“The environmental impact and future sustainability of companies using coal-fired boilers in production processes”

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The environmental impact and future sustainability of companies using coal-fired boilers in production processes

Abstract

The purpose of this article is to assess the impact of Environmental Management Accounting System (EMAS) as a waste management assessment and decision tool on organizations using obsolete technologies to perform operational activities. The new waste legislation will affect the future sustainability of manufacturing companies generating large amounts of waste in developing countries, such as South Africa. This article is based on a case study of a paper and pulp manufacturing companies in Kwa-Zulu Natal. EMAS was used as a waste assessment and decision tool to investigate the negative impact of the large amounts of boiler ash generated on the company's environmental and economic performance. The excessive amount of boiler ash (waste) generated during the steam generation process contained large amounts of unburned coal. This represented a loss of natural resources costing the company millions of Rands. The companies are currently disposing this ash at a local landfill site (DCLM). However, the new waste laws, prevents companies from disposing any waste containing carbon to landfill sites. Results of the finding indicate that companies operating coal-fired boiler plants will need to adopt Cleaner Production technologies and techniques to reduce boiler ash waste in order to continue business operations in the future. Current waste legislation will not allow companies to dispose of boiler ash to landfill sites within the next 5 to 7 years. Ultimately, management needs to consider investment in cleaner technologies or best-available technologies (BAT) as a strategy to improve environmental and economic performance to ensure their future sustainability.

Keywords: waste legislation, sustainability, cleaner production techniques, cleaner technologies, boiler ash, environmental and economic performance.
JEL Classification: Q50, Q55.

Introduction

The pulp and paper industry is an over capacitated commodities industry that is highly sensitive to global market influence on price and cost. Bras et al. (2004) describe the industry as one with excessive production capacity, high fixed costs, cutthroat pricing schemes, increasing competition from foreign impacts, yet still producing more paper even though this meant higher marginal cost implications of the law of diminishing returns. Paper and pulp manufacturing operates in a cyclical industry with global economic conditions causing volatility in paper and pulp prices. Therefore, cost reduction and improving efficiencies are considered a priority (Andres and Pearce, 2011; Aziz and Layeghi, 2008). Finding lower cost raw materials and alternative fuels, minimizing waste, improving manufacturing efficiencies and implementing energy saving initiatives are some measures taken by the industry to mitigate risks (Bras et al., 2004; Despeisse, Oales and Ball, 2013).

1.1. Problem statement. In many developing countries, an increase in industrial activity, electricity demand and transportation results in emissions and poor air quality have become a major issue (Stringer, 2010). Higher energy and raw material prices are causing cleaner production to grow in relevance and importance (National cleaner production strategy, 2004; Lakhani, 2007). The amount of waste to landfill is increasing steadily.

Most companies are using inefficient processes and technologies that are obsolete, instead of state-of-the art processes resulting in higher production costs which, in turn, affects their profitability and competitiveness (Schaltegger et al., 2010). Managers of paper mills perceive investments in pollution abatement technologies as 'unproductive' because they have 'no marketable and quantifiable effect in terms of productivity' (Bras et al., 2004) and cleaner production opportunities cannot be seen (Baas, 2007).

Boiler ash (hazardous waste) is generated in large amounts daily. Managers are concerned that this bottom boiler ash contains large amount of unburned coal which ultimately represents a loss to the company. Coal is currently costing companies millions, and is the largest cost factor in the steam production process.

The rising costs input resources and increasing environmental cost have had a negative impact on the companies' profitability.

The company has invested large amounts of money on end-of-pipe technologies and the wastewater treatment plant to reduce the negative impact of their production processes on the environment. This has, however, not solved their environmental issues nor has it reduced their resource use in production. The technology used in the steam production process is outdated and obsolete.

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To ensure their future sustainability and competitiveness, management needs to consider adopting Cleaner Production (CP) techniques and technologies which will address waste issues at its source. CP is perceived by management as a costly strategy that requires innovation with no financial returns to the company in the short term. They are unaware of how high their environmental costs are, since the company uses conventional accounting methods to allocate costs.

1.2. Aim and objectives. The aim of this study is to identify the use of Environmental Management Accounting System (EMAS) as a sustainability tool to assess the efficiency of the mills current technology used in the steam generation process.

Objectives:

- Identify possible causes of the large quantities of waste generated (unburned coal in boiler ash).
- Evaluate their current waste management processes.
- Discuss the impact of the new waste legislation on the future sustainability of the mill.
- Make recommendations to management on how to improve their environmental and economic performance to ensure that their business operations are sustainable in the future.

1.3. Research design and methodology. A case study methodology was implemented to collect and analyze the company's data. The researcher analyzed production cost schedules, technological flow charts and financial statements of the companies that participated in the study. Environmental managers and cost accountants of the companies were also interviewed by the researcher. Therefore, both quantitative and qualitative methods were applied to analyze data.

2. Literature review

2.1. Economic and financial performance. Packaging paper plays an important role in an environmentally conscious world and is driven by population growth, urbanization and higher standards of living. However, volume and prices remained flat in 2012 in the South African market. Cost saving initiatives have been strategically adopted to boost margin growth in business (investor reports – focus on innovation, 2012).

2.2. Production strategies. The pulp and paper industry objective is to try to keep expenditure at low levels and to spend the balance of their cost aimed at maintaining their production facilities. They also aim to provide job opportunities to the local community (Paper and paper packaging, 2011).

Du to consolidation of the paper business after the period of restructuring of the companies, South African mills could result in an improvement in performance in a very competitive market (Investor reports, 2012).

Fig. 1. Elements for production strategies

Source: Southern Africa sustainability report (2012).

2.3. Environmental Management Accounting (EMA). EMA is a broader concept of accounting and an approach to corporate environmental information management which uses accounting tools and practices to support company-internal management decision making on environmental issues and its impact on company performance (Schaltegger et al., 2011, p. 2). It also provides the information needed by managers to identify CP opportunities in their companies by accurately calculating and reallocating the cost to the relevant products and processes. This will allow for inefficient processes with high environmental impact to be identified.

2.4. Cleaner Production (CP). According to the United Nations Environmental Program (UNEP), CP is defined as follows: "Cleaner Production can be described as a preventative, integrated strategy in which costly end-of-pipe pollution control systems are replaced by measures which reduce and avoid pollution and waste throughout the entire production cycle, through efficient use of raw materials, energy and water and emissions of any kind at the source rather than dealing with them at a later stage." Aims of CP are to use resources more efficiently, reduce the amount of undesired outputs and improve monetary returns by reducing material and energy consumption. Capital investment may be required to adopt Cleaner Production (Schaltegger et al., 2010, p. 7).

Numerous pilot studies have been undertaken by CP experts and have demonstrated that CP is a sign of more efficient production and companies that have adopted CP have reported reduction in cost and environmental impact at the same time (Schaltegger, et al., 2010, pp. 4-11; Burritt, 2004). A brief overview of some of these studies is presented below.

There is a growing demand of raw materials by paper industries as a result of worldwide increase in the production and consumption of paper and paperboard. It is expected that paper consumption will increase to over 490 million tons per year by 2020 (Mousavi et al., 2013, pp. 420-424). Strict environmental legislation, market pressures and the urgent need for sustainability have created a major challenge for the paper and pulp industry (Despeisse, Oales and Ball, 2013, pp. 31-41; Andrews and Pearce, 2011, pp. 1446-1454; Aziz and Layeghi, 2008, p. 1; Stringer, 2013, p. xiv-3). This has led to the introduction of sustainable development in business practices (Persson and Berntsson, 2010, pp. 935-943).

In order to achieve sustainable competitive advantage, businesses need to adopt Cleaner Production processes (Fore and Mbohwu, 2010, pp. 314-333; Pons et al., 2013, p. 134).

Pilot studies by CP experts remain merely as niche examples and decision makers in companies have failed to adopt this as a corporate strategy due to a shortcoming in the discrimination of information about the economic and environmental potential of CP (Schaltegger, 2010, pp. 5-11).

Cleaner technologies shared environmental gains of less pollution and reduced waste generated at the end of the production process and financial gains of lower maintenance costs and more efficient use of raw materials. Positive results were concluded in all departments in the environmental management system whereby the clean technology had been deployed (Promoting Sustainable Use of Industrial Material, 2013; Acemoglu et al., 2012, p. 1). The ‘Porter Hypothesis’ of the win-win scenario suggests that well designed environmental regulation can inspire innovation and strategy formulation aimed at ‘enhanced resource productivity’ which could make companies more competitive (Bras, Realff and Carmichael, 2004, p. 12; Foelkel, 2008, p. 4).

This change towards Cleaner Production processes may require investment in Cleaner Production technologies (Christ and Burritt, 2013, p. 163; Schaltegger et al., 2012, pp. 11-15). Actions generated in clean technology should no longer be seen only as costs, as they represent a number of benefits to industries by assisting them in their endeavors in sustainable development and achieving their goals of the “triple bottom line” (Mendes, 2012, pp. 100-106).

2.4.1. Role of Environmental Management Accounting (EMA) in Cleaner Production implementation in developing countries. The benefits of using Environmental Management Accounting (EMA) in practice as an environmental and sustainability tool to collect, evaluate and interpret the information needed to estimate the potential for Cleaner Production saving with particular emphasis on non-product output costs and to make decisions to choose the right CP options have been established in several business cases.

However, the level of implementation of EMA in practice is low because of the significant gap in academic knowledge concerning EMA and its role in identifying inefficiencies in a production process and benchmarking environmental costs to yield superior environmental and economic performance (Burritt, Herzig, and Tadeo, 2009; Christ and Burritt, 2013, p. 165; Schaltegger, et al., 2010, pp. 11-15; Thant and Charmondusit, 2010, pp. 427-439; Chius and Leung, 2002, pp. 10; Van, 2012, p. 3).

Although CP has proven to be a good tool, it has not yet been well implemented internally. South Africa’s commitment to Cleaner Production led to the formation of the United Nations Industrial Development Organization (UNIDO) National Cleaner Production Centre (NCPC).

The United Nations Development Programme, as part of the Department of Sustainable Development, reports EMA as an important management tool for businesses to adopt whilst responding to environmental challenges and still focusing on the triple bottom line, which is achievement of environmental, social and economic benefits by the company (Ambe, 2007, p. 7). UNEP educates and encourages companies on the benefits of using EMA. Following these international developments, South African companies have considered environmental issues in their decision making processes regarding products and processes. They have identified potential savings of implementing good environmental management by using EMA to accurately trace and identify environmental costs (Ferreira et al., 2010; Christ and Burritt, 2013, p. 165; and Ambe, 2007, pp. 11-12). A study conducted by Jonall (2008, p. 2), revealed that the EMA method identified material purchase value of non-product output costs to be the largest cost category.

A test project undertaken by Schaltegger et al., (2010, pp. 17-19) to assess the sustainable performance of companies after a combined application of EMA, CPA and Environmental Management system (EMS) generated positive outcomes and contributed to the enhancement of CPA/EMS projects by increasing awareness of the economic implications of the environmental impact of non-product output and costs and provided a systematic method of controlling these costs in the short, medium and long terms. EMA also helped to quantify monetary benefits of adopting alternative CP options (V’an, 2012, p. 5).

2.4.2. Benefits of Cleaner Production technologies for the pulp and paper industry. CP link to sustainability is based on two principles: discussions on wastes and emissions should be concentrated on sources rather than symptoms, and that only by a higher degree of input material utilization can minimization of waste and emission be obtained (Fore and Mbohwa, 2010).

During the Central Project in Europe, it had been concluded that Cleaner Production technologies increase the resource efficiency in production, reduce consumption of input resources and the quantity of waste generated. Furthermore, need for end-of-pipe-technology may be eliminated resulting in major costs savings for the organization (Access to Technology and Know-how on Cleaner Production in Central Europe, 2008-2011).

However, changing from pollution-control to pollution-prevention technologies takes time, money, and a holistic approach to managing the environmental issues associated with pulp and paper manufacturing. In order to remain competitive, mills will have to respond with new technologies and if this decision results in the firm incurring high costs, these costs are most likely to be passed on to purchasers (Bajpai, 2010). Therefore, paper companies must consider how much capital needs to be invested in order to reduce operating costs (Environmentally friendly production of pulp and paper, 2010).

Recent survey of recovery boilers found that over 70% were more than 25 years old and will, therefore, have to be rebuilt or replaced in the next decade.

Minor renovations, replacement of individual pieces of equipment and the elimination of bottlenecks will have to proceed at a greater rate than major renovations or expansions. It can be concluded that integrating pollution-prevention strategies into pulp and paper manufacturing needs to be part of the capital planning process that integrates a long term vision for environmental progress with improvements in quality, productivity and lower operating costs (Bras et al., 2004; Oh, 2010).

2.5. Energy consumption. Approximately 80% of the energy needs of mills are met by the combustion of fossil fuels (mainly coal) to generate steam and hot water for evaporative and heating processes (Benchmarking energy use in Canadian pulp and paper mills, 2008). Energy consumption depends on how old the technology is and the range of products being produced. Certain processes are very energy intensive. Energy is an area where substantial savings can be made through simple housekeeping efforts. However, considering the price of coal and its impact on the environment, the company needs to consider the adoption of cleaner production technologies that will improve both the environmental and economic performance of the company. This would require capital investment in more efficient boilers in the medium to long term (Ernst, Lynn, Maarten, Christina and Nan, 2007).

The following housekeeping measures suggested to reduce the amount of energy needed to produce steam are: improving insulation on heating and cooling systems and pipe work, regular maintenance to optimize energy efficiency of the equipment, maintaining optimal combustion efficiencies on steam boilers, and eliminating steam leaks. There are opportunities for using more environmentally benign sources of energy, such as replacing coal with cleaner fuels like natural gas and co-generation of electricity (Ernst, Lynn, Maarten, Christina and Nan, 2007). During a benchmarking study by the Pulp and Paper Research Institute of Canada, it had also been found that maintenance and equipment/technology impact on operating conditions (Giglio, 2013).

3. Environmental impacts of 'coal'

Coal, as a source of fuel, generates and releases large amounts of CO_2 which has a negative impact on the environment, causing land and air pollution. Increased risk of climate change has placed organizations under tremendous pressure to use cleaner fuels in their operational activities.

In Durban, the largest contributor of GHG is the industrial sector. In this sector, a total of 52% of all industrial emissions comes from electricity consumption followed by coal which comprises of 17%. Coal is often used as fuel in the industrial sector as it is cheaper than other energy sources. It is, however, more carbon intensive and thus contributes to pollution to a greater extent than other fuel sources (Giglio, 2013).

Industrial sectors that consume excessive coal, like the wood and wood products sector, as reported by the eThekwini Municipality, are targeted to switch from coal to other cleaner fuels. Long-term projects aimed at improving boiler efficiencies by reducing electricity consumption include the introduction of combined heat and power (CHP) systems or the initiation of cogeneration systems in which waste heat is used as power in a secondary process. Pollution control measures, such as phasing out of 'dirty fuels' to reduce SO_2 emissions were also introduced. Industries have changed from using high-sulphur coal to low-sulphur coal, and implementing 'end-of-pipe' pollution control technology (Academy of Science of South Africa (ASSA, 2011).

Research by Thompson and Fowler (2009) into the use of coal as a source of fuel in industrial technologies reported findings that carbon capture and sequestration (CCS) are essential tools needed to reduce the environmental impact of coal. There is a need for cheaper but more efficient CCS technologies. It is now possible for new and older coal burning power plants to produce power in an economical and environmentally responsible manner because of technological breakthroughs (Giglio, 2013). New coal power plants have been established in China, and India is also set to develop new coal generation capacity.

Recent statistics revealed that world coal capacity is likely to double by 2030, and, if conventional coal technology is used, CO_2 emission is expected to grow by about 12.6 billion metric tons annually by 2030. The increased need to reduce CO_2 emissions by 50% to avoid the impacts of climate change has been the suggestion by scientists Mathews and Caldeira. The climate scientists stated that "stabilizing climate requires near-zero emissions". Hence, the need for cleaner technology is imperative (Thompson and Fowler, 2009). Research shows that no single technology is capable of achieving the target of zeroing global CO_2 emissions by 2050.

According to a publication *'User guidelines for waste and by-product materials in pavement construction* (2012)', boiler slag is formed from cyclone boilers that burn crushed coal. It had been concluded that the composition of bottom ash or boiler slag particles is controlled primarily by the source of the coal and not by the type of furnace. Bottom ash usage is identified as structural fill, road base material, concrete and production of cement. It is believed that as the acceptance of the use of boiler ash increases, markets have the potential to utilize all of the bottom ash produced.

However, to reduce the amount of boiler slag available, older cyclone boilers needs to be retired (Coal fly ash, bottom ash and boiler slag, 2014).

The future sustainability of companies generating large amounts of boiler ash containing unburned coal particles is questionable. There is a possibility of groundwater contamination by trace elements that are commonly associated with by-products produced during coal combustion. Bottom ash and boiler slag also contain radioactive materials called TENORM – Technologically Enhanced Naturally Occurring Radioactive Materials (Coal fly ash, bottom ash and boiler slag, 2014). This hazardous waste has negative impacts on the company's environmental and economic performance.

3.1. Advantages of Cleaner Production versus end-of-pipe technologies

Table 1. Cleaner Production versus Pollution Control

Cleaner Production	Pollution Control
Continuous improvement	Temporary/immediate solutions to individual problems - 'on-off'
Progress towards continuous cycle processes- cradle to grave	Disposal of waste materials including loss of resources resulting from inefficient processes
Shared responsibility – cooperation and teamwork essential	Solutions are developed by experts and are expensive – done in isolation
Avoidance of pollution and waste is voluntary- proactive stance	Response to pollution and waste after they are generated – reactive response
Environmental problems are eliminated at their source	Waste treatment equipment and methods are used to control pollution
Involves change in practices, technologies, techniques and management attitude.	Involves technical improvements to existing technologies

Source: Self-generated.

3.2. Cleaner Production case studies done on boiler plants. Case study findings reported by the Cleaner Production Case Studies Directory EnviroNET Australia (2003) presented results of a Cleaner Production assessment that was done on coal fired boilers used by the AMH group which operated five coal-fired boilers, situated at different locations. The CPA assessment revealed differences in coal burning performances of the boilers and opportunities to improve boiler performance were identified. It had been found that between 2% and 29% of coal used were not combusted. The unburned coal that remained in the boiler ash was disposed to landfill. The investigation showed significantly high production costs due to wasted energy and higher steam costs. It had been found that the boiler operating staff had difficulty in operating the boilers to meet steam demand. The company conducted an in-house training programme to develop operating and management skills of staff involved in operating the boilers. The programme was successful resulting in immediate reduction in percentage of unburned coal from 25% to 2% and improved boiler efficiency from 70% to 98%. Coal usage decreased by 27% resulting in a savings of approximately $65.000. An added benefit was reduced ash disposal to landfill by 275 tons per year. The evidence of this case study contradicts the perception of company managers that CP options are costly to implement. CP is not always a costly approach and may be the only solution for companies facing tough economic downturns.

The UNEP conducted an investigation of the boiler house of a textile company in India, as part of the ACME project (Applying Cleaner Production to Multilateral Environmental Agreements (ACME)). Unburned coal in ash was identified as a waste stream during CPA analysis. Recommended CP options to reduce unburned coal ash were: conversion to FBC boiler, to ensure coal is properly crushed and sieved to achieve optimal coal size, to reduce gaps between rods by modifying existing grate, use of stoker firing to achieve optimal firing rate.

Advantages of FBC boilers: high efficiency as fuel is burned with a combustion efficiency of over 95% irrespective of ash content and operational efficiency of 84% (+-2%).

4. Current waste legislation and impacts on organization

4.1. Waste management: legislative overview. According to the National Environmental Management Waste Act 2008 (NEMWA) (Act 59 of 2008), it had been stated that waste needed to be classified according to its characteristics to ensure responsible handling, storage, processing, treatment and disposal of waste that also satisfies legal requirements (Wood, 2013). Boiler ash generated is normally transported via conveyor belts and stored in enclosed silos. However, an alternative option adopted by many organizations is that they allow contractors that have beneficial use for it to remove the ash and use it in other manufacturing processes (example: brickmaking).

It is a legislative requirement that ash be stored in an area licensed in terms of NEMWA: GN R. 718 of 03 July 2009, Category A3 (2).

Boiler ash is often used as daily cover material at landfills. The presence of unburned carbon in boiler ash is evidence of poor operating practices. It is the duty of the producer of the waste, such as ash, to ensure that it is disposed of correctly. Godfrey, Rivers and Jindal (2014) discussed trends in waste management in developing countries, such as South Africa. Some of challenges faced were similar to those experienced by developed countries:

- Growing waste demands placing greater pressure on the provision of infrastructure;
- Changes in terms of socio-economic issues;
- Disposal to landfill being the dominant means for waste management;
- Problematic waste streams, such as organic waste and hazardous waste;
- Low levels of recycling; and
- Inadequate environmental legislation regulating waste management activities.

In South Africa, greater emphasis was placed on recycling and recovery. Up until 2011, approximately 90% of all general and hazardous waste generated was disposed to landfill. South Africa still relies heavily on landfilling as its waste technology solution. About 9.8% of waste generated is recycled and 0.1% treated. Waste recycling in South Africa is mainly driven by the informal waste sector. A survey conducted by the National Waste sector in 2012 revealed that South African private and public sectors rely heavily on landfilling as a technological option to waste management.

Majority of waste technologies patented are non-South African owned, indicating clearly that international companies see South Africa as an attractive market for the introduction of waste technologies. Companies have begun to protect their intellectual property due to the growing trend towards innovative waste technology (Godfrey, Rivers and Jindal, 2014).

The People's Republic of China (2011-2015) has identified 'developing a circular economy' as the strategic area of focus to address the socio-economic development issues relating to waste management. The trend towards the circular economy together with the principle of the waste hierarchy is prompting change within South Africa. Currently, South Africa is largely at the peripheral of this global transition.

Strategic evolution towards managing waste, such as coal ash within the next 3-10 years, involves research on minimizing ash and cleaner technologies.

5. Analysis of results and findings

5.1. Findings. *5.1.1. Summary of empirical findings.* The study yielded the following results:

The researcher, during the interview with the cost accountants of the companies, discovered that the environmental costs are perceived to be insignificant and only accounted for annually using a traditional accounting system. Therefore, investment in CPT to improve environmental performance and reducing environmental cost was not viewed as a necessary measure by the organization. It was also evident that the companies only consider their waste disposal and water treatment costs as environmental costs. Scavone (2006, pp. 1276-1285) states that by adopting an EMA system, a company can develop proactive environmental programmes which, in turn, improves profitability and competitiveness, reduces business costs, increases worker productivity and morale, enhances brand image, and improves relations with regulators and local communities.

Their material losses are not evaluated and added to NPO costs. All raw materials used are allocated to product cost irrespective of whether they actually form part of the final product. Energy and system costs, as identified by MFCA, are also not considered when costing wastes. Therefore, no decisions are made towards improving production processes and moving towards CPT.

The cost of investing in CP technology is not justified, due to the inaccurate assessment of environmental costs resulting in it being underestimated. Environmental costs are also reflected under the general overhead account and are not being traced back to the product or process.

During the investigation using EMA, it had been discovered that the largest cost category was the material purchase value of NPO.

It had been concluded that EMA could be used to support strategic decision making in companies that improve environmental performance of a company and also highlight the potential for large cost savings.

Schmidt and Nakajima (2013, pp. 358-369) found some weaknesses in conventional cost accounting in that it cannot give all the required data. Monetary value flows are traced and interpreted as product cost in a conventional cost accounting (CCA) system. The next section deals with primary data collection and analysis of the steam generation process to identify the possible saving opportunities and improved environmental performance by adopting CP techniques.

The first step in the process involves a CPA of the steam generation process.

5.2. Cleaner Production Assessment (CPA). The qualitative review was conducted during the CPA stage. It involved an overview of the company's production and environmental aspects.

The CP assessment framework was used to capture data during the CP audit process as per the CP model. Analysis of the process flow chart shows inputs, outputs, and environmental problem areas of the steam generation process. Quantitative data analysis involved the calculation of NPO using MFCA, a tool of EMA. This was used to identify potential savings options for the company should they adopt CP processes. Schaltegger et al. (2010) highlight the following warning signs of inefficiencies which become evident during the CPA: higher raw materials cost compared to those prescribed by technological standards, higher energy costs, maintenance needs and higher level of undesired output.

The first step of CPA involves the process of flow chart analysis of the steam generation process to identify waste generated resulting in negative environmental impact.

5.3. Cleaner Production Assessment. Table 2 presents the results of the boiler comparisons.

Table 2. Paired samples test

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
					Lower	Upper			
Pair 1	Boiler 1 - Boiler 2	.17359	2.73371	.78915	-1.56333	1.91050	.220	11	.830
Pair 2	Boiler 1 - Boiler 3	.29703	.66553	.19212	-.12583	.71988	1.546	11	.150
Pair 3	Boiler 1 - Boiler 4	.12888	.26159	.07551	-.03732	.29509	1.707	11	.116
Pair 4	Boiler 2 - Boiler 3	.12344	2.73905	.79070	-1.61687	1.86375	.156	11	.879
Pair 5	Boiler 2 - Boiler 4	-.04470	2.69466	.77788	-1.75681	1.66740	-.057	11	.955
Pair 6	Boiler 3 - Boiler 4	-.16814	.57483	.16594	-.53337	.19709	-1.013	11	.333

When compared to each other, the mean values are not significantly different.

Calculation of boiler efficiency is as follows:

Input/output efficiency of current technology for the period under review was: 1 ton coal: 6.3 tons of steam (amounts reflected in the accounting records will be used in this calculation).

Technological standard: 1 ton coal: 7 tons of steam = 1/7 = 0.143. This shows that boilers are functioning below technological standards resulting in loss of coal during the process.

5.3.1. Causes of waste generated during steam production process. Identify possible causes of waste generation from the steam production process.

During the steam generation process, large amounts of unburned coal are found in the bottom of the boiler ash. Hence, the steam production process is inefficient, resulting in excessive raw material wastage. The input/output ratio, according to technological design, is not being achieved. Therefore, the amount of coal used to generate steam is in excess to what is prescribed in the technological flow chart manual.

The information above indicates that the three of the four boilers are functioning well below test standards of 1:7 and state-of-the-art technological standards of 1:8. In order to identify operational savings, managers need to look at ways to reduce the NPO costs caused by sub-optimal functioning of boilers.

It should be noted that the total cost of material losses was limited to raw material flow only. No energy costs or water costs will be included in the calculation. Material purchase value of NPO is the most significant of all costs incurred in process steam.

Unburned coal/carbon content of boiler ash (solid waste) has been estimated to identify non-product output costs of raw materials that do not form part of the final product (steam). Material loss/waste is quantified and calculated using the purchase price of coal. Monetary value of NPO is calculated using the equation as follows:

Monetary value of loss = quantity loss in tons x input price of coal.

5.4. Analysis of accounting documents and records. Accounting documents and records were analyzed to identify production costs and non-product output costs of steam generation process. The aim of this research is to identify potential saving opportunities by introducing Cleaner Production techniques and technologies. There are two major costs considered significant in the steam generation process and would be used in calculation of payback period for investing in new boilers or upgrading existing boilers to improve efficiency. The costs are as follows:

- Cost of disposal of bottom boiler ash to landfill (transportation and handling cost of waste); and
- Loss of raw material (coal) due to inefficient processing (calculated using MFCA model proposed, which is a tool of EMA).

Table 3. Benchmarks based on technological efficiency

Standards	Actual	Technological	State-of-the-art technology
Coal (fuel) input	1 ton	1 ton	1 ton
Steam output	6.3 tons	7 tons	8 tons

Table 3 shows that boilers are operating below technological standards and that there is significant saving potential by switching to state-of-the-art technology in the future.

Figure 3 shows the tons of steam generated at different efficiency levels (indicated by coal usage).

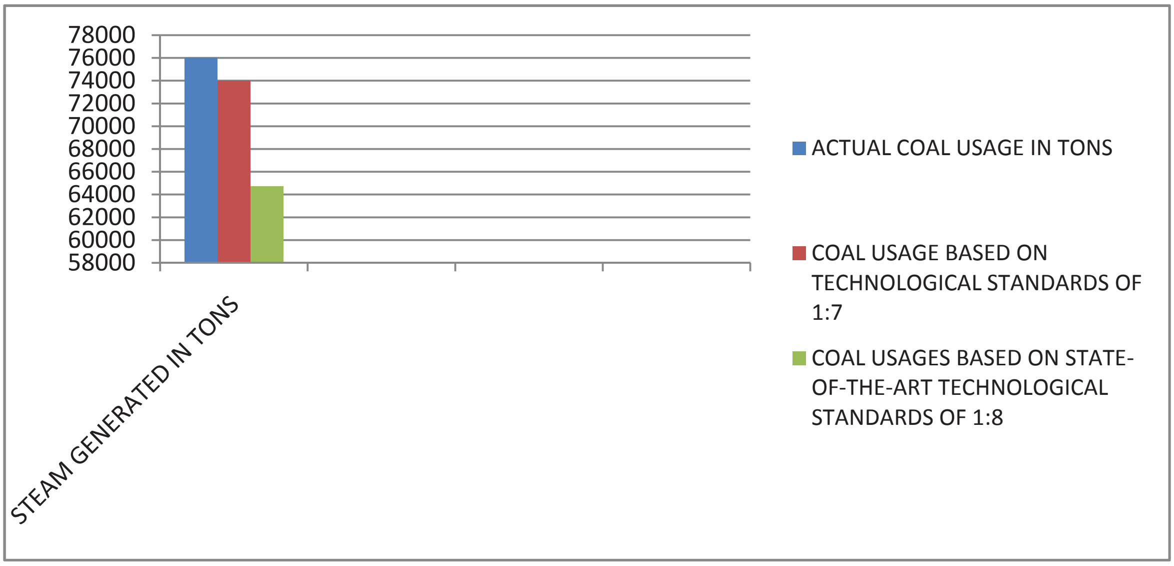

Fig. 3. Coal usage

Figure 3 indicates that coal usage is lower when technological standards are achieved and much lower when state-of-art technology is used in the steam generation process. This can result in savings in input resource use for the company. State-of-the-art technological standards of 1:8 were established by most advanced boiler makers in the industry (Edgar, 2014).

Calculation of investment payback period. John Thompson Boilers were consulted to estimate values for cost of replacing boilers and upgrading the back-end equipment to reduce emissions and improve boiler efficiency and performance.

Total cost:

1. New boiler = R60 000 000.00 per boiler (approximately R240 million).
2. Boiler upgrade = R5 000 000.00 per boiler (approximately R20 million).

Total savings:

Material lost (non-product output value based on 20 percent loss of coal during steam generation process).

Total investment cost/Estimated total savings per annum

Replacement costs of boilers are extremely high. Therefore, upgrading costs will be used in calculating payback period. This will be used in strategic decision making process.

Payback: 1.74 years

Efficiency level using newer, upgraded technology is 1 ton coal: 8 tons of steam

Savings in reduced raw material consumption = 1/8 = 0.125

5.5. Possible causes of waste and inefficient production process. *5.5.1 Coal (raw material).* The quality of coal needs to be considered as a possible cause of material loss. Poor quality coal would reduce efficiency levels of the boiler resulting in larger amounts of unburned coal generated as bottom boiler ash (waste).

According to Sheldon (2001), coal-related issues affecting the operation of a boiler are:

Temperature imbalance – too much or too little heat transferred from combustion zone to the feed water or from convective section to the saturated steam.

Slagging – the slag formed reduces overall heat transfer. This ultimately results in inefficient operations and reduced economic performance.

Corrosion and abrasion – damage to boiler walls increases the need for future maintenance and repairs in addition to reducing the economic performance of the boiler.

Inferior quality fuels have a negative impact on operational flexibility making the boiler more susceptible to slag deposition and heat balance upsets.

According to Schaltegger et al. (2010), warning signs of inefficiencies are: higher raw materials cost compared to those prescribed by technological standards; higher energy costs; maintenance needs; and higher level of undesired output. Therefore, it can be concluded that the steam production process is inefficient.

5.6. Waste management and environmental costing procedures implemented by the companies. Cost of disposal and handling of boiler ash was not indicted as environmental costs in the company's financial statement. Environmental cost related to steam production process was nil.

Environmental costs were hidden as production costs (excess raw material waste in form of unburned carbon in ash). Boilers were obsolete and functioning below technological standards. This resulted in excess waste generated, higher disposal cost and poor environmental performance. The salary of the environmental managers and other staff members involved in environmental issues are also not included in environmental costs. Depreciation of end-of-pipe technologies used to treat pollution and reduce impact of production processes are also not included in environmental costs.

Therefore, it can be deduced that the environmental costs reflected in the companies records are incorrect as most of the costs that should be included in the cost calculation are omitted. The reason for this is strongly attributed to the conventional accounting system being used by the company.

Recommendations

6.1. Recommendation 1

Environmental revenue

In the short-term this boiler ash can be used as a by-product in other industries. This is an opportunity cost of lost revenue through sale of this by product.

6.2. Recommendation 2

It is suggested that the companies implement some form of EMA system by restructuring the accounting system, and allocating the major environmental costs to responsibility centres.

Potential saving opportunities have been identified (savings in coal used in steam production and less disposal cost of boiler ash) should the company upgrade their current technology or move towards cleaner production in the future. This capital investment decision will not only improve environmental and economic performance but also ensure future sustainability of the organization and greater competitive advantage as highlighted in previous case studies discussed in the literature review.

Information obtained during informal interviews with boiler manufacturing experts confirms that by changing to newer, cleaner technology, the company would greatly reduce waste, improve process efficiency and reduce resource consumption. The boilers currently used by the companies have also been identified as a major cause for the environmental issues.

Investment in Cleaner Production technologies is expensive, however, in order to improve environmental and economic performance organizations needs to adopt a cleaner production strategy. Therefore it is advisable that in the shorter term the company must ensure that their current technology is operating efficiently and according to technological standards. In the short term, waste cannot be totally eliminated and, according to technological specifications, the loss of coal is estimated to be approximately 10%. Excess carbon, present in the waste, indicates poor operational practices. The companies would also reduce the cost of disposal of ash to landfill and since disposal of carbon to landfill is prohibited, this would ease off the environmental burden to the company.

According to Giglio (2013), companies can optimize their existing plants. This is considered as the 'low-hanging fruit' of technologies, because it makes the best possible use of what the company already has.

6.3. Recommendation 3

Regulatory and legislative compliance

Recent legislation on waste management and impact on organization

During a conference held by Enviroserv at Suncost in Durban (April 2014), recent legislative changes and impacts thereof on organizations had been discussed and were deemed to be relevant to the company. Landfill disposal previously governed by 'minimum requirements' had been amended in August 2013.

The first requirement for any waste is that the company must have it analyzed in order to classify the waste so that it could be disposed of to the correct landfill site (EnviroServ, April 2014). The company would, therefore, initially incur a cost of approximately between R20 000 to R30 000 to have the ash analyzed.

This process could however be beneficial to the company as the analysis would reveal beneficial use for the bottom boiler ash and it could be used in other processes, thereby generating additional revenue for the company. This would also reduce disposal cost. Since the government is trying to reduce the amount of waste to landfill, current waste disposal cost is likely to increase significantly in the next 3 years. This strategy is expected to force companies to try and reduce waste at its source and promote cleaner production processes.

According to Johan Schoonraad (EnviroServ, 2014), the new legislation states that within the next 5-10 years waste to landfill will be prohibited.

Currently waste that contains carbon or any other type of fuel or energy that could be a useful by-product is strictly prohibited from landfill disposal. Hence the bottom boiler ash contains approximately 20% unburned carbon and is, therefore, not legally permitted to be disposed to landfill sites. Therefore, it can be concluded that based on current legislation and loss of raw material used in the steam production process, management needs to implement strategies to reduce bottom boiler ash produced and invest in cleaner technologies in the long term in order to ensure the future sustainability of the company.

In light of the above regulations, the company will have to have their bottom boiler ash analyzed and classified. They would further have to identify a use for the carbon in the boiler ash as they would not be allowed to dispose of the ash to landfill in the near future. It has been estimated that although the purchase price of the coal may be around R450 per ton, disposal to landfill will cost around R3000 per ton, almost 7 times more.

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