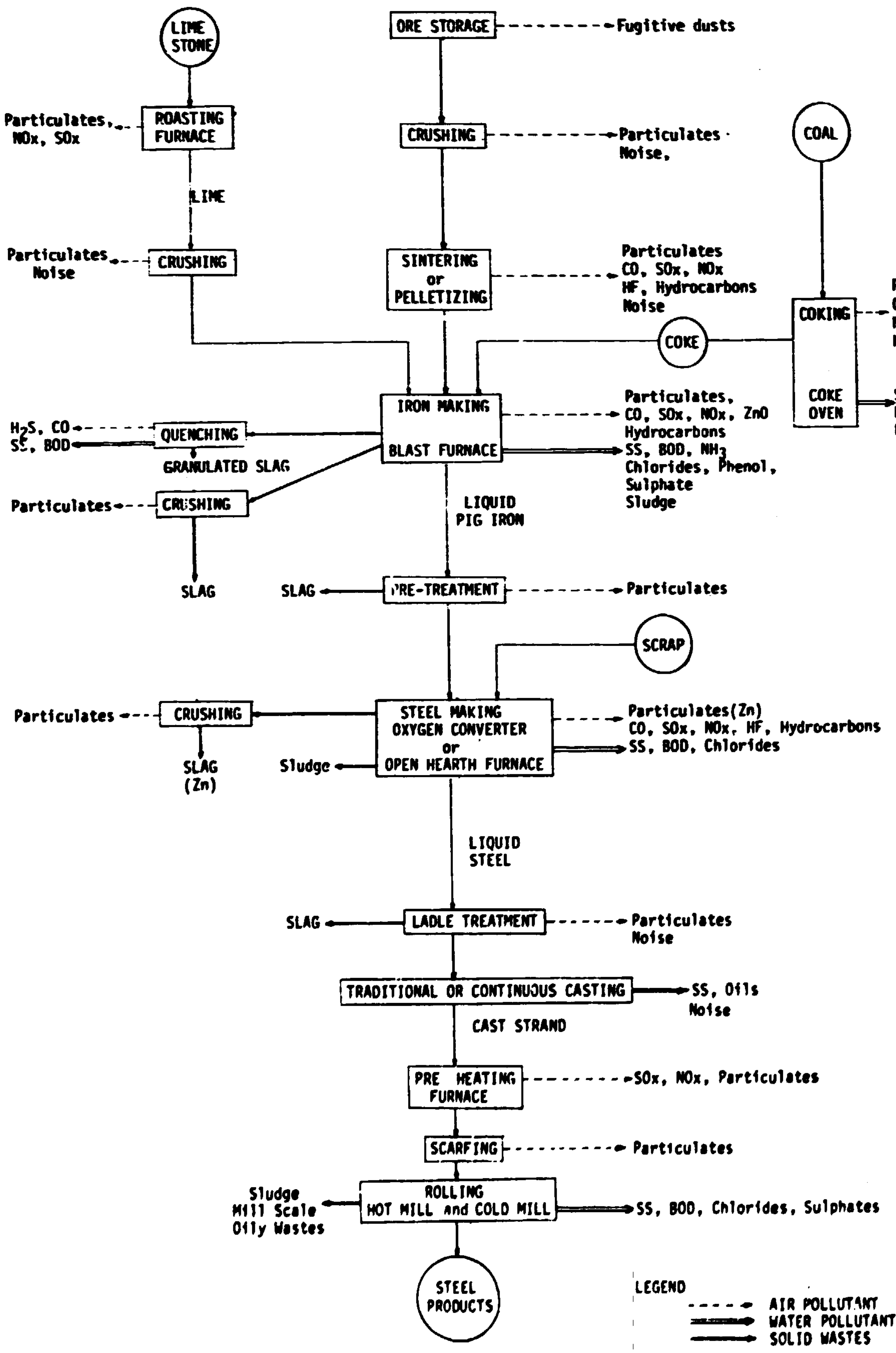
In addition, H_2S and fluorine may also be emitted. The nature and quantity of emissions depends upon the quality of fuel used. In the case of electric mills, emissions of SO_2 are comparatively less.

Table 3. Typical pollutants from an integrated steel plant

	Water	Stack emission	Fugitive or secondary	Solids
Transport	Suspended solids Run off water		Dusts: iron oxide, coal, limestone	Spillage muds
Blending and bedding	Suspended solids. Run off water		Iron oxides, coals, recycled dusts	Baghouse dusts
Sinter and pellet plants	Scrubber waters. Suspended solids. Lime, acids	SO_x, NO_x, F^-, (CO?), particulates	Dusts from sinter plant coolers, noise	Baghouse dusts with Zn, (Pb), alkalies, filter cake
Coke ovens	Phenols, cyanides, tars, ammonia	Smoke, SO_x, NO_x, steam, gas flare	Coal or coke dusts, sulphurous or carcinogenic emissions, smoke, benzene,, BaP, steam	Carbonaceous solids from baghouses, pitch, tar, refractories
Blast furnace	Suspended solids. fluorides, lead and zinc compounds. Chlorides, heat	H_2S, SO_2. Steam from slag cooling beds	Iron oxides, H_2S, casthouse fume, CO coke dust, noise	Baghouse dusts, blast furnace slags, refractories, filter cakes
Hot metal treatment	Alkalies. Suspended solids	Particulates, alkalies, fluorides	Na_2O, K_2O, lime dust, kish, iron oxide fume	Baghouse dusts with high lime corrosive slags
Steelmaking	Scrubber waters. Suspended solids. Zinc compounds	CO flare, CO_2, SiF_4, fluorides, iron oxides	Fine iron oxides, alloy fume, noise	Skimmer, EAF, BO & ladle slags; refractories, baghouse dusts
Casting	Oil, fluorides. Suspended solids, heat	Lead, So_x	Fume, fluorides	Slag from exothermic compounds, refractories filter cake
Rolling	Oils. Suspended solids. Chromates, acids, alkalies	SO_x, NO_x, CO_2, smoke	Scarfing fume	Mill scale, oily mill scale, filter cake, ferrous sulphate
Coating	Chromates, phosphates, alkalies, acids, oils, suspended solids		Chlorinated hydrocarbons, solvents, acid mist	Neutral sludges, filter cakes, carbon

Figure 2

Flow Chart of principal operations and sources of pollutants in an integrated steel works



Emissions of NOx are mainly from the sintering plant. NOx emissions are less from Mini-Steel Plants in comparison with integrated Steel Plants. Emissions of pollutants from integrated plants are higher in comparison to mini-steel plants. Suspended materials in the liquid effluents are less in Mini-Steel Plants in comparison with integrated steel plants. Computations of control costs were worked out based on the US dollar value in 1983. Due to the drift in exchange rates and inflation, control costs as worked out in 1983 may not be applicable in toto in 1985, but they give some idea of the control cost. The cost of pollution control equipment varies from country to country, based on legislation and other local conditions existing in the particular country. The conclusions are:

Emission Factors (kg/t raw steel)

	Integrated works	Mini-mills
dusts	1 - 9	0.3 - 3
SO_2	2 - 11	2 - 7
NOx	0.4 - 3	0.1 - 1.2
CO	65	10

Control Costs

Investment ($ 1983/t installed annual capacity)

	Integrated Works	Mini-mills
air pollution control	65 - 125	6 - 9
water pollution control	14 - 42	8 - 23
Total	79 - 167	14 - 32

Operating Costs ($ 1983/t raw steel)

Integrated Works	Mini-mills
7 - 31	1 - 3

Table 4. Emissions from the main operations of an integrated steel plant, kg per one ton of rolled products[a/]

		Operation						
Source	Factor	Sintering	Coking	Ironmaking	Steelmaking	Casting and rolling	General	Approximate total
Fugitive	Dust, fume and grit	3	1	2	0.5	0.6	-	7
Stack gases	SO_x	4	0.3	0.2	0.2	2.0	-	7
	NO_x	1	0.2	0.2	0.1	0.5	-	2
	CO	40	0.3	8.5	15.0	0.33	-	60
	HF	0.04	trace	trace	0.4	variable	-	0.5
	Hydrocarbons	0.1	0.2	0.15	0.05	0.2	-	1
Waters	Suspended solids	0.28	0.06	0.24	0.07	0.20	-	1
	Oxygen demand	0.05	0.08	0.16	0.20	0.14	-	0.5
	Ammonia	-	0.03	0.08	-	-	-	0.1
	Phenol	-	0.005	0.006	-	-	-	0.01
	Cyanides	-	0.02	0.03	-	-	-	0.05
	Chlorides	...	-	0.05	0.05	0.20	-	0.50
	Sulphates	...	...	0.003	-	0.40	-	0.50
Solids	Dust	recycled	) 2	12	30		-	) 70
	Sludge		)	12	15	10	-	)
	Slag	-	-	300	100	10	-	400
	Millscale	-	-	-	-	30	-	30
	Oily wastes	-	-	-	-	10	-	10
General	Refractories	-	-	-	-	-	20	20
	Debris	-	-	-	-	-	40	40
	Human wastes	-	-	-	-	-	10	10
							Approximate total	660

a/ Levels are indicative only and are rounded from Ref. 9 and other information. Individual plants vary widely depending on raw materials used and the anti-pollution equipment installed.

Notes: 1. These figures assume environmental controls.
2. Many slags are now recycled or sold.

5. Environmental Management for plant site selection, design and operations

5.1 Siting

Management should be concerned from the moment of initiation of a steel plant project to minimise its environmental impact and in working towards preventing pollution damage.

Plant siting is controlled by economic and political factors, raw material availability, port or railway access, market considerations and the acceptance by society in the form of governments or local governments of the need for the plant.

Alert planners and entrepreneurs will be aware that in every case the establishment of an industry in an area will lead to some impact on the environment. Change as it occurs must be made compatible with the forward aspirations of the region.

Quite simple considerations - such as the desirability to separate public transport systems from those required for the plant; to site the plant away from residential and commercial areas; to screen it from its surroundings; and to maintain grassed and tree covered areas in the works with trees around the perimeter - can lead to a lowering in the degree of environmental impact, in the dissemination of dust and grits and in the tension between the community and the plant.

Obvious concern to apply anti-pollution measures is only one of the many steps needed to create a harmonious interaction between the plant and its surrounding community.

5.2 Need for assessing environmental impacts

Within the economic and political factors outlined above there must be room for choice and with proper forethought many future problems can be avoided. For example, a steel plant which of necessity carries out high temperature combustion processes and emits NOx should not be placed in close proximity to or indeed in a major wind direction from or to a petrochemical plant. Otherwise photo-chemical smog will almost certainly be encountered in the area. Separated, neither plant will be likely to offend.

The assessment of environmental impact during the development stages of a project is essential to managers and to environmental protection agencies (even if preparation of a formal Environmental Impact Statement is not enforced) in order to understand these problems, determine economical solutions and minimise community objections. Early establishment of an environmental control organisation within the structure of the company is desirable.

5.3 Scope of environmental impact assessment

Such a statement should include analyses of economic, aesthetic and social impacts on the region; consideration of the present land use and the way in which land use is expected to move in future; the demands that the plant and its potential expansion can make on the infra-structure of the area; effects on the atmosphere and meteorology of the region; on water supply and use; on fauna and flora; and, very importantly, on the problems of solid waste disposal, since this will be a continuing requirement.

Disaster precautions should be considered and risk analysis of major hazards should also be carried out. Accident controls, e.g. should spills or flooding occur, need to be provided.

5.4 Plant Design

5.4.1 Target

Before the design stage of plant facilities, a target of environmental control should first be set by the top management of the company. The target corresponds to emission standards, to standards that regulate the quality of the ambient air and water. If government regulations already exist, the target will need to meet these standards first.

The significant environmental component, i.e. air, water, land, plants, flora and fauna, or aesthetic features etc., may vary from country to country and from locality to locality. The relative value of these environmental components also differs according to each specific plant site.

The target should be set in consideration of the results of environmental impact assessment, with regard to the priority of the environmental components to be protected and in relation to the cost-effectiveness of control measures. Subsequently, plant facilities should be designed to meet these requirements. The design itself should be flexible enough to accommodate any changes in the foreseeable future as retrofitting is very costly.

5.4.2 Design

Selection of production process and technology with fewer environmental problems (reduced generation of pollutants and wastes) is essential to minimize environmental control cost. Recycling of wastes materials should be considered in the stage of process design.

Pollution control technology has become an integrated part of the production process in many industries. It is recommended that pollution control facilities should be designed as an integral part of the production facilities.

5.5 Monitoring pollution and equipment maintenance

Before the commencement of operations management should be concerned to ensure that targets are set for the levels of environmental protection against each of the emissions and impacts of the plant. Also, it should see that these targets are understood and agreed by whatever local and national authorities will later be involved in the activities of the plants.

Well in advance of the plant's construction, monitoring should be established to collect data on levels of noise, contaminants, air borne particulates and wind direction and variability so that at a later time accurate comparisons can be made and assessments made of the actual impact of the industry in the area. Measurements need to be made of all the parameters which will later be assessed, e.g. dust, SO_2, NOx, CO, fluorides, noise, water analysis and temperature, etc.

In any newly established plant it should be the objective both of the plant management and of the environmental protection agency responsible for the area to ensure within the limits of available methods that the level of pollution control technology is fully in line with the latest economically acceptable developments throughout the world, will meet the targets required by emission standards within the nation and will be installed as an integral part of the production facility.

If these criteria are met, since retrofitting is very expensive, then the agency should be prepared to make consent agreements (except those which involve a health risk) until new construction is required, should emission standards change after the plant is established.

Careful control will also alert management to failure of pollution control equipment. Procedures for regular maintenance and preventive maintenance should be instituted when plant is installed and practices should be checked by pollution control equipment. Procedures for regular maintenance and preventive maintenance should be instituted when plant is installed and practices should be checked by pollution control agencies.

5.6 Education and training

Environmental control cost can be minimized by proper operation of production facilities and good housekeeping. These are also essential elements in ensuring the worker's health and safety.

Disciplined behaviour on the part of the workforce is essential if its health and safety is to be ensured.

Managements will need to make provision for the training of personnel in the correct operation of pollution control equipment. Education on the desirability and necessity of minimizing environmental interactions is also needed and will require reinforcement from time to time. Goals for continuing improvement in pollution control performance (economic and absolute levels) should be incorporated in the objectives for the performance of operational management, these can be based on the monitoring equipment installed.

5.7 In-plant hygiene

Workers' health must be respected in establishing the standards for environmental control and should be closely considered in determining the security that must be achieved.

5.8 Environmental standards

For the design of plant facilities and the operation of the plant, environmental standards on the ambient air and water quality, and emission standards on various pollutants, needed to be established by the government or by the industry itself.

These standards should be established preferably after a study of environmental impact assessment, along with the various local conditions of the plant site (topographical, meteorological, geographical, land use etc) and the size of the plant.

The standards for working conditions to protect workers' health however can be universal but actually government standards vary considerably in different countries.

6. Recent Control Measures and Topics for Selected Environmental Issues.

6.1 Raw materials handling

Unloading, storage and transportation operations of dry fine raw materials generate fugitive dusts. Various methods are available to control these dusts:

- use of water curtain or dedusting by evacuation to a bag filter while unloading,
- enclosure of the receiving hopper,
- design of equipment for unloading with a minimum height of fall,
- spraying of the stockpiles with water, with or without chemicals for surface coating added,
- building walls to serve as wind-breaks,
- enclosures at transfer points of belts and evacuation at high rates to a bag filter,
- spray installation at transfer points, but care is required to avoid blockages and wastage of water.

6.2 Sintering and Pelletizing

6.2.1 Dusts

Fugitive dust can be recovered by the installation of suction hoods and bag filters.

Particulates in main waste gases (stack gases) is generally removed with electrostatic precipitator.

6.2.2 Removal of SOx

It is not normally necessary or economically desirable to treat stack gases. However, when emission of SOx needs to be reduced, it is highly recommendable to coke ovens gas, natural gas or low sulphur oil for fire the kiln.

Practically the most developed method, particularly in Japan, to treat the stack gas is wet scrubbing with alkaline liquids (e.g. milk of lime). Over 90 per cent of SOx can be removed.

6.2.3 Removal of NOx

Removal of NOx from stack gas is also a very expensive operation and generally not popular. However, some local condition may require this operation to reduce ambient air concentration of NOx in that area.

Two processes are currently being developed in Japan as methods of eliminating NO and NO_2:

(i)Reduction of nitrogen oxides to molecular nitrogen

This reduction is brought about by ammonia in the presence of a catalyst Fe_2O_3-Al_2O_3 at a high temperature (200° to 400°C depending on the circumstances). Two industrial plants are in operation in Japan, one at Nippon Kokan Keihin and another at Kawasaki Steel Chiba (SR process) for the denitration of gases produced by sintering.

(ii)Use of an electron beam

A process studied a few years ago on a pilot basis by the Technological Research Association for Abatement and Removal of NOx in the Steel Industry at Nippon Steel Yawata consists of adding NH_3 and of bombarding the gases by an electron beam.

6.3 Coking

Coking is, in environmental aspects, the most problematical operation in the integrated steel plant. Strenuous efforts have been made in every plant to improve environmental control. However, satisfactory results are still hard to get in many old plants.

The details of recent control practices are in ANNEX 1 and in reference [12].

6.3.1 Charging of coal to coke oven

There are two methods of preventing emissions during charging, i.e., suction by the ascension-pipe ejector and suction by the dust collector for charging car. Various improvements have been made on suction lines.

(a) Ascension-pipe ejector

Emissions during charging are partly sucked by the ascension-pipe ejector. In recent years high-pressure gas liquor is used in this system although steam has so far been used.

(b) Dust collector for charging car

The gas to be sucked is inflammable. Therefore, fumes are first sucked into a suction hood and are usually conducted into a combustion chamber installed between the suction hood and a suction duct. The suction duct is connected to a fixed duct and dust is collected by a dust collector on the ground. Venturi scrubbers are much used as the dust collector in consideration of a misfire during combustion.

(c) Prevention of fume leakage from charging-car hood

When dust is collected using a dust collector for charging car, it is important to prevent the leakage of emissions from the hood and various measures are taken for this purpose.

(d) Closed charging method

New techniques such as preheated coal charging, have been developed to solve problems in the coke industry, such as the shortage of high-quality coking coal. Under the pre-carbon method, for example, wet coal is preheated to about 200°C in a drying tower and is transported by a chain conveyor installed above the coke oven to above the coking chamber after the recovery of dust coal by a cyclone. These new techniques are favorable also in terms of environmental protection.

6.3.2 Carbonization

(a) Oven-door seal

The conventional oven-door seal is of such a construction that knife edges installed around the oven door are pressed against a frame fixed on the side of the oven. With this construction, however, it is difficult to completely prevent gas leakage due to the adhering of tar to the frame, thermal strains, etc.

In recent years, therefore, a few new sealing methods have been adopted with satisfactory results.

(i)By pressing the knife edges by springs it is possible to adapt to continuous thermal strains.

(ii)An air-cooled oven door is used in which a gap is provided between the oven door proper and the brick in order to reduce thermal strains of the oven door.

(iii)An attempt at forced sealing is being made by injecting high-pressure air from outside against the seal surface to prevent gas leakage.

(b) Seals for ascension-pipe lid and charging-hole lid

Since the ascension pipe is subjected to high temperatures of about 600°C, the lid and lid-receiving metal fitting undergo great thermal strains. To prevent gas leakage, water sealing has been adopted with good results. With respect to the charging-hole lid, there is an example in which liquid mortar is automatically poured in to make seals. One example of retrofitting of Self Sealing Doors for a coke oven is attached as ANNEX 2.

(c) Repair of oven walls

Various repairing methods have so far been adopted. These methods, however, have drawbacks such as bad refractories and short life of about two months. In recent years, flame gunning repair techniques eliminating these disadvantages have been developed.

Flame gunning repair methods

FOSBEL CWP	LAVAFLAME
O_2 + ceramic powder (containing SiO_2 and Al_2O_3) heat of metal oxidation	O_2 + LPG + ceramic powder (containing SiO_2 and Al_2O_3) LPG flame

The principle of these techniques involves melting of refractory powder in a high-temperature combustion flame and injecting the molten refractory onto damaged parts. Repaired parts by this method have lasted more than seven years. However, service life of at least five to ten years can be expected and the effect on environmental protection is great.

6.3.3 Coke pushing

(a) Dust collection at coke guide car

The general practice in a country today is to install a hood on the coke guide car, which is connected to a fixed duct and dust is collected by a dust collector installed on the ground. Venturi scrubbers, wet-type electrostaticprecipitators and bag filters are used for dust collection.

(b) Combustion control

In addition to dust collection, the coking condition of coke being pushed out is important for the problem of dust generation during pushing. Therefore, it is necessary to enhance combustion control in general, including the reduction of fluctuations in the coking condition among chambers and the improvement of the flue temperature distribution.

6.3.4 Coke quenching

(a) Wet quenching

Modern methods of wet quenching involve rapid addition of limited quantities of water to the bed of hot coke to ensure that the coke surface temperature is quickly lowered but that sufficient heat remains in the coke after quenching to dry it. The systems lead to smaller releases of steam than the former practices of very heavy quenching. They also reduce the amount of quench water that has to be handled by the coke ovens water treatment plant. The product has low moisture levels and must be handled correctly (see below for dry quenched product) to avoid dusting or to recover dusts released.

(b) Quenching tower equipment

The steam generated during the quenching of incandescent coke by water sprinkling is discharged by drafts. This steam contains coke dust. Measures to catch this dust have been contrived and one of them is the quenching tower which has the following features:

(i)The ascending speed of steam is lowered by increasing the area where steam rises.

(ii)Dust collection using inertia force is used which is produced by baffle plates and hurdles.

(iii)High-pressure spray nozzles are installed to increase the effects of collision, coagulation and washing.

The concentration of dust can be controlled to about 0.02 g/Nm^3 using this method.

(c) Coke dry quencher (CDQ)

Dry coke quenching offers the removal of visible release of steam, but it it capital intensive and can be expensive to run, unless the price of electricity is high, when there is an economical case for energy recovery by heat exchange to raise steam for electricity generation. CDQs have been gradually adopted in Japan and the outfit ratio (number of coke ovens equipped with CDQ in operation/total number of coke ovens in operation) in 1984 is 35%, and production ratio (production from CDQ-equipped coke oven/total coke production) in 1984 is supposed to be about 60%. However, CDQs are not always perfect in terms of environmental problems. Conversely, this equipment produces a new source of dust in the coke delivery line. This is because dust becomes more apt to scatter in the CDQ system in which the moisture content of coke has decreased to 0.1 to 0.2%, whereas it is about 4% in the conventional quenching tower system.

For this reason, it has become necessary to improve the dust collection in the coke delivery line.

6.3.5 Waste water treatment

The amount of gas liquor generated by the coking process is about 0.1 to 0.2 m^3 per ton of charging coal. This gas liquor contains ammonia, phenol, cyanide and other COD components. Gas liquor is usually treated by activated sludge. Treatment technologies are detailed in ANNEX 1 and in Reference [12].

6.3.6 Desulphurization of coke oven gas

The coke-oven gas contains 4 to 7 g/Nm^3 of H_2S, which must be removed from the standpoint of pollution control and to prevent the corrosion of COG distribution equipment. Desulphurization methods are divided into the dry process and the wet process. The latter wet process, which is suitable for mass treatment, is widely used. For example, in the Fumax process, an alkaline aqueous solution is brought into contact with COG in a desulphurization tower and the H_2S in the gas is absorbed and removed. On this occasion, HCN is also absorbed. The liquid which has absorbed these substances is oxidized in a regeneration tower by the action of air and a catalyst, and sulphur is formed. This liquid is thus regenerated to the original alkaline solution, which is re-used.

The desulphurization rate and cyanogen removal rate by this process are almost 100%. Thus this process contributes to the removal of SOx and NOx. Recovered sulphur is burned to form SO_2, which is deoxidized to SO_3. The SO_3 thus obtained is caused to be absorbed by water and is recovered as sulphuric acid.

6.4 Reduction

6.4.1 Direct reduction (DR)

It has been said that in regard to environmental control, the DR process particularly using natural gas, causes less problems than the conventional blast furnace process. In conventional ironmaking, the total emissions of pollutants from coke ovens has always been a focus of attention. Any process which could eliminate coke ovens could be considered as a favorable process as far as environmental control is concerned.

In addition, there are many reasons why the installation of DR should be encouraged in developing countries, particularly where there are abundant natural gas reserves.

In fact, the number of DR units and consequently the production capacity of DR have been increasing, mostly in the developing countries that process natural gas reserves. In 1984 the world production of DR reached 9.25 million tonnes, while production capacity is said to be 20 million tonnes. Also it may be true that at present most of the new installations for ironmaking capacity could be DR units. (Table 5 and 6 show world-wide DR capacity by country and by process).

Table 5

Worldwide direct reduction capacity (million tpy)

Country	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Argentina							0.33	0.33	0.75	0.75	0.75	0.75	0.75	0.93	0.93	0.93
Brazil				0.07	0.32	0.32	0.32	0.67	0.67	0.67	0.67	0.32	0.32	0.32	0.32	0.32
Burma												0.02	0.02	0.02	0.04	0.04
Canada				0.44	0.44	0.79	1.03	1.63	1.63	1.63	1.63	1.63	1.63	1.35	1.00	1.00
Egypt																
India											0.03	0.03	0.03	0.18	0.21	0.21
Indonesia									0.58	0.58	1.15	1.15	2.30	2.30	2.30	2.30
Iran								0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	1.53
Iraq										0.49	0.49	0.49	0.49	0.49	0.49	0.49
Italy				0.01	0.01	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.01			
Japan								0.05	0.15	0.15	0.15	0.15	0.15			
Libya																
Malaysia															0.85	1.25
Mexico	0.92	0.92	0.92	0.92	1.39	1.39	1.39	2.02	2.02	2.00	2.00	2.00	2.00	2.03	2.03	3.03
New Zealand	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Nigeria													1.02	1.02	1.02	1.02
Peru											0.10	0.10	0.10	0.10	0.10	0.10
Qatar									0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
South Africa				0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.23	0.83	1.11
Saudi Arabia													0.40	0.80	0.80	0.80
Sweden												0.07	0.07	0.07	0.07	0.07
Trinidad											0.42	0.42	0.84	0.84	0.84	0.84
UK										0.80	0.80	0.80	0.80	0.80	0.80	0.80
USA	0.30	0.70	1.03	1.03	1.03	1.03	1.03	1.03	1.09	1.09	1.09	1.09	1.09	1.03	0.70	0.40
USSR														0.42	0.42	0.83
Venezuela							0.76	1.12	1.12	2.39	3.80	4.50	4.50	4.50	4.50	4.50
F.R. Germany	0.15	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	1.43	1.28	1.28	1.28	1.28
Total	1.49	2.29	2.82	3.29	4.01	4.36	5.73	8.15	9.66	12.20	14.73	16.06	18.86	19.61	20.23	28.42

Source : MIDREX CORPORATION

Table 6

Worldwide direct reduction capacity by process (million tpy)

Process	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Midrex	30	1.10	1.10	1.50	1.50	1.50	1.83	2.79	3.61	5.66	6.10	6.98	8.82	9.82	10.47	11.78
HyL I	.92	.92	.92	.92	1.64	1.64	2.00	2.63	3.21	3.43	5.41	6.11	7.26	6.79	6.79	6.79
HyL III										.25	.25	.25	.25	.75	.75	1.75
NSC								.15	.15	.15	.15	.15	.15	.00	.00	.60
Purofer	.15	.15	.15	.15	.15	.15	.15	.83	.83	.83	.83	.48	.33	.33	.33	.33
Armco			.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.00	.00
Fior							.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Plasmared												.07	.07	.07	.07	.07
USCO																.25
KM				.01	.01	.01	.05	.05	.05	.05	.05	.07	.03	.02	.04	.04
SL/RN	.12	.12	.12	.19	.19	54	.54	.54	.59	.59	.72	.72	.72	.72	1.00	1.00
DRC									.06	.06	.06	.06	.06	.08	.08	.08
CODIR				.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
ACCAR				.04	.04	.04	.28	.28	.28	.28	.28	.28	.28	.15	.15	.15
DAV																.03
Total	1.49	2.29	2.62	3.29	4.01	4.36	5.73	8.15	9.66	12.20	14.73	16.05	18.85	19.61	20.23	23.42
Gas Based	1.37	2.17	2.50	2.90	3.62	3.62	4.71	7.13	8.53	11.07	13.47	14.77	17.61	18.49	18.81	21.97
Coal Based	.12	.12	.12	.39	.39	.74	1.02	1.02	1.13	1.13	1.28	1.28	1.24	1.12	1.42	1.45

Source: MIDREX CORPORATION

However, it must be kept in mind that DR is still a developing process and despite the sharp increase in the number of units, its impact on the world steel industry is not as large as it seems (less than 1.5 per cent).

There are many limiting factors for the successful operation of a DR plant, such as the need for a secure supply of inexpensive natural gas and high quality iron-bearing metarial. The local economic conditions affect the price of scrap and its availability play an important role in the economics of steelmaking. We can see examples of coal-based DR plant which have been built in New Zealand and South Africa where the scrap supply is restricted.

Already from the purely technical viewpoint, there is a tendency for conventional DR processes which produce sponge iron to evolve into a more advanced smelting reduction process, where the melting process makes the separation of gangue possible.

For environmental control of the DR process, it is not fair to compare the natural gas-based DR and the conventional coke-based blast furnace process. The availability of natural gas should be considered as an advantage that does not exist in all parts of the world. Considering the high efficiency of the blast-furnace basic oxygen steelmaking process, we have to recognise that the mainstream of steel production processes will continue in the form of coke oven, blast furnace, basic oxygen furnaces and scrap-base electric arc furnace. Environment control technology for direct reduction route to steel making is detailed in UNEP document [3].

6.4.2 Blast furnace smelting

(a) Blast furnace gas

The blast furnace gas, a valuable resource to the steel plant, is not a pollution problem, but must be very clean before it can be used as a fuel.

Gas is frequently taken from the top of the blast furnace at the pressure of operation of the furnace and, laden with dust, expanded through a turbine in order to recover electrical energy.

Stages of cleaning include : collection in a dust catcher, and occasionally cyclones, followed by high energy scrubbing and electrostatic precipitation. The use of dry electrostatic precipitator or bag filters followed by a back pressure recovery turbine is a recent development.

(b) Water treatment

The intense cleaning of the blast furnace gas uses a large volume of water and this requires treatment. The water contains suspended and dissolved solids, phenols, cyanides and ammonia. In general the controls include settling tanks, filters, chemical treatment for coagulation, clarifiers, chlorination and carbon absorption.

The low concentration of organics makes biological treatment of these waters difficult and chlorination to achieve low levels of pollutants make carbon absorption necessary. Recirculated water systems require strict control of their chemistry. Once-through systems, if salt water is available, using thickeners and chemical treatment have been found to be easier to operate.

While coke oven and blast furnace waters might be considered for treatment together it appears advisable to treat blast furnace water separately from others. Very high variations can occur in the level of pollutants, e.g. of cyanides, in the material passing from the blast furnace because of sudden changes in operating conditions within the furnace. Biological treatment plants recover only slowly from such challenges. Sinter plant scrubber waters however can be compatible with blast furnace water.

(c) Casthouse dedusting

In the casthouse the use of side extraction equipment adjacent to the tap hole, troughs and pour point is now common. Runners are covered with refractory lined steel cover and hoods are placed over transfer points. The aspirated gases pass to baghouse for the recovery of particulates. It is an effective method of maintaining clean operating conditions and freeing the floor of the casthouse for relatively unencumbered movement. Where the floor is enclosed, casthouse evacuation and air cleaning roof monitors etc. are used.

Where runner side or roof extraction is employed the most important principle is to provide very high extraction volumes to ensure good working conditions for staff. An example of casthouse dedusting system is detailed in ANNEX 3.

6.5 Steelmaking

6.5.1 Basic Oxygen Furnace

Gases from the basic oxygen converter may be burnt in open combustion and the oxides dust recovered. More commonly to-day the combustion of the gas is suppressed or eliminated by hoods which descend around the mouth of the vessel during the blowing period.

If either in open or closed combustion the waste gases are washed through high intensity scrubbers, then the raw wastes waters from the scrubbers must be treated. More recently high efficiency electrostatic precipitators have been installed to allow greater energy recovery and improved dust recycling.

The collection of secondary fume (fugitive emissions) by roof monitors or by surrounding the furnace with an enclosure ("dog-house") is usual.

Closed combustion practices are to be recommended for large converters and have the advantage of reducing the total amount of gas to be treated and therefore allow the use of more compact pollution control equipment, usually high intensity scrubbers or electrostatic precipitators.

An energy saving can be made from the recovery of the off-gases and their use for combustion purposes through the plant. An example of retrofitting of an emission control system of a BOF shop is in ANNEX 4.

6.5.2 Electric Arc Furnace

(a) Gas and Fume

Emissions escaping from the furnace body are collected either by point source hoods, in large roof monitors or in both. This involves capturing large volumes of dust laden air, and the capital and operating costs are correspondingly high.

Another technique which may be considered in treatment of gases in the roof of the furnace hall is the installation of an electrostatic precipitator roof monitor. This relies on the hot plume of air from the furnace to provide the motion of dusts through it.

In most electric arc steel works, because of the need to collect both primary and fugitive emissions, the volume of gas which must be treated is so high that high intensity scrubbers are no longer advocated, and (since the colder roof monitor gases can be used to cool the hotter furnace gases) bag filters are generally used. Details of recent control technologies are in reference [12].

(b) noise

Partial enclosure of the entire furnace appears to be a simpler system for handling the problems of fume and noise from arc furnaces. The advantage is that a much smaller total volume of material needs to be extracted. There are disadvantages in an unpleasant dusty work environment when actions have to be carried out in such enclosures.

With modern technology it is possible to arrange for : -

(i)the fans to be operating or extraction to become more intense when fume is emitted and when people are in the enclosure,

(ii)valves to move by remote control to ensure that higher volumes of extraction are correctly directed to areas where they are required.

It appears essential to provide acoustically insulated rooms for the operative staff.

6.5.3 Open hearth furnace

Since no new open hearth furnaces have been constructed in recent years, an advanced pollution control technology appropriate to the specific process has not developed and control is tending to follow the patterns established for oxygen steelmaking. It is suggested that the use of electrostatic precipitators and roof monitors are all that could reasonably be expected of older plant.

6.6 Casting

Continuous casting

The role of continuous casting in crude steel production has greatly increased in recent years. Continuous casting has totally eliminated the emission of pollutants into the atmosphere and heat exposure to workers during casting, stripping, charging and discharging in and out of soaking pits, primary rolling and mould preparation. Moreover, the achievement of relatively high yields from crude steel to semi-finished products and greatly reduced energy consumption are an indirect contribution to environmental control in steelmaking. This is a good example of how environmental improvements could be achieved while, at the same time, reducing cost. In the last ten years the rate of continuously cast steel has increased up to 60% in IISI member countries, and about 6% improvement in yield has been recorded.

6.7 Water pollution

Recycling of waste water is a general practice to reduce the volume of wastewater to be discharged and to save the cost of treatment.

The following methods are currently in use in the steel industry for wastewater treatment:

(a) settling lagoons, clarifiers and filters, for suspended solids removal,
(b) skimming, filtration, air flotation and ultrafiltration for oil removal,
(c) carbon absorption and biological treatment for organic and toxic pollutants removal,
(d) advanced treatment technologies such as iron exchange and osmosis are possible alternative treatment systems.

The details of those technologies are explained in a UNEP document [3].

6.8 Solid waste recycling and disposal

6.8.1 Solid wastes

There are many different kinds of solid waste which are generated during the steelmaking process. These are:

Slags from the blast furnace, steelmaking furnaces and other vessels,

Dust and sludges recovered from processing units and material storage,
Mill scales from rolling mills,
Spent acid from pickling equipment,
Metal dross from coating facilities,

Refractory waste from relining of metallurgical furnaces and vessels,
Pitch waste and acid waste arising from by-product processing from coke oven batteries,
Ash from boilers and gas product plants.

The recycling of solid waste has been developed for many years and in industrialized countries a very high percentage of it is utilised inside and outside steel plants. In some plants over 90% utilisation has been observed.

Even so, since the amount of steel produced is very large, dumping of waste has been a serious problem for the industry not only from an environmental point of view but also to secure adequate space for this purpose.

Fortunately most of the solid waste from a steel plant is not toxic. However, due consideration must be taken of the possibility of leaching by rainwater or groundwater of such toxic substances as lead and hexavalent chromium.

6.8.2 Utilisation of slags

The slag from the blast furnace can be utilized entirely in the cement industry and in civil engineering construction. In Europe apart from the utilisation of all the slag generated, old slag stacks have also been consumed.

For steelmaking furnaces and ladles, slag metal recovery has been carried out for many years for economic reasons, and now a part is recycled to the steel plant as fluxing material, and some is utilised in road construction or the neutralisation of farm land in some countries. Further developments to utilise this material are still necessary.

Further details can be found in the International Iron and Steel Institute publication "Utilisation of BF and BOF slags"[13].

6.8.3 Utilisation of dust, sludges and scale

This waste could be recycled in steel plants since the main constituent is iron oxide. However, some waste contains a small amount of zinc and alkaline metals and after recycling, these elements may accumulate and cause trouble in furnace operation. The recycling of zinc rich dust of sludge must be avoided.

After enrichment, this material could be sold to zinc smelters, although smelters prefer other raw materials.

6.8.4 Utilisation of other wastes.

Spent acid could be treated chemically; acid and metallic oxide are recovered. Metal dross is sold to smelters. Part of the refractory waste could be recycled as raw material.

6.8.5 Current status of dumped solid waste

(Based on the 1982 survey of the IISI Committee on Environmental Affairs (ENCO) represented by 16 member countries).

(a) In most cases there are statutory controls on the dumping of industrial waste, such as:

Permits before dumping
Lists of banned waste
Checks before dumping
Regular analysis during utilisation,

in which regulations are enforced more by local authorities rather than by national authorities.

Examples of practical conditions which apply are:

Watering on unpaved roads and cleaning of paved roads
Plastic lining for leak proof bases
Clay bases for some offending waste, such as oily millscale
Dams
Re-vegetation after closing of dump site
Groundwater monitoring.

Moreover, special monitoring is carried out for some waste products, such as:

Transport of benzene waste in a container
Special lagoons for sludge and oily waste
Special sites for asbestos waste.

(b) Trouble or incidents concerning the dumping of solid waste from steel plants are mostly as a result of complaints from the neighbouring inhabitants regarding air pollution, smells and noise.

No detectable contamination by lead, cadmium, but contaminations by hexavalent chromium zinc and sulphur have been reported.

However, there are some incidents caused by coke oven activities, principally concerned with surface water contamination of cyanides, phenol, ammonia, nitrates and suspended solids.

(c) Most steelworks conduct checks on their dumps by means of:
Visual inspection,
Register with the list of wastes, and their composition.
Chemical analysis of the dumped material and the water from time to time.

In Germany, monitoring and control of the surrounding groundwater is requested at every dumping site.

(d) In the future, it is foreseen that in general difficulties will arise during the expansion of existing sites or in finding new sites with dumping facilities because of:

lack of space
surface water pollution
air pollution.

6.8.6 Leaching tests

Some members of IISI's Committee on Environmental Affairs are conducting leaching tests on sludge, dust and slag. Since no standardized leaching tests for this particular purpose have yet been established, Environmental Committee of IISI is making a comparison of leaching tests which are used in each country.

The primary tests show that with different leaching methods there is a considerable effect on the analytical value of heavy metals in the samples. The five different leaching methods used are classified in three major categories and show differences which cannot be overlooked.

6.9 Occupational health and safety

WHO is now preparing a very comprehensive document on occupational health technology for the iron and steel industry. This document contains health effects associated with occupational hazards in the iron and steel industry, health hazards control measures and monitoring methods etc. [14]. There is also an ILO publication on occupational safety and health in the iron and steel industry [15].

6.10 Other subjects

Recent practices of Noise Control, Control of Heavy Metals, Monitoring of Fugitive Emissions and Comparison of Dust Collectors are discussed in reference [12].

7. Conclusions

The Iron and Steel industry is a very large and complex industry with a long history. Its potential impact to the environment is also very large.

By and large, some kind of legislative framework is existing in most of the countries for tackling pollution problems. Many new laws and regulations have also been brought out in recent years. In several developed countries, iron and steel industry had to spend a large amount of money to control environmental problems, and most of the main issues were settled. However, the existing rules and regulations under the various Environmental Acts have also either already been reviewed and updated or are being reviewed in several countries, and the industry is being requested to take further steps to control the environment.

In many developing countries also, the industry is making an effort to control the environment. However, there are many constraints for them such as, lack of technology, lack of management, lack of economic resources etc.to control the environment. While they may represent useful national ventures, small and medium-scale industries are posing considerable environmental problems, as often they are not equipped with control equipment, and utilize simplified processes which are less efficient in utilization of resources and are more energy-intensive. Even if it is very expensive, retrofitting of pollution controls to existing plants may have to be adopted to meet newly accepted standards.

Developed countries have gained considerable experience and expertise and are in a position to offer not only environmental control technology, but also industrial technology which is more productive and cost-effective and poses a minimum of pollution problems.

Environmental management is expensive. However, if it can be done today, it might be less expensive than to do it tomorrow.

The Industry and Environment office of UNEP is ready to co-operate with developing countries, in information, technology transfer and training in the field of environmental management, and is looking forward to collaborate with UNIDO towards industrial development with minimum environmental harm.

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SOMMAIRE

Ce document a été préparé pour l'ONUDI par l'Office de l'Industrie et de l'Environnement du PNUE. Il commence par une série de dix recommendations destinées à une meilleur compréhension des problèmes environmentaux dans la sidérurgie et des méthodes de leur traitement par des nouveaux procédés aux déchets réduits, par reconstruction, par recyclage ou bien par un traitement à la sortie du procédé.

Après avoir passé en revue les procédés technologiques moderns dont la sidérurgie est composée, l'étude examine en détail les sources des problèmes de l'environnement. Parmis les pollutants de l'air, il y a des problèmes faciles à résoudre comme l'émission des poussières et des autres plus difficiles qui demandent des mesures plus couteuses, comme les gases toxiques. La situation des pollutants dans les eaux effluentes est similaire. Malgré la quantité du matériel importante, la question des déchets solides est relativement inoffensive.

Le document met l'accent majeur sur la gérance des problèmes de l'environnement. Les procédés d'évaluation des effects sur l'environnement pour les nouvelles usines de sidérurgie sont exposés. Puis, l'étude décrit l'état actuel des méthodes de traitement des pollutants pour chacun des composants d'un complex sidérurgique integré: traitement des matières premières, agglomeration et pelletisation, cokerie, procédés de réduction, procédés d'usinage de l'acier, fonderie. Le recirculation des déchets est recommendé partout où la possibilitée en existe.

Le traitement des eaux usées à la sortie de l'usine, la possibilitée de recyclage des déchets solids et l'utilisation des déchets non recyclables pour inoffensive remblayage sont brievement abordés à la fin du document.

EXTRACTO

Este documento fué preparado para la ONUDI por la Oficina de Industria y Medio Ambiente del Programa de las Naciones Unidas para el Medio Ambiente (PNUMA). Comienza con una serie de diez recomendaciones con el fin de mejorar la comprensión de los problemas del medio ambiente en la industria siderúrgica y qué hacer para mitigarlos, ya sea por medio de procesos tecnológicos nuevos de baja producción de desecho, retroajuste, reciclaje o tratamiento en la etapa final del proceso.

Después de un bosquejo breve de los procesos tecnológicos modernos que son los componentes de la industria siderúrgica, el estudio examina en detalle los orígenes de los problemas del medio ambiente. Dentro de las emisiones en el aire están aquellos problemas que se pueden controlar fácil y económicamente, como ser el polvo, y aquellos más difíciles y caros como ser gases tóxicos. Una situación análoga existe para los contaminantes en las descargas de agua. Aunque el volumen de desechos sólidos es considerable, éstos son relativamente inocuos.

El manejo del medio ambiente recibe la mayor atención en el documento. Se explican procedimientos para asesorar el impacto en el medio ambiente de una planta nueva siderúrgica. Luego se presenta una discusión state-of-the-art para el control de contaminantes dentro de cada uno de los componentes de un complejo siderúrgico integrado : manipuleo de materia prima, sinterización y peletización, producción de coque, procesos de reducción, procesos de maquinado siderúrgico y moldeo. Se recomienda el reciclaje de desechos en donde sea posible.

Al final del documento se trata brevemente el tratamiento en la etapa final del procesamiento de aguas de desecho, posibilidades de reciclaje de desechos sólidos y el rellenado sin peligro de terrenos con sólidos que no se puedan reciclar.

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QUESTIONNAIRE

Environmental management in the iron and steel industry

	(please check appropriate box) yes	no
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