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Research needs in environmental and waste management in iron & steel industries

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ABSTRACT

A large number of processing steps from ore handling to steel finishing involved in the manufacture of steel, consume substantial resources and lead to complex problems of environmental pollution with local as well as global impacts. Paper identifies various global and local environmental issues that steel industry presents before the mankind. Among the global issues, the large emissions of carbon dioxide from steel industry is a major cause of concern to environmentalists. The quantity of this green house gas constitutes a significantly large proportion of the global CO_2 load and hence it contributes significantly in the global warming phenomenon. Some of the important methods have been briefly discussed to reduce these emissions through major energy conservation programmes and implementation of energy efficient processes. Among local issues are the problems of air, water and noise pollution along with the generation of large quantity of solid wastes. Under each area some of the programmes have been identified which could provide major research directions towards making the steel industry increasingly more environment friendly.

INTRODUCTION

The integrated iron and steel industry, with its inherent complexities, poses a serious challenge to environmentalists. These complexities emanate from a large number of diverse processing steps that contribute individually and collectively to produce the final product i.e. steel. Each major process presents unique environmental problems which call for equally unique approaches to effectively combat them. Compliance with increasingly stringent demands by regulatory authorities for environmental protection has necessitated used of progressive technologies [1] which are capable of assimilating future needs. A decision in the early stage of planning, based on anticipated future changes, will be less expensive than if pollution control equipment has to be retrofitted at a later date.

A rough estimate shows that production of 1 tonne of steel and 0.2 tonne of by-products through efficient steelmaking practices and use of good quality raw materials, requires about 12 tonne input materials viz. 6t of air, 3t of water and 2.8t of ore, coal, limestone etc. [2]. It generates 9.7t of dust laden gases, 0.5t of effluent water and 0.4t of solid wastes (Fig.1). In the present Indian conditions, however, where the raw material and technologies employed are both of inferior quality, the consumption of input material is rather high and emissions are also correspondingly much higher. Such a situation calls for a high degree of responsibility in the management and control of environmental impacts.

The emissions from the steel industry can have both global as well as local effects. The global considerations are now being increasingly recognised by governments in international agreements (e.g. Montreal Protocol, 1976; Earth Summit 1992 etc.) and these are being backed by internal enforcement of legislations. These efforts essentially aim at controlling the factors that may

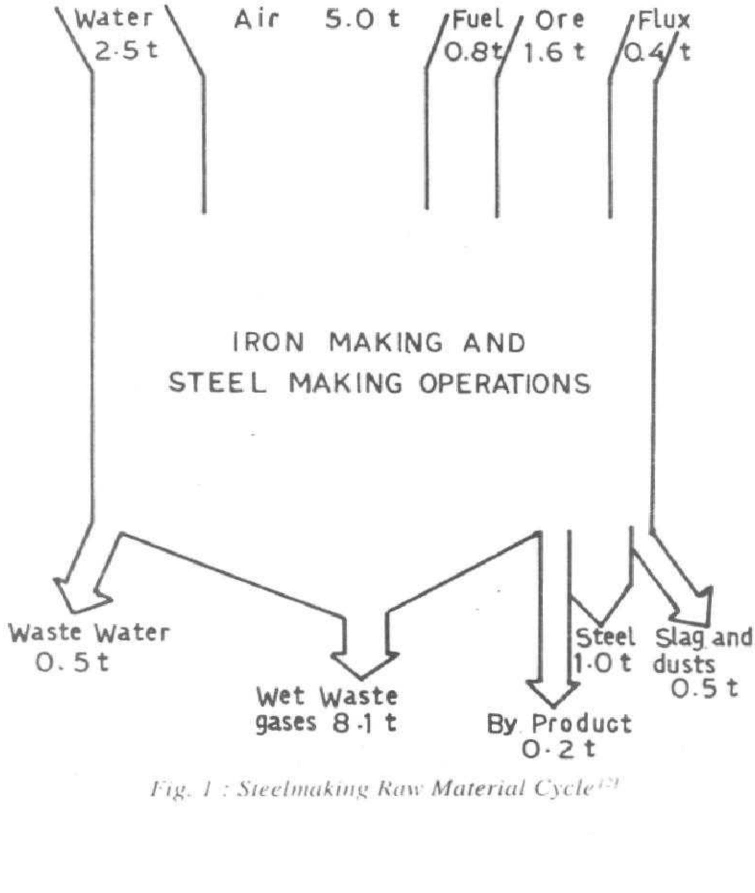

Fig. 1 : Steelmaking Raw Material Cycle [2]

cause world-wide damage, thereby reducing the overall pollution load on the planet. The role of carbon dioxide in global warming is of particular concern to the steel industry. The emission of CO_2 is essentially related to the carbon containing raw materials, be it in the form of coal, hydrocarbons or charcoal, which are basic requirements of the steel industry. The carbon is used both as a reductant and as a fuel and it ultimately results in emission of carbon dioxide. The carbon recovered as a by-product gas from coke-ovens, blast furnaces and steelmaking converters, is also released ultimately as CO_2 after these gases are burnt as fuel in the works.

Among the local effects are the high particulate and other gaseous emissions, discharge of large volumes of effluents and generation of huge quantities of solid waste arisings. In addition, noise pollution, although of restricted impact, may be significant if a large number of persons are affected. The environmental problems, caused by steel industry on account of these effects, are enormous and need sustained efforts by continuously developing technologies to overcome them. Much work has been done in the past and equally large efforts continue in this direction, as evidenced by the huge volume of published literature in the area [1-6] However, there is a need to put focussed attention on some of the key areas in order to supplement the efforts already underway. These could be in the form of R&D programmes undertaken to meet specific objectives.

In the context of Indian Steel Industry, the inferior quality of raw materials, use of old technologies and inadequate maintenance of pollution control equipment necessitates in-depth examination of environmental issues. The present paper attempts to briefly highlight some R&D inputs that could make the existing technological efforts more viable and bring steel industry closer to its ultimate goal of "Zero discharge".

Contribution of Steel Industry to Global Warming and Control of Emissions of Green House Gases

Carbon dioxide is the predominant green house gas emitted by steel industry[7,8].. According to an estimate, 2.28 tonne of CO_2 are produced per tonne of steel in a typical steel plant. Assuming 750 to 800 million tonne of annual production of steel world wide, steel plants' contribution amounts to about 1.7 Gt/a i.e. 35% of the total CO_2 (6 Gt/a) entering the atmosphere from fossil fuels. The problem of global warming caused by CO_2 is thus a matter of great concern to steel industry.

The level of atmospheric CO_2 has increased significantly [9,10] during the last three centuries as shown in Fig. 2. Though there has been a steady upward trend in the last 200 years, the rise has been quite alarming during the past few decades. The corresponding increase in mean global temperature is shown in Fig. 3. The figure indicates [11] that the last 100 years have witnessed an increase in the atmospheric temperature by 0.5°C. A report of Intergovernmental Panel on Climate Change (IPCC) estimates the rate of increase in global mean temperature during the next century to be approximately 0.3°C/decade [8] due to fossil fuels alone (Fig.4). This is likely to imply an increase in the sea levels by about 6 cm per decade on an average during the next century [8] as shown in Fig. 5.

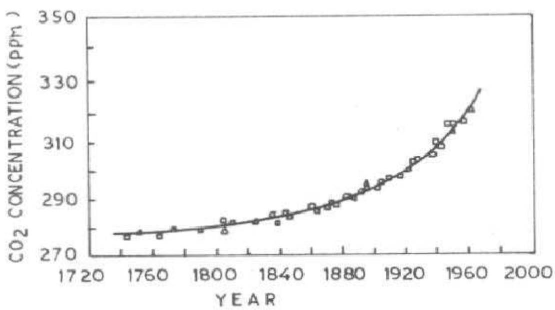

Fig.2 : Increase in the atmospheric CO_2 level during the past 250 years [9-10]

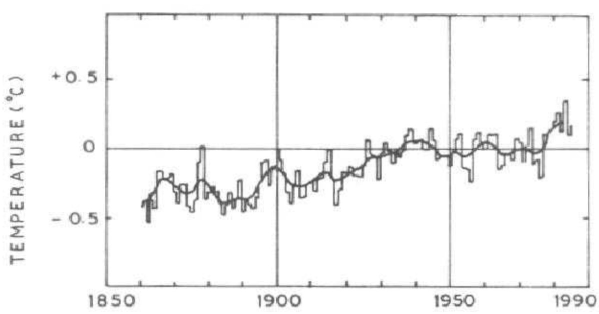

Fig.3 : Global mean surface temperature during the last 120 years [11]

The contribution of various countries [12] to the worldwide CO_2 emission from fossil fuel consumption is shown in Fig. 6 which clearly indicates that advanced industrial nations account for the large part of the emissions. At the present global population of over 5 billion, the worldwide average per capita emissions is approximately 5t/person in the United States alone. In view of a substantial proportion of CO_2 emissions originating from steel industry, it is impeative that efforts are made to arrest the rise. Since CO_2 emissions are associated with various energy sources, the most realistic method of reduction of CO_2 emissions would be by energy conservation.

Energy Saving Schemes in Steel Industry

The measures to effect energy savings could be related to improvement in operations and equipment which could include :

- increased usage of energy efficient facilities.
- deletion of old and introduction of new processes.
- recovery of waste energy.

Though there are known methods of energy saving through operational and equipment improvements (such as those given in Table 1), thrust needs to be given to carry out intensive R&D programmes in collaboration with energy conservation departments in identifying areas consistent with above three requirements. The experience at Mizushma works [13] shows that savings of over 22% could be achieved through energy savings and waste heat recovery programmes. Some of these programmes are :

- recovery of sensible heat of red hot coke by coke dry quenching.
- recovery of heat from sintered ore while also reducing the coke ratio.
- recovery of waste heat from the hot stoves of blast furnaces and electricity generation through top gas pressure recovery turbines (TRT's).
- recovery of LD off-gases.
- introduction of hot charge rolling and improvements in the operation of reheating and heat treatment furnaces through installation of waste heat recovery systems by employing heat exchangers.

The energy saving measures undertaken by Mizushima works has parallely resulted in substantial reduction of CO_2 emissions. The unit CO_2 emission per tonne of crude steel could be brought down from 368 kg carbon equivalent in 1974 to 268 kg carbon equivalent in 1987. The recycling of resources are also found to contribute to energy savings and hence in reduction of CO_2 emissions. Table-II shows the extent of energy savings [8] with blast furnace cement as compared to portland cement. Correspondingly the unit CO_2 generation is reduced by 85 kg carbon equivalent/t or 36%.

Table-1 : Environmental Benefits from Energy Conservation in Integrated Steel Plants

Sources/Measures	Benefits
Coke Ovens	
Charging of briquettes	Reduced charging emissions
On-main charging	Elimination of charging emissions
Steam driven exhausters	Better availability of steam to ammonia stills
Sinter Plant	
Improved material input	Less emissions in sinter making
Increased bed height	Reduced emission per tonne of sinter
Plug air leakages	Reduced volume of gases, higher efficiency of control equipment
Waste recovery from coolers	Reduced overall emissions
Blast Furnaces	
Charge distribution	Reduced dust entrainment
High top pressure	Reduced dust entrainment
Injection of alternate fuels	Reduced coke rate (indirect environment benefits in coke making), low slag volume.
Cast house granulation	Less generation of waste slag
BOF Furnaces	
Low sulphur, silicon	Low slag volume
Ladle management	Reduced fume emissions during waiting periods, reduced skull
Waste heat recovery	Reduced emissions
Others	
Continuous casting	Higher yield, less waste generation
Coke dry quenching	Reduced quench emissions
Product mix optimization	Lesser waste generation
Ore bedding of raw materials	Consistent quality, less waste generation
Rotative speed control	Indirect benefits
Improved furnace condition	Less mill scale generation
Yield improvement	Indirect benefits due to less waste generation

Table-2 : Comparison of Specific Energy Consumption and Specific Carbon Dioxide Emission of Portland Cement and Blast Furnace Cement [8]

	Coal kg/t	Electricity kWh/t	Limestone t/t	Specific CO_2 emission kg carbon equivalent/t
Portland Cement	110	110	1.2	235
Blast Furnace Cement (type B)	67	92	0.7	150

In spite of great efforts in the recovery of waste heat, about 40-50% of the total energy input at steelworks still remains unrecovered. These fall in the category of low temperature waste heat. This, if recovered, would present a surplus in works. This heat after recovery can be utilised by supplying heat to some neighbouring enterprises and to the general population of the area. A major R&D input is required to find ways to recover and utilise this waste energy.

Introduction of new Processes for Major Energy Savings and Reduction of CO_2 Emissions

Alternate Route for Ironmaking :

Traditionally the ironmaking through Blast Furnace route requires coke and lump ores as the blast furnace cannot accept ore fines. The fines are agglomerated in sinter plant which also recycles many other fines like coke fines, mill scale, metallurgical sludges (after pelletisation) lime fines, etc. Apart from recycling the fines to form sinters, the sinter plant causes air pollution problems in a number of ways.

Coke ovens is another big source of air and water pollution. The coke ovens not only emit particulate matter but also release hydrocarbons (BTX and PAH) which are toxic and even carcinogenic. The effluent discharged from the by products recovery lines of coke ovens also contain toxic substances like ammonia, phenol and cyanides apart from having high BOD-COD. The treatment of this effluent to safe limits as per IS-2490 is yet difficult to achieve in our country. One of the best treatment plants is operated by TISCO having

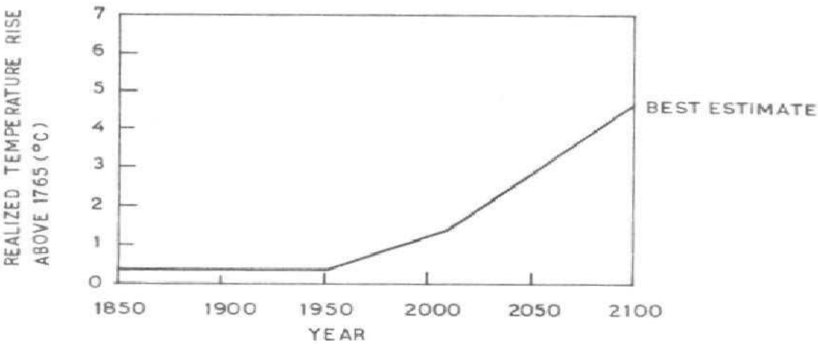

Fig.4 : Predicted increase in the global mean temperature upto 2100 AD from the business as usual emission [8]

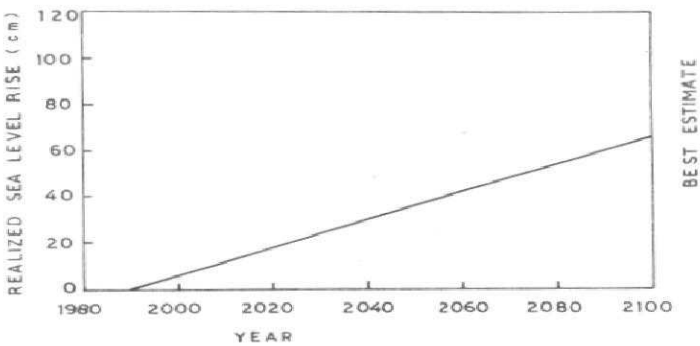

Fig.5 : Predicted rise in the sea level resulting from business as usual emissions [11]

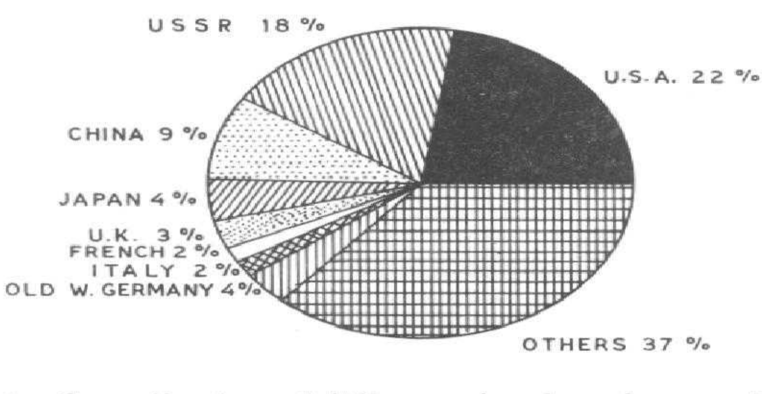

Fig.6 : Contribution of different developed countries global CO_2 emissions from fuel combustion in 1985[12]

ammonia still and two stage BOD plant. Though the pollution load of the final discharge is considerably lower in terms of BOD-COD, cyanides etc, the chemicals added during the treatment remain with the stream and may cause serious problems later, use of such chemicals also increases cost of treatment. It is estimated that the cost of pollution control system in coke ovens is about 20-25% of cost of coke oven itself.

In view of the above efforts are being made to develop alternate technology to produce metal from iron ore. Presently efforts are being made in two directions [14]. Firstly to replace the BF either with its upper part, the shaft (shaft furnace, crucibles and others to produce sponge iron) or its lower part, the hearth (plants of liquid phase reduction with liquid metal to be produced). This separation of the BF is forced by the quest for a less scarce fuel than coke.

In Russia, trends show that the shaft furnace is economically not viable. However different patterns of liquid phase metal reduction from ore are widely discussed and industrially tested. The advantage of this trend is replacement of coke with less scarce solid fuel, optional ore enriching and lumping in a number of cases and possibility of producing, in passing, a high quality gas reductant from readily available solid fuel. These processes however have a number of negative traits :

(a) Lack of possibility of producing various metal grades.
(b) Loss with slag of Chromium and Manganese in burden.
(c) Difficulty in producing low sulphur metal.
(d) High fuel consumption.
(e) Higher loss of iron with slag compared to BF.

However, major R&D efforts are required to overcome problems like stabilisation of product quality, cleaning of off gas for subsequent use as a fuel and recovery of sensible heat and valuable metals from slag.

Alternative Steelmaking Processes

The electric furnace steelmaking from ferro-scrap consumes about one third or one quarter of the energy required by the BF route, enabling proportionate reduction in CO_2 emissions. Thus increasing use of alternative route comprising a combination of reclaimed refining furnace and a multi-energy combind furnace, secondary refining furnaces and a continuous caster can be very useful.

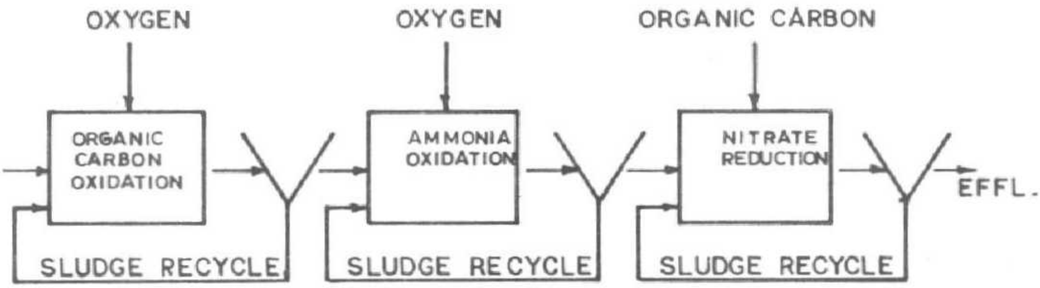

Fig.7 : Three stage-activated sludge process for treatment of effluents[25]

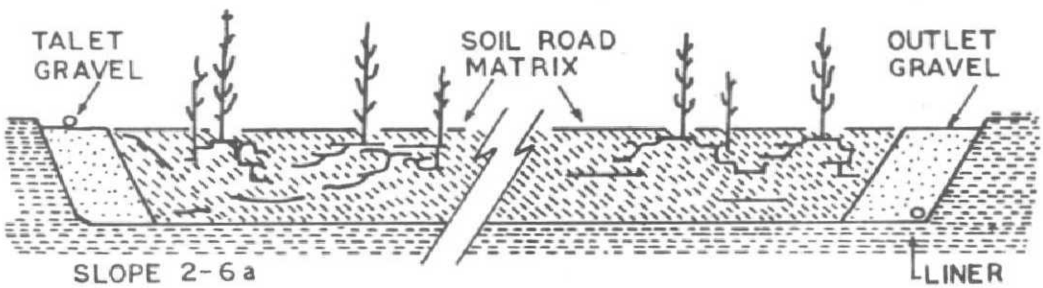

Fig.8 : A typical Root-Zone bed for treatment of effluent water [25]

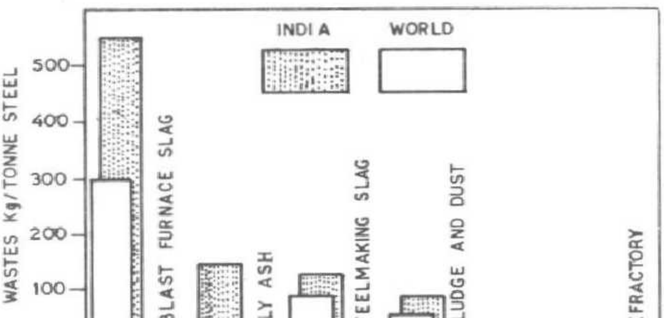

Fig.9 : Generation of solid wastes in Indian Steel Plants compared to typical world data [27]

One of the major environmental problems faced by the EAF route is the treatment and disposal of dust collected from the gas cleaning plant as it contains toxic heavy metals like zinc, lead and cadmium [15]. New technologies have been developed for reducing toxicity of the dust and utilising the metal values, particularly zinc.

The method of treatment of EAF dust depends on the nature of dust and its chemical composition. The melting and refining of iron and scrap in EAF leads to generation of 10-15 kg dust/tonne of steel. Some of the metallic and other elements in EAF dust are soluble and cause serious ground water pollution due to leaching from disposed dust dumped without pretreatment.

In developed countries like USA, Europe and Japan, where a large quantity of galvanized scrap is recycled through the EAF route, the dust contains appreciable quantities of zinc, cadmium and lead. Zinc level up to 25-30% have been reported in EAF dust.

The detoxification process for low zinc dust involves mixing the dust with suitable binder and treating it to produce complex silicates so that the material is suitable for land filling.

In case of dust containing appreciable quantity of zinc, the dust is mixed with a reductant like coal or coke and treated in a rotary kiln. The metal vapours like zinc are oxidized in the kiln atmosphere. These are extracted and used for zinc manufacture. The non-toxic silicious slag is suitable for dumping.

The scenario of toxic metals in the dust in Indian industries is not so complex as the quantity of galvanised scrap is very low. But increasing emphasis on stricter laws for regulating emissions, commissioning of new galvanising lines, extensive use of zinc for corrosion prevention and recycle opportunity for galvanized scrap are expected to lead to serious problems. Research should be concentrated to develop economically viable process to treat the dust before disposal as the cost of treatment adds to the cost of steel.

Local Issues

The large number of processes coupled with the use of variety of raw materials in steel industry present a number of local environmental problems [2, 16-18]. These are basically in the form of particulate and gaseous emissions, generation and discharge of toxic effluents and generation of solid wastes. Some major sources are summarized in Table-3. Though a series of technologies have been developed or are in the process of development for assessing and controlling the impacts, there are a large number of areas where intensive R&D inputs could bring about enhanced effectiveness. Some of these are discussed below:

Air Pollution

As a first step towards solving the problem of air pollution, the potential impact of particulate and gaseous emissions need to be assessed. For these, one needs highly sensitive techniques for assessment and equally sensitive dispersion model to use these data to accurately predict the impacts of these emissions. While the developments in instrumentation have made it possible to assess most of the pollutants fairly accurately and rapidly, the areas which need attention fall in the category of organic emissions. The problem is encountered essentially in the carbonisation process of coal in the coke-oven batteries. The exposure of workers to some potential carcinogens e.g. aromatic and poly-aromatic hydrocarbons and their derivatives needs special thrust. There have been developments [19-21] including those in SAIL R&D in the laboratory techniques for assessment of these pollutants. However, in an industrial environment rapid on-site assessments are extremely beneficial and are therefore to be developed through research investigations. In continuous casting shop slag forming mixtures (SFM) are used as lubricants. These are nothing but compounds with low melting points and form a layer between the liquid steel and the caster to prevent sticking of metal with caster. These SFMs contain fluoride bearing materials like CaF_2, $NaAlF_2$, AlOF, along with SiO_2, CaO, Al_2O_3 etc. It is established that during casting, fluorine gas is emitted which posses serious problems to the workers in that area specially in presence of moisture. Russian laboratories have developed methodology for the analysis of the kind and amount of the fluoride compounds extracting from the SFM at the continuous casting. This can become the basis of developing the new environmental friendly fluoride free SFM with high operation characteristics. More research is required towards developing new SFM and also faster assessment technologies.

Air pollution modelling requires hourly information on meteorological parameters like wind speed, wind direction, temperature, cloud cover, stability class, mixing height, solar insolation etc. It also requires plant emission data averaged over a large period and topographical details including type of terrain. The source characteristics can be measured quite accurately. Topography and terrain details can also be collected from Govt. agencies, but the hourly values of various meteorological parameters are not readily available. Moreover, *Table-3 : Source of Pollution and their Characteristics in Integrated Steel Plants*

Sources/Measures	Characteristics
<u>Raw Material Handling</u>	
Air	Fugitive dust emissions during material handling, emissions due to high winds from stock piles
Water	Waste water contaminated with solids.
Noise	Crushing and screening operations.
Solid	Rejecteed fines in the process.
<u>Coke Ovens</u>	
Air	Process emissions, oven leakages; coke quenching emissions.
Water	Large quantity of toxic waste water containing phenols, cyanides, ammonia and oils.
Solid	Coke breeze; coal spillages; decanter sludge etc.
<u>Sinter Plant</u>	
Air	Process emissions, sinter cooler emissions; fugitive emissions in material handling, proportioning etc.
Water	Solids contaminated waste water.
Solid	Rejects, fine sinter, spillages etc.
<u>Iron Making</u>	
Air	Fugitive emissions during material transport; casting fumes, ladles etc.
Water	Waste water contaminated with ammonia, phenols, cyanide and suspended solids.
Noise	From tuyeres and turbo blowers.
Solid	Large volume of slags; flue dust and slurries
<u>BOF Steel Making</u>	
Air	Fugitive emissions from ladles, furnaces, material handling, furnace charging etc.
Water	Water contaminated with solids, pH etc.
Solid	Slags, spillage scrap and rejected refractories.
<u>Rolling Mills</u>	
Air	SO_2, NO_x. from furnaces, acid fumes from pickling operations.
Water	Water contaminated with solids and oils
Air	Particulates, SO_2 and NO_x emissions
Noise	Rolling operation
Solid	Steel scrap, mill scales etc.
<u>Power Plant</u>	
Water	Water contaminated with solids, oils and dissolved solids.
Noise	Turbo machines; steam leakges
Solid	Large volume of fly ash in slurry form.

stability class is required to be determined using various empirical formulae. Also extrapolation of these meteorological parameters over the entire receptor grid is to be done in order to carry out the modelling. Model though is based on Gaussian theory, utilises a number of empirical formulae for calculating plume rise. Thus the modelling is presently being done with all the above limitations.

While air quality can be measured with adequate confidence, prediction of GLC shows wide variance. Literature shows that for elevated point sources, flat terrain, steady meteorological conditions for short distance (1 km) and 1 hr. averaging time, the accuracy of predicted GLC may vary by a factor of 3.

To add to this uncertainty, Gaussian plume model requires the knowledge of atmospheric stability plume rise, dispersion parameters etc. The methods of obtaining these parameters are all borrowed from western countries. Some of these methods are highly empirical and some are semi-empirical as the science is not clearly understood. Thus to improve predictability of dispersion models, there is need to generate more site specific data on meteorology and carry real-time modelling so that the empirical formulae used in the model can be suitably modified. RDCIS has acquired meteorological system which can generate meteorological data including mixing height (using SODAR) and also developed a software to obtain stability class from hourly meteorological data. More research efforts are required to validate the programme.

Among the pollution abatement technologies available, even the most widely used ones suffer from working at much reduced efficiency. Efficiencies of ESP's, Bag filters etc., for example, depend largely on the dust characteristics. Some of the important characteristics of dust particles like specific resistivity tend to be ignored while characterising these particles.

This factor along with complete size distribution analysis and optimum operating conditions like temperature, humidity, gas flow rate, dust loading etc. can help in achieving maximum efficiency of an ESP. Studies on these lines for ESP's and development of materials for bag filters are areas where research input will prove beneficial. Also the dust collected often poses problem of handling and disposal. Proper care should be taken to design the system to incorporate dust handling system. Dust conditioner involving a screw conveyor with a very fine spray can be used to condition the collected dust to avoid handling problem. Also suitable dust recycling salvage scheme should be prepared to finally end up with zero pollution.

Water Pollution

1) An integrated steel plant requires large quantities of water for direct and indirect cooling, for scrubbing of air pollutants and for process reagents. Depending on local conditions 100 to 200m^3 of circulating water is required to produce one tonne of crude steel [22]. The actual consumption and discharge can be reduced to 3-6 m^3/t of crude steel depending upon the level of recycling and reuse.

The actual quantity of water required per tonne of steel produced is a function of product mix, steel making technology, pollution control technology, recycling opportunities, water availability and relative cost. Japan has reported a circulation rate of over 90% [23]. In the Indian Steel Industry specific water consumption varies in the range 10-50 m^3/t of crude steel as against the norm of 16m^3/t of crude steel.

Discharge of effluents generated in steel industry into contiguous water bodies viz rivers has resulted in high pollution load on many Indian rivers rendering their water unsafe for human beings as well as domestic animals. Damodar river is an example where the values of suspended solids, BOD, phenol and iron are higher than the norms as reported at some stretches of the river [24]. Several instances of concentration of non-biodegradable toxic constituents like heavy metals (e.g. Lead or Mercury) has been reported in the acquatic life. Several places like Salem have high fluoride level in the ground water and this places a severe restraint on the fluoride content of effluents discharged. Research/Investigation/Survey are urgently required to be conducted to assess the extent of pollution caused to rivers by industry and identify suitable remedial measures. Waste water treatment begins at the point of generation and ends with the ultimate disposal, this can be divided into two components namely in plant control and end of the pipe treatment.
In-plant control can be achieved through

- appropriate selection of raw materials
- cleaner technologies for production
- water conservation through recycle and reuse
- by-product recovery

Waste water treatment can be divided into Primary, Secondary, Tertiary and final polishing stages.

Coke oven effluents are regarded as the most toxic and complex waste water generated in steel plants and its treatment methodology is still an area of active research the world over.

The biological oxidation method, commonly used for the treatment of coke oven effluents, poses major challenges due to wide fluctuations in flow and composition of pollutants in the influent stream. A typical arrangement of a biological treatment processes [25] including steps up to denitrification-nitrification processes in shown in Fig. 7. Though aerobic systems along with packed bed-attached growth (trickling filters) systems have been used in tandem, the efficiency of the BOD plants to reduce CH^- and NH_3 to desired levels is not very satisfactory. An anaerobic system in combination with the other two seems to be a probable solution and needs to be examined.

Among the alternative processes, the Root-Zone effluent treatment process developed at the State University of Germany [25] is of very recent origin and offers promise. It exploits the natural ability of phragmites reed to transfer large quantity of oxygen from the atmosphere to its root zone where bacteria in the soil effect biological removal of pollutants present in the ground water. Both aerobic and anaerobic and micro-organisms are present in the active rhizosphere of the Phragmites up to 60 cm in depth due to development of aerobic and anaerobic zones in the reed bed. As a consequence of this, nitrification and denitrification processes occur, together with the degradation of organics, thiocyanates and cyanides. A cross section through a typical reed bed system is illustrated in Fig. 8 and the design characteristics of the root zone system at British Steel Llanwern works to treat 90 m^3/h of crude liquor in a total area of 18 hectares are given in Table-4. The major disadvantage of Root Zone technique consists in its occupying large area of land and fairly long duration (up to 3 yrs.) for full growth of the reeds. However, the benefits like low capital costs (70% of conventional alternative), low running costs (about 90% of conventional alternative), consistent effluent quality, ecological acceptability and zero sludge disposal makes it an attractive process for further examination and investigation with focussed attention to improve efficiency of and reduce time duration for reed growth.

2) In the direction of zero discharge of effluent, a process based on reverse osmosis for water treatment and new methods for gas cooling have been

developed [26]. More research in this method is needed as the reverse osmosis process has been successfully used for treatment and recovery of acid from waste pickle liquor.

The ion exchange method of coke plant waste water treatment is another potential area of research as this promising technology is yet to be industrially established [27].

Another important area that needs intensive process of examination lies in evolving a scientific approach to total water management in steel industry. With the growing depletion of water resources, the cost of water will have significant impact on the production cost of Indian steel industry unless the specific water consumption is reduced to international level. This calls for intensive programmes on increased recycleability and reduction in wastages.

Waste Utilisation

The process of steel manufacturing also generates about 500-1000 kg of solid by-products and wastes for every tonne of steel produced. A typical data on solid waste generation and its utilisation in SAIL steel plants is given in Table-5 and a comparison between Indian and a typical world data on solid waste generation is shown in Fig. 9. Barring some BF slag which is sold in granulated form and some sludges, dusts and mill scales which are recycled through sinter route, a major quantity of slag is dumped. Though there have been serious attempts in the last few years by Indian steel industry [28] to utilise fly ash in brick-making, SMS slag as Rail ballast, the utilisation rate has not improved significantly. The developments in the following areas based on the typical compositions of the wastes generated in Indian steel industry could solve this gigantic problem to a very large extent :

(a) Utilisation of fly ash in soil conditioning for improved growth of plant and forest species.
(b) Partial use of SMS slag in cement making.
(c) Use of all major wastes with optimised compositions in making quality roads and highways.

Each of the above is a major area of research with potential benefits to steel plants. The initial developmental work carried out at the R&D

Table-4: Design Characteristics of the Root Zone System at British Steel's Llanwern Works [27]

Parameter	Feed concentration mg/l	Maximum concentration in effluent mg/l
COD	6,400	500
NH_4^+-N	3,500	100
Cyanide	138	3
Monohydric phenols	190	10
Sulphide	890	25

Table-5: Generation and Utilisation of Solid Wastes in SAIL Steel Plants during 1992-93

Solids Waste	Generated	Utilised	% Utilisation
1. Granulated BF slag	1.73	1.72	99.4
2. Coke Breeze	1.46	1.20	82.0
3. BF slag (Air cooled)	2.81	0.029	1.03
4. SM slag	1.87	0.27	14.4
5. Fly Ash	1.48	0.02	1.35

Centre of SAIL have shown promising results which need to be further exploited to make them commercially implementable.

Environmental Impact Assessment

Environmental Impact Assessment (EIA) is a powerful tool for environment management and helps in decision making for project selection.

In Battelle Environmental Evaluation System of EIA, experts distribute 1000 units to the various parameters according to their importance (PIU) and transfer a parameters measurements e.g. Dissolved oxygen into a common scale (0-1) of environmental quality (EQ). Fig. 10 [29] shows the value function for dissolved oxygen. To assess whether a project will cause environmental deterioration or not, PIU is multiplied with EQ value an the value of the product is compared for 'with' and 'without' project situations. Research into such EIA process with generation of more accurate prediction of impacts and environmental evaluation is needed.

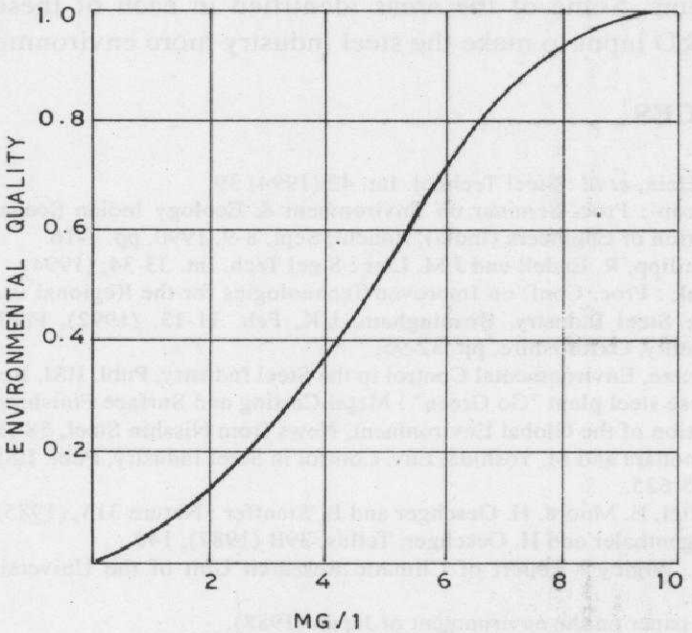

Fig.10 : Value function for dissolved oxygen[29]

CONCLUSION

The manufacture of steel has an adverse impact on the environment. The impacts could be both global and local in nature. It is observed that future efforts in maintaining global environment and supporting continued development will depend heavily on steel. Owing to a fairly large proportion of the contribution to the global CO_2 load by steel manufacturing processes, the future trends in global warming will have to be monitored closely with respect to steel industries' capabilities to minimise Co2 emissions through energy conservation programmes and by developing and using energy efficient processes. Further, R&D efforts in steelmaking processes have to be directed towards processes which require least amount of carbon as a reducing agent.

The iron and steel making operations also pose serious localised environmental challenges owing to their inherent capability to influence all aspect of local environment viz. air, water, noise as well as problems associated with generation of large quantities of solid wastes having widely varying characteristics. However, ways have been evolved over the last few decades to overcome these problems. Some of the areas identified in each of these aspects need intensive R&D input to make the steel industry more environment friendly.

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