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STEEL PLANT WASTE MANAGEMENT AND ENVIRONMENTAL POLLUTION AT A GLANCE

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ABSTRACT

Reduce, Reuse, and Recycle (3 Rs) philosophy and efficient waste management is needed to be adopted by the steel industry. Steel Plant Solid Wastes Management technique must be adopted in order to have Green Environment. Raw materials for steel making necessarily exist in nature in compound form, hence metallurgically the process of steel making is basically purification of iron. Impurities (gangue) are separated as slag (single largest solid waste generated in a steel plant)[i]. Iron & Steel industry has been notified under one of 17 highly polluting industries in India by Ministry of Environment & Forest. In an integrated steel plant, 1-1.2 tons of solid wastes are generated for every ton of steel produced. Though conventionally being dumped, sustainability of Indian Steel Industry critically depends on management of these wastes. This paper enumerates the waste management practice, starting with emphasizing on continual reduction of waste generation, recycling and reuse, and thereby ultimately minimizing adverse impact of steel plant solid waste on mother earth. The production of steel in an integrated steel plant involves several operations starting from preparation of the natural occurring raw materials like iron ore, coal and flux stones in production of hot metal in blast furnaces, conversion of hot metal into steel and the subsequent rolling of steel into finished product in the rolling mills[2]. Several other activities such as power generation, production of refractories etc. are also performed in varying degrees inside the integrated steel works. A large quantity of wastes is generated in view of the above activities. These wastes have a wide ranging impact on the environment.

Keywords- *Steel Plant Solid Waste, Management, Reuse & Recycle solid waste, industrialization, urbanization, emerging, environmental, improvement*

I. INTRODUCTION

In terms of crude steel production, India presently holds the 4th position in world, producing 87.67 MT in 2013-14(1). Broadly there are two types of producers in India viz. integrated producers and secondary producers. Integrated steel plants (ISP) consume raw materials e.g. iron ore, coal in typical Blast Furnace (BF) /Basic Oxygen Furnace (BOF) route and produce finished products e.g. Plates, Coil, Structural etc. Secondary producers (SSP) use steel scrap or sponge iron/direct reduced iron (DRI) or hot briquetted iron (HBI) in Electric Arc Furnace (EAF) and Induction Furnace (IF) units. In addition, there are 120 sponge iron producers; 650 mini blast furnaces, and 1,200 rerollers in India. Steel is one of the most basic materials required for industrialization and plays a vital role in the country's economic development[3,9]. The waste management in steel industry is an emerging complex issue and can be implemented after regulating through monitoring, analysis, legalization, addition of infra-structural facilities for enforcement, waste auditing, change of process technology etc. The paper reviews current knowledge of waste management in Indian Steel Industry, approaches to environmental improvement. The rapid progress of steel industry has aggravated environmental and waste management problems. With the rapid and extensive industrialization and urbanization in many parts of India, there is a dawning realization that ultimate prerequisite for man's survival could well be the preservation of environment. We live under horns of dilemma[4]. However, our expectations and our perceptions of what constitutes a minimum standard of living have put increasing pressure on both the public and private industrialists to ensure clean and healthy environment, All waste materials are economic assets. It is only when they are accidently or intentionally dispersed at lower concentrations into a benign or otherwise beneficial matrix such as air, soil or water that the essential management element or control is lost and human may become exposed to their short or long term hazards. Recently EA has been introduced for the first time by Ministry of Environment and Forests for continuation of NOC's for industries. Recently EA has been introduced for the first time by Ministry of Environment and Forests for continuation of NOC's for industries[6,8].

Any industrial growth breeds pollutants and steel industry is no exception. Environmental management programmes must be put on a technically, rational and scientific basis rather than on emotional one so as to achieve the maximum benefit to society. Indian steel plants should recognise that if they are to remain competitive they must take a fresh look at ways to minimise waste/prevent pollution arising from their production processes and supporting activities . A sustai ned WM/PP programme in steel plants could pay substantial dividends[5].

Integral steel units should also motivate employees to come forward with new ideas and achieve WM/PP target not only to reduce the impact of industrial activity on the environment but also to improve the Company's image and its relationship with the community. Solid waste management in steel industry is broadly classified in "4 Rs" i.e. reduce, reuse, recycle and restore the materials. Reuse and recycling the entire solid waste generated in the process of steel making is a viable solution in targeting a clean, green and zero waste technology leading to sustainable development of the steel industry. Solid waste management has gained importance in steel industry in view of its uncertainty, volatility and speculation due to world competitive standards, rising input costs, scarcity of raw materials and solid waste generated like in other sectors. The challenges that the steel Industry faces today are the requirement of a sustainable development by meeting the needs of our present generation without compromising the ability of future generations. Technologies are developed not only for gainful utilization of solid wastes in manufacture of conventional products but also for conversion of same in to completely new products [7, 8].

Molten iron is produced in BF in presence of coke and molten steel is produced in BOF in presence of oxygen [2]. Smelting and refining process involves carbon reduction in BF to produce molten iron and decarburization of molten iron to produce molten steel. After BF and BOF process molten steel is controlled to a target composition and temperature for processing into continuous casting machine to produce slabs, billets etc. Finally the castings are rolled to the required dimensions in the rolling mill to get finished steel product [6]. Solid waste such as power plant fly ash, acid sludge from by product plant, tar sludge, coke breeze, granulated B.F. slag, steel slag, calcined lime and dolomite dusts, steel scrap, etc., are generated in huge quantities causing environmental degradation. Like industrial waste waters, in this case also a preliminary survey is to be conducted to assess the source, quality, quantity, physical and chemical characteristics, pollution load, toxicity etc. before planning for dumping, selling or treatment. Source of solid wastes generated in steel industries is thus coke oven by product plant, sinter plant, refractory materials plant, blast furnace, basic oxygen furnace, steel melting shop, rolling mill.

The types of solid wastes in steel industry are mainly classified as coke and coal dust, BF slag, SMS slag, mill scale, scrap, oil sludge, fly ash, acid sludge, refractory wastes etc [2]. A major thrust therefore needs to be given on the scope of reuse of these solid wastes. Presently the production of solid wastes per ton of production of steel is 1.2 ton in India compared to 0.55 ton of that practicing in abroad due to inferior quality of raw materials used 02. Out of total solid wastes generated in the steel plant in our country 63% are dumped which needs to be recycled or reused to target a zero solid waste as being done in many developed countries.
Environmental pollution in steel industry Iron and steel industry which comprises, mining of ores, preparation of raw materials, agglomeration of fines in sinter plant, feeding of burden to blast furnace,
manufacturing of coke in coke ovens, conversion of pig iron to steel, making and shaping of steel goods, granulation of slag for its use in cement plant, recovery of chemicals from Benzol and tar products etc. etc. All the above mentioned operations add to air, water, land and noise pollution.

II. State-of-the-art techniques in solid waste management:

By making improvement in operational practice:
Coal and Coke
Partial briquette blending of coal (PBCC) first developed in Japan has now been adopted in South Korea, China, South Africa, Russia and recently been introduced in Bhilai Steel Plant. Bhilai blends (with 30% imported coal) had shown that the technology has the potential of improving the M,C value of the coke by nearly 2 points thereby minimizing generation of waste fines during handling, transportation and charging in blast furnaces. For indigenous coal, the potential is even higher by nearly 4 points. PBCC has been selected for introducing at Durgapur and Rourkela also. Recently, stamp charging technology has been installed at TISCO which besides other benefits will improve quality yield and minimize waste generation of fines. Groupwise crushing technology, which is expected to improve coke strength has been envisaged at Vizag. This is also expected to minimize waste generation of fines[6,8,10]. Coke dry quenching is another new technology which minimizes the water consumption and thereby reduces the volume of waste water from the coke ovens. Dry quenching also improves the general ambient environment in the coke oven area. The technology has been introduced at Vizag Steel Plant.

Sintering

Except IISCO Burnpur, all steel plants of the country use agglomerated ore fines in the form of superfluxed sinter. Ratio of sinter to iron bearing charge in the SAIL plants varies between 50 and 75%. Modernization programme envisages sinter charge to the extent of 70-80%. Increased charge of superfluxed sinter would minimize the coke rate, thus, reducing the eventual waste associated with coke making. However, a very large amount of fines are generated in the operation of sintering plant. New technologies are being introduced to minimize fine generation. Modification of sinter machine ignition hood, improvement in the chemistry and granulometry of the raw feed, improvement in the sinter machine suction are a few of the technologies being introduced currently which improve the strength and hence minimize the generation of sinter fines during handling, transportation and charging into the blast furnaces. High pressure sintering, developed recently for manganese ore fines by SAIL Research & Development, will have interesting implication for iron ore sintering also[10].

Iron making

Minimization of waste generation in the blast furnace is mostly associated with the reduction in slag volume. High ash content of the Indian coal is t.oa very large extent responsible for high slag volume in the operation of blast furnaces. Therefore, reduction of coke rate would minimize the waste generation. All technologies, therefore, which improve the energy efficiency, reduce the coke rate or improve productivity of the blast furnace wou ld be c lassified as waste minimization technologies. Control of Alkali input through the burden, movable throat armour/bell less charging system, oxygen enrichment
of blast, high blast temperature, natural gas injection to the tune of 50-801 1m/thm etc. to reduce coke rate would minimize waste generation in the blast furnace operation.

Steel making

A number of new energy efficient technologies have been developed in the past two decades which have vastly improved the productivity of the steel making processes used in the integrated iron and steel works. Twin hearth furnace, KORF process, etc.are derived from the open hearth technology. A number of variations of oxygen blowing technology have also been developed. SAIL has developed SAIL combined blowing (SCB) process which has already been adopted in the converters A & B of Bokaro and converter X of RSP and currently under implementation in one converter at Bhilai and other converters at Bokaro and Rourckla. Facility of bottom injection of inert gases nitrogen, argon etc. through semi permeable refractory elements or tuyers has been provided in SCB. High metallic yield, lower use of ferro alloys, cleaner steel, better S&Ppartitions between metal and slag, higher recovery of manganese, higher lance life etc. arc the advantages derived from these modifications. The benefits derived from this technology at RSP and Bokaro have been listed in Table-1 and 2141. The major benefit is improvement in the quality which ultimately minimizes the rejection rate of finished products and hence waste generation[4,8].

Environmental waste management means "Management" as the Act, manner or practice of managing, handling or controlling something. Waste management is a problem susceptible to the application of classical engineering analysis and solution . Hence by extension of the most fundamental planning and management techniques, the problem can be solved in a manner which will protect man and improve his environment. All waste materials are economic assets. It is only when they are accidently or intentionally dispersed at lower concentrations into a benign or otherwise beneficial matrix such as air, soil or water that the essential management element or control is lost and human may become exposed to their short or long-term hazards.
Molten slag is converted to small round balls, which is later used as a blasting material or in cement admixtures. Vitrified tiles can be prepared with the slags generated from EAF and SMP03 [3]. Recycling of ladle slag as a source for lime is also being carried out. The dry slag products have been widely used in concrete roads, floors and blocks, cement admixture, new fossil cotton products etc. Steel slag has made great progress in the application of composite admixture, dry-mix mortar and so on. The application of steel slag works as a low cost and high allowable bearing pressure. Steel slag as floor materials gives
resistance higher than that of ordinary aggregate concrete. Some of the steel slag is recycled to the blast furnace while a major portion is used in road construction (e.g. asphaltic or unbound layer) because of its very high stability, superior skid and high wear resistance [1].

Air pollution

Steel plant operations are vulnerable to air pollution. This can be visualized by the huge consumption of coal, iron or, limestone, dolomite, sulphur etc. During the process large amounts of emission (stack and fugitive) consisting of dust, gaseous pollutants like SO2, NOx etc are generated. To have an effective control over the pollutants first step for environmental management consists of conducting an emission inventory or pollution survey by visiting the plant at various locations such as blast furnace, coke oven, sinter plant, refractory plant, etc. to get a first hand information on the process and practices and also to carry out stacks and ambient air quality monitoring to establish the nature, quality and quantity of pollutants, emitted by the source, evaluate the performance of pollution control equipments if any, and also to compare it with emission standards so as to assess the necessity of controlling the emissions either at source by suitably altering the process parameters or by improving the efficiency of pollution control measures[1,5]

III. Present status and future prospects of utilization of waste

In an integrated Steel plant for every tonne of finished steel about 5 tonnes of input materials of iron ore, coal, fluxes, Mn ore, Ferro alloys, etc are required and nearly 3.5 tonnes of solid wastes like slag, dusts, sludge, fly ash etc are generated. Collection, transportation and dumping of these wastes are very expensive warranting large space on land. The volume of waste generated in a steel plant is an indicator of its state of efficiency/ inefficiency in operation. Reduction of waste generates and gainful utilization & recycling of these wastes not only improve the economics of operation but also prevents degradation of eco-system to maintain an amicable environment in and around the steel plant. In terms of quantity, BF slag, SMS slag and fly-ash-the three important solid wastes constitute about 94% of total waste generated at BSP. Smaller quantities of under size raw materials are generated during the sizing and screening process of various raw materials. These materials may informally be considered as waste, which can be reused as sinter feed. Botha (1994) has reported the recycling of waste via the sintering process. Even some researchers like Heiss et al (1993) has reused dust in form of hot briquettes [2, 4, 10].

Though some of the integrated steel plant solid wastes are recycled/ reused in various ways (Roy et al.), a considerable quantum of them is left out as dumps because of their unsuitability for further utilization. Efforts have been made by several workers to characterize these wastes in-depth (Suito et al., 1977; Hagni and Hagni, 1991; Karakus and Hagni, 1991; Goldrig and Jukes, 1997) and to recover some of the Dumped Recycled valuables from them (Franault, 1982; Kurbatskii et al, 1992; Strohmeier, 1993; Reddy et al, 1996) but optimum utilization has been difficult because of some inherent problems. Some such problems on utilization of solid waste samples generated from its different unit under reference are discussed below. The main objective is to focus the trouble shooting phases present in them.

IV. Problems of utilization of BF waste

BF crystalline slag is usually used in road making while BF flue dust is being dumped and hence studied in some detail. The different phases identified in BF flue dust are already mentioned as harmful components like Pb and Zn, as reported from many parts of the world restricts its reuse in Blast furnace. Even some workers have established processes to recover Pb Aand Zn values from dust (Doremieux et al, 1979; Stamatovic and Themelis, 1993; Imris, 1995; Peek et al, 1995). These are mostly derived from recycled scrap. However, BSP flue dust is free from these elements as only 0.7% scrap is added as one of the input materials to Blast furnace.The flue dust of BSP is being recycled as sinter feed due to comparatively low alkali content (Na+K oxides=1.70), unlike the flue dust of RSP which contains a higher percentage of alkalis. The presence of these alkalis attributed to limestone and coke added as input to Blast furnace. Alkali elements often accumulate in the Blast furnace and corrode the refractory lining. Reuse of BF dust is still an unsolved problem in many countries of the world (Fosnacht et al, 1981). Attempts have been made to minimize the level of alkali from flue dust by different beneficiation techniques but total elimination of potassium is not possible in view of its complex association with other elements. Only a part of SMS slag is recycled as input material into Blast furnace because of two following problems: i) the slag is of calcic composition and is volumetrically unstable being liable to expand and disrupt with time & ii) it contains phosphorous which restricts the reuse in any furnace. Reforming of BOF slag for synthetic fluxes has been reported by Ryu et al(1995). Broad utilization of metallurgical slag has been reported by Kurbatskii et al, (1992).

LD slag contains portlandite. This material is well known for its ease of hydration causing local microcracking. The hydration gives rise to localized volume increase that widens that widens the cracks and forces aggregates of the altered slag apart. Okamoto et al. (1981) found that hydration was effected initially by the formation of a surface layer up to about 50 micron in thickness that eventually exfoliated. When hydration proceeds further, cracks formed in the particles that led to disintegration. LD slag is more prone to volumetric instability than BOF slag[3,9].

SMS slag has phosphorous as the deleterious impurity with P2O5 content going as high as up to 5.00% (BOF having more P2O5 than LD slag). These are mostly attributed to manganese ores used in the furnace. Higher level of P2O5 content in SMS slag is due to higher proportion of manganese ore input. It is not possible to remove P from the slag by acid leaching, carbon reduction and gravity separation, high gradient magnetic separation and flotation carbon and non ferrous metals by size classification through hydro cyclones has been attempted by some workers (Toda et al, Schriefer, 1997). It is reported that Zinc and lead present in the blast furnace flue dusts may be recovered by size classification, flotation and acid leaching or by selective reduction under reduced pressure (Doemieux et al, 1979). However, total separation of valuables from these waste and recycling them together as sinter feed or as briquette have been least attended too.

V. Beneficiation of Metallurgical dusts/ sludge

Most of these solid wastes from Iron and steel making furnaces contain useful phases of iron, carbon, lime etc. which may be considered as reusable resources in steel plants. Many researchers in the past ; (Fosnalnt, 1982; Hay et al, 1993; Strohmeier, 1993; Rehmat, 1996; Reddy et al, 1996) have worked on recovery of iron and carbon values from BF dust but with limited success.

VI. BF dusts/ sludge

The complete chemical analysis of the BF flue dust sample is given previously shown. The sample contains around 42.6% of Fe2O3 and carbon 31%. The high percentage of both unburnt coke and Feminerals show the abnormal accumulation of these elements in the flue dust sample. The BSP sample does not have appreciable amount of Na2O and K2O, for which it can be used in sinter making. The alkali elements are mainly contributed by limestone/ dolomite. However total replacement of limestone by Dunite in raw mix substantially reduces the alkali level (Formose et al, 1997). The BSP sample however does not contain any significant amount of Pb and Zn as reported in flue dust samples from other parts of the world (Roy et al, 1998).

VII. Increasing Awareness inside India

Post Kyoto Summit, environmental concerns have been taking the centre stage in every sector, steel industry definitely feels the heat. Ministry of Steel, Govt. of India set target of 100% utilisation of solid waste (National Steel Policy 2011). Under Charter on Corporate Responsibility for Environment Protection (CREP), steel plants are required to set mutually agreed targets with the purpose to go beyond the compliance of regulatory norms for waste utilisation. Probably the most fundamental changes are those of public attitude, awareness and acceptability with respect to waste. These changes are increasingly applying pressure to minimize waste, encourage waste recycling and demanding waste disposal as landfill to be the last option[5,9].

VIII. Increasing Awareness outside India

In the United States, the Environmental Protection Agency (EPA) is the national agency that works to protect human health and the natural environment. EPA establishes and enforces national environmental protection standards, conducts research on environmental problems, and assists other organizations in protecting the environment through grants, technical assistance, and other programs[]10].

IX. CONCLUSION

On the basis of the above discussion following points may be expressed as the conclusion of this review:
Minimization and efficient utilization of waste or co-product of Iron and Steel is an essential step in effective and efficient waste management in order to have a better pollution control on the environment by adopting the following measures:
(a) By making improvement in operational techniques, the waste can be minimized significantly.
(b) By adopting new technologies, minimization of waste can be achieved to a greater extent.
(c)The technology alone will not minimize the generation of waste material. It can be accomplished through increased awareness of people involved and a sustained change in the attitude.

(d) The organization structure should be such that the responsibility for profit is pushed as far down in the organization as practicable. Shared values and commitment to goals are important factors for success.
(e)The organizational environment should be such that constant review of tactics and strategies are measurable in real time and success and problems are communicated to everyone involved. This would enable pursuit of excellence with commitment.

(f)With growing shortages of energy and materials and to keep up with Environmental Legislation and Regulations and The Economies of Disposal in the present scenario, solid waste should be treated as one of the potential resources in the steel industry. Most economic management practices in steel industry of developing countries for minimizing the generation of solid wastes and maximizing the recycle of collected wastes can be opted in the following ways:

- A waste audit should be done to define sources, quantities and types of solid wastes generated from different sub processes including hazardous wastes.
- Reasons of generating these solid wastes to be found out
- An advanced technology with economical feasibility options for minimizing wastage of resources to be evaluated.
- To treat the waste as raw material of related industry on the base of avoiding secondary pollution.
- To build up series of integrated utilization programs, from the industry system technologies and products systems.
- To develop technology focused competitive products based on deep processing of wastes and by-products.

A zero waste approach should be considered viewing solid wastes as potential raw materials to be conserved or reused As in nature where nothing goes waste, steel makers also use some process units like Sinter Plant as scavenging units where wastes and by products from other process can be combined to produce high quality input material as a replacement for virgin iron ore thereby saving precious natural resource. Near future as being predicted, competitive sustainability shall be dependent on waste utilization efficiency and environmental footprint. Similar to the Kimberley Process Certification Scheme (KPCS), clean chit for waste management may be demanded from customers before opting for any steel product. Utilizing solid waste is an option today, but it's likely to be a necessity tomorrow.

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