A Cleaner Production (CP) Perspective for the Metal Industry Processes: Case Study

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***Abstract* – The study investigated the metal processing industry and established gaps in its application of cleaner production initiatives. Major processes were reviewed through use of material balance diagrams for typical operations. Upon which feasible CP options were generated to minimize waste and emissions from the metal industry. The specific framework guidelines for CP implementation were outlined for various metal industry sector processes.**

Key words – cleaner production; metal waste; recycling; eco-efficiency; metal fabrication

I. INTRODUCTION

Metal industries have always been a major contributor to the wealth and wellbeing of people, despite the fact that they are associated environmental challenges. With the current trends in population growth and industrialization, waste and pollutants are released faster than the earth can absorb them, and natural resources are consumed faster than they can be restored [1, 2]. If sustainable development is to be achieved, production processes, products and services have to be re-oriented towards new trends in order to alleviate environmental stress and achieve improved productivity.

Green pressure groups are against the build-up of persistent organic pollutants and are in favor of the precautionary principle, where any technology is rejected unless it is proven not to cause significant harm to the health of living things or the biosphere. Thus prevention of waste generation and pollution at source is gaining wider application across the industries for compliance and environmental protection. One such approach is Cleaner Production (CP), which when applied reduces environmental burden as well as improving the manufacturing operation bottom line [3].

CP is a proactive and integrated solution to pollution problems by eliminating or reducing pollutants at source during production process [4]. It could also be adjusted to suit application in small to medium enterprises (SMEs) where quite a lot of metal fabrication is carried. The acceptance of waste avoidance and minimization is being enforced by very strict discharge limits and environmental regulations that the government seems to be progressively adopting for products and services competitiveness, and environmental protection.

Over the years, it was noted that accidental waste discharges have resulted in raw sewerage finding its way into the water sources raising serious health challenges in the city of Harare. Also the available landfill sites are fast filling up for further use in the future. It is only the minimization of waste generation at workshop floor that could be employed to address this issue. The need for preventive approaches to industrial pollution has been recognized, and the systematic implementation of CP has to be put in place for the major metal organization to achieve environmental improvements, product competitiveness and greater profits.

II. CLEANER PRODUCTION (CP) REVIEW

CP is defined as a continuous application of integrated preventive environmental strategy to processes, products as well as services to increase the overall manufacturing efficiency, and to reduce risks to humans and the environment [5]. Thus in a manufacturing environment, CP entails saving of raw materials and energy, elimination of toxic raw materials as well as reduction of quantities and toxicity of waste and emissions. CP is problem solving strategy that uses a collection of analytical tools to improve the efficiency of production processes and improve profitability. It is a focused, profit driven approach that is relevant to all sizes of enterprises, from home based to international companies.

The goal of CP is to achieve a higher percentage of raw materials are turned into valuable products instead of being wasted. The typical characteristic of CP is that many improvements could be made in the manufacturing processes at no or marginal cost to the business. CP could be an efficient way to undertake processes, manufacture products and provide services. It has the net effect of reducing cost of waste and emissions, reducing liabilities associated with adverse environmental and create penetration of new markets through improved product competitiveness. CP would not treat symptoms but gets down to the bottom of the source of the problem [6].

To achieve sustainable development, manufacturing operation should move from waste disposal to industrial ecology as shown in Fig. 1.

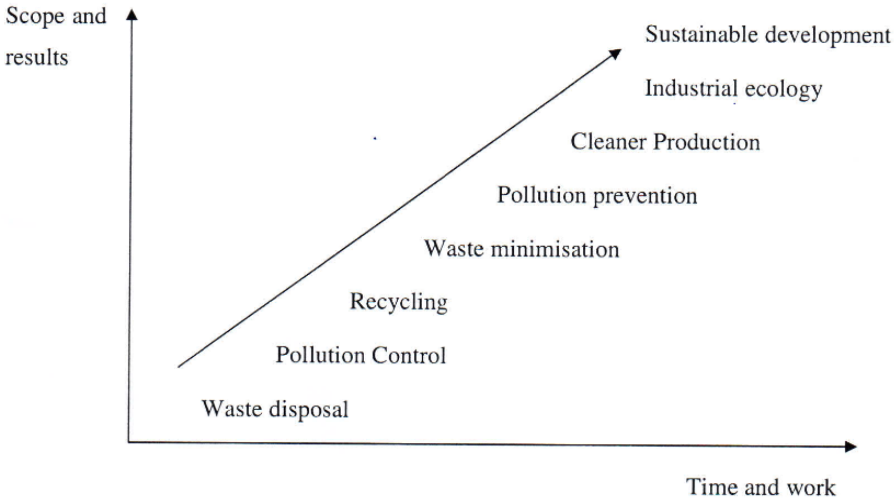

Fig.1. Environmental management concepts [6]

Costs associated with waste may include charges by external waste contractors, as well as personnel cost for employees working on waste treatment rather than productive business.

The key implementation aspect of CP is hinged on the collaboration of employees and operators. Employees are involved with daily operations and maintenance on the shop floor, and would have a good understanding of why waste and emission are generated, and in most cases are able to come up with effective solutions to the same problems.

A systematic approach of identifying polluting processes, CP assessment, CP option generation, evaluation and implementation of selected CP options based on the feasibility, complexity, cost and availability of technology; would be undertaken to reveal solutions to address pollution and wastage challenges.

Environmental management systems (EMS) which normally fall under ISO 4001certification gives the framework for organizational structure, planning of activities, responsibilities, practice procedures and resources for developing, implementing, achieving, reviewing and maintaining the environment policy. EMS seeks to provide order and consistency for firms to address environmental concerns through the allocation of resources, assignment of responsibilities and ongoing evaluation of practices, processes and procedures [7].With EMS framework in place, it would be easy for CP to be implemented for an organization.

III. METAL FABRICATION INDUSTRY

The metal fabrication industry in the country is diverse with firms mainly producing from agricultural to transport equipment. The two broad categories within the sector are metal fabrication that is manufacturing of metal products, and metal finishing which entails finishing product surfaces with either metallic coating like electroplating, galvanizing or painting [8].

In the country, the metal industry on environmental issues is guided by *Waste and Solid Waste disposal Regulations, Statutory Instrument No. 6 of 2007*, which regulates the disposal of effluent and solid waste. It prohibits any person from disposing waste into public stream or ground water without taking adequate measures to mitigate the resultant environmental impact. It also stipulates that every generator of waste should have a waste management plan which deals with quantity of waste, components of waste, goals for reduction of waste quantity and pollutant discharges of the waste, transportation and disposal of the waste and adoption of environmentally sound management of waste. It is an offence for any generator to fail to produce the waste management plan [9].

IV. METHODOLOGY

The study used a sample that was representative of the metal fabrication industry. The plant surveys were done to assess what waste emissions are generated, why those waste streams are generated and possibly how they could be avoided or minimized. Some of the information that was gathered was on production reports, cost reports, environmental reports and material safety data sheets. Process flow charts and material balances were generated from the survey. Questionnaires and interviews were also used to gathering depth details of the metal industry. The generated CP options were evaluated for feasibility, technical and environmental evaluations to come up with CP framework.

V. RESULTS AND DISCUSSION

A. Major processes

In most organizations that were visited, waste in form off cuts and machining swarf was generated and put in waste bins for land fill disposal. The most common processes employed by the firms were pipe fabrication, coach building, electroplating and painting as shown in Table I below.. Material flow charts for these processes were looked at in detail.

TABLE I. MAJOR METAL FABRICATION ORGNIZATIONS

Name	**Processes**	**Products**
Modcraft Engineering	General fabrication	Trailers, tractor units, vehicle bodies, canopies, scotch carts
William Bain & Co	Agricultural equipment manufacturing	Commercial tillage equipment range, castings
Hastt Zimbabwe	Agricultural equipment manufacturing	Ox-drawn implements, trailers, implement spares
Tube and Pipe Industries	Steel tube fabrication	Galvanized pipes, tanks, borehole casings, irrigation pipes & fittings, roofing sheets
Zimplow	Agricultural equipment manufacturing	Ox-drawn implements, metal fasteners, disc harrows
Brown Engineering	General fabrication	Gears, mining & industrial spares, tanks
Cochrane Engineering	Heavy duty fabrication	Industrial boilers, pressure vessels, cyclonic waste furnaces, industrial spares
Industrial Galvanising and Fabricators	Structural fabrication	Electric towers, landings, access ladders, cable ladders, lighting protection, galvanized components
Morewear Industries	General fabrication	Fuel storage tanks, steel pipes & fittings, grain silos, ducting, railway rolling stocks, trailers & bowsers
Deven Engineering	Automotive	Bus & truck bodies
AVM Africa	Automotive	Bus & truck bodies and chasis

B. Pipe fabrication

Fig.1 gives the inputs and outputs flow of the pipe fabrication, in which steel strips are used to produce steel pipe. Waste generated in form of metal off cuts, water effluent, metal swarf, fumes, heat, contaminated coolant and spillage effluent was noted.

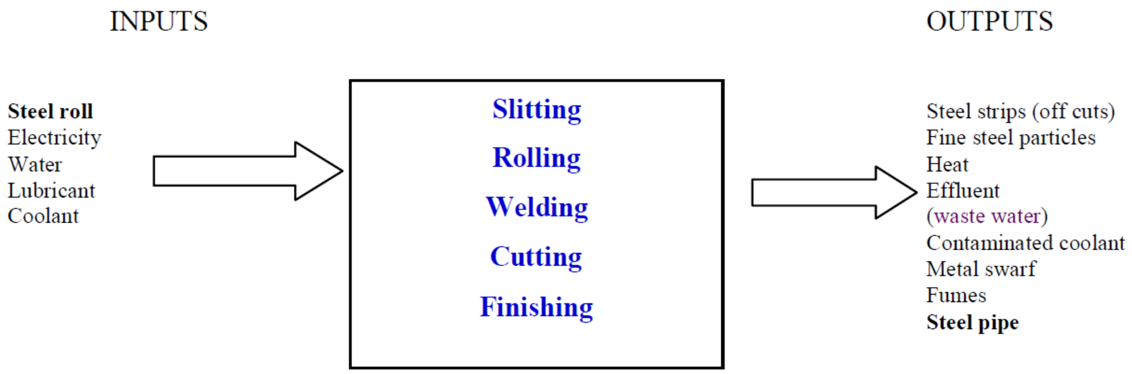

Fig.1. Pipe fabrication process flow

C. Spares fabrication

Fig.2. gives the inputs and outputs flow of the spares fabrication where raw metal work pieces undergo an array of processes like cutting (sawing, torching, pressing), machining (turning, drilling, grinding, milling), forming(bending, pressing), welding and finishing (grinding, sand blasting) to get the final metal work piece like a gear plate. It was noted that a lot of waste like waste coolants and lubricants, contaminated scrap metal, fumes, metal off cuts, waste sand and dust was generated during these processes.

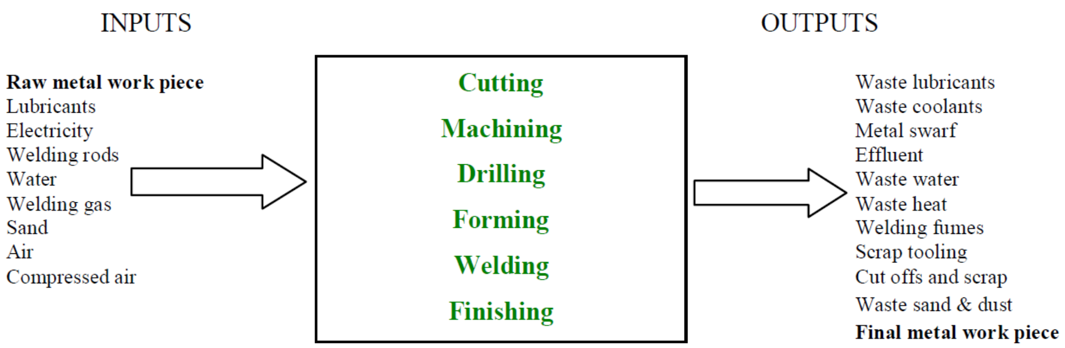

Fig.2. Spares fabrication process flow

D. Galvanizing process

The three major processes of galvanizing are degreasing, pickling and the actual galvanizing, and each process is followed a rinse bath in preparation for the next process. Due to extensive use of chemicals like caustic degreasers, acids and zinc chloride; the major wastes were in form of spent degreaser, acidic water, zinc dross and ash as indicated in Fig. 3 below.

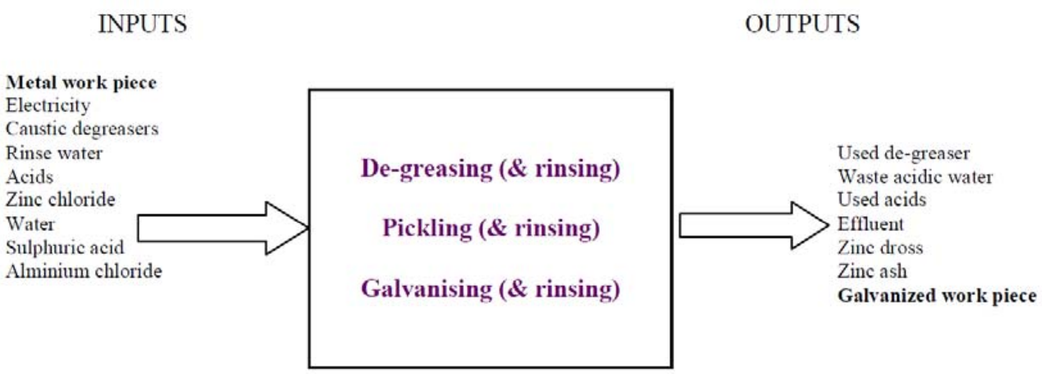

Fig.3. Galvanizing process flow chart

D. Painting

Painting flow chart in Fig. 4 shows that the major processes involved are degreasing, drying and spray painting of the metal work piece to get the final painted job. Major waste noted was in form of fumes, spray emissions, over spray and used degreasers.

Fig.4. Painting process flow chart

E. Coach building

Major processes in coach building were cutting, bending, welding, grinding and assembling to get a final fabricated body. According to the Fig. 5 below the waste observed were in form of scrap metal, contaminated coolant and lubricants, fumes and metal practices.

Fig.5. Coach building process flow chart

The processes were subjected to CP assessment and it was found out that the cost of waste was attributed mostly to cost of raw materials, input energy, intermediate products and final product lost in waste streams mentioned above. It was also in form heat content exhausted in waste streams. The other common cost involved treatment, handling and disposal of waste such as tipping or discharge fees by municipal authorities.

VI. CLEANER PRODUCTION (CP) OPTIONS GENERATION AND EVALUATION

As the CP methodology was applied on all the processes above, a number of CP options were generated for the metal industry. These were categorized as housekeeping, process optimization / new technology, raw material substitution, new product design and recovery of useful by products.

Housekeeping CP options

- Proper operation and maintenance of equipment and machinery
- Preventing the building up of oil and dirt
- Standardizing the use of coolants and lubricants
- Minimizing and re-using of paints
- Minimizing color changes in painting by moving from light colors to dark colors
- Minimizing water use by shutting off taps when not in use
- Galvanizing and pickling to be done at minimum chemical concentrations

Process optimization and new technology options

- Use of high pressure jet in cleaning since it uses less water
- Alternative materials such as plastic pellets or carbon dioxide ice can be used for sand blasting
- High frequency welding can replace conventional arc welding since it is fast and more efficient
- Proper ventilation of and exhaust systems can be installed in welding areas
- Agitation in rinsing baths and degreaser can be improved by employing mechanical means or air injection
- Using painting process with minimum overspray e.g rollers or electrostatic painting

New product design options

- Standardize dimensions in products so as to reduce machining operations
- Avoid complex product shapes that consume a lot of paint
- Employ weak acid in galvanizing operations e.g hydrochloric acid instead of sulphuric acid
- Replace welding where possible with techniques like adhesive bonding

Recovery of useful by products

- Segregate scrap metal and swarf so that they can be sold to scrap metal dealers
- Install water recycling loops so that water can be continuously reused in operations such as pressure testing of pipes
- Zinc ash can be melted to recover the zinc element
- Recover used oil for reuse and resale.

At the time of the study, greater importance was given to financial consideration for cost effectiveness, followed by environmental for operational compliance and finally the technical feasibility came third. In light of the above, the following weights were proposed:

- Economic feasibility (50%)
- Environmental consideration (30%)
- Technical evaluation (20%)

Ten options were weighed and ranked as shown in Table II below.

TABLE II. CLEANER PRODUCTION RANKING

Option No.	Option	Technical	Environmental	Economic	Total	Rank
Weight		20%	30%	50%	10	
1	Preventing the build up of oils	6	8	7	7.1	6
2	Standardising use of coolants	7	6	8	7.2	5
3	Minimising & reusing waste paints	6	7	9	7.5	4
4	Minimizing colour changes by moving from light to dark colours	9	7	8	7.9	2
5	Shutting off taps in use	9	6	9	8.1	1
6	Minimum chemical concentration for galvanizing & pickling	7	9	7	7.6	3
7	High pressure for cleaning	8	6	7	6.9	8
8	Use of rollers /electrostatic painting	7	7	7	7.0	7
9	Suppliers to bring cleaner raw material	6	7	5	5.8	10
10	Minimise use of oil as oil as protection against rust	6	8	5	6.1	9

The evaluation gave top priority to cost effective options for implementation, and the industry would gain in terms financial savings on reduced wastage cost and environmental compliance achievement.

VII. RECOMMENDATIONS

Waste generation exist in the metal industry as if it is a normal and inherent part of doing business. It is therefore recommended that CP should be taken to company level and to be site specific to capture the uniqueness of each firm in coming up with options and their feasibility on implementation. There would be a need to keep a register of waste generated in a facility such as off cuts and swarf and their sources with view to reduce these.

Most organizations did not have an EMS framework of operation, thus there would be need to put one in place as a way to set environmental targets and continuously seek to reduce environmental impact, and improving the efficient of the firms in the metal industry.

Benchmarks should be put in place on resource consumption with regard best practices, and other aspects like maintenance and workmanship could be controlled to achieve reasonable performance and efficiency. All fabrication processes would need to be standardized by having written down procedures and work instruction which would be reviewed from time to time to accommodate improvements.

On the chemicals used such as the acids and de-greasers, there would be need for documentation of the specific chemicals the types as well as the processes where they are used. Each one of these chemicals should have an MSDS (material safety data sheet) provided by the respective suppliers to ensure that relevant precautions are adhered to in applying and disposing the material. Any emission resulting from use of chemicals should be handled through installing pollution control systems to safeguard the environment.

VIII. CONCLUSION

CP study was done on the generic processes for the metal industry by considering the firms in Harare. It was noted that despite the fact that tons off cuts and swarf were generated by the firms, it was considered normal hence no records were kept to keep track with view to reduce this inherent waste. It was recommended that individual companies develop Environmental Management Systems (EMS) as a facilitative guideline for organizations. Once the companies implement EMS and get certified, and they have to maintain this system in an effective way to achieve the envisaged CP improvements. The metal fabrication sector needs to improve on recording, monitoring and controlling of the environmental data; and this would make it feasible to quantify improvements that could be made through implementation of CP efforts.

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BIOGRAPHY

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Charles Mbohwa is a Professor of Sustainability Engineering and currently Vice Dean Postgraduate Studies, Research and Innovation with the University of Johannesburg, SA. He is a keen researcher with interest in logistics, supply chain management, life cycle assessment and sustainability, operations management, project management and engineering/manufacturing systems management. He is a professional member of Zimbabwe Institution of Engineers(ZIE) and a fellow of American Society of Mechanical Engineers(ASME).