CHAPTER 2
LITERATURE REVIEW

Foundry has good potential for Implementation of Cleaner Production and could be implemented successfully for the sustainable development applications. This chapter reviews various attempts made by researchers and various agencies and finally narrate the conclusions reveals from the literature review.

2.1 PART I- FOUNDRY WASTE
The foundry is a very diverse mechanical industry including ferrous and non-ferrous metal reshaping. It has small to very large components having different sizes and shapes. The main difference is ferrous and non-ferrous foundries (Prevention, I. P., 2004).

The waste produced related to the metal type, the furnace type also molding technology used. Foundries sand molds generate the most waste from sand. Cupola furnaces generate more air pollution than that of induction furnaces on account of coke use and sand castings generate more solid wastes than permanent molds due to sand fines that cannot be reused. Air emissions arise from the binder during mold making, the vapors comes from metal melting and in the pouring and shakeout steps. Air emissions generally contain metals, semi-volatile and volatile organic compounds. They mainly come from the melting departments. Pouring as well as cooling contributes near about 16% of the total organic and semi-volatile wastes from foundries. Foundry is also a source of various emissions as shown in figure 2.1(a) (Kristen, 2013) and 2.1(b) (Fore, S., & Mbohwa, 2010).
Fig. 2.1 (a) Typical foundry waste sources

Fig. 2.1(b) Inputs and outputs in foundry
Slag waste contains a variety of contaminants from the scrap metals such as metal oxides, melted refractory, sand, and coke ash. Fluxes can also be added to help remove the slag from the furnace. Slag can be hazardous if it contains lead, cadmium, or chromium. Ferrous foundry slag may be highly reactive if calcium carbide is added to desulfurize the iron.

Dry reclamation may produce huge quantities of dust. These air emissions can be monitored and captured by control equipment. Dry sand reclamation may not be able to removing binders up to some extent necessary for reuse.

Various outputs are generated in terms of waste is as in figure 2.1(a) (Kristen, 2013). That are generally depends upon types of products, sand, types of casting etc. It also depend upon quality of coal, residues etc.

The major iron foundry processes and operations that emit HAPs (Hazardious Air Pollutants) are shown in figure 2.2 (Crandell, G., & Mosher, 2006)

![Diagram of ferrous foundry HAP emissions](image-url)
2.2 PART II: ENERGY CONSERVATION AND MANAGEMENT.

Foundry needs huge amount of energy as well as produce tons of wastes and substantial impact on environment (Yuanyuan, et al., 2010).

Energy is a main cost for all foundries, accounting for around 10% of the total production costs. Furnaces grab significant proportion of the energy consumptions in foundries, around 60% for typical iron foundries. Figure 2.3 shows typical energy demands for an iron foundry as reported in a survey (Australia and New Zealand Environment and Conservation Council, 1998).

Energy management practices are not practicing in a foundry in SME or MSME foundry industries. The estimation of the energy efficiency of a process or systems is a vital step towards the control of the energy utilization and energy costs, the energy audit may starts from a straightforward stroll through the study at different stages. It additionally gives a intend to viably impart energy data for industries (Gilen D and Taylor, 2009; G.L.Datta, 2001; Saniuk, S, et al., 2015).

![Fig. 2.3 Typical energy demand iron foundry](image-url)
Present energy consumption of the different foundries can easily be compared with standard norms as per Best Available Techniques (BAT) and can be used to implement easily (Arasu, M., & Rogers, J., 2009).

The foundry industry is most energy intensive sector. Energy consumption in this sector mainly depends on electricity resources (Saha VJ, 2010). The energy efficiency in this sector depends mainly on the melting section (Eppich R et al., 2007). Recently global warming is building pressure on decision policy makers to formulate as well as adopt energy policies (Rohdin, P., et al., 2007). Energy accounting tool is essential to establish where and how energy is being consumed and how capable is the energy management system (Marasu, et al., 2007). Energy conservation and emission reduction is directly related with the survival as well as development of the industry, and it is also a crucial point of sustainable development (Li yuanyuan, et al., 2010). A cost reduction strategy that can have an immediate impact on productivity. Energy costs will rise and decline in response to world energy market conditions but will continue on a steady upward trend Without top CEO / President level hold energy-saving efforts will fail because of misconception that only plants with new equipment can be energy capable.

Indecent production methods lead to wastage of resources, economic losses, poor working conditions and environmental pollution. On the other hand, production processes that are more energy efficient, use fewer resources, and re-use waste materials not only reduce environmental impacts but may also reduce economic costs (Frijns, J., & Van Vliet, B., 1999). About 40% and 25% respectively of the studied mills and foundries may be categorized as flourishing when it comes to energy management practices. (Thollander et al., 2013).

Developing countries account for 60% of industry's total final energy consumption. Industry has improved its energy efficiency in early decades but continues to grow due to demand of production. Production is definitely expected to increase substantially in the coming decades, in developing
countries. So energy savings and measures need to be implemented (Saygin, D., et al., 2010).

The very first step for saving energy is to know energy consumption. It’s impossible to implement your energy saving options if one cannot measure the energy consumption pattern in main processes (Worrell, E, 2011).

Ministry of Power of Government of India released The annual load generation balance report; LGBR, in May 2013 for the year 2013-14. From that report it is cleared that the country is expected to experience energy shortage of 6.7% and peak shortage of 2.3% (Ministry of Power of Government of India, 2014). Energy management and conservations may play a major role in the industrial energy applications and instruments for energy efficiency and sustainability (Thollander, et al., 2013).

Government need to give funding of research to improve the paybacks of Energy-efficiency investments (Punnaiah Veeraboina and Guduri Yesuratnam, 2013). Energy consumption and emissions of CO₂ in the environment has made energy efficiency concern for energy policies in most countries (Kwong, Q.J et al., 2013).

Policy to reduce the emissions from Indian power sector is vital and may be controlled by energy management system (Mallah, S. and Bansal, N.K., 2012). A relevant contribution to improved energy efficiency could come from the industrial sector, due to its significance on total energy use (Trianni et al., 2013). Energy consumption, and economic growth, is one of the most important inputs in all economic activities (Xia, Y. 2012). Small as well as medium-sized Enterprises (SMEs) have been totally overlooked regardless of appealing consequences for their on the whole energy consumption and their con-current low levels of acceptance of energy-efficiency measures Trianni et al., 2013).

Research reveals that by using energy management practices in foundries 40% of the total energy may be saved (Thollander et al., 2013).
The ISO 50001 defines general requirements for the operational and organizational structure for companies but the standard gives no information about how to realize energy efficient processes on productive or non-productive level (Marcus Dorr et al., 2013).

In India, most initiatives to increase energy efficiency in the small scale industrial units have achieved little in terms of enhanced efficiency or environmental improvements (Dasgupta, N, 1999).

The electric motors in a compressed air system may save about 2 % of the energy input, and whole system could save up to 37 %. Energy has costs and environmental impacts and desires to be manage fit in order to add to the business for profitability and competitiveness, as well as to lessen the significance of these impact (Guide to Energy Efficiency, 2004).

The energy pattern is very important in a foundry and helps to identification of prior areas where waste may occur and where feasible scope for total improvement may be possible as shown in figure 2.4 (Brakes India Limited, 2004).

Fig. 2.4   Power distribution tree of foundry
The energy consumptions as shown in table 2.1 are helpful to minimize energy cost by focusing vital sections and considering full scope for improvement (Arjunwadhar et al., 2008). As per India is concerned the energy saving potential changes industry to industry, starting from 10% to 02%. A investigations of Administrative Staff College (ASC) Hyderabad India reveals that very few companies were maintained records of energy use (G.L.Datta 2001).

<table>
<thead>
<tr>
<th>Sections</th>
<th>Energy consumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting Department</td>
<td>70%</td>
</tr>
<tr>
<td>Moulding and core making</td>
<td>10%</td>
</tr>
<tr>
<td>Department</td>
<td></td>
</tr>
<tr>
<td>Sand Department</td>
<td>06%</td>
</tr>
<tr>
<td>Lighting Department</td>
<td>05%</td>
</tr>
<tr>
<td>Compressor Division</td>
<td>05%</td>
</tr>
</tbody>
</table>

TERI conducted energy audits time to time in Howrah and Agra foundry clusters, they found root causes of low energy efficiency; they are Poor furnace design, Poor operating practices, and Non-uniform size of charge material. Others studies related with this point out that melting are the most energy intensive stage in the foundry t is observed that melting consumes a major portion of total energy consumed (Arjunwadhar et al., 2008)

2.3 PART III: FURNACES –ECOFRIENDLY APPROACHES
This literature survey basically based on operations and emissions of furnaces.
Foundries melt metals in various types of furnaces on the type of metal being used as presented in table 2.2 (Peden. et al., 1998). CI may be melted in the cupola-furnace as well as induction furnace or in the rotary furnace. The electric arc furnace is seldom used for the making of CI. Figure 2.5 depicts process flow diagrams for the cast iron foundry for main three different furnaces showing sequence of operations (Prevention I.P, 2004).

Table 2.2 Metal melting furnaces

<table>
<thead>
<tr>
<th>Furnace</th>
<th>Raw- Materials</th>
<th>Output</th>
<th>Main -Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cupola</td>
<td>• Iron ore</td>
<td>• Molten metal in terms of iron</td>
<td>• Melting by hot gasses with coke combustion.</td>
</tr>
<tr>
<td></td>
<td>• scrap</td>
<td></td>
<td>• Impurities react with the lime.</td>
</tr>
<tr>
<td></td>
<td>• iron lime</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• coke</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric arc Furnace</td>
<td>• Scrap</td>
<td>• Molten metal</td>
<td>• Carbon electrodes melt the scrap metal.</td>
</tr>
<tr>
<td></td>
<td>• iron</td>
<td></td>
<td>• The flux reacts with impurities.</td>
</tr>
<tr>
<td></td>
<td>• flux</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Induction Furnace</td>
<td>• Scrap iron</td>
<td>• Molten metal (iron)</td>
<td>• Copper coils heating using currents.</td>
</tr>
<tr>
<td></td>
<td>• Non-ferrous materials</td>
<td>• Non-ferrous material</td>
<td>• The flux reactions with impurities.</td>
</tr>
<tr>
<td>Reverberator or Crucible Furnace</td>
<td>• Non-ferrous metals, flux</td>
<td>• Molten non-ferrous metals</td>
<td>• Melting of metals in batches by crucible.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• The flux reactions with impurities.</td>
</tr>
</tbody>
</table>

The average melting rate of cupola furnace is 4 MT/hr, but the emission from a group of units in a cluster could be very significant to pollute the air quality. Cupola furnace emissions contain CO, SO, and NO along with the particles
of iron and other metal oxides, lime dust, coke breeze and fly ash. In India cupola furnaces have not control technology for emissions to air. Thus there is a vital scope of designing control system to control air pollutants from cupola (Manthapurwar, N. S et al., 1996).

A lot of foundries may use a baghouse and scrubbers to clean air from foundries. The baghouse and a fabric filter used to collect furnace emissions. They can be installed on all types of furnaces (Saygin, D., et al., 2004).

Fig. 2.5 Process flow for the melting of CI foundry
Bughouses may also be used for pollution reduction at any other points in the process. Wet scrubbers absorb the pollutant (EPA, 2015).

Prior studies had shown cupolas saves a 20% to 25% overall energy in terms of cost savings than Induction melting. The total heat of coke for a cupola has near about 42% of the energy contributed to the metal and rest of creates Carbon Dioxide (CO$_2$) and Carbon Monoxide (CO). Cupolas burn off the CO in the upper stack and thus may lose the potential heat energy which may be recovered (Crandell G et al., 2006; Gignate.G, 2010).

Cupola may be acid and basic in nature Induction furnaces can be of number of types but the two major categories are coreless induction and channel induction furnaces. The former unit is mainly employed for melting duties, the latter almost entirely for holding/dispensing operations. Now a day’s coreless furnaces are mostly used (GUPTA, R., 1995).

Air pollution devices depend upon number of factors such as the cupola design, openings, door enclosures, height of stack, etc. which decide size, cost, and efficiency of control systems. Effluent gas properties, such as temperature, volume etc (Robert W. McIlvaine, 1967). The main pollutants emitted by cupola are SPM and SO$_2$. The Divided Blast Cupola (DBC) is different than this. It increases the thermal efficiency of the cupola furnace also less coke consumption as well as more melting rate (Garg Pardeep, 2012; Fatta, D.et al., 2004).

Design changes are needed to enlarging the shaft height so that shaft height: cupola internal diameter ratio which is about 5.5 - 6. This cause rise in the thermal efficiency of the cupola. In addition the height of cupola above the change door should have a similar ratio i.e.5.5- 6 with the internal diameter for complete combustion of CO to CO$_2$. This reduces the CO emission level and to reduce the SPM. Stack discharge height should be minimum 20 meters. An appropriate air pollution control device like scrubber, cyclone or bag filter need to be installed to lower the SPM below the present permissible value (i.e. 150 mg/Nm$^3$). An after burner may be used for Spontaneous combustion of CO (Bandopadhyay, A., et al., 1995).
SPM level in cupola gases may be brought down below 150 mg/Nm³ with proper design and operation for pollution control devices (Bandopadhyay, A et al., 1996). It was found that a venturi scrubbers are the most effective devices to cut down the emissions of particulate emission limit of 150 mg/Nm³ (Pal .P 2006). Environmental consciousness and energy saving principle for a cupola furnace include: Installation of a recuperative hot blast system which use the energy from burning CO for the hot blast air. Cupolas work most efficiently when pre-heated air is used for combustion.

Adding oxygen into the tuyeres. This oxygen recovers the latent heat, due to which coke required will be lowered by up to 30%. For minimization of water use, a dry cupola slag handling system is useful and it can be recycled.

Oxygen-fuel burners can increase energy efficiency along with dust rejection systems and can provide a method of recycling foundry-generated residues such as cupola dusts well as finishing dust, and sand reclamation dust (Crandell, G. R. et al., 2006; Wang, Y et al, 2011; G.L.Datta, 2001; Villar, A, et al., 2011).

Pollution levels can be reduced by various means as suggested by NML (Tamhane, et al., 1996).

- A combination of design
- Operational changes
- Installation of gas cleaning devices and the process flow for the dry gas cleaning is as in figure 2.6 (Tamhane SM. et al 1996).

The various studies conducted and results reveal that lowest dust exposure, moderate and highest dust concentration based on the stack height.

The energy required to melt the charge material mainly depends on the solid specific heat, latent heat of fusion, and liquid specific heat of the charge material thus the power needed to melt the charge can be determined. Control of SPM needs appropriate collector as in table 2.3 (Tamhane SM. et al 1996).
Fig. 2.6 Cupola furnace -dry gas cleaning system

Table 2.3 Control of SPM from cupolas.

<table>
<thead>
<tr>
<th>Melting Capacity</th>
<th>Collector needed for control of SPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 4 (MT/hr)</td>
<td>• Simple (dry wet arrester)</td>
</tr>
<tr>
<td>5 to 10 (MT/hr)</td>
<td>• Simple</td>
</tr>
<tr>
<td></td>
<td>• Multicyclone</td>
</tr>
<tr>
<td></td>
<td>• Medium scrubbers</td>
</tr>
<tr>
<td>11 to 14 (MT/hr)</td>
<td>• High intensity scrubbers</td>
</tr>
<tr>
<td></td>
<td>• Fabric filters</td>
</tr>
<tr>
<td></td>
<td>• Electrostatic precipitators</td>
</tr>
</tbody>
</table>
In India first DBC was commissioned in August 2003 and still it is in working and investment has proved to be financially beneficial and saving in coke in foundry unit. DBC has reduced rejection rate. Thus that there may be a huge potential for energy saving as well as GHG (Green-House Gas) reduction in conventional cupolas in the small scale sector in India.

TERI carried out energy audits for cupolas furnaces in Howrah as well as Agra foundry regions considerable points that were suggested for poor energy efficiency

- Inaccurate -blast rate
- Subsidiary- blast air pressure
- Inaccurate supply of air between the top and lower positions of tuyeres (Pal P et al., 2008).

Tata Energy Research Institute (TERI) has demonstrated cupola plant in foundry unit, with support of Indian Foundry Association (IFA) in Howrah. The results of the project reveal a huge potential for energy saving as well as pollution reduction in India. Technical assistance for the purpose of design, implementation of energy efficient cupola furnace is available at subsidized cost starting from Design to post implementation such as energy audit, environmental performance (Luis, C. et al., 2002).

TERI had applied these techniques in many foundries and they are applying continuously in different foundry hub. The results reveal the full scope in Indian foundries pertaining to economical as well as environmental considerations.

Now a days there is demanding pollution control norms in the world particularly in developed countries so there is also a need of upcoming awareness regarding environmental parameters in India specially in small-scale foundry units because of huge share in India (Ahmed, M. M., Masoud, M., & EI-Sharkawy, A. M., 2009; Pal .P, et al., 2008; Yadav& et al., 2008; Mukharjee D.P, 2011). With this regards various modules has been techno-economically proved (Biswas D K et al., 2001).
Thus the foundries will optimize processes and materials to produce high quality castings for the consumer at a profit if some assumptions that are to be based on low emissions processes (Lafay V S et al., 2007).

2.4 PART IV: SAND USE- APPROACHES

In foundries, sand can be defined as “material composed of granular particles of mineral matter ranging from 0.5 to 2.0 mm in diameter”. Foundry sand varies in shape and plays an important role in molding in metal casting. Different types of sands can be blended to have specific compositions. Now a days it either in a natural state which is bonded with clay and in a chemically state mixed with chemical resin or oil, which is cured by baking or by chemical reaction (Stanley T. Krukowski, 2013). In foundry, huge tones of spent materials are throwing away in the world out of which 70% materials is of sands (Ji, S., Wan, L., & Fan, Z., 2001.)

Foundries involve a variety of sands, generating residues in the sand. The presence of residues such as dust and other foundry waste materials may limit the reusability of sand. Foundries use magnetic separators to separate reusable sand from other wastes and to separate particles of varying sizes. By carefully observations foundries may ensure that most sand is free of excess contaminants and may be qualified as a non-hazardous industrial by-product (Lindsay, B. J., & Logan, T. J., 2005; Winkler, E. S., & Bol’shakov, A. A., 2000). The most common casting process used in the foundry industry is the sand cast system where green sand is used. Green sand consists of

- Silica sand
- Bentonite clay (10 percent as the binder)
- Water (2 to 5 percent)
- Sea coal (5 percent, to improve surface finish)

The type of metal which is to be cast decides which additives, what gradation of is to be used.
Table 2-4 lists the chemical composition of a typical sample of spent foundry sand (Chesner, W. H. et al., 1998).

Table 2.4 Typical physical properties of spent green foundry sand

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk Relative Density, kg/m³ (lb/ft³)</td>
<td>2590 (160)</td>
</tr>
<tr>
<td>Absorption (%)</td>
<td>0.45</td>
</tr>
<tr>
<td>Moisture Content (%)</td>
<td>0.1-10.1</td>
</tr>
<tr>
<td>Clay Lumps and Friable Particles</td>
<td>1-44</td>
</tr>
<tr>
<td>Coefficient of Permeability (cm/sec)</td>
<td>10.3-10.6</td>
</tr>
<tr>
<td>Plastic limit/plastic index</td>
<td>Non-plastic</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.39 - 2.55</td>
</tr>
</tbody>
</table>

Waste foundry sand (WFS) can be used various ways such as road construction, tile manufacturing, road shoulders, parking lots, floor slabs, utility trenches, bridge abutments, tanks and vaults, construction or architectural fill, other similar uses as in figure 2.7 (Federal highway U.S. 2004). Thus having different uses (Siddique, R., et al., 2011; Guney, Y., et al., 2010; Denga, 2009; Yoon, S., et al., 2006.).

Foundry sand has nearly all the properties of natural or manufactured sands; it can normally be used as a sand replacement.

WFS alternate uses offer cost savings opportunities for foundries and user industries, also an environmental related benefit for the local as well as national level (Kleven, J., Edil, T., & Benson, C. 2000; Guney et al., 2010)

Foundry sand successfully used in CLSM and its applications has increased in recent periods as in table 2.5 because it is now becoming a viable option
for use in Controlled Low Strength Materials due to its lower cost, availability, and highly satisfactory performance.

Fig. 2.7 How sand is reused and becomes foundry sand

Table 2.5 Foundry sand applications

<table>
<thead>
<tr>
<th>Rank</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>Embankments or Structural Fills</td>
</tr>
<tr>
<td>Two</td>
<td>Road base or Sub base</td>
</tr>
<tr>
<td>Three</td>
<td>Hot Mix Asphalt</td>
</tr>
<tr>
<td>Four</td>
<td>Flow able -Fills</td>
</tr>
<tr>
<td>Five</td>
<td>Soil-Horticultural</td>
</tr>
<tr>
<td>Six</td>
<td>Cement or Concrete Products</td>
</tr>
<tr>
<td>Seven</td>
<td>Traction- Control</td>
</tr>
<tr>
<td>Eight</td>
<td>Other Applications</td>
</tr>
</tbody>
</table>
It was estimated that for each ton of metal castings produced common foundry generates approximately one ton of waste sand. Applications of these sands may have practical uses as a means of recycling as well as achieving costs savings in brick production (Bhat, S., & Lovell, C. 1996; Siddique, R et al, 2010). Recycling end products may be used in ceramic industries (Alonso-Santurde, R et al., 2012).

Near about 90% of foundry sand may be reused specially in case of green sand. Chemically bounded sand should be reused for much lower rates due to degradation during treatment processes (Dalquist, S., & Gutowski, T. 2004). Sand sometimes may contain hazardous chemicals so dumping is not a solution but sand reclamation process that cleans the sand so that it can re-use in the foundry operation. Different reclamation systems exists which leads confusion which system or combination of techniques gives optimum results.

The thermal-mechanical reclamation, offers both benefits ecological as well as economic advantage (Lahl U, 1992). It is most important that sand is reused again and again, but its lifespan must be increased. Wet reclamation needs more water as compared to other reclamation techniques, but lower emission as well as long use. Furthermore thermal reclamation technique even if need low material requirements, but demand more energy producing organic and particulate emissions. So In this case no direct comparison is possible, the decision have to be made on the economic justification of particular process (Dalquist, S., & Gutowski, T. 2004).

The general treatment is as presented in figure 2.8 (Integrated Pollution and Control, 2004). This internal recirculation for green sand with minimum treatment is called primary regeneration.

Sand Reclamation is nothing but process of reconditioning of used or demoulded sand in a foundry without lowering its original properties (Integrated Pollution and Control, 2004).
Sand reclamation may be of following types.

- Mechanical
- Thermal
- Combination of the above
- Wet Reclamation

Sand reclamation is very important not only for cost purpose but it highly affects the recourse utilization.
Now a day’s sand availability in terms of quality may lays a very important role.

The generalized system for thermal is represented as in figure 2.9 (Aniruddha Ghosh, 2012)

Thermal reclamation sand is far better than mechanically reclamation sand in terms of following points

- Lower thermal expansion
- Better mould stability.
- More rounded in shape
- Lesser binder demand.
- Thermally reclaimed sand can be used with any chemical binder system
Different regeneration systems for foundry-sands are as represented as shown in table 2.6 (Integrated Pollution and Control, 2004).

Table 2.6 Different regeneration systems for foundry-sands

<table>
<thead>
<tr>
<th>Type of sand</th>
<th>Regeneration technique</th>
<th>Regeneration equipment</th>
<th>Utilization</th>
<th>Borderline conditions</th>
<th>Minimal quantity (tonne/h)</th>
</tr>
</thead>
</table>
| Cold-setting resins | Mechanical Thermal | • Mechanical: pneumatic chafing  
• Thermal turbulent bed  
• Fluidized bed | Only 20 to 25%  
New sand is required | Mechanical | 1.5 |
| Cold-Box, SO2, Hot-Box and Croning sand | Mechanical or thermal | • Pneumatic chafing  
• Fluidized bed  
• Thermal-turbulent bed,  
• Fluidized bed | As per requirements of core | Mechanical | 0.75 |
| Resol-ester methyl formate hardened sand | Mechanical | • Mechanical friction  
• Pneumatic chafing | In Mould Making With methyl format sands | lower yield | - |
| Green sand | Mechanical | • Pneumatic chafing, grinding | Renewal sand for green sand circuit | Requires predrying re-use of fines | 0.75 |
| Sodium silicate sand | Mechanical | - | Restricted to making of moulds and cores | Embrittlemen t for binder components at 200 ºC | 0.5 |
2.5 PART V: TRACKING THE IMPACT OF QUALITY PROGRAMMES ON CLEANER PRODUCTION

Traditionally, productivity is the amount of output per unit of input used. Productivity is also influenced by the internal organization of any company; in simple words, improvement in organizational effectiveness means improving productivity. At first, productivity focus on quantity; i.e. outputs. A cost reduction approach generally used to improve profitability of any organization for effectiveness; hence a numerous quality related systems come out such as Total Quality Management (TQM) and Total Preventive Maintenance (TPM), the Quality Systems for example ISO 9000 series, Environmental management systems (EMS) as shown in figure 2.10 (UNIDO, 2013).

![Influence of quality programmes on productivity](Image)

7R which stand for Reduce, Recycle, Reuse; Remove, Renewable, revenue, and Read (Goetz, S. J., & Swaminathan, H., 2006). With this regard TPS philosophy can be used for elimination of the several forms of waste (Herrmann, C., et.al, 2008).
Figure 2.11 elaborates how the traditional (UNIDO/UNEP 2013) concept of productivity changed progressively from the old ‘quantity based ‘and’ cost reduction approaches to environmental concerns along with quality.

![Diagram of productivity growth]

**Fig. 2.11** Major milestones for the area of productivity

Modified Quality control procedures are a necessary now days to avoid defects in the products (Vijayaram, T. R., et al., (2006). Department for Environment, Food and rural Affairs elaborates a solid waste stream arising from foundries (Dunster, A. M. (2007). Lean methodologies may be used for economically and environmentally sustainable foundries. The backing pillars for implementation for lean and green system are Process improvement are as below (Torielli, R. M.et al., 2011).

- Throughput improvement
- energy efficiency
- Innovative technology
- community partnerships
Framework for foundry lean and green implementation is as shown in figure 2.12 (Torielli, R. M.et al., 2011).

![Diagram of foundry lean and green implementation framework]

**Fig. 2.12** Framework for foundry lean and green implementation

The ISO 14000 Environment Management System standard was developed exclusively for environmental management system (Melnyk, S. A.et al., 2003). The ISO 14000 is a used EMS, for environmental sustainability (Jasch, C. et al., 1994). ISO 9000 and ISO 14000 are not entirely different systems, but mutually helping each other. ISO 14000 gives guidelines for Life-Cycle Assessment (LCA) which identifies the major steps as well as processes for the life of a product identifying and quantifying environmental impact (Zarbo, R. J., & D’Angelo, R., 2006). Six Sigma methodologies can be applied to a
small-scale foundry industry to reduce the rejections and rework processes (Desai D.A., 2012).

The foundry industry facing specific challenges pertaining to economic and environmental sustainability which is due to wastes because Small- and Medium-sized foundries (SMEs) are not using their full resources. The various tools such as lean manufacturing are; Value stream mapping, 5 – S, Total Productive Maintenance (TPM) can be used to overcome this limitations because these tools proved to be effective measures in the foundry industry which are adopted worldwide (Fresner, J., 1998; Torielli, R et al., 2011; EPA, 2015).

With this regards the (CP) approach has brought significance know how (Visvanathan, C., & Kumar, S., 1999). However, Use of CP in Small and Medium Enterprises (SME) needs to be done based on CP main areas. These are:

- Integration of pollution prevention as well as control
- Interaction among energy, environment including climate
- Development of technology, processes based world class benchmarking
- Identification of various internal and external factors pertaining to CP
- Capacity building
- Technology development as well as transfer
- Financial packaging

The Development Commissioner Ministry of Micro, Small and Medium Enterprises (DC-MSME) Govt of India in 11th plan focuses on Lean initiative through a series of measures by including identification and elimination of waste, improving employee participation and work culture among others (Roy, 2011).

The salient features from literature review explore many things but major contributing factors are precisely listed in next section.
2.6 FINDINGS OF LITERATURE REVIEW

The significant study of literature reveals the following conclusions;

1. Environmental degradation is root cause of all the problems UNIDO/UNEP are taking initiatives for minimum further loss but this is not sufficient there is a need to investigate the potential consciousness in all the fields.

2. Environmental consciousness is not up to the mark in developing countries.

3. Above review of literature reveals, relatively few studies have focused on the plant wide application of CP approach to the foundry industry in the context of the developing countries. SD is to be implemented in all the operational areas including foundries.

4. End of pipe technologies will be disappeared shortly, there is need to convert that into CP techniques progressively.

5. In India there is large number of ferrous MSME/SME foundries that is to be studied for further work as it generates lot of waste.

6. Cleaner production is most vital tool which may be used in foundries but very few researchers /agencies are using that tool in foundries, reasons are to be explored.

7. Indian foundries particularly SME are not aware with the potentional of use of CP in current condition, process improvements needs to be justified.

8. Energy requirement in foundry is more. Energy optimizations activities are being carried out in developed countries in scientific ways but in India particularly SME/MSME are unaware of this fact, being a huge share it is to be investigated and there is need to recommend energy efficient technologies with proper justification in particular cluster.

9. Melting department is a major energy consuming department in a foundries as per literature surveys, two furnaces are widely used which are Induction and cupola and they can be run efficiently
minimising emission, In Indian foundries its suitability is to be investigated.

10. Various quality tools are used by researchers in foundries but very few were used in SME/MSME foundries. There is a scope for implementing it by integration of CP techniques.

11. There is close relation between productivity and SD. General meaning of productivity is efficiency and effectiveness of resources use thus the elimination of wastes, means productivity improvement. Furthermore, the main purpose of productivity improvement is to have a better, safe quality of life for the whole world. A degraded and polluted environment means a threat to the quality of life of individual and poses a direct challenge to productivity improvements activities.

12. The Government has amended rules from time to time. However, the progress is very slow. The Public intensive awareness and social pressure are the main driving forces to get the goal. Resource conservation and optimum utilization result in higher productivity as well as profit which is aim of green productivity.

13. Used foundry sand is a high volume industrial waste that can be more widely reused as an alternative to landfill disposal in literature; investigations are mainly available in developed country. Some attempts are observed in the European countries .Various techniques are suggested for reclamation as well as use in developed countries in big foundries .Sand reclamations system is not justified in small foundries that should to be focused thus there is need for qualifying reuses of sand Currently few states are also planned ban on mining sand in India.