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Research Article

RECYCLING AND UTILIZATION OF SOLID WASTE GENERATED IN THE ROURKELA STEEL PLANT, ODISHA

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ABSTRACT

Now-a-days developing countries compete with each other in primarily metal production. India occupies the 2nd position in metal production after China in the world. So this creates its own challenges in terms of management of solid waste produced from metal manufacturing industry. Amongst the metal manufacturing industries, Steel industries contribute largest amount of solid wastes. In India there is very rich deposits of hematite and contains higher percentage of alumina and inferior cokes. Steel plant produces a variety of solid waste material viz. BF slag (Air cooled & granulated), SMS slag. BF GCP sludge, sinter sludge, coke breeze and fly ash etc. The granulated BF slag is used for cement production but the slag containing high amounts of Fe is a major challenge to human being. This paper discusses the issues pertaining to the solid waste generation in Rourkela Steel Plant, Odisha in terms of volumes toxicity, challenges and efforts towards recycling and utilization in eco-friendly manner.

INTRODUCTION

The major causes of environmental pollution are industrialization, population explosion, urbanization and rising living standard of people. Industrialization is very important for economy but it causes serious problem of pollution to our air water and soil. What Modern man produces today and considers as best it becomes the waste of tomorrow. Dumping of waste materials are increasing day by day (Singh, *et al*., 2013; Das, *et al*., 2007) There are several types of solid wastes thrown to the nature viz., industrial waste, debris due to new construction, demolition, plastics, ceramics, municipal waste, biomedical waste etc (Murthy, *et al*., 2017).

Rourkela Steel Plant (RSP) is an integrated Steel Plant and uses the LD (Linz-Donawitz) method of steel manufacturing. It had an associated fertilizer plant that produced nitrogenous fertilizer, but now is not in operation. At present the capacity is 4.5 million tons of hot metals, 4.2 million tons of crude steel and 3.9 million tons of saleable steel which is likely to be expanded to 10.8 MTPA by 2025 (Kumar, *et al*., 2006; Bence and Albee, 1968).

According to MOEF, Steel industry is one of the polluting industries. An integrated steel plant involves a number of complex industrial operation viz. mining and preparation of raw materials, iron and steel production etc. These are carried out through material handling plant, coal beneficiation, coke ovens, blast furnace, sinter plants, steel manufacturing, rolling mills, captive power plants etc. During these operations, huge amounts of various types of solid wastes are generated (Pradhan, et al., 2005; Braeza and Nelson, 1991).

Steel plants generate BF-slag, steel making slag, fly ash, BF sludges, dust from BF, steel manufacturing, refractories and coke etc. as solid wastes. The generation depend upon the amount and quality of raw materials used. We emphasis here on the types and amount of various solid wastes produced in RSP and its utilization along with plans to reduce in future (Cathy, *et al*., 1998; Chatterjee, *et al*., 1993).

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Steel Industry Scenario

Currently steel with varying composition are available. The global steel production is growing each year. India became the world's third largest steel producer in 2016 due to availability of raw materials and cost effective work force and continuous modernisation. The Indian steel industries have always strived for continuous up gradation with higher energy efficiency level to compete with global market (Pradhan, *et al.*, 2005; Gomez, *et al.*, 2009).

There was a healthy growth of 11% in steel production in 2016-17 with a growth of 10.7 million tons of crude steel output during Jan-Mar, 2017 in India. A significant shift has been noticed in the production of steel in world scenario. USA contributed 37% of global steel production in 1990 which is about 14% now. Steel produced by Asian countries accounts for almost 40% in the post war period. After 1960, recycled materials are used continuously in steel production and at present over 40% steel are produced using recycled material including steel scraps (Wouter, *et al.*, 2005; Pires, *et al.*, 2011).

The seven integrated steel plants in India are:

- TATA Steel
- Bhilai Steel Plant (BSP)
- Rourkela Steel Plant (RSP)
- Durgapur Steel Plant (DSP)
- Indian Iron & Steel Company (IISCO)
- Bokaro Steel Plant (BSL)
- Visakhapatnam Steel Plant (VSP)

The market demand of Indian steel has risen continuously. India exported 42% more steel in 2017 as compared to 2016. India may rise to second positon globally as steel manufacturing country 2018 (Norgate, *et al.*, 2007; Fosnacht, 1982)

Types of Solid Wastes Generated in Rourkela Steel Plant

Several operations practised in the production of iron and steel generate solid wastes. The amount of solid wastes varies depending upon the manufacturing process used and pollution control measures taken by different plants. 8 tons of gases with moist dust and 0.5 tons of solid wastes are generated per of ton of steel produced using quality materials and effective procedure (Esezobor and Balogun, 2006; Prakash, *et al.*, 2007) In steel plants of SAIL high waste are generated which varies from 820 kg/tcs to 1045 kg/tcs. The main solid wastes generated from Rourkela Steel plant (RSP) comprise of

i. BF Slag
ii. Granulated BF Slag
iii. Sludge from sintering and gas cleaning system
iv. Flue dust
v. Mill scale
vi. Fly Ash
vii. Coke Breeze
viii. Waste Refractories
ix. Lime/Dolomite dust

Categories of Solid Waste

Basically the solid wastes are classified into three categories:

i. Fly ash
ii. Ferruginous solid waste
iii. Non-ferruginous solid waste

Fly Ash: Fly ash is produced in the captive power plants of RSP. Presently 36000 T/month of fly ash is generated in the plant most of which is disposed of in ash ponds by using wet method.

Ferruginous Wastes: Ferruginous wastes are nothing but iron containing wastes generated at various steps of steel production. These have greater recycling potential and can replace raw materials like iron ore, lime stone and coke breeze (coal) (Patel, 2006; Katsuura, *et al.*, 1996; Markkonen, *et al.*, 2002).

Non-Ferruginous Wastes: The wastes with non-iron components are known as non-ferruginous wastes. They include waste refractory bricks, lime and dolomite fine particles, fly ash and sludge. They are generated during calcination, refractory lining of converter and power plant operations Table 1 and (Fig. 1).

The steel plant solid wastes can be divided into following according to the source

(i) Solid Waste generated from process unit
(ii) Solid waste generated from Pollution control units

Generally, quality of raw materials and process adopted decide the quality and quantity of solid wastes produced in a steel plant. Solid waste management has posed a great challenge to the engineers and scientists. The steel plants established after 1970 generate huge amounts of solid wastes and are associated with huge unutilized air cooled

Table 1. Solid waste production and utilization.

S. No	Variables	Production (Kg/Ton of raw Steel)		Utilization (%)	
		Developed Countries	RSP	Developed Countries	RSP
	A. Process Waste				
	Coke Breeze	--	80	--	100
	BF Slag	200-410	450	100	60
	SMS Slag	70-140	165	65-90	35
	Mill Scale	20-25	25	100	90
	Waste refractory bricks	5-6	8	--	59
	B. Waste from Pollution Control Measure				
	Dust/ Sludge (sintering)	--	37	100	100
	Dust (BF Flue gas)	5-11	22	100	60
	Sludge (BF GCP)	3-9	12	30-75	1
	Sludge/Dust (SMS)	7-15	10	100	37

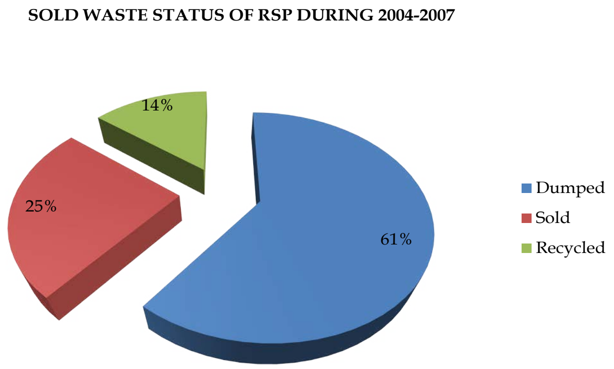

Fig. 1 Sold waste status of RSP during 2004-2007.

slag and fly ash which causes various environmental problems (Shekdar, 2009).

Developed countries have reduced the quantity of waste drastically from 1200 kg to 200 kg per ton crude steel by following advanced steel making processes and better quality materials. Strict environmental regulation and legislation and innovative waste reduction methods have also helped in the waste reduction process. Their utilization rate is around 95-97% as compared to 40-70% recycling and utilization rate in India. Thus in India increase in cost of production decrease in productivity which leads to further environmental degradation (Koros, 2003; Pan, *et al*., 2016).

Solid wastes from process units are characterized by their size and composition. They have low moisture content and high percentages of Fe, Ca, Mg, Carbon particles etc. which make them suitable for recycling and to be reused by other industries (Pal, *et al*., 2003).

METHODOLOGY

Solid wastes can be assessed by the standard analytical procedure prescribed by Bureau of American Health Standard, Washington DC-2005 and Quantitative methods by I. Vogel. Both proximate and ultimate analysis will be made to determine the percentage of carbon, Sulphur, nitrogen, oxygen etc.

A. **Mineraeological Analysis:**

i. **X-Ray Diffraction Study:** It is carried out to identify various mineralogical phases and to find out the relative abundance of them by means of diffract meter.

ii. **Optical Microscopy:** This method is adopted to determine the texture, microstructure etc. by means of reflected light microscope

iii. **Electron Microscopy:** This method is used to study the size, shape and micro morphology of materials by means of electron microscope.

B. **Chemical Analysis**

It is used to analyse waste materials and to separate them from each other on the basis of chemical contents.

i. **Atomic Absorption Spectroscopy:** This method is adopted to analyze the traces of heavy metals like Ca, Ni, Co, Pb and Zn by means of Atomic Absorption Spectrophotometer.

ii. **X-Ray Fluorescence:** It is used to study the major and minor constituents of various slags by means of X-Ray spectrometer.

Physical properties and chemical compositions of the waste samples have been depicted in the following Tables 2-5. The projected data is less than the actual data as it depends on quantity of production and extension of the production unit.

Solid wastes generated from RSP is given in above table. Among which BF Slag, Slag & Sludge from SMS are not fully utilized. The utilization of sludge

Table 2. Physical properties and composition of BF-Flue dust (Prakash, 2007).

Elements/Compounds	Average %	Elements/compounds	Average %
C	29.90	MnO	0.58
Fe_2O_3	51.10	K_2O	1.22
SiO_2	6.31	Na_2O	0.47
Al_2O_3	5.12	Fe(T)	35.73
CaO	4.90	Bulk density (g/cc)	1.4
MgO	0.88	Specific Gravity	2.59
Pb	0.024	Porosity (%)	45.15
Zn	0.042		

Table 3. Composition of steel slag.

Elements/ Compounds	%	Elements/ compounds	%
CaO	40-52	Al_2O_3	1-3
SiO_2	10-19	P_2O_s	0.5-1
FeO	10-40	S	< 0.1
MnO	5-8	Metallic Fe	0.5-10
MgO	5-10	Mg	1-2

Table 4. Constituents of BF slag.

Elements/Compounds	Percentage	
	Average	Range
CaO	41	34-48
SiO_2	36	31-45
Al_2O_3	13	10-17
MgO	7	1-15
FeO/Fe_2O_3	0.5	0.1-1.0
MnO	0.8	0.1-1.4
S	1.5	0.9-2.4

& slag is less than 50% (Fig. 2-5).

Reycling and Utilization of Non-Biodegradable Wastes

Wastes are categorized as per their hazardous nature as follows:

a. Hazardous waste

b. Non-hazardous waste

Disposal of Waste in RSP

In the steel industry wastes are disposed in a very systematic manner so that the effluents do not pollute and damage domestic water, soil, air quality, human habitat, flora and fauna.

On the basis of reutilization capabilities, these wastes may be of three types:

a. Wastes which are non-hazardous and successful recovery recycle and reuse of valuable materials is feasible.

b. Hazardous solid wastes which must be treated suitably

c. Non-hazardous waste from which recycle recovery and reuse may not be economical

Utilization of BF Slag

BF slag is utilized in cement and ceramic industries. Silica gel from BF slag can be recovered by leaching with H_2SO_4 followed by separation of gypsum. Silica gel is precipitated at pH 3.2. The ceramic tile was prepared by mixing calcium silica at various properties.

Removal of lead can be done using Freundlich method. The efficiency of removal of lead at equilibrium increases with increase in slag concentration but this decreases sorption capacity. The method can be used for granulated slag for removal of lead from industrial waste (Shi, 2004; Ramachandra and Saira, 2004)

Utilization of BF Dust

Presence of Na, K, Zn, Pb, Cd, S, Cyanides, oils etc in flue dust hinders the reutilization process. Na, K, S can cause operational hindrances and are not acceptable in hot metal composition. Due to presence of alkalis, the melting softening temperature is decreased They also cause lots of permeability problem and damage of refractory bricks. Alkali cyanides so formed cause environmental problem. Zinc is also considered as a problem as it increases the coke consumption by creating circuit in the furnace.

Utilization of Steel Slag

The steel slag is different from BF slag. Generally steel slag is used as aggregates for making granular base, embankment, filling materials and in hot mix asphalt pavements.

Utilization of L.D Slag

It is used as soil conditioner, fertilizers. It can be utilized for recovering metal values LD slag can be used to increase soil fertility and PH for the better production of tomato, potato, onion, spinach etc.

The studies on LD slag revealed that it can be used on posture farming, agro forestry and forestry. Smelting

Table 5. Solid waste generated in RSP (Das, 2003).

S. No.	Solid Waste	Source	Amount in Tons	Composition		Utilization (2008-2009)
1	BF Slag	Blast Furnace	881897	Fe	46.52%	82.47%
				CaO	22.30%	
				MgO	4.10%	
				MnO	2.6%	
				SiO_2	26.31%	
2	SMS Slag	Steel Melting Shop	3455349	FeO	18-21%	45.05%
				SiO_2	16-18%	
				CaO	47-53%	
3	BF Flue Dust	BF Dust Catcher	15960	C	2.13%	100%
				LoI	19.4-43.69%	
				Fe	30-40.5%	
				SiO_2	7.4-11.6%	
4	SMS Sludge	Waste Water Regiment Plant of SMS	366917	C	2.13%	20.29%
				MgO	2%	
				SiO_2	2.1%	
				Fe	51.8%	
				S	0.21%	
				CaO	12.8%	
				LoI	6.7%	
5	Scale	Roll Mill Water Treatment Plants	34960	Mixed Iron Oxide	--	97.71%
6	Sludge	Acetylene Plant	2502	SiO_2	4-6%	100%
				Al_2O_3	1-3%	
				CaO	60-70%	
7	Calcined Lime Fine	Calcination Plant #2 & LDBP	33181	CaO	70-80%	100%
				MgO	3.5%	
				SiO_2	1.7%	
				Al_2O_3	3.5%	
8	Used Refractory Bricks	From Recycling of Convertors, Furnace and Ovens	4359	Ca, Al_2O_3 and traces of Fe_2O_3, MgO	--	100%

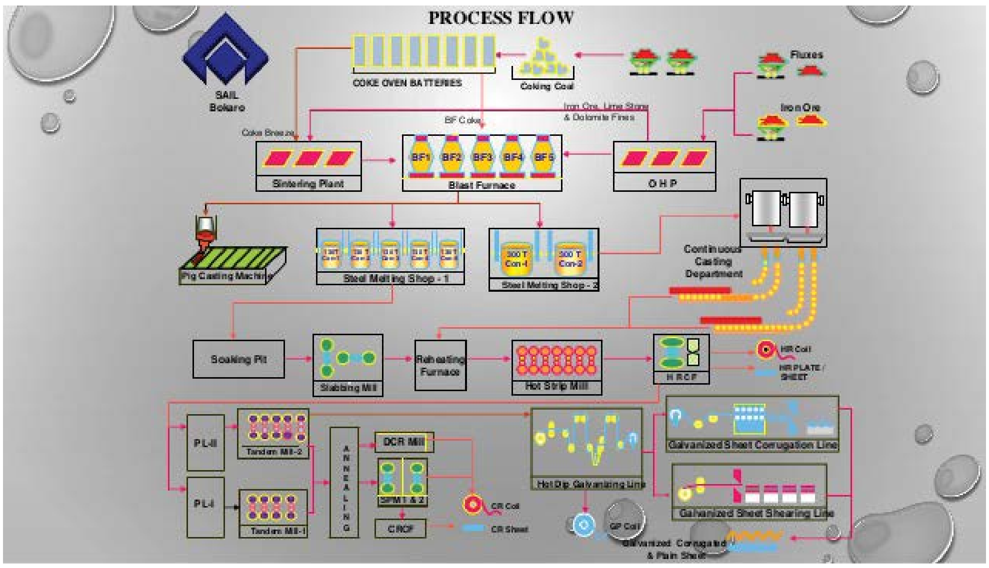

Fig. 2 Flowchart of production process.

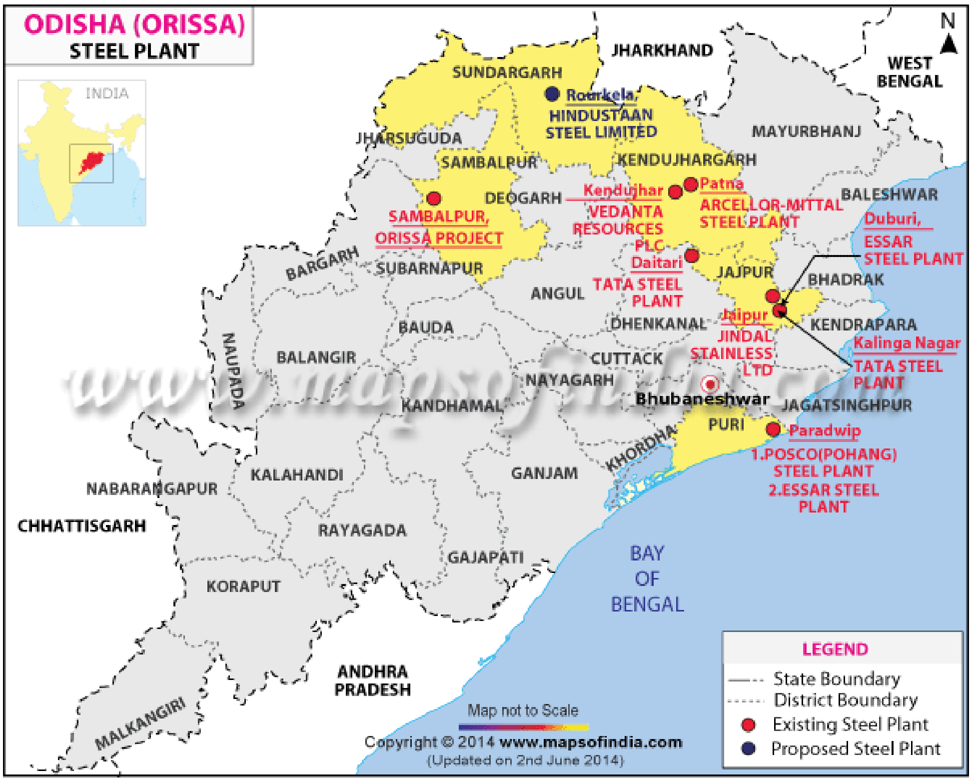

Fig. 3 Location map of Rourkela steel plant.

Fig. 4 Overview of Rourkela steel plant.

reduction technique is applied to recover valuable materials such as vanadium and chromium. LD Slag can also be used as road stone. It can also be tested and used in rail ballasts.

Utilization of LD Sludge

LD slag is pelletized to make best use of the use of LD sludge in sintering process. It can be used for production of hot metals by recycling. It is used to agglomerate the fines. It was revealed that LD sludge can give enough strength when mixed with mill scale. Generally, for pellet making 2% lime, 6% organic binder is required.

Towards Sustainable and Best Management Practices

Generation of slags are very high in Indian steel plants due to presence of higher ash content of coal, higher alumina and silica content in iron ore as compared to other developed countries. This can be avoided by proper combination of indigenous and imported coals and increased use of washed low

Fig. 5 Sitalapara dump yard of steel slag.

alumina iron ore during sintering and Blast Furnaces operations. This will reduce metallurgical slag. Coal Dust Injection (CDI) and Coal Tar Injection system can be used to reduce BF slag. Optimization of Furnace operating parameters is required to reduce the coal dust generation.

Slag waste in Blast Furnace can be decreased by introducing high top pressure and oxygen enrichment. Ore beneficiation plant can reduce the impurities in raw materials. Installation of in-house slag granulation facilities is required to solve the problem of spillage in road during transportation and slag solidification.

Optimization of charging practices, reduction of furnace heat time and optimization reducing cycle through operation EAF will reduce solid waste generation. By proper control of limes, silicon and Sulphur, extra slag volume and loss of iron in the blast furnace, EAF and BOF can be avoided. To recover steel metals from steel slag, pit slag and used refractory materials slag processors need to be developed. Best utilization of steel slag in India should be considered to be used as cementing component which is viable from technical, economic and environmental point of view.

DISCUSSION AND CONCLUSION

waste is now considered as a potential to meet the challenges of shortage of energy and raw materials. This will also help to comply with environmental legislation regulation. Steel industry, ready-mix concrete companies, builders should be encouraged to use waste by products for Concrete and other building materials with a view to saving energy and reducing CO_2 emission. In Indian steel industry generation of solid waste can be minimized by opting the following methods.

- Identification of sources, qualities and types of solid wastes produced duringsteel making process.
- Finding out reasons of solid waste generation.
- Use of advanced and innovative technology to minimize waste along with economic feasibility.
- Improvement in yield.
- Developing technology focusing on cost effective products based on proper processing of wastes and by product.

Thus conservation of potential resource and fully reuse of wastes can lead to zero waste management which poses a great challenge today.

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