Solid Wastes Recycling Through Sinter - Status at Tata Steel

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ABSTRACT

Integrated steel plants generate several by-products rich in iron, flux and fuel values, categorised as waste. These by-products contain, besides mineral values, hazardous constituents causing damages to the environment. The environmental quality consciousness, the product cost competitiveness and the high mineral values of these wastes have resulted in attempts to recycle these materials. Recycling recovers the mineral values, preserves the decreasing natural resources and deteriorating environment and eliminates the disposal cost. Sinter plant provides an avenue for recycling of these wastes. Recycling decreases the cost of sinter and hence the cost of steel produced. Present paper outlines the status of waste generation, their characteristics, and the quantity being recycled via the sinter plant at Tata Steel. Furthermore, it highlights the problems, which restricts its further recycling and discusses its influence on cost and quality of sinter.

Key Words : Solid wastes, recycling, sinter, iron making, dumping.

INTRODUCTION

Integrated steel plants, through various unit processes, process iron ore, coal and flux to produce steel. Each unit process produce one or other by-products. Although many of them are very rich in iron, flux and fuel values, a general term wastes or in-plant wastes has been given to them. During over last one-decade, the environmental awareness and recognition of the mineral values in wastes have resulted in attempts to recycle them and recover their associated minerals up to the extent possible. Recycling recovers the mineral values, eliminates the disposal cost and preserves the environment. Sinter plant, which was developed to convert the iron ore fines, a waste at that time, into a desirable blast furnace feed has further offered an avenue for recycling of these wastes. Today a large number of in-plant wastes in various quantities are recycled through sintering route without impairing its performance and product quality to appreciable extent. Recycling of wastes decreases the cost of sinter and hence the cost of steel produced. Several sinter plants in the world recycle [1-2] the waste material up to the extent of 180-200 kg/ts. The sinter plants facilitate meeting the statutory regulations on environment and make an effective utilisation of natural resources. Thus sinter plants work as a 'waste to value' converting unit. Present paper outlines specific quantities of wastes generated in steel plants, their characteristics, and the status of their recycling via sinter at Tata Steel. Further more it discusses its influence on sintering and highlights the technical problems, which restricts its further recycling.

STEEL PLANT WASTES

The word waste is embarrassing. The steel plant by-products contain values, they are not wastes but co-products or second or third products etc. This makes the term debatable. There are three schools of thoughts. The first considers materials which have to be dumped, i.e., only those which cannot be used in any way. Second, includes virtually all by-products from processes even when they are processed to a specification then used/sold. Third, uses this word in a very general sense and includes the materials, which is not usable without any treatment. Thus all plants have their own lists of wastes. The present paper covers all by-products. Hence, all most all unit processes of an integrated steel plant generate certain waste during their operation as reject of the input or as by-product or secondary product of the process. Table 1 presents common wastes as they arise in the different production steps of a steel works. Out of these many are not being treated as waste and used as regular input for some other unit process, like coke breeze, lime, iron ore & sinter fines, coke oven, BF & LD gas, coal tar etc. are few such examples.

Table 1 :By-products in an integrated steel plant

Unit Process	By-product
Coke ovens	Coke breeze, tar, coke oven gas
Calcination plant	Lime fines, semi-calcined lime, lime stone undersize
Refractories plant	Refractories waste
Sinter plant	Electro-filter dust, air borne dust
Blast furnaces	B F gas, top gas dust & sludge, cast house & bunker house dedusting, and granulate from slag treatment
H M desulphurisation	Slag, dust and vessel quarry
L D	L D gas, slag, sludge, primary & secondary dedusting dust, vessel slopping and quarry
Secondary steelmaking	Slag, dust and vessel quarry
Rolling mill	Mill scale
Pickling line	Sludge
Others	Foundry sand, biological sludge, rubble, used oil etc.

Generation

The amount of waste generated depends on factors like, the quality of raw materials, technological status, operating philosophy, the final product mix etc. The average specific rate of waste generation, under typical Indian condition has been tabulated in Table 2. The typical conditions are : coal ash – 16 %, coal VM- 26 %, coke ash-20 %, coke sulphur-0.60 %, Al_2O_3 in iron ore-2.40 %, sinter Al_2O_3 –2.60 %, phosphorus in iron ore-0.10 % and sulphur and phosphorus in steel less than 0.020

and 0.010 % respectively. It is a typical observation, which may vary depending upon the actual condition. Thus, as per Table-2, one million tonnes capacity integrated steel plant generates 0.375 million tonnes B F slag, 0.18 million tonnes LD slag, 0.012 million tonnes LD sludge, 0.01 million tonnes B F sludge, 0.005 million tonnes various quarries, 0.015 million tonnes dusts and 3 million tonnes of various gases.

Table 2 : Specific rate of waste generation in a steel plant

Wastes	Amount kg/tcs
Coke oven gas	200
Tar	28
Sinter plant ESP dust	8
Sinter plant air borne dust	0.3
BF slag	375
B F sludge	5
Flue dust	15
B F gas	1900
L D slag	180
L D sludge	12
L D slopping	5
L D quarry	2.5
Ladle quarry	3.5
L D gas	75
Sec. steelmaking slag	10
Mill scale	20

Characteristics

The wastes are characterised by their physical, chemical and high temperature properties. Physical properties (size, flowability, grindability etc.) describe ease in the pretreatment and recycling of the materials. The chemical composition decides its suitability for recycling. The high temperature (physical and chemical behaviour at high temperatures) properties explain their behaviour during sintering operation and influence on sintering and product sinter.

The recycleability of any material is decided by considering all these aspects along with target unit process. Based on its recycleability and target unit process a waste may contain (a) desirable (b) undesirable and (c) harmful constituents. A categorisation, of the common integrated steel plant wastes has been shown[3] in Table 3.

The chemical composition of wastes depends on local parameters like composition of input raw materials, technological status, operating philosophy and the quality requirements of final product mix. The chemical composition of wastes under a typical Indian condition can be seen in Table 4.

Table 3 : Categorisation of steel plant wastes

Wastes	Desirable constituents	Undesirable constituents	Harmful constituents
B F slag	CaO	Al_2O_3, SiO_2	S, Na_2O, K_2O for ironmaking
B F dust	Fe, C	Al_2O_3, SiO_2	Na_2O, K_2O for ironmaking
B F sludge	Fe, C	SiO_2	S, Na_2O, K_2O for ironmaking
H M de-S slag	CaO	S, SiO_2	S, Na_2O, K_2O for ironmaking
L D slag	CaO, Fe	SiO_2, Al_2O_3	P for steelmaking
L D sludge	CaO, Fe	-	Zn
Sec. steelmaking slag	CaO	Al_2O_3	SiO_2, Al_2O_3 for ironmaking
Mill scale	Fe	-	Oil for sintermaking
Semi-calcined lime	CaO	Loss on ignition	-

Table 4 : Chemical composition of steel plant wastes

Wastes	Chemical composition, %									
	CaO	SiO_2	MgO	Al_2O_3	P	TiO_2	T. Fe	K_2O	Na_2O	S	C
L D slag	48.91	14.93	2.29	2.16	1.16	0.9	18.22	0.153	0.183	0.17	-
LD sludge	10.84	1.84	0.81	0.9	0.108	0.06	59.05	0.279	0.153		-
Mill scale	0.31	0.55	0.16	0.27	0.032	0.02	70.2	-	-	-	-
W R P	25.71	8.72	2.18	2.18	0.56	0.7	49.37	-	-	-	-
Flue dust	3.66	7.9	1.34	3.0	0.17	0.37	39.5	0.344	0.151	0.32	25.5
B F slag	32.42	33.06	8.69	19.33	-	1.11	0.35	0.76	0.1	1.00	-

WASTES RECYCLED THROUGH SINTER PLANT

Recycling recovers values from wastes; high mineral value wastes are potent for recycling. Worldwide sinter plants are recycling[1] wastes up to 180-200 kg/tcs. Fig. 1 shows the amount of wastes recycled through sinter plant over the years at Tata Steel. The decrease during the year 1998-1999 and 1999-2000 is the result of more than one aspects, described later. Blast furnaces screen iron ore and sinter before charging into furnace and return the fines, which is not usable to the blast furnaces. Fig. 2 presents the amounts of total wastes including iron ore and sinter fines from blast furnaces that the sinter plant recycles. The recycling of some of the individual wastes can be seen in Fig.3 through Fig. 6. The decrease in the recycling of LD slag and flue dust during 1998-99 and 1999-2000 is due to phosphorus and alkali problems respectively. The specific rates of waste recycling can be seen in Fig. 7 and Fig. 8. These figures show that on an average the wastes constitute approximately 10 percent of the input material without iron ore and sinter fines and 14 percent with these fines. It is clearly seen from above figures that both the amount and the specific rates of the waste recycling have increased considerably. This shows our concern over recovering the value from the waste.

A slight decrease in the mill scale recycling is due to closure of old mills and hence the generations of this waste itself. Similarly a decrease in the recycling of WRP (metallics) during 1998-1999 is due to relocation of the department. Table-5 lists the typical amount of important wastes being recycled through sinter.

Table 5 : Recycling of waste through sinter

Materials	Extent of use, kg/t sinter
L D slag	25
L D sludge	20
Mill scale	15
W R P metallics	20
Lime fines	10
Flue dust	2

INFLUENCE OF RECYCLED WASTES ON SINTERING PROCESS

In general the recycling of wastes through sinter have cost and environmental benefits but it impairs other aspects of sintering such as plant productivity, fuel rate and quality of the product. Following sub-section outlines the effects of some of the individual wastes on sintering and sinter.

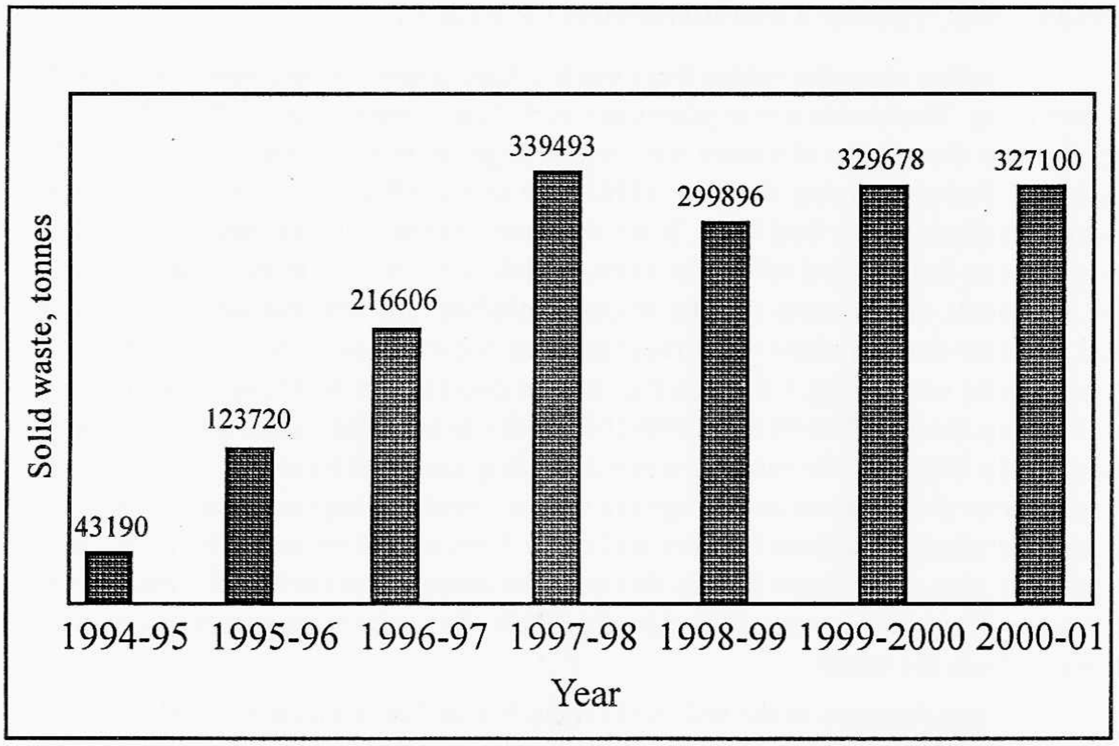

Fig. 1: Recycling of solid wastes

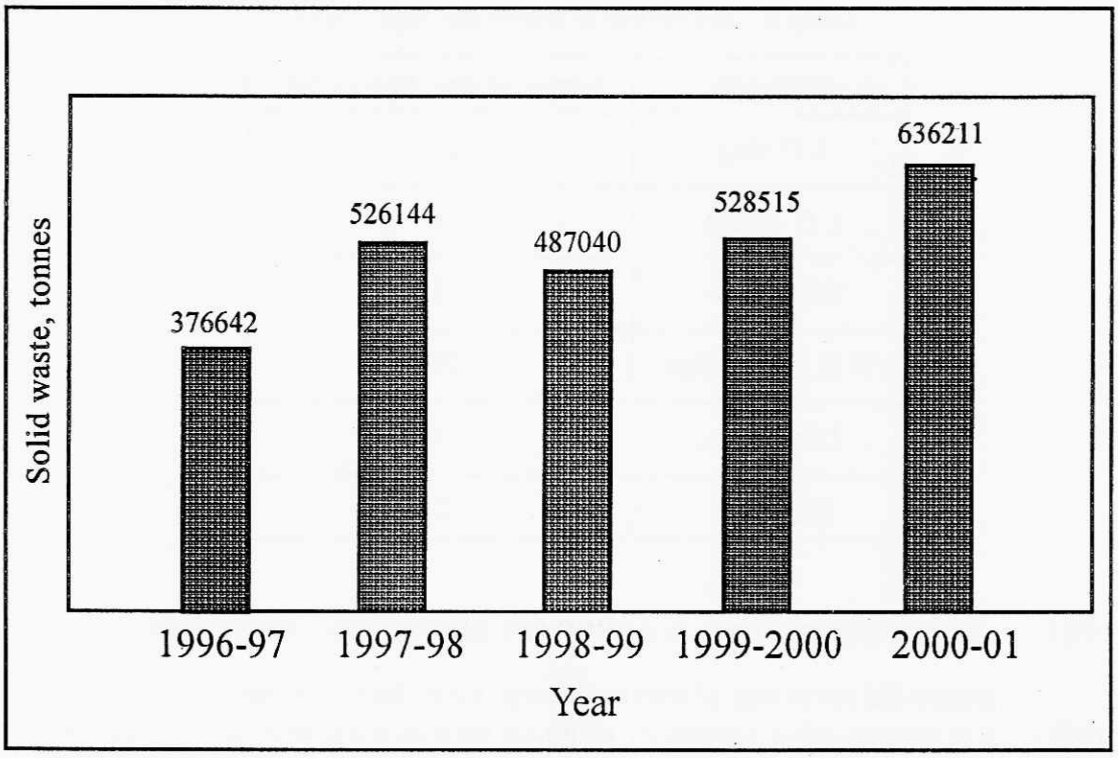

Fig. 2 : Recycling of solid wastes (including I/O and sinter fines)

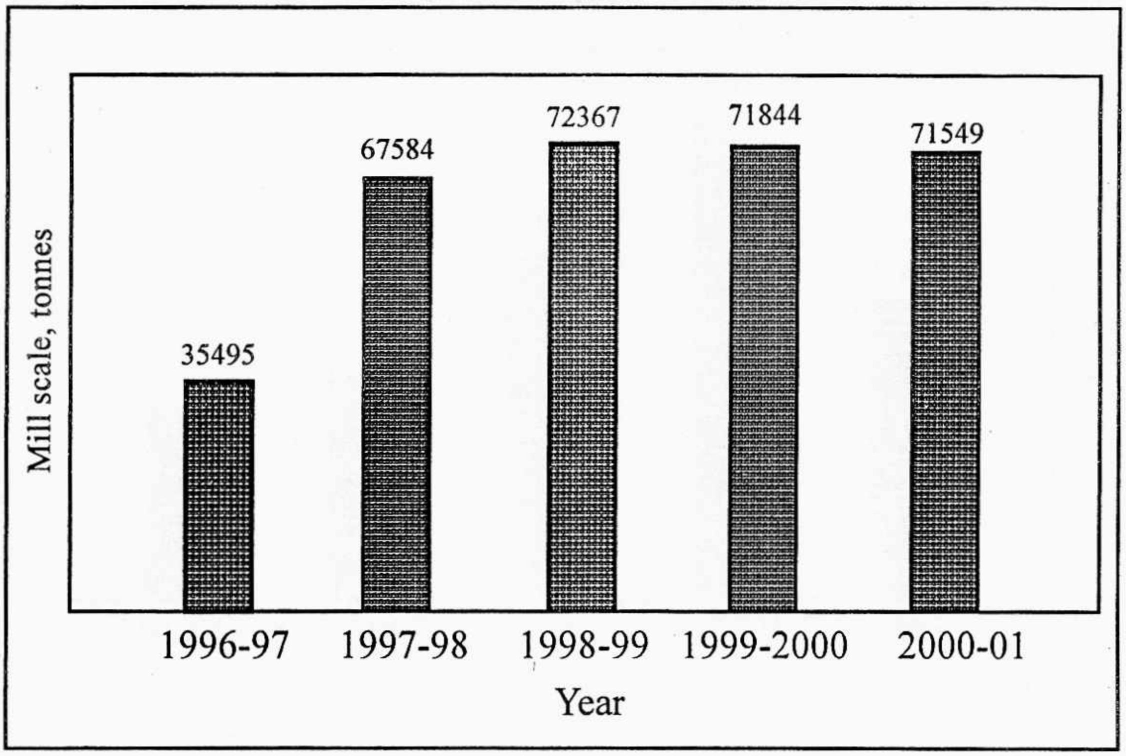

Fig. 3: Recycling of mill scale

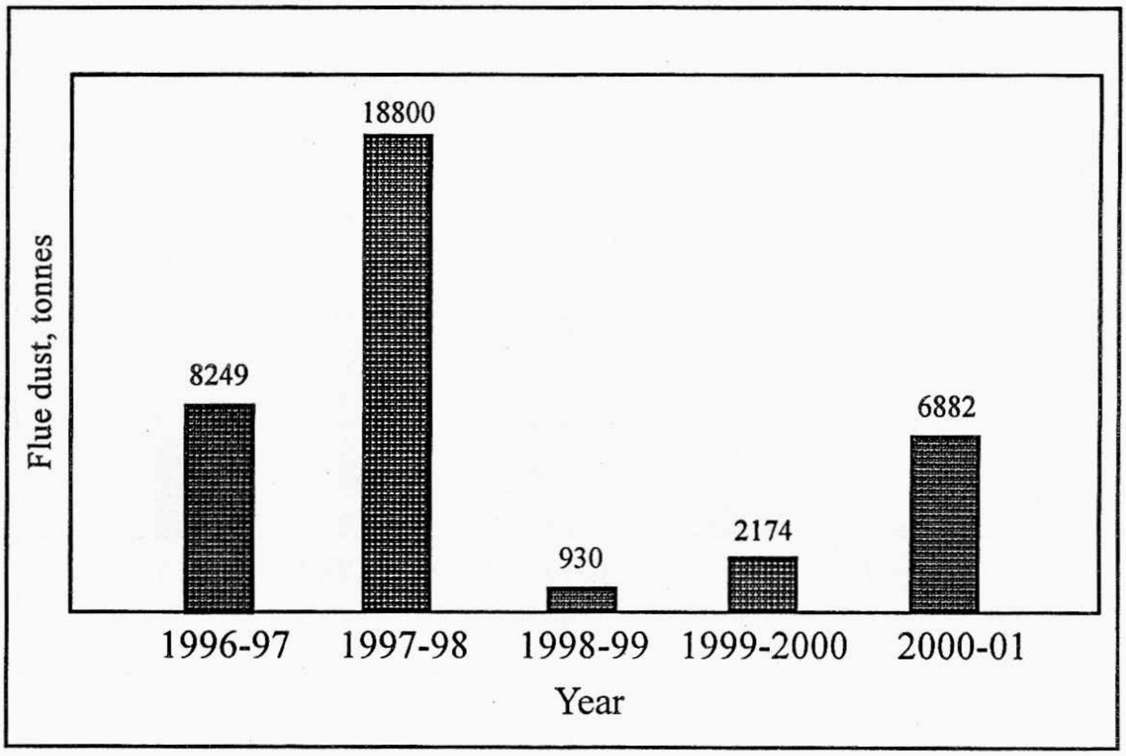

Fig. 4 : Recycling of flue dust

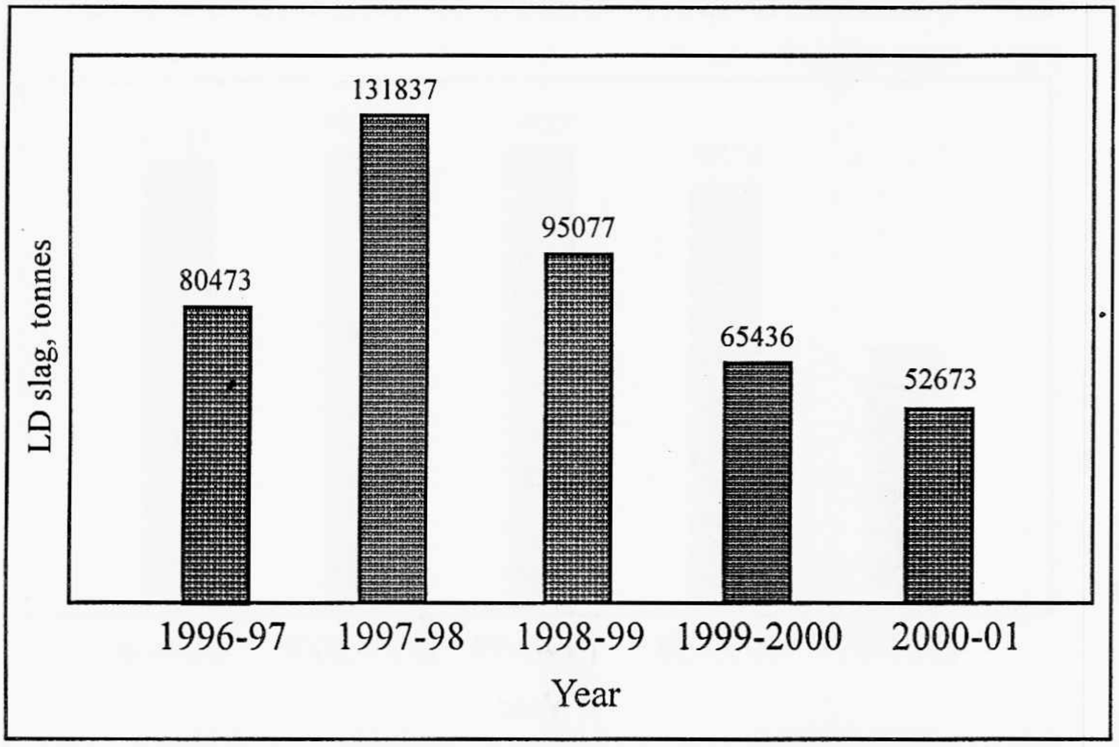

Fig. 5 : Recycling of L D slag

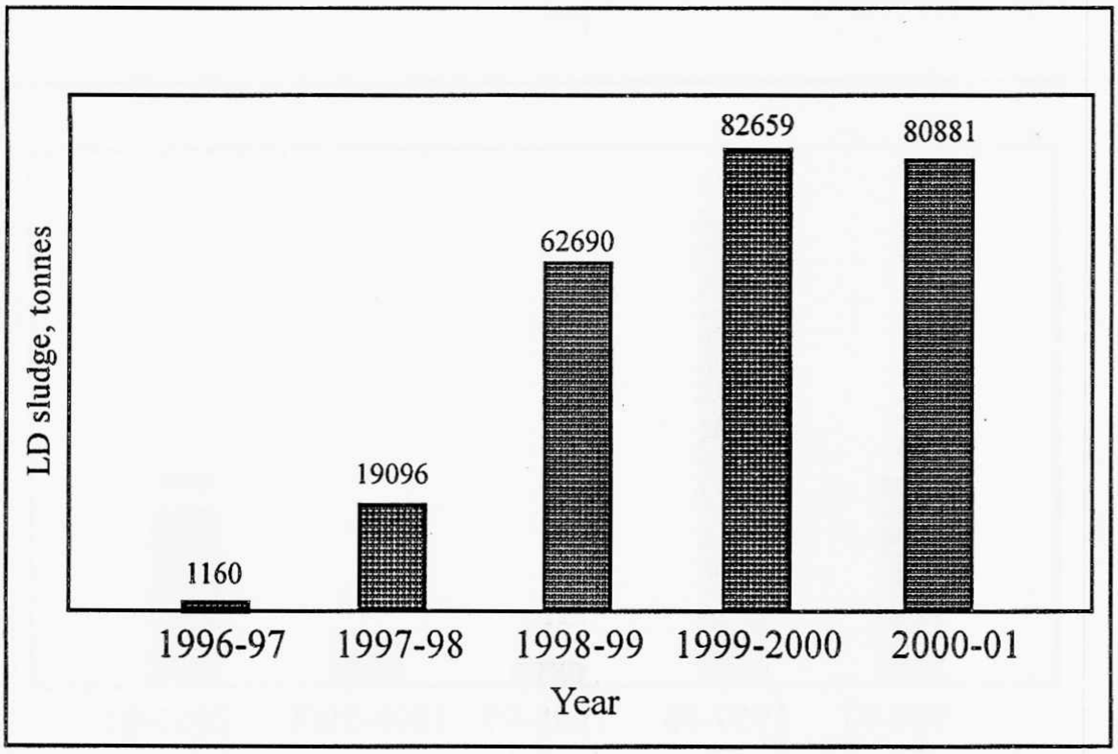

Fig. 6 : Recycling of LD sludge

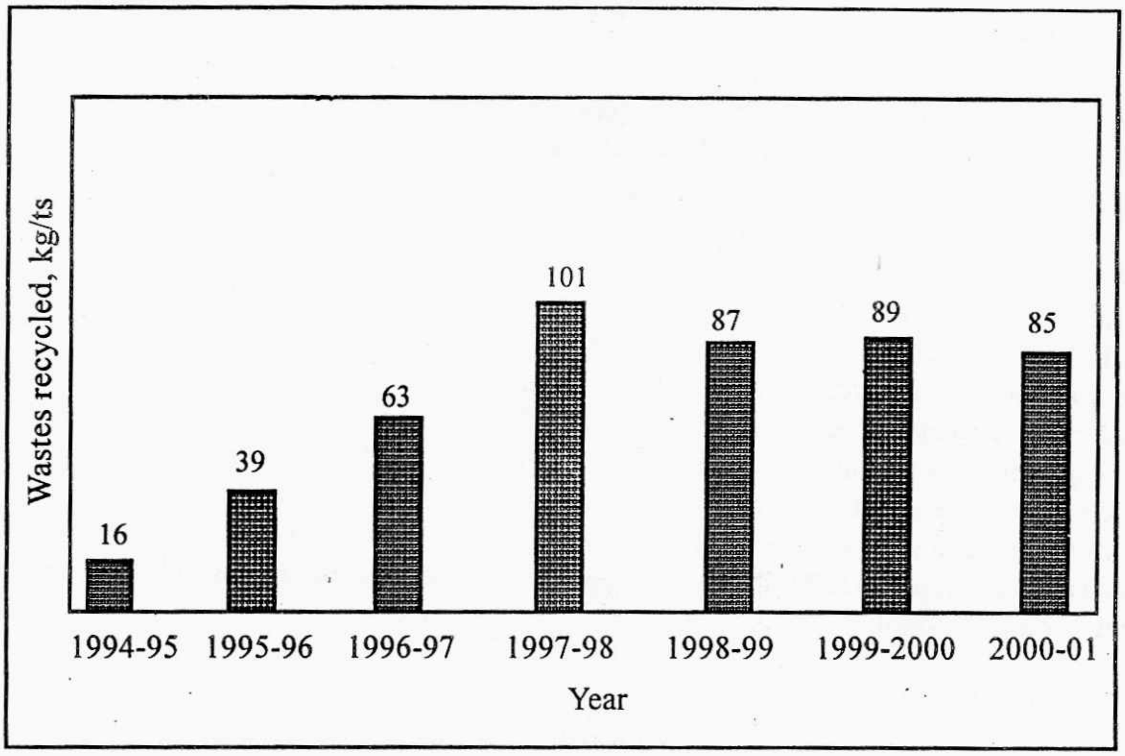

Fig. 7 : Specific recycling of solid wastes

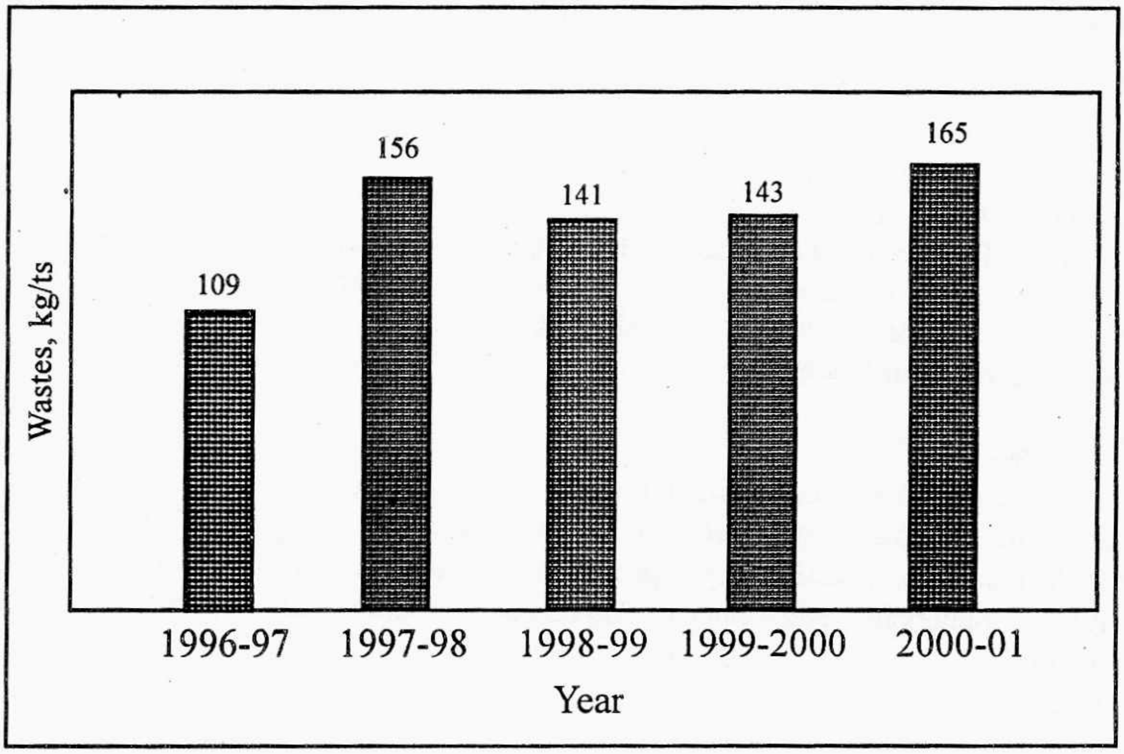

Fig. 8 : Specific recycling of solid wastes (includes I/O and sinter fines)

Mill Scale

Mill scale, very high in iron and low in unwanted impurities accounting for 1-2 % of the steel rolled, is a major waste generated during the rolling of steel. At Tata Steel the present generation rate is 1,00,000 tpa of which 90,000 tpa is non-oily coarse category and 10,000 tpa is oily mill sludge[4]. Almost 100 % of the generated non-oily mill scale is recycled through sinter . The associated oil and grease, from the rolling process, is the main problem with this material, which may emit undesirable organic compounds during sintering. The high and unstable oil content of mill scale is undesirable. If added in the sintering mix the oily compounds condenses in the electrostatic precipitator, reduces its efficiency and has a danger of subnormal burning such that the electrostatic precipitator can glow fires.[5] They are generally porous, flat in shape and consist of mainly wustite and magnetite. They behave exothermally during sintering and are effective in reducing SO_x emission and RDI of sinter. Due to its high ferrous content a saving in energy consumption results. Due to lower mean size of the mill scale as compared to the iron ore the insufficient assimilation results and sintering time becomes longer.[6]

Blast Furnace Dust

The blast furnace dust or flue dust is a very common material being recycled through sinter. The high iron and carbon content of this material makes it very attractive for recycling. The high alkali content and the fine particle size, which impairs the sinter bed permeability, is a problem with this material. This does not demand any treatment before recycling. It is transported to the bedding and blending yard where it is bedded on piles for its recycling.

Sinter Plant Electro-filter Dust

The recycling of sinter plant electro-filter dust depends on its chemical composition. The high and varying alkali contents of this material is the negative aspect for its recycling. The alkalies originate principally from ores and coke breeze as well as from recycled materials such as, flue dust. The alkali chlorides affect the precipitation rate of the electro-filter negatively, and therefore, cause higher sinter plant stack emission. Although the higher alkali content is a restriction for its use in high proportion, normally most of the plants recycle the entire dust generated.

L D Slag

LD slag is absolutely essential from process viewpoint such that steelmakers take pride in making slag of required chemistry but from cost point of view it is a problem material. It costs money to produce it and then again money is needed for its disposal. Remarkably every tonne of slag dumped contains roughly 500 kilograms of lime and 180 kilograms of iron and 30 kilograms of MgO. Recycling it through sintering process recovers lime, iron and magnesia making a saving of flux material and iron ore but at the cost of plant productivity, fuel rate and product quality. The mineralogical composition of LD slag is dicalcium silicate, calcium ferrite and calcium-wustite. The calcium silicates are high melting compounds (Table 6), and so are the solid solutions rich in silicates. The CaO in LD slag does not exist in free form but as dicalcium silicate, dicalcium ferrite and calcio-wustite. Unavailability of free CaO for assimilation during sintering delays the initial liquid phase formation resulting in insufficient mineralogical microstructure formation. With usage of LD slag the sintering reaction gets delayed leading to decrease in productivity and inferior sinter quality[7]. Due to higher melting temperature of the LD slag than lime, the temperature of the liquid at the interface between the iron ore and the LD slag is higher than that between iron ore and burnt lime or limestone[8] suggesting a higher heat demand for the process. The dicalcium silicate is stabilised by P_2O_5 content of the slag, which prevents the disruptive phase inversion. Some free lime and free MgO also exist. They occur both as the precipitate from the melt and as unassimilated particle.[9] Although a general trend on recycling of LD slag through sinter has started[10-16] the higher phosphorus content is the restricting factor for its further recycling. Experiments carried out have suggested 10 percent replacement as optimum.[15] Before use it is crushed and screened like limestone. Mass balance calculations[16] shows that LD slag up to 50 kg/t sinter can be used without phosphorus build-up problem.

Table 6 : Melting points of calcium silicates

Compounds	Melting point, °C
$CaO.SiO_2$	1544
$2CaO.SiO_2$	2130
$3CaO.SiO_2$	2070

LD Sludge

L D sludge is a high iron, high CaO material. Chemical composition wise except higher percentage of alkali, Zn, Pb, etc. is it a profitable material for recycling through sinter. It causes loss of bed permeability due to its finer size. Hence, in general, the alkali balance and permeability restricts its further use after a critical percentage. Under our conditions these problems are not very critical hence the full amount generated is recycled through sinter.

WRP Metallics

WRP metallics are the plant wastes mostly from the steelmaking units. Metallics lost through slag and slopping are recovered here. They are rich in iron and flux. Entire WRP (metallics) generated is recycled through sinter.

WASTES NOT BEING RECYCLED THROUGH SINTER

Although the sinter plant has opened a very promising avenue for recycling of steel plant waste, there are still a large number of materials, which are not being recycled through sinter. The reason for not recycling lies solely with the chemical composition of individual materials. The materials containing high percentage of alkali, phosphorus, sulphur, zinc, chromium, nickel and oil as well as those containing low percentage of iron, fuel and flux are not suitable for recycling. Circumstances in which the undesirable constituents are in lower percentage, these materials are recycled through up to the limit tolerable to the final sinter chemistry. L D slag, L D sludge, mill scale etc. are the example of such wastes. Some times too fine and too difficult to crush materials are also discarded from recycling. Table 7 lists the materials not being recycled to the extent of generation through sinter along with reasons for not recycling.

Table 7: Materials not being recycled through sinter

Materials	Reasons for not recycling
HM de-S slag	Sulphur and alkali content
L D slag	P, Al_2O_3 and Cr contents
Mill scale	Oil content
L D dust	Zn content
L D sludge	Zn, alkali and Pb content
L D quarry	Low in constituents for sinter
L D slopping	Low in constituents for sinter
B F sludge	High alkali and sulfur content
Sec. steelmaking slag	Al_2O_3, SiO_2

ECONOMICS OF RECYCLING

The impact of recycling is multi-fold; some are tangible and even more important is the intangible part. The tangible part includes the impact convertible into economic terms (money value). The intangible part includes the impact on environment. The cost of environmental hazards caused due to disposal of wastes, not easily convertible in money terms, is enormous. The tangible part includes savings in disposal cost and the cost of materials it replaces after compensating for extra processing cost (if any) up stream or down stream due to usage of waste materials.

The economics of recycling begins with the savings in disposal cost. It is known that several wastes demand some or other treatments before its disposal. Precisely the disposal cost depends upon type of material as well as distance to be covered before dumping it. The requirement of pre-treatment is decided by the type of materials. The transportation cost on disposal, which constitutes visibly major portion of economics, depends upon the distance to be covered. Notably some materials, of course smaller quantity, may be dumped inside works also without any treatment. On the other hand, materials generated in bulk have to be dumped far away from the works premises. At

Tata Steel the disposal cost are in the range of Rs. 75 to 100 Rs/t of waste. Moreover, the activity of moving the wastes has a hidden cost also in terms of bringing the operations to a halt merely because some thing has gone wrong with the process of moving the wastes out.

The economics of recycling works in totality. The saving due to recycling of any particular material comprises: (a) cost of disposal, (b) cost of processing before disposal, (c) cost of material it replaces (d) compensation for processing cost to make it recyclable. Thus considering similar disposal cost, depending upon the mineral worth, replacement ratio and processing cost of different wastes have different saving potential. For example, LD slag replaces equal amount of limestone. The disposal cost may be taken as Rs 80/t. The savings arising due to recycling of LD slag, after taking out the expenses involved in processing before its use, approximates to Rs.800/t. Tata Steel recycles around 5000 tonnes of L D slag per month. The total annual saving arising out of LD slag usage calculates to Rs 4.8 Crores. Disposal of this amount would cost approximately Rs 50 lakhs annually. Some other material can give a lower per unit saving on recycling.

Approximately 27000 tonnes of various solid wastes are recycled every month through sinter replacing around 80-90 kg of prime material/t sinter. The total annual saving to the company due to waste recycling translates to the tune of Rs 25 Crores.

CONCLUSIONS

Integrated steel plants generate several by-products, categorised as waste. Wastes are rich in iron, flux and fuel values. Sinter plants provide opportunities for recovering values from wastes or converting the 'waste to gold'. Flux fines, LD slag and sludge, BF dust, mill scale etc. are being recycled up to the extent of 100 kg/t-sinter without considering iron ore and sinter returns from the blast furnaces. Approximately 27000 tonnes of various solid wastes are recycled every month through sinter replacing around 80-90 kg of prime material/t sinter. The total annual saving to the company due to waste recycling translates to Rs. 25 Crores. Materials, which are chemically not suitable for recycling through sinter, are still being dumped. Such materials require technical solution for its treatment to remove some of the dangerous and harmful constituents to make it usable.

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