Potential for Improving Performance through Design for Environment (DFE) in a Ferrous Foundry

I.Madanhire[1], C Mbohwa[2]
[1]Department of Quality and Operations Management, University of Johannesburg, Johannesburg, South Africa
OR
Mechanical Engineering Department, University of Zimbabwe, Harare, Zimbabwe
[2]School of Engineering Management, University of Johannesburg, Johannesburg, South Africa
e-mail: imdanhire@eng.uz.ac.zw

Abstract **-The study dwelled on how to develop an implementation procedure for design for environment (DFE) management program. A ferrous foundry manufacturing organization was the subject of comprehensive assessment and recommendations in this research. The main thrust of this work was to develop theory on how DFE could be comprehensively and consistently managed in daily business situation of product development. The use of DFE for foundry industry would go a long way in preserving the environment and improving plant performance.**

Keywords- **DFE, environmental, green, foundry, competitiveness, performance, ferrous**

I. INTRODUCTION

The introduction of market-based instruments of control, such as environmental producer responsibility and environmental labeling, and the growing importance of green consumerism have strengthened the incentive for design for Environment (DFE) as a business strategy at the corporate level. The reasons behind this growth are probably that DFE gives companies an opportunity not only to decrease business risks due to evolving legislation and to increase product competitiveness but also to cut costs and find new products and market segments [1, 2].

In Zimbabwe, many organizations do not include environmental issues in their product development activities in the environmental management system. This study seeks to study how Design for Environment (DFE) could be integrated in ISO 14001. As a result, DEF would be conducted in the ISO 14001 cycle of plan-do-check-act (PDCA) with environmental objectives and DFE tools integrated into the traditional process of product development [5, 8].

II. LITERATURE REVIEW

A. Definition

Design for Environment (DFE) is the systematic consideration during design of issues associated with environmental safety and health over the entire product life cycle [3]. DFE can be thought of as the migration of traditional pollution prevention concepts upstream into the development phase of product before production and use. DFE is applied to the design of new and modification of existing products, processes and facilities.

B. DFE and product life cycle (PLC)

As global markets are undergoing continuous and rapid change, every company's ability to innovate and be flexible will be critical to its profitability [7, 8]. DFE strategy can stimulate product innovation in areas of choice of material, production techniques, finishing technologies and packaging methods. Also partnerships with suppliers/distributors/recyclers can open up new market areas and improve product quality. While most companies do not control the whole product life cycle, their design decisions do have an impact on upstream and downstream processes, from selection of materials to product service and end-of-life options.

C. DFE and (EMS) [3]

EMS such as 14001 is an organizational approach to facilitate environmental evaluation and management. The core requirement of EMS is that a firm should have a reasonable amount of information on environmental effects of its products and processes, and seeks continuous improvement. Pollution prevention is typical part of EMS concept.

Motivation for DFE program arises from need to reduce Non Product Output (NPO). The cost of NPO includes cost of material, warehousing, manufacturing as well as internal collection, treatment and external disposal or recycling. Hence, DFE seeks to minimize NPO or create valuable by-products from them. Typically for iron processing the NPO adds up to 15 to 15% of total output by weight [3, 8].

The other tools mainly used in DFE are Life Cycle Analysis (LCA) and Environmental Conscious Program (ECP). These tools seek to design for cleaner production, recycling and safe waste disposal.

It is important to note that high level of environmental performance can only be improved by regular reviews of related scientific information and existing environmental legislation.

III. METHODOLOGY

The study was done at the case study foundry to assess the environmental aspects of product throughout its life cycle. Effort was also made to identify the environmental priorities to be delay with by the DFE process implementation. MET – matrix was used to evaluate the priority areas [6]. Any other process inspections and interviews with operators were complementary to data collection to get more insights about the operations. Utility bills and purchases records provided the data required on resource consumptions for the various foundry sections.

IV. CASE STUDY

Foundry Company is a ferrous foundry establishment which manufactures iron castings. It is ISO 9002 certified. It has two cupolas with capacity of 750kg. A general manger heads the foundry with supervisor below him and then operators. It is mainly a green sand-molding foundry with some core made from CO_2 sand. The key sections of the foundry are the pattern shop, molding area, green sand reclamation, fettling section, cupolas, machine shop and the quality inspection.

A. Pattern shop

The pattern shop receives orders from customers with some bringing their own patterns with description of product they require and the dimensions. Some bring drawings from which patterns can be made.

The patterns are made from wood, aluminium, resin and grey cast iron. Also in this section bond fillers, vanish and hardeners are used. This mainly carpentry operation produces dust from wood shavings and sawdust, the dust is also from the adjacent sand blasting. Hence there is need to use protective clothing like respirators and goggles by the operators in this section of the operations.

B. Molding area

The major raw material used in this area is green sand for molding with other raw material being silk blacking (refractory material), bentonite, starch, water and coal dust. There are seven molding machines which during operation produce lots of noise. The use of green sand has been emphasized since it can be reclaimed against carbon dioxide sand process, which uses sodium silicate, and silica sand cannot be reclaimed on the background that silica sand is very expensive.

C. Green sand reclamation

The process of reclaiming the sand has its environmental impacts where the dust created goes into the atmosphere because the dust extraction plant is not functioning. There are also leakages from the pipes that transport the sand to be reclaimed. The dust has an adverse effect on people in the molding area. The sand is then mixed with new sand to improve on the quality. The sand is tested for quality before being used in the molding process.

D. Fettling section

This is where the cast is removed from the molds and the gating system is machined off. The area has noise from the grinders and the workers are recommended to put earmuffs.

E. Cupolas

The raw material fed into the cupola are large coke pieces to facilitate air movement, limestone, pig iron, cast iron scrap, NI hard, white iron and steel. The cupola should have uniform pressure so preparation is made to remove slag to maintain a uniform diameter of 92 cm. the refractory used is firebricks, side arch or standard.

F. Machine shop

The machine shop is the final area in the production of cast production. In this section a lot of swarf material is produced and sold as a by-product to other industries. Each operator cleans their work space at the end of the shift. Of concern is the high noise level, and there is need to use earmuffs by operators.

G. Quality inspection

There is limited inspection on the scrap material because of shortage of equipment like spectrometers. There are also checks done on patterns for tolerances. A prototype cast is made and verification is done on dimensions in liaison with customers. After verification then mass production is done as per requirement.

V. RESULTS AND DISCUSSION

Foundry Company is a ferrous foundry and has not taken any step towards EMS, making it a big potential for DEF opportunities. It being a foundry it deals with sand molding with its two cupolas being coke fired hence lots of dust is generated from the sand reclamation plant and sand blasting section. The foundry depends on raw materials which are fast depleting, and the aspect of recycling becomes a handy option for the organization. Foundry Company gets its major raw material as pig iron from a local producer. The organization has not attempted to adopt the process that leads to the certification to ISO

14001.

A. Yield Analysis

Yield analysis that shows the need for DFE

TABLE I
FEBRUARY 2013

Date	Charges	Weight Charge	Melt Loss	Runners	Cast Scrap	Total Good	M / Shop Scrap
28/01/2013	30	7 500	500	416	584	6 000	571
30/01/2013	60	15 000	500	1 181	480	12 839	580
31/01/2013	33	8 250	250	567	1 258	6 175	573
01/02/2013	32	8 000	500	754	389	6 357	429
04/02/2013	18	4 500	500	310	369	3 321	436
05/02/2013	41	10 250	750	1 171	284	8 045	324
06/02/2013	27	6 750	750	430	681	4 889	984
07/02/2013	43	10 750	750	617	252	9 131	1 062
08/02/2013	35	8 750	750	371	683	6 946	368
11/02/2013	49	12 250	750	972	1 531	8 997	742
12/02/2013	41	10 250	750	581	1 697	7 222	874
13/02/2013	40	10 000	500	827	925	7 748	2 878
14/02/2013	36	9 000	500	635	951	6 914	838
15/02/2013	37	9 250	250	526	655	7 819	824
16/02/2013	40	10 000	500	525	628	8 347	492
18/02/2013	37	9 250	250	315	443	8 242	128
19/02/2013	48	12 000	500	1 133	425	9 942	350
20/02/2013	38	9 500	500	598	550	7 852	420
21/02/2013	41	10 250	750	433	717	8 350	985
22/02/2013	32	8 000	500	448	364	6 688	665
25/02/2013	29	7 250	250	279	672	6 049	574
TOTAL	787	196 750	11 250	13 089	14 538	15 873	15 097

TABLE II
PERFORMANCE ANALYSIS

	Target %	Present %	Prior Month %
Runners	-	6.7	4.6
Swarf	-	15.6	21.5
Melt loss	-	5.7	5.8
Scrap rate	6	20.7	22.1
Good yield	70	57.8	53.4
Good yield FDY	80	72.6	-
FDY scrap	10	17.2	-

The above Table II shows that scrap rate is too high, which is causing an environmental burden and hence the need for implementation of DFE as way forward for the business and environmental protection.

B. Energy

There was a lot of high powered machinery which has high demand for power in the plant, meaning there existed poor load factor i.e maximum demand was higher than energy demand.

C. Casting area

Fig.1 gives the inputs and outputs flow of the Casting section to produce finished castings from the molten pig iron. Also waste generated in form of scrap sand cores, dust, effluent, swarf and scrap castings was noted. Table III below summarizes the adverse environmental impact of emissions produced by the processes in this section.

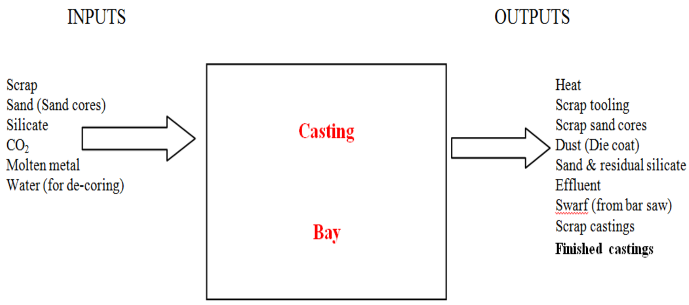

Fig. 1 Casting bay process material flow

TABLE III
ENVIRONMENTAL IMPACT OF CASTING

Affected element of the environment or Aspect	Impact / effect	Significance Rating (1 to 3), I
Air (atmosphere)	Air pollution SO_x, NO_x, CO, CO_2, contribute to global warming	3
Surface water	Pollution occurs when spillages occur	3
Underground water	Pollution by leaching	2
Flora	Affects the growth of vegetation	1
Humans	Particulate matter if inhaled can cause respiratory problems Contact with molten metal can causes serious burns	3
Fauna	Affects aquatic life	2
Land	Sterilize the land if spillages occur	2
Natural resources	Depletion of natural resources	2
Use of machinery	Noise, potential accidents	2
De-coring	Waste sand is alkaline and contaminates the water when washed away	3

Impact effect (level of danger) shown in the table, is rated as follows:

- If the risk is fatal or leads to penalty I=3
- If the risk is presented in the long term the I = 1
- If the risk is presented in short term then I=2

D. Fettling process

Fig. 2 gives the inputs and outputs flow of the Fettling section to produce cleaner casting by removing the sand cast. Here water is extensively used. Waste is generated in form of swarf, effluent, and scrap castings. Table IV below summarizes the adverse environmental impact of the mentioned waste produced by the processes in this section. Scrap casting is re-cycled back into production.

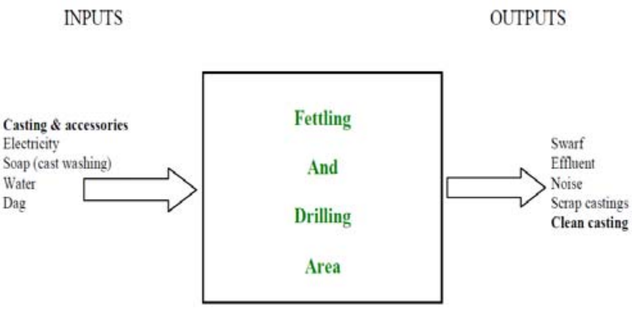

Fig. 2 Fettling process material flow

TABLE IV
ENVIRONMENTAL IMPACT OF FETTLING SECTION

Affected element of the environment	Impact / effect	Significance Rating (1 to 3), I
Surface water	Potential spillage lubricant contaminating the storm water drains & sewer	3
Underground water	Potential contamination if effluent seepage occurs	3
Land	Waste sand is alkaline and contaminates the water when washed away	3
Natural resources	Depletion of natural resources	2
Flora	Destroys vegetation	2
Fauna	Affects aquatic life	3

E. Machining shop

Fig.3 gives the inputs and outputs flow of the machining section to produce clean and final castings for dispatch to customers. Also waste generated in form of used machining oil, water effluent, swarf and scrap castings was noted. Table 5 below summarizes the adverse environmental impact of the mentioned waste produced by the processes in this section.

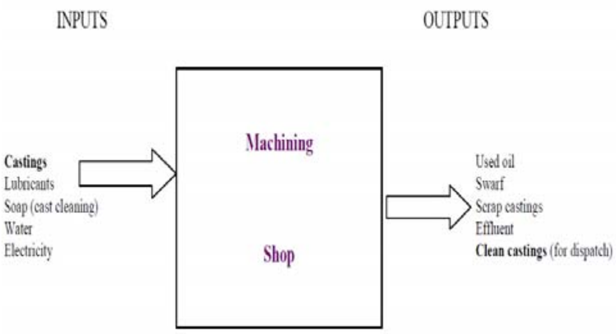

Fig. 3 Machining process material flow

TABLE V
ENVIRONMENTAL IMAPCT OF MACHINING

Affected element of the environment/ Apect	Impact / effect	Significance Rating (1 to 3), I
Surface water	Pollution of surface water if spillages occur & released untreated	3
Underground water	Pollution of underground water if leakages occur	3
Land	Pollution if lubricant leakages occur	3
Humans	Particulate matter if inhaled can cause respiratory problems Noise problems	2
Flora	Destroys plants if effluent finds its way to & waters	3
Natural resources	Depletion of resources	2
Swarf disposal	Depletion of land fill space	1
Use of electricity	High energy intensity	2
Use of machinery	Noise pollution	1
Fauna	Affects aquatic life	3

F. Tool room

Fig.4 gives the inputs and outputs flow of the tool room to produce tools for use in the plant and repairing them. Also waste generated in form of fumes, swarf, scrap steel and used oil spillage effluent was noted. Table VI below summarizes the adverse environmental impact of the mentioned waste produced by the processes in this section.

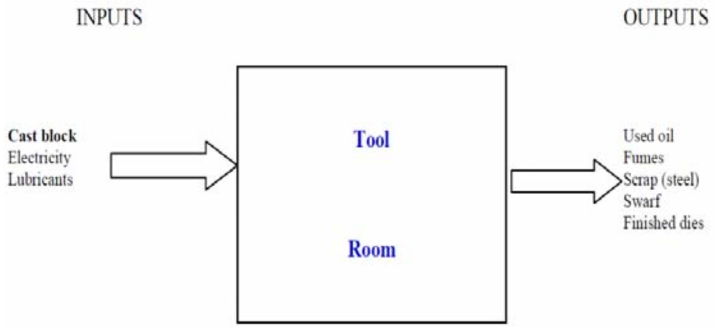

Fig. 4 Tool room process material flow

TABLE VI
ENVIRONMENTAL IMPACT FOR TOOL ROOM

Affected element of the environment/ Apect	Impact / effect	Significance Rating (1 to 3), I
Surface water	Pollution of surface water if spillages occur & released untreated	3
Underground water	If seepage occurs	3
Land	Land contamination if spillages occur	3
Fumes	Air pollution	2
Humans	Can have harmful effects if contact with skin, inhaled etc.	2
Flora	Destroys plants if effluent finds its way to & waters	3
Emissions from tanks	Injuries to workers when contact with skin, inhaled or ingested	3
Disposal effluent	Sewer, land & water pollution	3
Used lubricants	Sewer, land & water pollution	3
Use of machinery	Noise pollution	1
Fauna	Affects aquatic life	2

It was noted that use of carbon dioxide, heat, lubricants, water and sand resulted in generation of fumes, effluent spillages and waste water effluent to the detriment of the environment. This also posed a high risk to operators if they inhale the fumes or get injured when the work without protective clothing like gloves.The environmental review of operations at the foundry has revealed a number of shortcomings such as the uncontrolled exposure to and release of substances potentially hazardous to health. Poor in-plant containment and management of waste products which were contaminating land. Also noted was ignorance of requirements relating to effluent discharges, and contamination risks to surface water drains and sewers arising from inadequate storage of materials. Air pollution resulted in neighborhood nuisance from fumes, dust and odor emission.

VI. RECOMMENDATIONS

High power demand could be reduced through load shedding and staggering the times of switching on equipment in the plant. As well as sub-metering various sections of the plant with view to closely monitoring major consumer sections as well as maintaining a good load factor for key equipment.

There is extensive use of lubricants for machining and lubrication and oil interceptor has to be installed as well as used oil to fire up the furnaces by burning it for environmentally friendly disposal. This measure would effectively reduce the possible contamination of storm water drains.

On the input raw material, recycling is used to handle the high scrap rate of 20.7% in Table 2, this can be cause for high level of electricity consumption through re-working of scrap castings. It is recommended that the scrap rate is reduced to 6% for cost effectiveness in the plant.

Processes like sand reclamation and sand blasting produce a lot of dust, hence it is recommended to use dust extraction fans to reduce dust inhalation by operators.

VII. CONCLUSION

The analysis of the case study has shown that in Zimbabwe, most organizations are not aware of DFE and have not taken EMS as a competitive advantage. Some of the DFE techniques adopted so far at the case study organization as part of their best practice initiatives, have yielded significant benefits. The areas identified for DFE implementation are designing for resource conservation, low-impact material, biodiversity conservation, cleaner production, reuse, recycling and safe disposal in the ferrous foundry. The issue now would be to implement companywide DFE and constantly evaluating and reviewing progress through guidelines of ISO 4001 or full benefits to accrue to the organization.
has to be to the whole life cycle of the products.

REFERENCES

[1] M. Akdere, "An analysis of decision-making process in organisations: Implications for quality management and systematic practice". Total Quality Management Business & Business Excellence, 2011. Routledge, London W1T, UK. Vol. 22 (Dec) page 1317-1330.

[2] J. Baitler ," The Power of effective procurement and strategic suppliers". Strategic Finance, 2010 (Aug): 36 -40

[3] UNEP, "Industrial sector guide Cleaner Production assessment in Metal finishing: Electroplating, Conversion coating and Paint Finishing", 2004.

[4] S. L.V. Lam, " The relationship between TQM, learning orientation and market performance in service organization: An empirical analysis". Total Quality Management Business & Business Excellence , 2012. Routledge, London W1T, UK. Vol. 23 (Jan) page 1277-1297.

[5] L. Fischerh, " Envrionmental cost management, Cost savings in Production", 2007. Bulawayo.

[6] T. Powell, "Total quality management as competitive advantage: a review and empirical study". Strategic Management Journal, 2014. John Wiley & Wiley, New York, USA.Vol 46 (mar) page 15-37

[7] I. Madanhire, C. Mbohwa, "Application of Just In Time As A Total Quality Management Tool: The case of an Foundry Manufacturing". Total Quality Management & Business Excellence. Routledge, Taylor & Francis – UK

[8] SIRDC/NCP . "Product innovation for cleaner production, Stakeholder Training workshop ", 2010. Harare