Triple bottom line accounting for the chemical manufacturing sector in South Africa.

By

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PREFACE

The work presented in this thesis was carried out in the School of Agricultural, Earth and Environmental Sciences, Faculty of Science and Agriculture, University of KwaZulu-Natal, Durban, South Africa, from January 2012 to September 2014 under the supervision of Dr. Srinivasan Pillay.

This study represents the original work by the author, Vasagie Moodley, and has not been submitted in any form for any degree or diploma at this or any other tertiary institution. Information sources and the work of others that has been utilised in this study have been duly acknowledged as such in the text.

DEDICATION

For my mother

Sakunthalai Reddy (1933 – 1994)

ACKNOWLEDGEMENTS

This study would not have been completed without the assistance of the following people to whom I convey my sincerest gratitude:

- I thank God for the continued strength and perseverance that is granted to me to continue this journey called life.
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- My sister, Celia Reddy for her continued assistance and support with my children and my home.
- My children, Joran, Valeska and Preandra for the joy and challenges that they bring to my life.

DECLARATION – PLAGIARISM

I, Vasagie Moodley, declare that:

1. The research documented in this thesis, except where otherwise indicated, is my original research.
2. This thesis has not been submitted for any degree or examination at any other university.
3. This thesis does not contain other persons' information, data, pictures or graphs unless specifically acknowledged as being sourced from other persons'.
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ABSTRACT

The chemical manufacturing sector of South Africa and particularly the Durban Chemicals Cluster members are accountable for numerous environmental and social impacts in its pursuit of financial gain. Increasing legislative and external pressure has forced the sector to review and replace typical end-of-pipe pollution prevention strategies with a “cradle to grave” approach to environmental management.

The triple bottom line of four voluntary organizations within the Durban Chemicals Cluster was determined by analysing the financial, environmental and social costs and benefits of sustainable development. An environmental management accounting system, adapted from the template proposed by the United Nations Division of Sustainable Development was implemented in each organization for the calendar years 2012 and 2013 to determine the internal environmental costs of each organization. The external costs due to waste water discharge, emissions release and solid/semi-solid discharge of these organizations were determined using European environmental taxes and external studies. The effect of the external environmental costs on the gross domestic product or green gross domestic product for the chemical manufacturing sector was determined.

The implementation of the environmental management accounting system into the organizations of the Durban Chemicals Cluster provided actual monetary values of total environmental expenditure that was previously not amalgamated and known and this expenditure amounted to millions of rands per annum for each company. Prevention and environmental management activities accounted for the majority of environmental expenditure incurred by the participating organizations of the Durban Chemicals Cluster. These costs ranged from R1 269 333 to R31 883 724 amongst the companies studied for 2012 and R172 182 to R32 641 619 in 2013. Waste and emission treatment costs comprise the second largest portion of environmental management costs followed by material purchase value of non-product output and processing costs of non-product output. Environmental expenditure contributed significantly to the organization’s production costs, in the region of 0.52% of production costs or R4 229 644 to 1.28% of production costs at R36 735 393 to 8.69% of production costs at R18 263 783 for 2012. A similar trend in environmental expenditures contribution to production cost was seen in 2013.

Environmental costs severely erode the organization’s profits and threaten to continually decrease the bottom line if not managed, optimized and reduced. Environmental revenue was realized by the organizations in the Durban Chemicals Cluster through recycling efforts. Monthly monitoring and recording of these costs enabled prompt reduction and optimization opportunities to be identified and

implemented. The chemical manufacturing sector of South Africa through the production of air emissions, waste water and solid and semi-solid waste contribute to external costs on the environment and society estimated to range from R64 688 to R4 873 337 in 2012 and R73368 to R2 280 086 in 2013; an average of 0.375% of production costs for organizations studied within the Durban Chemicals Cluster for both 2012 and 2013. External costs as a result of chemical manufacturing activities reduced the gross domestic product of the chemical manufacturing sector by 0.006% which equated to R621 888 873 for 2012 and R612 175 018 for 2013. Key performance indicators identified from the study included effluent/waste water cost per kilogram of product, hazardous waste cost per kilogram of product, destructed material cost per kilogram of product and reworked material cost per kilogram of product. The average projected cost of each of these indicators was determined for 2014 via the utilization of the actual costs of these indicators relative to the total production volumes for 2012 and 2013.

The social sustainability aspect of triple bottom line accounting was addressed by analyzing key social performance indicators. Generally social sustainability issues amongst all the organizations were being addressed and improved upon. The deficiency in scientific, technical and industrial skills amongst the female population of South Africa was highlighted by the lower number of women employed in these areas by the participating organizations within the Durban Chemicals Cluster. The advantage of continuous employee training and education was realized and budgeted for within the chemical manufacturing sector; health and safety in the workplace was a key focus area and community development was beginning to gain increased importance. As illustrated by the study the expansion of conservative financial accounting and reporting to include environmental and social accounting and reporting is a time consuming, labour intensive task; however the benefits achieved in reducing environmental expenditure and the impacts of manufacturing activities on society and the environment is worth the effort.

It was recommended that organizations within the chemical manufacturing sector of South Africa amalgamate environmental costs into a single environmental management accounting system; that a ‘cradle to grave’ approach to waste management is adopted in this sector and that waste water re-use initiatives be implemented. The implementation of key environmental performance indicators within the chemical manufacturing sector was recommended as a tool to optimize production processes and reduce operational costs. It is imperative that the South African government actively promote environmental management accounting and triple bottom line accounting in South African and ensure the incorporation of environmental management accounting practices into financial and management accounting systems in the country. It is recommended that government applies the Polluter Pays principle to the chemical manufacturing sector of South African through the implementation of environmental taxation. The South African government is urged to actively address the skills deficiencies amongst the female population of South Africa.

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AEL	Atmospheric emissions license
ANOVA	Analysis of variance
BOD	Biological oxygen demand
Cd	Cadmium
CFC	Chlorofluorocarbon
CH_4	Methane
COD	Chemical oxygen demand
CO_2	Carbon dioxide
Cr III, Cr VI	Chromium
DEAT	Department of Environmental Affairs and Tourism
DCC	Durban Chemicals Cluster
EMA	Environmental management accounting
EMAN	Environmental management accounting network
ESCOM	Electricity Supply Commission
GAC	Granular activated carbon
GDP	Gross Domestic Product
Green GDP	Green Gross Domestic Product
GPI	Genuine Progress Indicator
GRI	Global reporting initiative
GWP	Global warming potential
HFCs	Hydrofluorocarbons
IFA	International Federation of Accountants
ISO	International organization for standardization
IUCN	International Union for Conservation of Nature
KPI	Key performance indicator
Ni	Nickel
NO_x/NO_2	Nitrous/nitrogen oxide
NR	No result
P	Phosphorus
Pb	Lead
PET	Polyethylene terephthalate

PETCO	Polyethylene terephthalate company
PFCs	Perfluorocarbons
pH	Potential hydrogen
$PM_{2.5/10}$	Particulate matter
POPs	Persistent organic pollutants
SF_6	Sulphur hexafluoride
SO_2	Sulphur dioxide
TBL	Triple bottom line
TEQ	Toxic equivalents
UNDSD	United Nations Division for Sustainable Development
VOC	Volatile organic compound

CHAPTER 1: INTRODUCTION

1.1 Introduction

The pollution of land, water and air systems by industrial and manufacturing organizations in South Africa is a consequence of rapid economic growth within the country (DEAT, 2006a). Whilst organizations are compelled to comply with environmental legislature in mitigating environmental impacts, a compromise between the costs of these activities and the profitability of the organization must be reached. Internal and external environmental pressure to reduce natural resource degradation has resulted in increased environmental costs as organizations strive to comply with environmental regulations.

Environmental stewardship (the responsibility to protect the natural environment) and the efficient management and reduction of environmental costs and impacts are internationally compelled by government and legislature (IFA, 2005). Public and community concerns, environmental “green” groups and company stakeholders consisting of directors, shareholders, employees and customers; compel organizations to pursue environmentally viable business procedures (Medley, 1997). In so doing, organizations realize that the optimal and efficient use of natural resources also result in financial rewards (IFA, 2005). Given the range of stakeholders that any chemical organization must be accountable to, it has become imperative for companies to adopt some form of accountability measure(s) (such as environmental accounting) to ensure that the expectations of the various constituencies are upheld (Medley, 1997). Further, the costs of the implementation and operation of such measures should derive benefits for the organization over the long term.

Environmental accounting is a management tool that is used to achieve the financial rewards derived from optimized industrial activities. According to the International Federation of Accountants (IFA) (2005) environmental accounting promotes sustainable development whilst fulfilling the requirements of all stakeholders through efficient environmental activities. Environmental accounting enables the organization to identify, quantify, optimize and communicate environmental costs. Over the past decade, environmental accounting in South Africa has focused primarily on environmental sustainability reporting and disclosures as a result of legislative requirements (Ambe, 2007b). Whilst collection of physical information on environmental accounting such as quantities of material and energy input, products, wastes, emissions and their related costs are recorded for much of the industrial sector of the country; there is little evidence of an established environmental management accounting system that supports sustainable decision making processes (Ambe, 2007b). This study focuses on the implementation of the environmental management accounting system in the chemical manufacturing sector in order to emphasize the sustainable development efforts of organizations within this sector.

1.2 Environmental management accounting (EMA) in South Africa

In 1998 the United Nations' Division for Economic and Social Affairs studied organizational decision making factors which included business competitiveness, environmental management activities and implementation of international standards and codes of practice, that led to the commissioning of an EMA Expert Working Group; who in conjunction with the International Federation of Accountants compiled and issued an international guidance document on EMA in August 2005 (Ambe, 2007b). EMA was introduced to address the limitations of traditional financial and management accounting systems in addressing management decision making processes related to environmental costs and impacts. EMA integrates the economic and environmental aspects of sustainable development and provides organizations with the economic motivation to pursue sustainable development processes and activities (Mohr-Swart, 2008).

The Environmental Management Accounting Network (EMAN)-Africa, founded in 2005, is a division of a globally recognized EMA network that consists of professional and academic members working towards the development and promotion of EMA in the African region and is based in Pretoria, South Africa (Environmental Sustainability Solutions, 2009).

EMA as defined by the United Nations Division for Sustainable Development (UNDSD) only accounts for internal environmental costs and not the external or social costs that occur when the economic activities of an organization adversely affects society and the environment. However internal and external environmental costs, social and financial costs all need to be considered in sustainable management accounting. The three aspects of sustainable development and their related costs and benefits comprise the triple bottom line of any organization.

1.3 Triple bottom line accounting in South Africa

Corporate governance emphasizes the shift of focus of organizations from "profit only" to "business responsibility to the society and environment" in which they operate. Concepts of sustainability and triple bottom line reporting are gradually being introduced into the South African marketplace.

South Africa's second King Report on Corporate Governance (Institute of Directors, 2002) emphasized a shift in focus from the single bottom line that advocated profits only, to the triple bottom line that includes the economic, environmental and social dimensions of the organization's activities. The third King Report on Corporate Governance (Institute of Directors, 2009) calls for the further integration of the economic, environmental, and social and governance aspects. King III calls for the use of the Global Reporting Initiative's (GRI) principles in sustainability reporting (Institute of Directors, 2009). The recommendations provided by King III and the GRI provide opportunities for organizations to derive economic and non-economic benefits from complying with sustainable business practices (Institute of Directors, 2009). The issue of sustainable development in any country is a critical factor that allows for a compromise to be attained between the profit motive of any organization and care for the environment.

1.4 Sustainable development in South Africa

South Africa has accepted the Brundtland Commission's definition of sustainable development and has defined sustainable development in the National Environmental Management Act No. 107 of 1998 as follows: *"Sustainable development means the integration of social, economic and environmental factors into planning, implementation and decision-making so as to ensure that development serves present and future generations"* (DEAT, 2006b:18).

According to the Department of Environmental Affairs and Tourism (DEAT) (2006a) economic growth in South Africa is critical for the elimination of poverty among the majority of its citizens. Sustainable economic growth within South Africa is vital to ensure that the increased utilization of natural resources and waste production does not reach unsustainable proportions. For instance, increased economic growth in South Africa has dramatically increased electricity usage in the country over the past few years, resulting in natural resource depletion as well as increased greenhouse gas emissions (DEAT, 2006a). Similarly, agriculture, industrial activity and population growth has resulted in increased water usage over the past few years, with concomitant soil contamination and a series of other challenges (DEAT, 2006a). The poorer communities in South Africa are the most affected by environmental-related issues such as climate change, pollution or access to good quality potable water (Ambe, 2007b). This is evidenced by communities located in the South Durban region living in close proximity to chemical and petroleum industries. These communities are continuously exposed to air pollution emanating from the numerous emission stacks operational in the South Durban basin (DEAT, 2014). In October 2000 the Multi-Point Plan was implemented by the South

African government that resulted in a 45% decrease in sulphur dioxide and fugitive gas emissions (DEAT, 2014). Sappi Saiccor, a chemical cellulose manufacturer located at Umkomaas on the KwaZulu-Natal south coast is a major polluter in the region. The health of the community is affected by controlled as well as fugitive emissions. Effluent from the mill is discharged into the sea resulting in the degradation of marine life at the pipeline outlet.

The challenge facing government and industry is to minimize and eliminate these social issues amongst the poorer communities (Adebowale et al, 2001). Organizations can do this by minimizing their environmental impacts and participating in the elimination of local social issues (Mohr-Swart, 2008). Industrial activities mitigating environmental and social impacts affect the organization's expenditure and profitability. In South Africa, as in many parts of the world, environmental management accounting has focused solely on physical accounting of quantities and flows of an organizations inputs and outputs instead of environmental costs. An environmental management accounting system is a management tool that allows an organization to quantify the costs and benefits of environmental impacts and mitigation activities within the organization.

1.5 Contextualization of the problem

Given that there is in the international community the recognition that the majority of companies dealing with hazardous substances have the potential to seriously damage the environment and given the recognition by most governments and environmental departments in the world that while there is a need for development; this development should not compromise the integrity of the environment. Although the worldwide driving factor for a business corporation is profitability, recently the idea of environmental management and the accounting of actions of an organization in pursuing the aim of profitability at the expense of the environment have come into question. This has given rise to the principles and policies ensconced in the EMA systems that have evolved in different parts of the world and at different levels and is now formalized by the United Nations Division for Sustainable Development.

Companies are now being made aware of their accountability in ensuring environmental sustainability particularly those that exploit the natural environment for its resources and produce a substantial amount of wastes and emissions that have the potential to seriously damage the environment. The chemical manufacturing sector of any country has the potential to create a substantial amount of such wastes and emissions. The chemical manufacturing sector of South Africa extensively exploits natural resources and is responsible for environmental and social impacts in its' pursuit of financial gain. Environmental legislature and external pressure emphasize the need for this sector to reduce its operational impacts (Mohr-Swart, 2008). Environmental stewardship and the efficient management and reduction of environmental costs and impacts are compelled by government and legislature (IFA, 2005). Public and community concerns, environmental "green" groups and company stakeholders consisting of directors, shareholders, employees and customers, compel organizations to pursue environmentally viable business procedures (IFA, 2005). In so doing, organizations realize that the optimal and efficient use of natural resources also result in financial rewards (IFA, 2005).

Given the range of stakeholders that any chemical organization must be accountable to, it has become imperative for companies to adopt some form of accountability measure(s) to ensure that the expectations of the various constituencies are upheld. Further the costs of the implementation and operation of such measures should derive benefits for the organization over the long term. Companies that make up the Durban Chemicals Cluster have been increasingly under internal and external pressure to become more accountable for their impacts on the environment and on society. Internal and external pressure to reduce natural resource degradation has resulted in increased environmental costs as organizations strive to comply with environmental regulations (IFA, 2005). Environmental costs has the effect of eroding the profit of each of these organizations and therefore it becomes imperative for these organizations to consider the implementation of an EMA system that will streamline operational procedures, acquisition and usage of raw materials and the storage and distribution of their products.

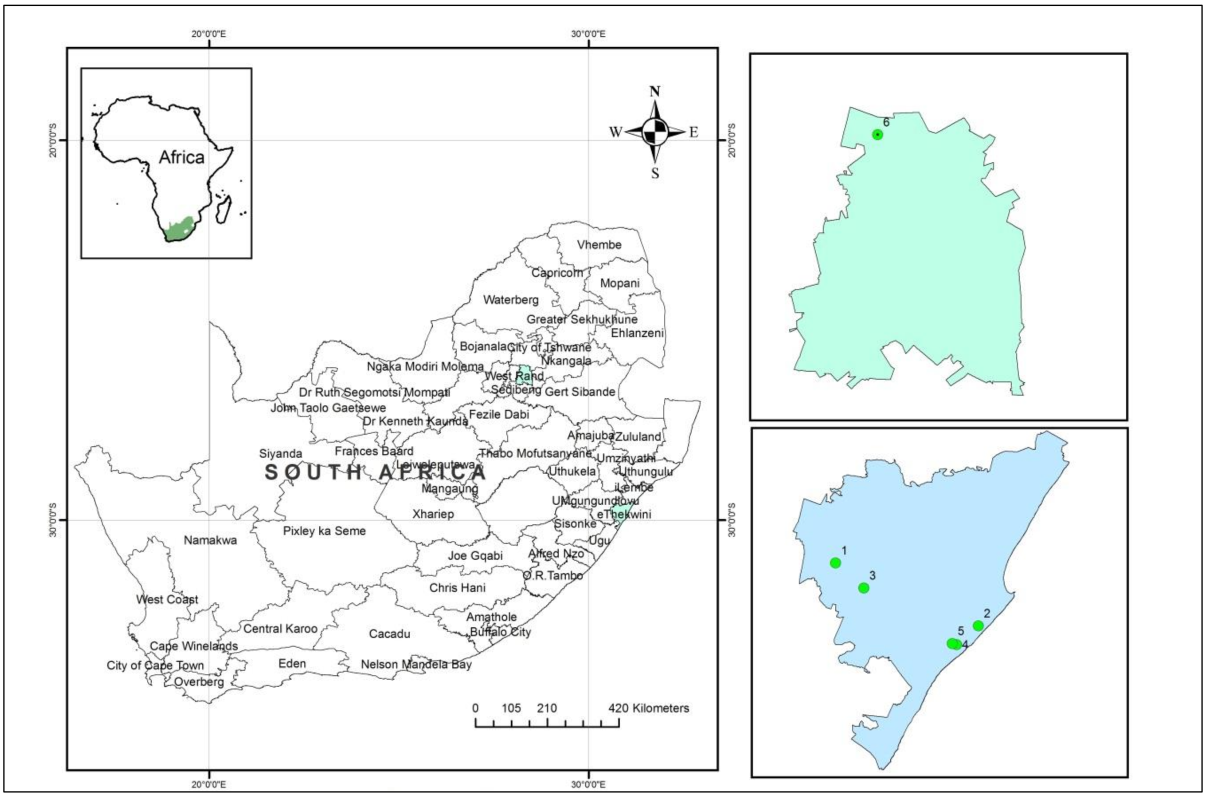
Consequently in this study, case studies of four voluntary organizations within the chemical manufacturing sector and specifically the Durban Chemicals Cluster are utilized to evaluate each of the organization's internal environmental costs through the introduction of an environmental management accounting system into each organization. The Durban Chemicals Cluster is an association of chemical companies that was established in 2008 to promote the development of the chemicals manufacturing sector in Durban and its surrounding areas (Durban Chemicals Cluster, 2012).

1.6 Description of the study area

Durban is a coastal city located on the Eastern seaboard of South Africa at 30º South latitude. Durban is the second most industrialized city in South Africa and has a well-developed chemical industry which is mainly situated in the industrial areas to the south of the city. This area has a pleasant subtropical climate with summer temperatures of approximately 25ºC, winters at 19ºC and annual rainfall of approximately 1000mm.

The study area is located within the eThekwini municipality area which is located in the province of KwaZulu-Natal, South Africa (Figure 1). The chemical industry located within the eThekwini municipality is known as the Durban Chemicals Cluster, which comprises of twenty seven major chemical companies. Of the twenty seven companies, four companies have participated in the study and are located as shown in the map (Figure 1). Three of the four participating case study organizations deposit their waste material at the Shongweni landfill site which is located 30km from Durban central (Figure 1). One of the participating companies uses an incineration facility based in Olifantsfontein, Gauteng to dispose of their hazardous waste material (Figure 1).

Enviroserv Waste Management (Pty) Ltd operates and manages the Shongweni landfill site and is responsible for the transportation and disposal of hazardous waste at Shongweni from three of the organizations studied within the Durban Chemicals Cluster. Shongweni landfill site has been in operation since 1976 and is a hazardous waste landfill (H:h) site that accepts wastes with a hazard rating of 3 which is moderately hazardous and 4 which has a low hazard rating, as well as accepting general wastes such as garden refuse, domestic waste, construction rubble and commercial waste (Ener-G Systems Natural Power (Pty) Ltd, 2011). The site consists of lined cells designed to technology specified by the Department of Water Affairs and Forestry (Ntsele et al, 2000). Leachate from the landfill site is collected and discharged to the Southern Wastewater Treatment Works (Baldwin, 2009).



1: Shongweni landfill site   2: Company D   3: Company B   4: Company A   5: Company C   6: Incinerator

Figure 1: Location of study area

1.6.1 Characteristics of the Shongweni landfill site

Leachate at Shongweni is treated with hydrogen peroxide which has a minimal impact in improving the leachate quality since hydrogen peroxide is quickly decomposed to oxygen and water in the presence of ferrous cations in leachate (Baldwin, 2009). The following information was reported by Dr D. Baldwin in his 2009 *Shongweni Hh Landfill Site: External Compliance and Environmental Audit* (Baldwin, 2009): Surface water contamination occurred at Shongweni as a result of spillages from sub-soil seepage collection tanks resulting in high surface water electrical conductivity readings and in August 2009 a borehole at Shongweni landfill site that was used for “washwater” was found to contain high concentrations of fluoride, arsenic, iron and manganese, which were over the Department of Water Affairs and Forestry’s drinking water limits. The audit found that while fluoride and manganese might occur naturally in the granite aquifer in the area, the source of arsenic was not known and that fractured aquifer boreholes were found to have increased levels of electrical conductivity values.

Since 2004 air sampling has been conducted at Shongweni landfill site to evaluate the risks to employees' health as well as neighbouring communities. Air sampling at different locations at the Shongweni landfill site incorporates analysis of non-methane organic compounds, methane, carbon dioxide, oxygen, hydrogen sulphide, the lower explosive limit, flowrate, ammonia, aldehyde compounds, acetaldehyde, formaldehyde, butryraldehyde and particulate matter (Baldwin, 2009; Baldwin, 2010). Cancer risks at the Shongweni site and off the site are typically in the low risk range. For the period August 2009 to October 2009, the ambient metal compounds in the air samples analyzed at the Shongweni landfill site were found to be below the standard requirements and continued exposure to these metal compounds would have a minimal effect on the health of employees and the surrounding communities (Baldwin, 2010).

1.7 Research aims and objectives

This research aims to implement environmental management accounting systems within four organizations in the chemical manufacturing sector of Durban, KwaZulu-Natal, South Africa in order to optimize production processes, reduce environmental expenditure and establish key environmental performance indicators within this sector. This research aims to quantify external costs and determine the Green Gross Domestic Product of the chemical manufacturing sector of South Africa.

The objectives of the study are to:

- Illustrate how an environmental management accounting system can be utilized in identifying issues and trends to facilitate decision-making in improving environmental performance in the chemical manufacturing sector of South Africa;
- Highlight the possibility of an existence of a lack of consistency between sustainability polices and management accounting systems;
- Highlight how careful consideration of environmental costs by utilization of an EMA system can lead to the identification of cost reduction and revenue raising opportunities;
- Establish key environmental performance indicators within the chemical manufacturing sector of South Africa;
- Illustrate how external or social costs can be quantified and integrated into an environmental management accounting system, by an internalization of external costs in the chemical manufacturing sector of South Africa;
- Determine whether the Green Gross Domestic Product can be estimated for the chemical manufacturing sector of South Africa;

- Develop a set of recommendations for possible inclusion into a policy framework.

1.8 Research methodology

Four companies within the Durban Chemicals Cluster of the chemical manufacturing sector in KwaZulu-Natal, South Africa voluntarily participated as case studies in order to evaluate their environmental costs through the introduction of an environmental management accounting system into each organization. Thomas (2011:511) defines the case study as an "*analyses of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more methods*". The case study approach is used as an experimental approach that provides an in-depth investigation of environmental management accounting systems within an actual real-life framework of existing chemical organizations (Yin, 1984).

In this study a unique variant of the case study approach involving the four participating chemical companies is utilized. Environmental management accounting systems were modified and implemented by the researcher within each of these organizations. The EMA systems implemented were operated for the duration of two calendar years during which monthly monitoring and evaluation of costs and impacts were undertaken. Environmental cost optimization opportunities were identified and recommended to the participating chemical companies.

1.8.1 Environmental management accounting model research

In depth literature surveys were conducted of current environmental management accounting procedures and principles and the utilization of EMA as a management tool to control costs and facilitate decision making processes. Prevailing international practices, theory and case studies were investigated. The recommended EMA model developed by the United Nations Division of Sustainable Development was modified and augmented to suit the organizations participating in the research study. While the existing EMA model advocates data collection on an annual basis, the recommended EMA model for this study stipulates data collection on a monthly basis in order to trend, monitor and react to cost data in a timeous manner that will ensure the maximum benefit in cost and environmental optimization efforts. Data for the EMA model was populated by the organization's safety, health and environmental managers, financial managers, human resources managers, production managers and engineering managers. Cost data for the EMA model were obtained from the existing accounting, recording and reporting processes within the organizations. The EMA template is included in Appendix 1. Figure 2 below is a presentation of the flow of cost accounting data that results in triple bottom line accounting that has the potential to increase organizational profits and reduce environmental impacts in the chemical manufacturing sector of South Africa.

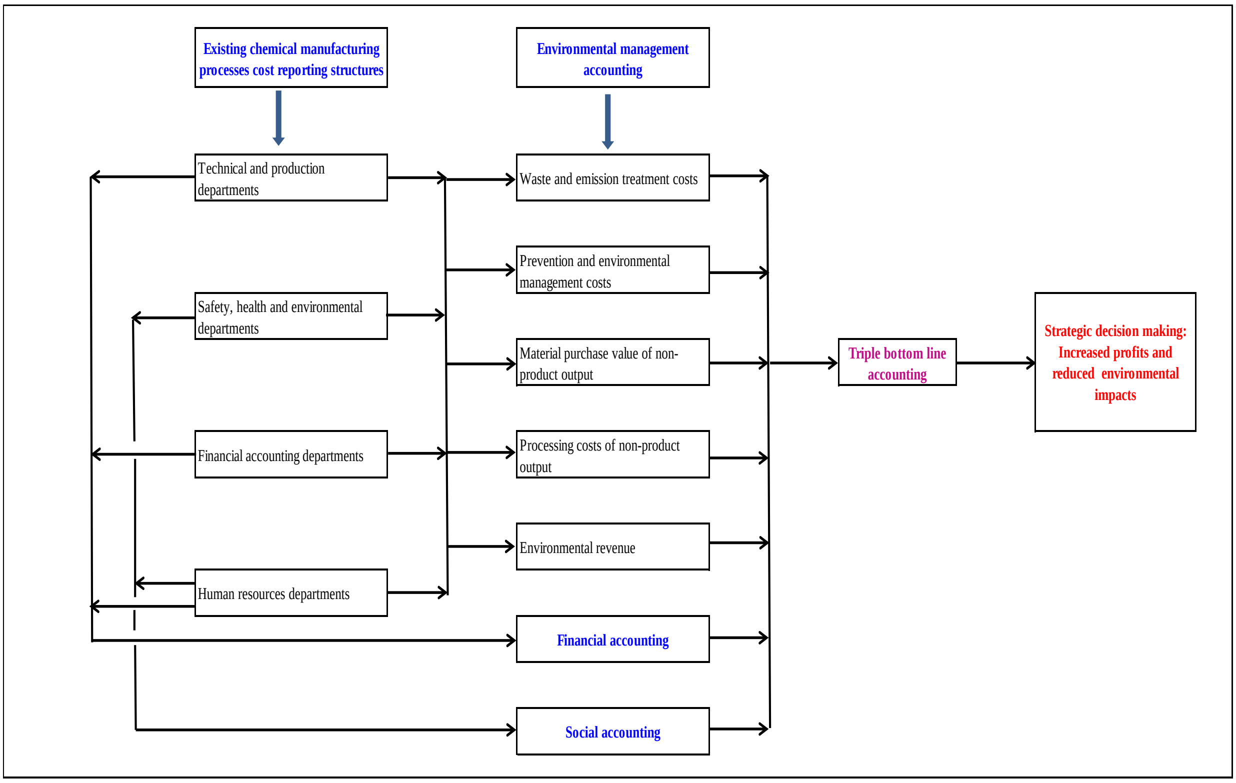


Figure 2: Representation of triple bottom line accounting for the chemical manufacturing sector of South Africa

1.8.2 Case studies selection

Letters of introduction requesting permission to introduce an environmental management accounting system into the organization as a case study were sent to twenty organizations within the Durban Chemicals Cluster. This letter introduced the researcher, the purpose of the study and included an outline of the scope of work involved in the study (Appendix 2). Several companies within the Durban Chemicals Cluster expressed an interest in the study and requested further information. A detailed letter defining and explaining triple bottom line accounting and environmental management accounting as well as providing a detailed scope of work outlining the type of information required from the organization and the data collection methodology to be used; was then sent to the interested organizations (Appendix 3). Several companies then requested that a presentation be made by the researcher to the organization's senior management teams in order to address any queries and concerns from the organizations.

Four organizations within the Durban Chemicals Cluster agreed to conduct the research at their organizations. The general managers of the participating organizations were then requested to sign a consent and disclosure/non-disclosure agreement to authorize the research at each organization. An unsigned copy of this document is enclosed in Appendix 4 and outlines the details of the research to be conducted as well as the organizational information that will and will not be disclosed in the publication of the results of the study. Additionally, the participating organizations were requested to sign the University of KwaZulu-Natal's confidentiality declaration form for research towards masters and doctoral studies (Appendix 5). Signed copies of Appendix 4 and 5 displaying the organization's name and the general manager's name will not be included as an appendix in order to ensure the confidentiality of the participating organizations. Confidentiality of the organization's identity, process operating conditions such as temperature, pressure and reaction time, raw material chemical composition and/or brand name, auxiliary material chemical composition and/or brand name, operating material chemical composition and/or brand name and company specific product brand names; amongst other non-disclosure information, were ensured due to the competitive nature of the business and legislative environment in which these organizations conduct their business activities.

1.8.3 Qualitative data collection

General organizational and environmental information on each company were obtained by utilizing a preliminary general questionnaire, enclosed in Appendix 6. Qualitative data collection also included action research and information accumulation through company site visits and meetings with key personnel and acquirement of process knowledge of the organizations' production and manufacturing activities *via* site walkabouts and equipment and plant familiarization.

1.8.4 Quantitative data collection

Normative research was conducted by proposing and implementing the environmental management accounting model. The aim of normative research is to improve and optimize the process or activity being studied by a person external to the organization, as well as create systems or ideas that are acknowledged as future improvement opportunities and methodologies (Routio, 2007). Numerical environmental cost data were collected *via* the EMA model. The organization's quantitative emissions and effluents compositions were analyzed *via* an inductive, grounded theory approach; that is, the development of theories from patterns and findings discovered during data analysis (Ke and Wenglensky, 2010).

Analysis of variance (ANOVA) was utilized as a statistical tool that compares the differences of means amongst groups by analyzing the variance in the data between and within groups (Hindle, 2013). A probability value (P-value) of less than 0.05 indicates that a minimum of one group mean is substantially different from the other group mean or means (Hindle, 2013).

1.8.5 Challenges imposed by the study

The primary challenge encountered during the study was in overcoming the attitude of managers that EMA data collection and analysis was merely additional work to their daily tasks. The long term value of monitoring and tracking environmental costs, trending these costs and optimizing these costs; on both the organization's profit margin and the economic, societal and physical environment in which it operates; could not be readily foreseen. Due to current environmental cost data being scattered in various accounting and documentation systems throughout the organizations, obtaining the data to populate into a single document was time consuming.

1.9 Thesis outline

Chapter 1 introduces environmental management accounting and triple bottom line accounting against the background of sustainable development and environmental accounting in South Africa. This chapter discusses the rationale for the study, describes the study area and outlines the research aims and objectives. The research methodology utilized and the challenges imposed by the study are described here.

Chapter 2 is a literature survey that discusses the environmental impacts of the activities of the South African chemical industry, defines the concept of sustainable development and expands on sustainable development challenges experienced in South Africa. The concept of triple bottom line accounting as conceived by John Elkington is introduced. The benefits and challenges of triple bottom line accounting are assessed in addition to the importance of triple bottom line reporting and the Global Reporting Initiative (GRI) as endorsed by the 2009 King III report. The significance of performance indicators in measuring, monitoring and trending the organization's activities are highlighted. Chapter 2 defines environmental management accounting and reviews its benefits to industry, government and society. The procedures and principles of environmental management accounting as outlined in the International Federation of Accountants' guidance document is summarized. External or social costs imposed by the organization on stakeholders and the environment is defined and external cost evaluation methods and external costs studies are presented. The concept of Green Gross Domestic

Product in comparison to Gross Domestic Product and the methods to theoretically calculate it are discussed. An overview of the South African chemical manufacturing sector and the legislative framework within which it operates is included in the literature survey.

Chapter 3 profiles the four organizations participating in the study within the Durban Chemicals Cluster. Process descriptions, process flows of activities and materials inputs and outputs analysis of each of these organizations are presented. The various environmental impact assessments of the four participating organizations are consolidated into a single assessment, as many of the impacts are similar across the organizations. The internal environmental costs for 2012 and 2013 as determined by the environmental management accounting system is analyzed for each company and compared to each other. The external costs of waste water discharge, emissions and solid and semi-solid waste discharge to landfill sites and incinerators are determined for each of the participating organizations. An indication of the Green Gross Domestic Product using the external costs of the participating organizations for the chemical manufacturing sector of South Africa is determined. The social sustainability aspects of the participating organizations are discussed.

Chapter 4 discusses the results of the implementation of the environmental management accounting system into each of the four organizations of the Durban Chemicals Cluster. Environmental cost categories are compared between the four organizations and cost categories as a percentage of total environmental costs are analysed. External costs of the four organizations are discussed and compared as well as the effect of the Green Gross Domestic Product due to external costs of the chemical manufacturing sector on the economy of South Africa presented.

Chapter 5 concludes this study and outlines the key findings and conclusions of the research undertaken within the organizations of the Durban Chemicals Cluster. This chapter also provides recommendations for the chemical manufacturing sector of South Africa as well as recommendations at a national policy implementation level.

CHAPTER 2 LITERATURE SURVEY

2.1 Introduction

The chemical manufacturing sector of South Africa is responsible for numerous environmental impacts due to its large scale electricity and fuel consumption that results in the emission of large volumes of pollutants; chemical reactions resulting in the production of hazardous gases and particulate matter; large-scale usage of non-renewable resources that restricts future availability of these resources; waste discharges that pollute land and groundwater; waste water discharges that contaminates eco-systems and waterways; land destruction for building purposes that destroys ecosystems and waterways and noise pollution (Kurup, 2007). The result of industrial activities on the environment needs to be assessed to determine existing and potential impacts that can be mitigated. An impact assessment evaluates potential impacts by the production process, the usage of environmental resources, emissions and wastes on the environment and human health. This chapter reviews existing literature on aspects relevant to the South African chemical manufacturing industry.

2.1.1 Life cycle assessment

Life cycle assessment is an environmental management tool that is used to assess the environmental impact from usage of natural resources to product manufacture and disposal i.e. from "cradle to grave" or in some cases "cradle to cradle" (if material is recycled); in other words throughout the product's lifecycle (Gauthier, 2005). Life cycle assessment as documented in ISO14040 consists of a life cycle inventory which is a quantification of the natural resource usage during a products lifecycle; environmental impact assessment; monetary evaluation of external costs and the quantification of the internalization of any external costs into the product price (ISO, 2006a).

2.1.2 Land pollution

Chemical, fuel and oil spillages from the chemical manufacturing sector results in land, air and water pollution that adversely affects human, animal and marine life. Spillages also result in legislative non-compliance, raw material wastage, remediation costs and damage to an organization's image and reputation (GRI, 2011). Transfer of contaminated soil from industrial sites onto neighbouring sites that are used as residential or agricultural land can occur through wind or water mediums; contaminated soil also contaminates surface water and groundwater which affects the health of invertebrates, plants and fish that exist in rivers, streams and seas (Government of Alberta, 2010). Wildlife and livestock ingesting contaminated soil via fodder or drinking contaminated groundwater are affected and crops that are subjected to groundwater (via irrigation or surface run-offs) and soil contaminants adversely affect human health (Government of Alberta, 2010). Landfill sites that handle the chemical manufacturing sectors hazardous and non-hazardous wastes is a major contributor to soil contamination.

2.1.3 Waste management

Waste is defined as the undesired solid, liquid or gaseous substance or a combination of the three states; derived from an activity or process and is classified into general waste such as domestic waste which may contain insignificant amounts of hazardous substances that do not pose a potential risk; commercial waste; specific industrial waste and builder's rubble which if appropriately managed poses minimal risk to human health or the environment and hazardous waste whose toxic, chemical and physical characteristics render it harmful to human health and the environment (South Africa, 1989).

It is estimated that approximately 120kg of methane is produced per ton of municipal solid waste and that landfill sites generate 10% of global methane emissions (Lohila et al., 2007). According to the Sigma Project (2003), solid waste disposed of at landfill sites have the following impacts on the environment:

- Ecosystems and biodiversity is degraded or eradicated due to the creation and running of landfill sites;
- Obstructions and emissions are created by waste transport vehicles;
- Hazardous chemicals and contaminants leach out into surface water and groundwater systems also resulting in soil contamination.

2.1.3.1 Landfill leachate

Leachate is the liquid material that migrates from waste piles while extracting components of the waste material as it passes through it resulting in high concentrations of hazardous and detrimental components being entrenched in the leachate (Henry, 1996). As the liquid penetrates the waste, the liquid helps in the bacterial decomposition of the wastes that result in an increase in the acidity of the wastes and leachate; which allows many metals to dissolve into the leachate as well as cause water generation which increases the leachate volume (Kjeldsen, 2010). According to Christensen et al. (1992) leachate from landfill sites that accept domestic, commercial and industrial waste consists of dissolved organic matter, inorganic matter, heavy metals and xenobiotic pollutants such as dioxins and polychlorinated biphenyls. Toxic leachate that contaminates water systems can severely destroy bio-diversity, decrease certain species population and result in health risks to human beings, animals and vegetation dependent on contaminated water streams for survival.

Three of the four organizations studied within the Durban Chemicals Cluster dispose of their hazardous waste at the Shongweni landfill site.

2.1.3.2 Landfill gases

Landfill gases consist of predominantly methane and carbon dioxide that in anaerobic conditions in typical landfills are generated in equal quantities (Scottish Environmental Protection Agency, 2002). Methane with its high calorific value can be captured and used to generate electricity via a generator. For an electricity generation unit of 1.15 MW capacity; it is estimated that the annual reduction in landfill emissions will be approximately 48881 tons CO_2 equivalent (Ener-G Systems Natural Power (Pty) Ltd, 2011). Generation of electricity from landfill gas decreases the global warming gas methane and reduces the utilization of environmentally degrading fossil fuels as a source of electricity generation as well as increases revenues and provides employment opportunities.

Incineration is the alternative to landfilling and is not a practice that has been widely adopted by the chemical manufacturing sector in South Africa.

2.1.3.3 Incineration

Incineration is the combustion of waste material at high temperature in a furnace resulting in the production of heat, water, vapour and gaseous emissions (Williams, 2005). Flue gases from incineration of waste products contain significant quantities of particulate matter, heavy metals of which mercury is highly toxic, dioxins that are a severe health hazard, furans, sulphur dioxide, hydrochloric acid, carbon dioxide and nitric acid (Knox, 2005). Waste incinerators are the main generator of furans and persistent dioxins that build up in the food chain and are being targeted by the Stockholm Convention on Persistent Organic Pollutants (POPs) for elimination (hiTemp Technology, 2012).

Advocates for incineration claim that incineration reduces the mass and volume of waste by up to 80% and reduces landfill space constraints in heavily populated locations; destroys the pathogens and toxins in medical and hazardous waste at high temperatures; provides the potential to generate electricity and steam and that there is no methane gas production as in landfills (Knox, 2005). Arguments against incineration include:

- Approximately 5% to 7% of the amount of incinerated waste is converted to “fly ash” that is a hazardous waste and has high quantities of dioxins and heavy metals and must be correctly disposed of at a landfill site (United Kingdom without incineration network, 2013);

- Approximately 25% to 30% of the amount of incinerated waste is converted to “bottom ash” which has high quantities of dioxins and metals and are disposed of at hazardous landfill sites (United Kingdom without incineration network, 2013);
- At landfill sites, pollutants present in bottom ash such as dioxins and heavy metals and in fly ash can leach out resulting in groundwater contamination that will eventually reach surface water systems (van Steenis, 2005);
- Some international authorities are promoting the utilization of bottom ash as a construction filler, which during the construction process is scattered around, making this a dangerous proposal as the metals and dioxins present in the ash slowly leach into the environment and groundwater systems (United Kingdom without incineration network, 2013);
- Dioxin and furan emissions are still a threat from old incinerators and studies have shown that although dioxin emission levels are reduced by utilizing filters; dioxin concentrations are high during start-up and shut-down periods when dioxins are not being monitored (United Kingdom without incineration network, 2013);
- Particle filtration equipment do not remove all the fine particles from the gases released into the atmosphere (van Steenis, 2005);
- Recycling, waste separation and re-use processes are hindered (van Steenis, 2005);
- Studies reveal that electricity production from incineration is extremely inefficient and produces approximately twice the amount of carbon dioxide per unit of power than carbon dioxide generated from fossil fuel (United Kingdom without incineration network, 2013);
- Incinerators are normally installed in rural, poorer communities who are unaware of the hazards of the pollution (van Steenis, 2005);
- Heavy metals emissions from incinerators are toxic at very small levels (van Steenis, 2005) and exposure to chlorinated organic compounds such as dioxins and heavy metals in filter ash can result in cancer and other serious health conditions (Greenpeace, 2012).

Incineration operators must comply with minimal emission standards as specified by legislature. One of the organizations studied within the Durban Chemicals Cluster uses the organization Thermopower Process Technologies (Pty) Ltd located in Gauteng to incinerate its hazardous waste (Figure 1). The South African National Environmental Management Air Quality Act 39 of 2004 minimum emission standards for the incineration of general and hazardous waste is presented in Appendix 7.

2.1.4 Wastewater or effluent

Water from rivers, streams and lakes are often a source of drinking, recreational and domestic water for poorer communities in South Africa and it is therefore imperative that these water systems remain free of contamination in order to prevent water borne diseases (Forster, 2000). Industrial wastewater treatment plants treat or partially treat contaminated waste water that occurs as a result of industrial processes and activities; before discarding the water into environmental water systems or re-using the water. Partially treated or untreated wastewater contains numerous organic, inorganic and biological pollutants that can contaminate water systems (GRI, 2011).

According to Forster (2000):- The Biological Oxygen Demand (BOD) is used to assess the efficiency of wastewater treatment plants and indirectly measures the carbon compounds in wastewater; by measuring the quantity of dissolved oxygen used by organisms to decompose organic material in a water sample at controlled temperatures during an allowed duration of time. The quantity of organic compounds in water is indirectly measured by the Chemical Oxygen Demand (COD) which quantifies the oxygen required to effectively oxidise a sample's carbon compounds under controlled conditions. High ammonium concentrations in wastewater forms nitrates and nitrites in water systems and results in the reduction of natural dissolved oxygen content in these systems as well as fertilization of these water systems and the poisoning of fish and micro-organisms. Measurements of ammonia in a wastewater treatment plant are essential to control the denitrification process. The presence of phosphate in wastewater also results in fertilization of water systems and therefore negatively affects the ecological balance of these ecosystems due to increased algae and seaweed growth.

2.1.5 Groundwater contamination

Groundwater is a strategic element of South Africa's water resources with approximately 15 million people in rural communities using groundwater as a drinking water resource (DWAF, 2004a; DWAF, 2004b). Unfortunately most of South Africa's groundwater resources are located in hard rock aquifers which consist of noncarbonated, fractured rock that are less utilized than high-yielding aquifers with soluble carbonate rocks due to their poorer yields, lower capacities, variability in the groundwater properties and difficulty in exploring, as well as the difficulty in performing quantitative and qualitative assessments on this resource (Daji Limaye, 2013). South Africa's main aquifers are located along the coast of the Cape and KwaZulu-Natal with less than 20% of these resources currently being utilized (DWAF, 2004a; DWAF, 2004b). Groundwater protection becomes an urgent priority as groundwater is a crucial resource in enabling the government to provide South Africans with potable water.

Contaminated groundwater can adversely affect human, animal and plant life, if used as potable and domestic water, agricultural water and industrial water. Contaminated groundwater may also result in a depletion of oxygen in groundwater systems that promotes the conversion of hazardous chemicals to even more highly dangerous human carcinogens such as trichloroethylene conversion to vinyl chloride; a human carcinogen (Jones-Lee and Fred Lee, 1993). According to the United States Environmental Protection Agency (2013) groundwater contamination can occur through:

- Transfer of pollution such as waste products, hazardous products and hazardous raw materials from the soil to groundwater via seeping rain or surface water;
- Seepage of liquid hazardous and non-hazardous substances into groundwater from industrial sites;
- Long term contact of groundwater with liquid hazardous substances that do not dissolve in groundwater but remain entrained within bedrock or soil;
- Leachate seepage from landfill sites;
- Leakages from above and underground storage tanks/containers and pipelines;
- Leakages from production, oil and gas wells and
- Natural contamination from sources such as plant remains and peat may also contaminate groundwater.

The elimination of pollutants and contaminants from groundwater is referred to as groundwater remediation and aims to decrease contaminant concentrations to appropriate levels and prevent the movement of contaminants to other areas (US EPA, 1994a; US EPA, 1994b). Groundwater remediation is a costly and technically challenging exercise that is sometimes incapable of totally restoring the contaminated land or groundwater quality thus rendering these resources unusable (Jones-Lee and Fred Lee, 1993). Treated groundwater sources are not reliable sources of drinking water because it is difficult to quantify and classify the removal of chemicals from the contaminated source; resulting in many contaminated aquifers being left untreated and unusable (Jones-Lee and Fred Lee, 1993). It is therefore imperative that groundwater management proactively prevent pollution of groundwater resources.

Groundwater remediation treatment technologies include granular activated carbon (GAC) adsorption which is the standard technology that is used to remove volatile organic compounds from groundwater; by pumping contaminated groundwater to above surface level and passing it through bioreactors containing activated sludge systems that promote microscopical organism growth that degrade contaminants (Stenzel and Fisher, 1987). The United States Environmental Protection Agency (1994a; 1994b) elaborates on the different groundwater remediation treatment methods:- Oxygen enhanced biodegradation of groundwater contaminants occurs when an oxygen source such as air, ozone or hydrogen peroxide is pumped into groundwater to aerobically supplement the breakdown of organic pollutants. Passive treatment walls are sometimes used where a penetrable wall containing a catalyst medium is inserted before a moving contaminant stream; that then interacts with the contaminants resulting in degradation of the contaminants. Contaminant separation from groundwater through vaporisation is accomplished by injecting air into groundwater to create an air stripping system and is known as air sparging. The method where undissolved liquid organic compounds floating on the subsurface are removed through pumping is known as free product recovery. Natural attenuation of contaminated groundwater normally occurs over a prolonged period of time and involves purging of contamination from groundwater systems via bacterial destruction of chemicals; for example, the gasoline elements benzene, toluene, xylene and ethylbenzene produce carbon dioxide and water upon degradation in groundwater.

2.1.6 Climate change

Climate change is affected by greenhouse gas emissions of which the predominant gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_x/NO_2), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) (GRI, 2011). Greenhouse gases are generated from the combustion of non-renewable energy sources such as coal, oil, gas and nuclear energy to produce electricity and steam; chemical production and usage activities and exhaust fumes from motor vehicles (GRI, 2011). Motor vehicles used by the organization in the transportation of raw materials, products and employees negatively impact the environment by emitting volatile organic compounds, hydrocarbons, carbon dioxide, nitrogen oxides, particulate matter and carbon monoxide contributing to global warming, smog creation, air pollution, noise pollution, health impacts, land and water systems pollution through chemical and fuel/oil spillages along the roadways.

Acid rain is created by the emission of sulphur dioxide from coal utilizing power stations and industries in South Africa, with the average pH of acid rain along the east coast of South Africa being 4.2 and occasionally reaching lower pHs of 3.7 (Remburssi Association of International Business, 1998).

2.1.7 Pollution prevention

Pollution prevention strategies reduce the amount of waste generated by an organization and increases profits and earnings by removing the source of pollution instead of treating and controlling the effects of pollution, thus eliminating or reducing control costs as well as the risks posed by pollutants to human health and the surrounding ecosystems (DEAT, 2000). Most organizations focus predominantly on the implementation of end-of-pipe technologies that are temporary solutions that eventually result in more raw material and energy usage. At project conception, the design of a process or equipment should incorporate sound environmental practices such as environmental impact assessments, risk assessments, hazard and operability studies and community involvement and participation during the planning, commissioning and implementation of all projects in order to eliminate or mitigate environmental degradation (Barnard, 1999). Cleaner technologies initially require a large capital investment but will eventually result in decreased environmental costs (DEAT, 2000). The efficient use of resources and cleaner technologies in South African industries is promoted through government implementation of the National Cleaner Production Centre of South Africa that enables industry to reduce its production costs by reducing its water, energy and raw materials costs as well as optimizing waste management (NCPC, 2015). Incentive schemes are offered to organization's participating in cleaner production activities in order to enhance local and international competitiveness. These schemes include (NCPC, 2015):

- The manufacturing competitiveness enhancement programme;
- The 121 tax allowance programme;
- The manufacturing investment programme;
- The automotive investment scheme;
- The green energy efficiency fund;
- Eskom.

Chemical manufacturing organizations and new developments are required to have certified environmental management programmes and systems that assist in preventing and alleviating negative environmental impacts. When an organization, despite its environmental management systems and strategies, still causes the degradation or pollution of the environment, the Polluter Pays principle; that internalizes external environmental costs, should apply (South Africa, 1998a).

2.2 Sustainable development

2.2.1 Definition of sustainable development

The Brundtland Commission, of which Norwegian Prime Minister, Gro Harlem Brundtland, was a member, introduced the concept of "sustainable development" in 1987 in a report called "Our Common Future" (Earthsummit2012, 2012). The Brundtland Commission defines sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (Beckenstein et al., 1996:9). Sustainable development consists of three interacting aspects; the economic, environmental and social dimensions of sustainable development. Sustainable development advocates that environmental and social degradation should not be the consequences of a country's economic growth. Environmental sustainability ensures that minimal negative impacts are experienced by the environment as a result of human interaction with the environment and advocates that the rate of consumption of naturally occurring renewable resources should be below the rate of replenishment of that natural resource and that the production of solid, liquid and gaseous wastes needs to be maintained at a level that can be easily assimilated into the environment (Centre for Sustainable Organizations, 2011).

Economic sustainability is the efficient use of an organization's assets and natural resources to assure the organization's future profitability (Business Directory, 2013). Whilst economic growth is necessary for the eradication of poverty in South Africa; it cannot occur at the expense of increased natural resource consumption and waste production. Eco-efficiency, also referred to as "producing more with less", is commonly used to determine the degree of an organization's sustainability and refers to the organization's level of efficiency in consuming and converting natural resources into the required end product with minimal waste (DeSimone and Popoff, 1997).

"Social sustainability" refers to the value added by an organization to society as well as its impact on society. The social sustainability aspect of sustainable development has received very little attention via research and development and occupies a symbolic position in the sustainable development model (Partridge, 2005). Social sustainability addresses the well-being and quality of life of present and future generations. A satisfactory quality of life means that all people, especially disadvantaged communities, must have access to basic human rights such as health care facilities, education, transportation, employment and food (DEAT, 2006d). Unlike an organization's impact on the environment which is predominantly adverse; social impacts can be either beneficial or harmful. Positive social impacts include aspects such as donations to the community and job creation while negative social impacts include for example, work-related injuries, accidents and human rights abuses (Sen, 2000; Anand and Sen, 1996). Poorer communities are the most affected by environmental-related issues, such as climate change, pollution or inadequate access to good quality potable water. The aim of sustainable development is to minimize and eliminate these social issues amongst the poorer communities.

Due to the lack of understanding and knowledge of social sustainability integration into an organization's business strategies and decisions; social sustainability has been largely ignored in sustainable reporting procedures. The greatest problem is the lack of definition of quantifiable measures for social sustainability. Social sustainability indicators have not been properly defined and accepted, and therefore cannot be analyzed and reported upon (Partridge, 2005).

2.2.2 Sustainable development challenges in South Africa

Natural resource depletion and ecosystem degradation continues its upward trend as South Africa's economy grows in the pursuit of poverty eradication. Environmental aspects most affected by economic activity are discussed below:-

2.2.2.1 Energy

According to the Department of Environmental Affairs and Tourism (2006a):-

Abundant coal supplies and inexpensive electricity has built a South African economy that is energy dependent. The increase in demand for electricity is a major challenge facing the South African economy. The Electricity Supply Commission's (ESCOM) inability to meet the increasing pressure to supply more electricity and the necessity to upgrade and commission existing and new electricity production units; continues to escalate the price of electricity in South Africa. Over 70% of energy in

South Africa is derived from coal. The development of alternative renewable energy technology such as energy from wind, biomass, biofuels and solar sources, in South Africa has been minimal, with little to no substantial progress being seen over the last few years.

2.2.2.2 Water

Water is a scarce resource in South Africa with variable and seasonal rainfall being experienced during the year. Water usage has increased substantially over the past few years due to population growth and industrial activity. The Department of Water Affairs has forecast that South Africa's demand for water will be more than the available quantity by the year 2025 (DWA, 2012b). The total annual surface runoff is approximately 55 billion cubic meters with only about 33 billion cubic meters being available to South Africans for utilization (World Resources Institute, 2010). Although the basic right to adequate water supply is enshrined in the Constitution of South Africa, approximately 710000 households do not have domestic water supply to their homes; with pollution of water systems and the environment, inefficient water usage and management and non-compliance to legislature compounding water supply issues (DWA, 2012a).

Groundwater is a valuable resource that needs to be further exploited in order to meet the demands of a growing population and economy in South Africa. Geologic conditions in South Africa limit the availability and access to groundwater. It is estimated the 10343 million cubic meters of groundwater is available per year, with only 7500 million cubic meters per year being available during periods of drought and that South Africans currently use approximately 2000 to 4000 million cubic meters per annum of groundwater, mostly in the rural and dry areas of the country (South African Water Research Commission, 2011).

2.2.2.3 Solid waste

The Department of Environmental Affairs and Tourism, (2006a) notes that:-

According to the Draft National Waste Information Baseline Report of 2012, 108 million tons of waste was generated in South Africa in 2011; of which 97 million tons went to landfills; general waste consisted of 59 million tons and unclassified, hazardous waste consisted of 49 million tons. There are more than 4000 landfill sites across South Africa of which less than 5% comply with the minimum environmental standards set out by the Department of Environmental Affairs and Tourism. Waste management challenges that South Africa confronts include lack of adherence to waste management policies; non-compliance of landfill sites with legislature; contamination of groundwater and aquifers with leachates emanating from toxic residues at landfill sites and a limitation to the number of landfill sites available. Waste management opportunities include the development and implementation of cleaner technologies which will reduce the generation of waste; the focused development and implementation of recycling and re-use programmes; stricter legislative control of landfill sites thus ensuring environmental and legal compliance; closure and remediation of overloaded landfill sites and the use of methane gas produced from organic waste streams at landfills as a bio-fuel to generate electricity.

2.2.2.4 Air quality

Currently the most pressing global environmental challenge is climate change due to human activities. Energy generation predominantly through coal usage is the main cause of increased concentrations of greenhouse gases, predominantly carbon dioxide, in the atmosphere that influences climate change. South Africa's dependence on fossil fuel utilization in the energy sector places the country among the top twenty greenhouse gas emitters worldwide; and the leading emitter in Africa (Letete, 2013). Although pollutants such as sulphur dioxide are released at a considerable height above ground level, via elongated stacks from power stations and industrial plants, these pollutants contribute to acid rain over a vast distance (Remburssi, 1998). Sulphur dioxide and particulate matter associated with vehicle exhaust emissions contribute to air pollution and related health problems.

Challenges associated with air pollution and climate change in South Africa is highlighted by the Department of Environmental Affairs and Tourism (2006a):-

Air pollution difficulties include the inability to quantify gaseous emissions due to lack of monitoring and measurement equipment; escalating health care costs as a result of air pollution; soil acidification and consequent degradation of food sources and the depletion of the ozone layer. Air emissions control can be realized via installation of catalytic converters on motor vehicles; optimal public transport usage; installation of end-of-pipe technologies such as gas scrubbers, precipitators and filters to reduce the amount of harmful gaseous emissions such as nitrous oxides, sulphur dioxide and particulate matter released into the atmosphere; replacement of domestically used coal, wood and paraffin with liquid petroleum products or electricity and the subsidization of research and implementation of alternate renewable energy sources. Potential climate change challenges include water supply shortfalls, changing rainfall patterns, the multiplication of insect-carried diseases such as malaria due to increased temperatures, reduced maize and wheat production due to temperature changes, reduced proteins in grasslands where livestock graze due to higher carbon dioxide levels, adverse effects on fisheries, food availability and employment due to changes in sea temperatures and biodiversity losses in the Cape floral regions that will result in a decline in the tourism industry.

2.3 Triple bottom line accounting and reporting

The "bottom line" is the profit or net income that is obtained after expenditures are deducted from revenue and is normally the last line of the income statement and is therefore referred to as the "bottom line". The term "triple bottom line" was conceived by John Elkington in 1994, who is author of the book, "*Cannibals with Forks: the Triple Bottom Line of 21st Century Business"* (Elkington, 1997). The triple bottom line (TBL) refers to the economic attributes of the three elements of sustainable development, that is, the economic, environmental and the social costs of sustainable development (Slaper and Hall, 2011). The three dimensions of TBL tend to imply that these three aspects can be measured, monitored and managed independently of each other; however, changes to one aspect of sustainable development will affect the other two aspects as well; making the three dimensions of sustainable development interdependent (Brown et al, 2006). This concept is often demonstrated by three interconnecting circles as illustrated in Figure 3 below. The three aspects of the triple bottom line are also known as the three Ps; which refers to People, Planet and Profit (Slaper and Hall, 2011).

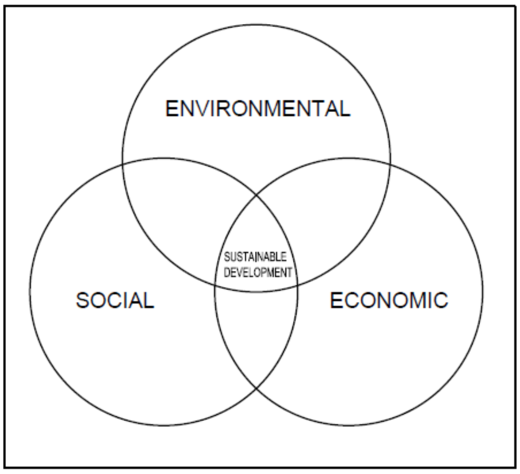


Figure 3: Sustainability diagram depicting the interrelated dimensions of sustainable development (Adapted from Barbier, 1987)

2.3.1 Triple bottom line accounting

TBL accounting endorses the generation of a "principled profit" in accordance with the principles of People and Planet and not at any cost to these two aspects since there can be no profit without people and planet (Group of 100, 2003). Triple bottom line accounting requires an organization to expand conservative financial performance accounting and reporting to include accounting and reporting for environmental and social performance (International Institute for Sustainable Development, 2013). With TBL accounting the organization's business strategy shifts to analyze the environmental and social dimensions of the company's activities. The social dimension of the triple bottom line assesses a company's performance in relation to social responsibility by assessing the welfare of the organization compared to the welfare of its employees, suppliers and the community; the economic aspect continues to determine the organization's performance using traditional financial tools; whilst the environmental aspect assesses the organization's impact on the environment as a result of its activities (Creel, 2012).

2.3.2 Advantages of triple bottom line accounting

TBL accounting balances an organization's financial performance analysis while demonstrating to the community its commitment to the social and environmental aspects of sustainable development thereby enhancing its reputation (Creel, 2012). Organizations accounting for TBL will endeavour to reduce environmental impacts and benefit the natural environment if possible; by the utilization of tools such as life-cycle assessments of products from growth, harvesting, extraction or manufacture of raw materials to end-user disposal of product; that will also assist the organization in measuring the true environmental cost of doing business (Group of 100, 2003). This will result in the identification and implementation of cost saving opportunities in natural resource consumption, raw material usage and waste management procedures; such as re-use and/or sale of waste products resulting in additional financial benefits (Creel, 2012). Measurement of an organization's social performance and impacts will compel organizations to improve and monitor their social performance which will potentially increase the long term profitability of the organization (Norman and MacDonald, 2003).

2.3.3 Challenges to triple bottom line accounting

Additional environmental and social analysis will incur higher operational costs and difficulty in financially quantifying the environmental and social aspects of TBL accounting (Creel, 2012). Quantification of the environmental bottom line and social bottom line has only recently come into focus and key performance indicators (KPIs) for the three dimensions of TBL has to be defined and measured (Group of 100, 2003).

2.3.4 Quantification of the triple bottom line

Environmental measurements of the triple bottom line include quantification of natural resource costs such as energy usage costs, water usage costs and raw material costs; quantification of wastes; quantification of emissions and quantification of the organization's impact on the environment and biodiversity (Creel, 2012).

Slaper and Hall (2011) contend that the quantification of "natural capital" (the environmental aspect) and "human capital" (the social or people aspect) presents numerous challenges. One option to quantify the TBL is to monetize the three aspects of sustainable development, which then poses the challenge of allocating values to environmental and social issues that will result in controversial and debatable challenges. Another option is to introduce an indexing system to quantify the three aspects of sustainable development, which then poses the challenge of the determination of the weighting of each aspect. Consequently, there is presently no accurate or standard methodology to quantify the three aspects of TBL and each organization can adapt TBL accounting to suit its individual activities.

According to the Global Reporting Initiative (GRI) (2006) the financial bottom line is the economic measurements obtained in traditional financial statements such as the Income Statement and the Balance Sheet. The Global Reporting Initiative Sustainability Reporting Guidelines advocates that an organization's economic impacts must take into account location of customers, suppliers and raw material costs, employees, investors and the public sector; which ensures that economic sustainability is seen to add value over a wider area instead of focusing only on traditional accounting aspects.

2.3.5 The Global Reporting Initiative

The Global Reporting Initiative was introduced in 1997 as a combined proposal of the United States non-governmental organization, the Coalition for Environmentally Responsible Economics and the United Nations' environment program with the aim of improving sustainability reporting (GRI, 2002). The Global Reporting Initiative Sustainability Reporting Guideline is the most common environmental reporting method used to assist an organization in the preparation of sustainability reports and can be utilized by any organization irrespective of its size or sector (Arnot, 2004). The GRI guideline is a voluntary reporting system that is endorsed by the 2009 King III report on corporate governance, which integrates governance, strategy and sustainability (Institute of Directors, 2009). The GRI economic, environmental and social performance indicators can be utilized to measure, monitor and trend an organization's activities (Bartelmus, 2008). The GRI performance indicators are grouped according to category, aspect and indicator (Kurup, 2007).

2.3.5.1 Environmental performance indicators

Environmental performance indicators compress wide-spread organizational environmental data into critical environmental information that can be measured, monitored and improved upon. These indicators can be used as benchmarking and reporting tools; assist in environmental performance analysis and identify improvement opportunities. The environmental aspects and indicators used in the GRI sustainability reporting system is tabulated below.

Table 2.1 Environmental aspects and indicators used in the GRI sustainability reporting system (Source: GRI, 2002)

Environmental aspect	**Indicator**
Materials	EN1 Materials used EN2 Quantity of recycled input materials
Energy	EN3 Direct energy consumption EN4 Indirect energy consumption EN5 Energy saved via optimization and efficiency improvements EN6 Reduction in energy usage as a result of energy saving initiatives EN7 Indirect energy consumption reduction initiatives
Water	EN8 Total water usage EN9 Water sources affected by water usage EN10 Percentage and total volume of water recycled and reused
Biodiversity	EN11 Location and size of land owned, leased, managed in/ adjacent to protected areas and areas of high biodiversity value outside protected areas EN12 Description of significant impacts of activities, on protected areas and areas of high biodiversity value outside protected areas EN13 Habitats protected or restored EN14 Policies and programs for managing impacts on biodiversity EN15 Number of International Union for Conservation of Nature (IUCN) red list species and national conservation list species with habitats in areas affected by operations, by level of extinction risk
Emissions, effluent and waste	EN16/17 Quantity of greenhouse gas emissions EN18 Greenhouse gas emissions initiatives EN19 Quantity of ozone-depleting substances emissions EN20 Quantity of NO_x, SO_x, and other significant air emissions EN21 Quality and quantity of water discharged EN22 Quantity, type and disposal method of waste EN23 Number and quantity of significant spills EN24 Weight of transported, imported, exported, or treated waste deemed hazardous under the terms of the Basel Convention EN25 Water systems and ecosystems affected by the discharges of water and runoff

Environmental aspect	Indicator
Products and services	EN26 Initiatives to mitigate environmental impacts of products and services EN27 Percentage of products sold and their packaging materials that are reclaimed
Compliance	EN28 Fines and non-monetary sanctions imposed for noncompliance with environmental legislature
Transport	EN29 Significant environmental impacts of transportation of products, raw materials and workforce
Overall	EN30 Total environmental expenditures and investments (presented in Table 2.2)

The table below (Table 2.2) details the environmental expenditures as set out in the GRI sustainability reporting system.

Table 2.2 EN30: Total environmental expenditure (Source: GRI, 2006)

Environmental aspect	**Expenditure related to**
Waste disposal, emission treatment and remediation costs	• Waste treatment and disposal • Emission treatment • Air emission licensing • Depreciation of related equipment, maintenance and operating material and services, related personnel costs • Insurance for environmental liability • Clean-up costs, including remediation costs for spills [EN22/EN30]
Prevention and environmental management costs	• Education and training costs of personnel • External services related to environmental management • External certification of environmental management systems
Prevention and environmental management costs	• Personnel involved in general environmental management activities • Research and development investigations and personnel • Installation of cleaner technologies • Environmentally friendly purchases • Other environmental management costs [EN22/EN30]

2.3.5.2 Social performance indicators

Social performance indicators measures, monitors and manages the impacts of the organization's activities on the surrounding community and society as a whole (GRI, 2011). The categories and aspects of social performance as defined in the GRI reporting system is tabulated below.

Table 2.3 Categories and aspects of social performance as defined in the GRI reporting system (Sources: GRI, 2002; Kurup, 2007)

Category	Aspects
Labour practices and decent work	Employment issues Relations between management and employees Health and safety issues Training of employees Education of employees Diversity of employees and opportunities afforded to them
Human rights	Management strategy Non-discrimination between races and gender Collective bargaining issues Child labour practices Labour practices
Human rights	Disciplinary procedures Security procedures Rights of indigenous people
Society	Community involvement and care Bribery and corruption issues Contributions to political parties Competition practices Pricing procedures
Product responsibility	Health and safety of customers Product packaging responsibility and labelling Service labelling Advertising and marketing Customer privacy consideration and respect

2.3.5.3 Economic performance indicators

The categories and aspects of economic performance as defined in the GRI reporting system is tabulated below.

Table 2.4 Categories and aspects of economic performance as defined in the GRI reporting system (Sources: GRI, 2002; Kurup, 2007)

Category	Aspect	Indicators
Direct economic impacts	Customers Suppliers Employees Investors Public sector	Profit Income Investment Wages Taxation Revenue

2.3.6 Triple bottom line reporting

A triple bottom line report is a single, amalgamated report that reflects the organization's economic, environmental and social performance over a fixed duration of time; and is sometimes published separately from other financial reports or integrated within annual financial reporting (GRI, 2011). TBL reporting can follow the guidelines set out in the Global Reporting Initiative Sustainability Reporting Guideline; discussed in section 2.3.5. Also referred to as sustainability reporting or corporate responsibility reporting, TBL reporting promotes organizational transparency and accountability to its stakeholders in measuring, managing and disclosing its economic, environmental and social endeavours and impacts (Norman and MacDonald, 2003). TBL reporting assists in the improvement and maintenance of a good organizational reputation through legislative compliance and demonstrates an organization's commitment to the community. TBL reporting assists in the identification of the environmental, social and economic risks of doing business, resulting in the management and mitigation of these risks and can be used to benchmark against other organizations and align management efforts with stakeholder requirements (Group of 100, 2003).

TBL reporting will progress only if the legal implications and business risks associated with TBL reporting is fully understood and the challenge of alignment with stakeholder expectations and the organization's business strategies is met (Group of 100, 2003). Romero (2008) advises that TBL reporting should not be used as a "greenwashing" tool, that is, the misleading use of sustainability marketing to boost an organization's image without authentic environmental and social sustainability improvements.

2.4 Environmental Management Accounting

2.4.1 Accounting

Financial and management accounting are the accounting systems that are generally utilized in organizations. Management accounting reports financial data that is used by management to realize the organization's goals; while financial accounting is largely used for external reporting according to authoritative standards and guidelines and encompasses collection of data, balancing of accounts, auditing and reporting (Atrill and McLaney, 1997). Management accounting provides both monetary and non-monetary data, such as personnel hours and raw material quantities which serve to assist managers in planning and budgeting activities as well as in efficient resource usage (Schaltegger & Burritt, 2000; IFA, 2005). Financial statements such as the income statement, provides data on annual revenue and expenditures, while the balance sheet provides information on assets, liabilities and equity for the specified period (Schaltegger & Burritt, 2000; IFA, 2005).

Costs associated with environmental responsibility are important aspects of the accounting discipline. Environmental aspects are incorporated into every facet of an organization's activities; from the purchase of raw materials, energy utilization, production and marketing to waste disposal. Organizations cater for environmental costs in management accounting through pollution control equipment expenditure, income generated from recycled materials and cost savings from the utilization of new energy efficient machinery (IFA, 2005). Environmental accounting is catered for in financial accounting through the organization's assessment and reporting of environmental related liabilities (IFA, 2005).

2.4.2 Environmental management accounting

Environmental accounting integrates accounting with environmental costing and aims to improve organizational environmental performance whilst optimizing operating efficiency and promoting sustainable development (Seakle, 2009). Environmental accounting, according to the International Federation of Accountants (2005), incorporates the measurement and reporting of environmental related financial data in financial accounting; the measurement and use of environmental physical and monetary data in environmental management and sustainability accounting; the estimation of external environmental costs and impacts in full cost accounting and accounting for the accumulation and movement of natural resources in natural resource accounting.

Environmental costs consist of internal organizational costs as well as costs external to the organization which occur as a result of environmental damage or environmental protection by the organization. Organizations face increasing pressure to reduce the environmental impacts of their activities and management needs information on the environmental costs incurred by their activities (Deegan, 2003). Environmental costs are often ignored or not understood by managers because the organization's accounting systems do not emphasize these costs (Deegan, 2003).

The International Federation of Accountants (2005:19) defines environmental management accounting (EMA) as: *"the management of environmental and economic performance through the development and implementation of appropriate environment-related accounting systems and* *practices."* The United Nations Division for Sustainable Development (UNDSD, 2001) defines EMA as the collection and analysis of physical information such as material flows and monetary information such as environmental related costs in order to support internal decision making.

EMA can be incorporated into an organization with simple adjustments to existing accounting systems or with more detailed EMA systems that combine conventional physical and monetary information systems that allows organizations to measure, monitor and improve both its environmental and financial performance (Deegan, 2003). EMA integrates the environmental and economic dimensions of sustainability and provides the financial perspective for an organization's participation in sustainable development (Burrit, 2004; Schaltegger and Wagner, 2006).

2.4.3 Benefits of environmental management accounting

2.4.3.1 Uses and benefits of environmental management accounting to industry

EMA is an environmental management tool that provides accurate data and costs that is required for internal management environmental initiatives and decisions; provides the justification for cleaner production via green technology and environmentally preferable purchasing and the implementation of environmental management systems; as well as allowing internal decision-makers and public authorities to link environmental data to traditional accounting systems (Seakle, 2006; IFA, 2005). Management understanding of environmental costs will result in a choice of alternatives that are beneficial to both the environment and the organization (Creel, 2012). Cost saving opportunities that are beneficial to both the environment and the organization include for example, substitution of toxic organic solvents with non-toxic substitutes thereby removing regulatory reporting costs, toxic waste handling costs and other costs related to the usage of hazardous materials (UNDSD, 2001).

EMA allows for the compilation and evaluation of all the organization's environmental costs into one central system. EMA allows accurate tracking and management of the use and flow of raw materials, energy and waste streams; which can then be used to optimize processes to reduce and manage increasing raw material, water, energy and waste management costs (Seakle, 2009). EMA aims to reduce wastage of natural resources used in production and manufacturing processes thereby ensuring future access to these natural resources as well as the prevention of overloading of waste management infrastructures such as landfill sites (Seakle, 2006). For the organization this translates into reduced purchasing costs of wasted resources and reduced waste management costs.

The International Federation of Accountants (2005) asserts that EMA allows management to consider the connection between environmental costs and productivity since poor environmental performance and a polluted working environment can motivate poor productivity, lower employee morale and result in higher employee absenteeism rates. EMA assists in bridging the communication gap between accounting and the environmental, technical and production departments, as each of these departments often utilize different information systems that produce different data due to the use of differing materials tracking boundaries which then make consistency checks difficult. The use of environmental performance indicators that combine monetary and physical measures become more meaningful when everyone in the organization has access to the same information and now "talk the same language".

2.4.3.2 Potential benefits of environmental management accounting to government

The justification and implementation by industry of environmental programs and initiatives on the basis of financial paybacks; reduces government's financial and political concerns for environmental protection (Ambe, 2007). The EMA system quantifies environmental costs and benefits arising from the industrial implementation of government policies and regulations as well as provides information on the financial and environmental benefits of voluntary partnership programs and innovations between industry and government (Ambe, 2007).

2.4.3.3 Potential benefits of environmental management accounting to society

The implementation of EMA will result in reduced usage of natural resources such as energy and water as well as reduced pollutant emissions and waste streams; thus conserving these resources for future generations. The costs borne by society for governmental environmental monitoring, control and remediation of industrial pollution are reduced via improved industrial actions that consequently result in reduced public health costs (Ambe, 2007). Improved industrial environmental information can be used to improve public policy decision making as well as utilized to evaluate the environmental conditions of different geographic regions in South Africa (Ambe, 2007).

2.4.4 Challenges to environmental management accounting

According to Seakle (2009), EMA faces the following challenges:

- EMA is a measurement of the internal environmental costs incurred within the organization and does not focus on the external costs to society;
- The lack of standard definitions for environmental costs make these costs difficult to quantify;
- There is no set methodology of integrating physical environmental information with financial/accounting information;
- The "language barrier' between environmentalists and accountants needs to be overcome;
- Changing the mind-set of managers to recognize that environmental costs significantly affect the organization's operations is difficult. Managers may not realize that production costs such as raw materials costs and the cost of waste production and discharge are environmental costs;

- Environmental costs are not measured, monitored and attributed to the appropriate processes and products but added to the organization's general overhead costs. Allocation of environmental costs to general overhead accounts results in management not fully realizing the costs associated with environmental issues and therefore lacking the incentive to reduce these costs.

2.4.5 Physical information under environmental management accounting

Information in section 2.4.5 is sourced from the International Federation of Accountants (2005) unless otherwise referenced.

EMA focuses primarily on the quantities and costs of raw materials (including water and energy) that contribute to the majority of the operating costs of an organization. The use of raw materials, water and energy and the by-products arising from this usage; such as wastes and emissions, is a major contributor to the impact that organizations have on the environment and on society. While most of an organization's raw materials are converted into a final product that is sold to customers; manufacturing activities also generate waste that should have went into the final product as a result of poor operating efficiencies, quality issues and/or product design issues, that result in unnecessary costs and environmental impacts. Manufacturing operations also use energy, water and raw materials that will not go into the final product but are required to manufacture the product; such as water to clean vessels and pipelines or fuel used for transport operations; that also result in the generation of wastes or emissions. The actual product manufactured, as well as the packaging of this product and any by-products manufactured can potentially impact the environment when it ends up on a landfill site on completion of its intended use.

The production of waste and emission streams adversely impacts the health and quality of life of human beings as well as detrimentally affecting natural ecosystems and the organisms living in those ecosystems such as plants, animals and marine life. Process and product designs and plant modifications to incorporate technological advances in the manufacturing industry can potentially reduce usage of raw materials, water and energy; resulting in a reduction of the environmental impacts of processes upstream to manufacturing as well, since the extraction of all raw materials has environmental impacts.

Data on the quantities and process flows of all raw materials, water, energy, products, wastes and emissions; is crucial information that an organization must monitor in order to manage and reduce environmental impacts resulting from their operations. This physical accounting or quantification of all the organization's inputs and outputs is referred to as a "materials balance" or "mass balance"; and can be done for the entire organization as a whole or for a specific site, process, product or production line. A material balance is based on the principle of conservation of mass which stipulates that what enters a system/process/plant (within defined boundaries) must leave the system/process/plant; either as a product, by-product, intermediate product, waste, loss or emission.

Materials flow accounting traces the flow of materials from purchase to product use and disposal; with quantities and volumes or flow rates attached throughout the lifecycle. This physical information is utilized to support the cost accounting component of EMA and to develop environmental performance indicators that assist in the assessment and reporting of the materials-related aspects of an organization's performance. Process flow charts outline the flow of material into and out of the various processes within an organization and assists in understanding the organization's process streams. Figure 4 illustrates a material flow balance.

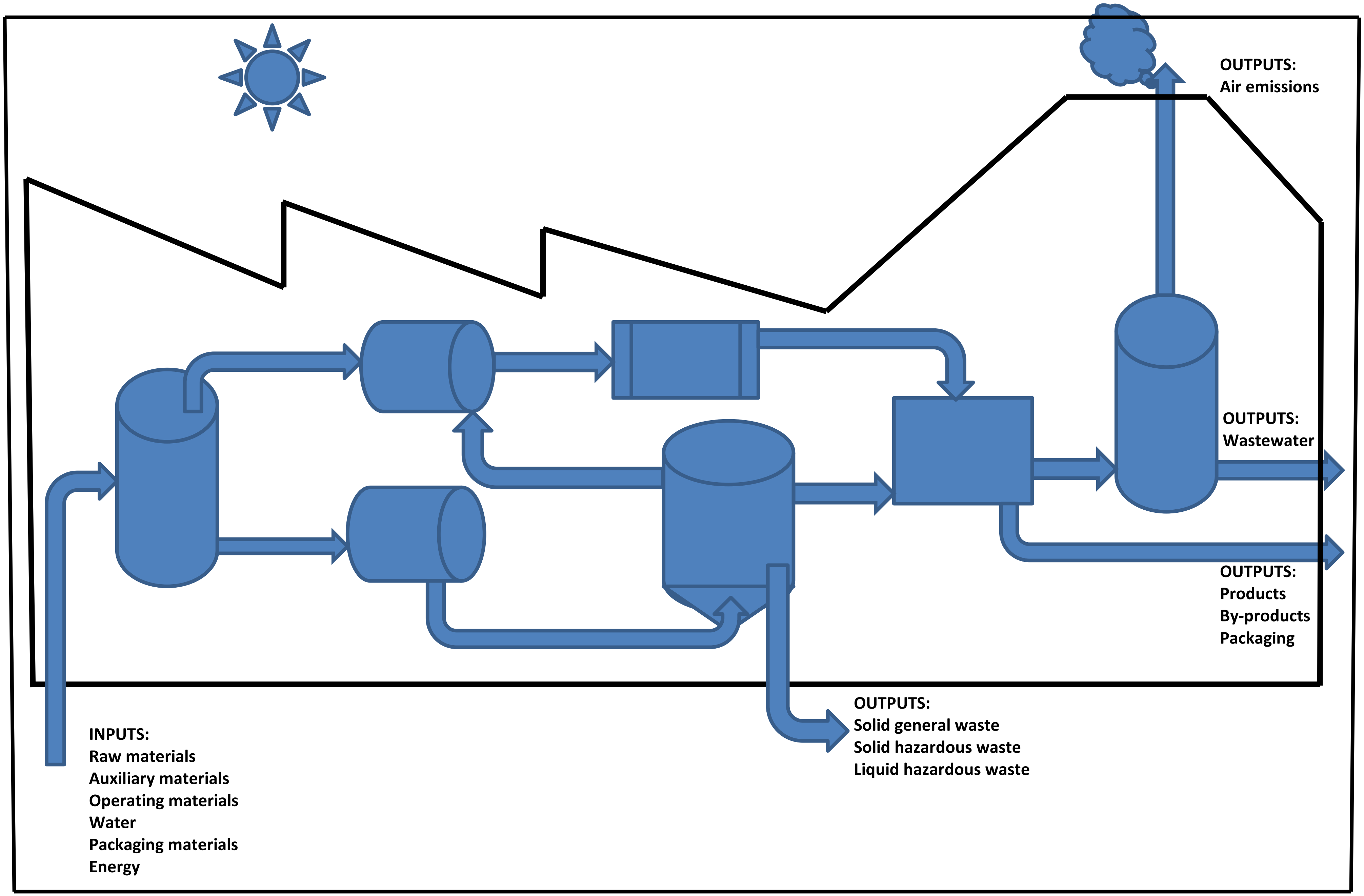


Figure 4: Illustration of a materials flow balance (Adapted from: IFA, 2005)

The United Nations Division for Sustainable Development procedures and principles document on environmental management accounting tabulates physical materials accounting into input and output types as shown in Table 2.5 below. An inputs and outputs analysis of material flows does not account for an organization's assets such as buildings and equipment since capital items do not enter or leave the organization as frequently as do other physical materials and are therefore not included in materials balances.

Table 2.5 Structure of an input-output analysis of material flows
(Source: UNDSD, 2001)

INPUT in kg or kWh	**OUTPUT in kg**
Raw materials	**Product:**
Auxiliary materials	Main product
Packaging	By-products
Operating materials	**Waste:**
Merchandise	Municipal waste
Energy:	Recycled waste
Gas	Hazardous waste
Coal	**Waste water:**
Fuel oil	Amount of waste water
Other fuels	Heavy metals in waste water
District heat	Chemical oxygen demand of waste water
Renewables (biomass, wood)	Biological oxygen demand of waste water
Solar, wind, water	**Air-Emissions:**
Externally produced electricity	Carbon dioxide
Internally produced electricity	Methane
Water:	Nitrous oxides
Municipal water	Sulphur dioxide
Ground water	Dust
Spring water	Volatile organic carbons
Rain/ surface water	Ozone depleting substances

2.4.5.1 Materials input flow into an organization

Materials inputs refer to raw materials which are the primary components of the product that enter into the organization's processes. Auxiliary materials are materials that are the minor components of the products that become part of the final product or by-product. Operating materials are materials used by the organization that do not become part of the products, for example office supplies and building cleaning detergents and are classified as non-product outputs when they are discarded. Packaging materials refers to the product or shipping packaging. Water as a raw material is accounted for separately and forms part of the final product or it may be used for cleaning or cooling processes and leave the organization as waste water or as part of the waste or emissions. Energy refers to all types of energy such as electricity, gas, coal, oil and any others that are utilized by the organization and is generally used to run machinery or to generate chemical reactions and is viewed as an operating material.

2.4.5.2 Outputs leaving an organization

Outputs consist of all material leaving the organization; such as products, by-products (products that are manufactured during the production of the main product and are then packaged and sold), packaging and wastes. Waste generation is created by return of products by customers, product destruction, re-packaging, quality control issues, production losses and inefficiencies, product spoilage, wastage of products and raw materials, storage decay and product shrinkage (Jasch and Schnitzer, 2002). Non-product outputs comprise of anything that is not products; such as wastes, waste water and air emissions.

Solid waste refers to solid non-hazardous waste such as waste paper, plastic, food and scraps. Hazardous waste, defined as "*infectious, flammable, toxic or carcinogenic*" consists of solid hazardous waste such as old batteries, liquid hazardous waste such as paint and solvents and a slurry or mixture of solid and liquid hazardous waste such as wastewater sludge (IFA, 2005:36). Wastewater consists mostly of water and contaminants such as high biological demand, high total suspended solids, high quantities of nutrients and high quantities of toxins. Air emissions are pollutant rich air streams resulting from organizational processes and generally consist of combustion by-products such as sulphur dioxide, nitrogen oxides, carbon monoxide, carbon dioxide, particulate matter, volatile organic compounds, metal particulates, radiation, noise and heat. The cost of waste production includes wasted raw and auxiliary material, wasted capital, wasted operating materials, wasted labor, wasted water, wasted energy, wasted packaging and waste disposal costs.

2.4.6 Environmental costs

Environmental costs are categorized by the United Nations Division for Sustainable Development (2001) as:

1. Waste disposal and emission treatment costs;
2. Prevention and environmental management costs;
3. Material purchase value of non-product output;
4. Processing costs of non-product output and
5. Environmental revenues.

These costs are first presented in Table 2.6 as the environmental expenditures and revenues categories and discussed in further detail in sections 2.4.6.1 to 2.4.6.5.

Table 2.6 Environmental expenditure and revenue categories for the different environmental media as developed by the United Nations Division of Sustainable Development (Source: UNDSD, 2001:19)

Environmental media → **Environmental cost/expenditure categories ↓**	**Air/Climate**	**Wastewater**	**Waste**	**Soil/ Groundwater**	**Noise/ Vibration**	**Biodiversity/ Landscape**	**Radiation**	**Other**	**Total**
1. Waste and emission treatment									
1.1.Depreciation for related equipment									
1.2.Maintenance and operating materials									
and services									
1.3. Related personnel									
1.4. Fees, taxes, charges									
1.5. Fines and penalties									
1.6. Insurance for environmental liabilities									
1.7. Provisions for clean-up costs,									
remediation									
2. Prevention and environmental									
management									
2.1. External services for environmental									
management									
2.2. Personnel for general environmental									
management activities									
2.3. Research and development									
2.4. Extra expenditure for cleaner									
technologies									
2.5. Other environmental management									
costs									
3. Material purchase value of non-product									
output									
3.1. Raw materials									
3.2. Packaging									
3.3. Auxiliary materials									
3.4. Operating materials									
3.5. Energy									
3.6. Water									
4. Processing costs of non-product									
output									
Σ Environmental expenditure									
5. Environmental revenues									
5.1. Subsidies, awards									
5.2. Other earnings									
Σ Environmental revenues									

2.4.6.1 Waste and emission treatment

2.4.6.1.1 Depreciation for related equipment

Environmental equipment consist of end of pipe technology or equipment that is used to reduce the environmental impact by clean up or remediation of the pollution; mostly to comply with environmental legislation and include refuse compactors, waste collection containers, waste transportation vehicles, waste heat recovery systems, air pollution filters/scrubbers, noise abatement investments, sewage treatment plants, waste water treatment systems/plants, waste disposal equipment, dust extraction systems, waste separation areas and sound insulation walls (UNDSD, 2001). Non-best available technology equipment, which is the part of the equipment that does not correspond to the best available technology thereby producing additional waste and emissions; can also be considered as environmental equipment (Jasch and Schnitzer, 2002).

Assets are investments that will lead to a future economic measurable cost saving and are capitalized and accounted for in the profit and loss statement as depreciation; which is the initial investment costs of the asset or equipment extended over the projected lifetime of the equipment. Environmental equipment rental costs may also be considered under environmental equipment depreciation costs.

2.4.6.1.2 Maintenance and operating material and services

According to the International Federation of Accountants (2005) maintenance and operating material and service costs include:

- Operating materials related to waste and emission treatment and control;
- Operating material used to operate environmental equipment such as environmental equipment cleaning detergents, waste handling containers, wastewater treatment chemicals and personal protective equipment and training materials**;**
- Maintenance costs, inspection costs and water and energy costs used only for waste and emission treatment objectives;
- Energy costs related to energy required for conveyor transport equipment, to operate equipment in the waste water treatment plant and for earth-moving equipment at a landfill that is situated on the organization's premises.

2.4.6.1.3 Related personnel

Personnel costs under this category include salaries, wages and benefits related to both internal and external personnel occupied in waste collection and handling facilities and personnel operating wastewater treatments plants and emission control equipment (IFA, 2005).

2.4.6.1.4 Fees, taxes, charges

Typical fees, taxes and charges associated with waste and emission treatment and control include solid waste disposal fees, sewer access fees, effluent and waste water discharge fees, licenses, environmental taxes, emissions taxes and permits for wastewater discharge and greenhouse gas emissions (UNDSD, 2001).

2.4.6.1.5 Fines and penalties

Fines and penalties are normally charged by government agencies for serious non-compliance to environmental legislature (IFA, 2005).

2.4.6.1.6 Insurance for environmental liability

Damage to people, property and the environment caused by dangerous activities and fire risks due to hazardous processes and substances are covered by environmental liability insurance (IFA, 2005).

2.4.6.1.7 Provisions for clean-up costs and remediation

Provision for future environmental risks allows the organization to anticipate future expenditure such as groundwater contamination remediation, surface water contamination remediation, unplanned air emissions (such as uncontrolled gaseous releases as a result of pollution treatment equipment failure), energy emissions (such as radioactive emissions), soil contamination remediation and recovery of affected ecosystems and compensation to third parties (UNDSD, 2001).

2.4.6.2 Prevention and environmental management

Prevention and environmental management costs includes the costs of activities such as the management of relevant ecosystems, cleaner production initiatives, greener purchasing activities, environmental management systems and accounting, environmental monitoring and auditing and environmental communication **(**IFA, 2005).

2.4.6.2.1 External services for environmental management

External services includes the costs of environment-related consultants, training, inspections, audits, certification, legal organizations and communication (UNDSD, 2001; IFA, 2005).

2.4.6.2.2 Personnel for general environmental management activities

These costs consist of salaries and benefits for both permanent and temporary internal personnel for environmental management activities such as environmental projects, audits, compliance and communication (UNDSD, 2001; IFA, 2005).

2.4.6.2.3 Research and development

Research and development includes contracts given to external parties for research as well as personnel hours for internal personnel research related costs; if environmental performance improvement is the primary focus of the project and not occurring as an additional benefit of the project (UNDSD, 2001; IFA, 2005).

2.4.6.2.4 Extra expenditure for cleaner technologies

Cleaner technology improves the efficiencies of production processes by using less water and energy and producing less waste streams and if quantifiable, the cost difference between environmentally favorable production technologies to an unfavorable solution may be considered; however, if cleaner technology is the current technology available it is not an environmental investment (IFA, 2005). Cleaner technologies are normally treated as production assets (UNDSD, 2001; IFA, 2005).

2.4.6.2.5 Other environmental management costs

Additional environmental management costs include cost of purchasing environmentally friendly materials instead of conventional materials, eco-sponsoring and donations, cost of publishing environmental reports for external stakeholders; environmental communication costs and environmental measurement costs (UNDSD, 2001; IFA, 2005).

2.4.6.3 Material purchase value of non-product output

Non-product outputs such as waste and emissions illustrate the inefficiencies of processes within an organization. The cost of wasted raw materials is a major portion of environmental costs since materials that end up as waste and emissions have been

- *"purchased (materials purchase value);*
- *transported, handled and stocked (costs for stock management, handling and transport);*
- *processed in various production steps (equipment depreciation, work time, auxiliary and operating materials, costs for finance, etc.);*
- *collected as scrap, waste, etc., sorted, transported, treated, transported, stocked again and transported; and finally,*
- *disposed of (disposal fees)"* (UNDSD, 2001:29).

Jasch and Schnitzer (2002) note that the cost of non-product output is paid for three times; once at purchase, the second time during production and the third time at disposal. The major contributor of all environmental costs is the purchase price paid for raw and auxiliary materials that are not converted into a product and is estimated at 40% to 70% of all environmental costs (Jasch and Schnitzer, 2002). Costs saving opportunities are possible by reducing the costs associated with non-product wasted material; which requires the evaluation and analysis of material flows through the organization; through tools such as the material balance and input-output analysis. The percentage of waste generated can be utilized to estimate the non-product output of raw materials (Jasch and Schnitzer, 2002).

2.4.6.3.1 Raw Materials

Non-product output of raw materials are most commonly discarded as solid waste or liquid products such as beer or milk and can be determined via material flow balances (UNDSD, 2001).

2.4.6.3.2 Packaging

Product packaging due to repackaging that cannot be returned or re-used is wasted and costly to dispose of (UNDSD, 2001).

2.4.6.3.3 Auxiliary materials

Wasted auxiliary materials are materials that are used to produce the wasted product but are not the main constituents of the product, for example glue in a shoe (UNDSD, 2001).

2.4.6.3.4 Operating materials

Wasted operating materials are materials that do not form a part of the wasted product and include chemicals/detergents for cleaning, solvents, lubricants, paints, office material and laboratory chemicals (UNDSD, 2001).

2.4.6.3.5 Energy

The use of energy to convert materials to non-product outputs can be estimated, calculated or measured. Water and energy used for waste and emission control and treatment processes must be recorded under the waste and emission treatment costs category (UNDSD, 2001).

2.4.6.3.6 Water

Material quality and quantities of waste water due to the production of non-product output is monitored as well as the cost of water used to produce the non-product output is accounted for under this category (UNDSD, 2001).

2.4.6.4 Processing costs of non-product output

Wasted personnel costs and capital costs such as depreciation; to manufacture the non-product outputs must be quantified (UNDSD, 2001).

2.4.6.5 Environmental revenues

2.4.6.5.1 Subsidies, awards

Organizations may obtain government subsidies or tax exemptions for environmental initiatives or projects, or receive external monetary awards for environmental activities, that are included under this category (UNDSD, 2001).

2.4.6.5.2 Other earnings

Environmental earnings include income from the sale of waste, energy or recycled materials (UNDSD, 2001).

2.4.7 Environmental cost data sources

All environmental costs are obtainable from the organization's accounting and information systems such as the balance sheet, profit and loss accounts, material flow balance, material stock numbers, stock keeping, production planning system, direct costs, overhead costs and calculations and estimates (UNDSD, 2001).

2.5 External costs

2.5.1 Definition of external costs

According to the National Treasury Department of South Africa (2010) the full extent of the cost of scarce and non-renewable raw materials resources, pollution and waste disposal on society is not fully evaluated and accounted for. Market prices of products and services do not consider the environmental affects that the manufacture of a product or service generates. The market failure to evaluate and price environmental resources results in the imposition of these costs to individuals not responsible and not included in the manufacturing activity and is referred to as an externality or external or social cost (Mikalonis, 2009). A negative externality refers to external costs and a positive externality refers to external benefits. External costs such as the emissions of toxic and harmful gases into the atmosphere resulting in building damage, human respiratory and health problems, crop and forest damage and global warming do not affect the polluting organization but only those members of the public or community prejudiced by the organization's activities (European Commission, 2003). External costs that are borne by society also include contaminated site remediation and air pollution that results in water and soil pollution when heavy metals and dioxins from air pollutants accumulate in water and soil resulting in contamination of the food chain that affects human health and water quality and contaminates soil (European Commission, 2003; National Treasury Department of South Africa, 2010).

Methods of internalizing external costs in order to force organizations to consider their external environmental impacts and pay for the true costs of their activities needs to be driven by government *via* legislature and taxes.

2.5.2 External cost evaluation methods

The cost of control or avoidance cost method places monetary values on external costs by utilizing the installation and operational costs of environmental control technologies used in the prevention of environmental damage as a stand-in for the cost of actual external damage (European Commission, 2003). For example, external emission costs can be evaluated by obtaining quotations for the capital cost to install pollution prevention or reduction equipment to decrease emissions by 60% to 100% (Forum for the future for the Sigma Project, 2003). The damage cost method uses organizational data and scientific and economic modelling techniques to estimate external costs of damage to the environment (IFA, 2005). The restoration cost method estimates the restoration cost of a contaminated site or environmental asset to return it to its original, undamaged condition and is commonly used as remediation costs are easily estimated (Forum for the future for the SIGMA Project, 2003). Monetization of emissions estimates the emission cost by using emission trading prices or emission treatment costs (IFA, 2005).

Studies on external costs and taxes are presented in the sections that follow and will be used in the evaluation of external costs resulting from activities in the chemical manufacturing sector.

2.5.3 External cost studies

2.5.3.1 Environmental taxes

2.5.3.1.1 Emission taxes

Environmental taxes compel organizations to internalize external costs and strive to maximize profits while minimizing pollution. The National Climate Change Response Green Paper of 2010 advocates the market-based instrument of carbon taxes to internalize the external cost of greenhouse gas emissions in order to assist in the reduction of these gases in South Africa (National Treasury Department of South Africa, 2010). South Africa's Greenhouse Gas Inventory (base year 2000) revealed that the energy sector contributed to 78.3% of South Africa's greenhouse gas emissions, the industrial sector to 8.0% and that waste management activities contributed to 4.3% (DEAT, 2009a). Studies estimate the external cost of greenhouse gas emissions at $5-$30 per ton of carbon dioxide at an atmospheric carbon dioxide concentration of 550 parts per million (National Treasury Department of South Africa, 2010).

South Africa will implement a carbon tax on the 1st of January 2015, at a rate of R120 per ton of CO_2 equivalent as an incentive to reduce industrial emissions (Urban Earth, 2013). South Africa has implemented fuel taxes on petrol, diesel and electricity (3.5cents per kWh), as well as a carbon emission tax on new passenger vehicles as part of its carbon pricing and reduction strategies (National Treasury Department of South Africa, 2010). Carbon tax is a Pigovian tax, named after Arthur Pigou, and should ideally be set equal to the damage cost or social cost of the emission of one ton of carbon or carbon dioxide (Carlton et.al., 1980). However the external or social cost of carbon is highly uncertain and varies in different countries with a combination of different exemptions.

Table 2.7 International carbon tax rates (SBS, 2013)

Country	**Unit of measure**	**Tax year**	**Carbon tax**	**Emissions trading scheme**
Australia	Australian dollar/ton CO_2	2012	23	
Australia	Australian dollar/ton CO_2	2013	24.15	
China		2013		√
United States (power sector only)		2009		√
Canada - Alberta				√
India	Rupees/ton of coal	2010	50	
Japan	Euros/ton CO_2	2012	3.20	
European Union		2005		
Finland	Euros/ton CO_2	2010	20	
Sweden(lower for industry than general activities)	Euros/ton CO_2	2012	34	
Norway (oil and gas producers only)	Euros/ton CO_2	2012	28	
Norway (oil and gas producers only)		2013	55	
Denmark	US Dollars/ton CO_2	2008	16.41	
Switzerland	Swiss CHF/ton of CO_2	2012/2013	36	
United Kingdom		2012/2013		√
Ireland	Euros/ton CO_2	2012	20	
New Zealand				√

2.5.3.1.2 Landfill taxes

Landfill taxes imposed by governments serves to internalize the external costs of the impacts of landfill sites (according to the Polluter Pays principle) on human health and the environment and acts as an incentive to decrease landfill loading by promoting recycling, composting and waste minimization activities (Revise Sustainability, 2013). Landfill taxes also serve to generate funding to assist in the reduction and eradication of waste disposal environmental impacts. Several European countries are paying landfill taxes, which is distinct from waste disposal charges imposed by waste removal companies that reflect the landfill processing costs. Landfill tax is generally paid by the landfill site operator who will recover this cost from organizations and local municipalities using the landfills, in addition to the standard landfill fees charged (Forum for the future for the SIGMA Project, 2003). Landfill taxes for the different European countries are presented in Appendix 8.

2.5.3.1.3 Incineration taxes

Waste incineration occurs on a larger scale in Europe than it does in South Africa. A presentation to the House of Commons Environmental Audit Committee noted that the external cost of incineration was higher than the external cost of landfilling for the United Kingdom (Edwards, 2012). The high social costs of incineration were also highlighted by Dijkgraaf and Vollebergh (2004) who quantify Dutch incineration environmental costs to be approximately 40% higher than Dutch landfilling environmental costs. Despite the high environmental costs of incineration, very few governments in Europe have implemented incineration taxes.

Table 2.8 Incineration taxes (Source: Revise Sustainability, 2013; Fischer et al, 2012)

European country	Description of tax	Year of introduction of tax	Incineration tax amount for the year	Tax amount in Euros/ton
Austria	Incineration tax	1989	2012	8
France	Incineration tax	1992	2013	14

2.5.3.1.4 Waste water taxes

Waste water taxes introduced to ensure compliance with regulatory standards, were adopted in France and the Netherlands in the 1970s and apply to direct waste water dischargers into water systems such as industries and municipalities (Ecotec, 2013). Municipalities then obtain these taxes from their suppliers by including it in their service fees. Waste water taxes are dependent on adherence to waste water quality standards. Effluent meeting environmental standards are subjected to reduced taxes and waste water that exceeds regulatory standards results in even lower taxes (Ecotec, 2013)

Table 2.9 European waste water taxes (Source: Ecotec, 2013)

European country	Tax amount for the year	Tax amount in Euros/damage unit
Germany	1998	36
		Tax amount in Euros/kg COD
Germany	1998	0.72
		Tax amount in Euros/kg of biological oxygen demand (BOD)
Denmark	1998	1.48
		Tax amount in Euros/kg of nitrogen
Denmark	1998	2.69
		Tax amount in Euros/kg of phosphorus
Denmark	1998	14.78

A damage unit represents one of the following:-

- 50 kg of COD or
- 25 kg nitrogen or
- 3 kg phosphorus or
- 2 kg organic halogens or
- 20 g mercury or
- 100 g cadmium or
- 500 g chromium or
- 500 g nickel or
- 500 g lead or
- 1,000 g zinc (Ecotec, 2013).

2.5.3.2 European Commission's external costs

Table 2.10 shows the average monetization of environmental impacts according to the European Commission's study on external environmental effects in Europe related to the life cycle of products and services, done in 2003.

Table 2.10 The European Commission's average external cost factors considered to monetize environmental impacts (Source: European Commission, 2003)

Environmental impact	Unit of measure	Average cost (Euros/g)
Air emission impacts:		
Stratospheric ozone depletion	g CFC11 equivalents	0.00068
Air acidification	g SO_2 equivalents	0.002235
(a) Sulphur oxides	SO_x as SO_2	0.00268
Greenhouse effect (direct, 100 years)/Global warming potential	g CO_2 equivalents	0.0000335
Photochemical oxidation	g ethylene equivalents	0.0008
(a) Nitrogen oxides (NO_x as NO_2)		0.00195
Human toxicity:	g 1-4-dichlorobenzene equivalents	
(a) Cadmium (Cd)		0.021
(b) Chromium (Cr III, Cr VI)		0.140
(c) Nickel (Ni)		0.003
(d) Arsenic (As)		0.171
Human health effects caused by dusts	g	0.03035
Human health effects caused by dioxins	g	20350
Waste water impacts:		
Eutrophication	g equivalents $P0_4$	0.0015
Phosphorus (P)		0.0047
Solid waste impacts:		
Disamenity caused by incineration	kg of waste	0.009
Disamenity caused by landfilling	kg of waste	0.019

2.5.3.3 Spadaro and Rabl's external costs

In a study done by Spadaro and Rabl in 1999 for Europe, monetary valuations of external costs yielded the results tabulated below.

Table 2.11 Spadaro and Rabl's economic valuations of external costs (Source: Spadaro and Rabl, 1999; European Commission, 2003)

Pollutant	Impact	External cost in Euros/kg of pollutant
Particulate matter ($PM_{2.5}$) from cars in urban Paris	Mortality and morbidity	2190
$PM_{2.5}$ from cars in Paris-Lyon	Mortality and morbidity	159
$PM_{2.5}$ from cars in rural areas	Mortality and morbidity	21.5
PM_{10}	Mortality and morbidity	15.4
SO_2	Crops and material	0.3
SO_2	Mortality and morbidity	0.3
SO_2 via sulphates	Mortality and morbidity	9.95
NO_2	Mortality and morbidity	Insignificant
NO_2 via nitrates	Mortality and morbidity	14.5
NO_2 via O_3	Mortality and morbidity	1.15
NO_2 via O_3	Crops	0.35
Volatile organic compounds (VOCs) via O_3	Crops, mortality and morbidity	0.9
Carbon monoxide (CO)	Morbidity	0.002
Arsenic	Cancer	171
Cadmium	Cancer	20.9
Chrome	Cancer	140
Nickel	Cancer	2.87
Dioxins, Toxic equivalents (TEQ)	Cancer	18 500 000
CO_2	Global warming	0.029

2.5.3.4 RDC Environment and Pira International's external costs

The external costs utilized in a study done by RDC Environment (an environmental consultancy) and Pira International (a commercial consultancy) in 2001 which intended to assess packaging waste costs across Europe is tabulated below. These costs were derived by analyzing previous studies.

Table 2.12 RDC Environment and Pira International's monetary external cost evaluation (Sources: RDC Environment and Pira International, 2001; European Commission, 2003)

Impact	Unit of measure	Valuation
Global warming potential (GWP) (kg CO_2 equivalent)	€/kg CO_2	0.01344
Ozone depletion (kg CFC 11 equivalent)	€/kg CFC11	0.68
Acidification	€/kg H^+	8.70
Toxicity carcinogens (Cd equivalent)	€/kg Cadmium (carcinogenic effects only)	22
Toxicity gaseous non carcinogens (SO_2 equivalent)	€/kg SO_2 from electricity production	1
Toxicity metals non carcinogens (Lead (Pb) equivalent)	€/kg Pb	62
Toxicity particulates and aerosols (PM_{10} equivalent)	€/kg PM_{10} from electricity production	24
Smog (ethylene equivalent)	€/kg VOC	0.73
Black smoke (kg dust equivalent)	€/kg smoke	0.66
Fertilisation	€/kg expressed as NO_2 mass equivalents	-0.7
Traffic accidents (risk equivalent)	€/1000 km travelled on an average road	17
Traffic congestion (car km equivalent)	€ per 1000 car km equivalents	86
Traffic noise (car km equivalent)	€ per 1000 car km equivalents	3
Water quality eutrophication (Phosphorus (P) equivalent)	€/kg P	4.7
Disamenity (kg landfill waste equivalent)	€/kg waste in landfill	0.037

2.5.3.5 Jieyan Liu and Peiyuan Guo's external costs

Monetary valuations of natural resources and pollution treatment as quoted by Liu and Guo (2005) from similar case studies in China are tabulated below.

Table 2.13 Monetary value of natural resources and pollution treatment in China (Source: Liu and Guo, 2005)

Item	**Unit of measure**	**Price per unit in Chinese RMB/Yuan**
Coal gas	m^3	1.79
Natural gas	m^3	2.31
Petroleum gas	kg	2.88
Waste water treatment	ton	0.63
Atmosphere (emissions) treatment	m^3	0.000221
Solid waste treatment	ton	76

2.5.3.6 Climate Care's external costs

The 2003 released Sigma Guidelines documents that the organization Climate Care (a consultancy specialising in carbon credits and environmental projects) in the United Kingdom charges the emission costs tabulated below.

Table 2.14 Climate Care's external emission costs (Source: Forum for the future for the SIGMA Project, 2003)

Emission	**Cost in Pounds/ton**	**Comment**
CO_2	5.45	Based on CO_2 restoration costs.
NO_x	1400	Based on the United States of America NO_x trading prices and other similar studies.
SO_2	2400	Based on environmental tax rates in Europe.

2.5.3.7 Groundwater remediation cost analysis

The cost associated with preventing groundwater contamination is much lower than remediation costs of contaminated groundwater. Due to the high costs of remediation, technical difficulty and long remediation periods involved in cleaning up a contaminated site, natural attenuation is often the most feasible option to be considered. However, not all sites are successfully remediated by the process of natural attenuation and may require the application of treatment technologies or be abandoned as a water resource (Zaporozec, 2002).

Table 2.15 indicates estimated capital, operating and maintenance costs of different remediation technologies as studied by the United Stated Environmental Protection Agency. Current groundwater remediation costs are difficult to obtain and vary considerably due to site specific aspects such as hydrogeology, type of contaminant groups, magnitude of the contamination, extent of remediation required and the volume of groundwater requiring treatment (US EPA, 2001).

Stenzel and Merz (1989) calculate the adsorption system remediation costs to be approximately $2.47 per 1000 gallons of treated groundwater as at 1989.

Table 2.15 Estimated capital, operating and maintenance cost of different remediation technologies as at 1994 (Source: US EPA, 1994)

Remediation method	Location	Type of technology	Costs as at 1994 (includes design, installation, operating and maintenance costs); US Dollars/1000 litres
Natural attenuation	In-situ (in ground) destruction	Conventional	No capital, operating and maintenance costs.
Oxygen enhanced biodegradation	In-situ destruction	Innovative	$0.79 - $2.64
Passive treatment walls	In-situ destruction	Innovative	Insufficient information to estimate a cost.
Air sparging	In-situ separation	Innovative	< $0.79
Free product recovery	Ex-situ (above ground) removal	Conventional	< $0.79
Bioreactors	Ex-situ destruction	Innovative	< $0.79
Air stripping	Ex-situ separation	Conventional	< $0.79
Carbon adsorption	Ex-situ separation	Conventional	> $2.64
UV oxidation	Ex-situ destruction	Innovative	$0.79 - $2.64
Slurry walls	In-situ containment	Conventional	< $0.79
Permeability enhanced groundwater extraction	In-situ containment	Innovative	Insufficient information to estimate a cost.

2.6 Green Gross Domestic Product

2.6.1 Gross Domestic Product

Simon Kuznets developed the Gross Domestic Product (GDP) in 1934 for a United States Congress report and advised that it was not to be used as a measure of the nation’s welfare (Kuznets, 1934). The existing United Nations System of National Accounts whose methodology is used internationally to calculate the GDP thus enabling global economic activity comparisons does not consider environmental issues (Jieyan, 2005). While GDP does not measure the standard of living of a nation, it is used as an indication of the standard of living on the basis that economic growth benefits all citizens (HM Treasury, 2013).

As discussed on the Maryland website (Maryland, 2011), the GDP as an indicator of social welfare has the following disadvantages:

- There is no consideration of the far-reaching consequences of economic pursuits;
- There is no product differentiation between products purchased as luxury items and products purchased as basic necessities and the differing distribution of affluence across the nation's population is not contemplated;
- Negative environmental and social impacts as a result of economic activities are not considered;
- Non-market activities such as household tasks and voluntary work is not taken into account in GDP;
- Natural environmental resource depletion is considered as income in GDP and declining natural resource stocks are not considered;
- Environmental pollution and remediation activities in GDP accounting increase the GDP which is an erroneous implication that environmental degradation benefits the country's economy (India.CarbonOutlook, 2009). There is no differentiation between progressive and destructive economic activity as it is assumed that every financial transaction benefits society;
- Natural disaster remediation activities as well as crime and accidents result in an increase in the GDP because of the money spent on these activities; even though the environmental and social welfare has been negatively affected.

For the GDP to be truly reflective of a country's welfare it needs to consider the environmental and social aspects of economic growth, as attempted by the Green Gross Domestic Product.

2.6.2 Green Gross Domestic Product

The Green Gross Domestic Product (Green GDP) is an economic growth index that considers the consequences of economic growth on the environment and society by adjusting conventional GDP to take into consideration the cost of environmental degradation and wastage of natural resources (Yin, 2008). In 2004, China chose to replace the Chinese GDP index with the Green GDP index and published its first and only Green GDP report in 2006. This Green GDP accounting report revealed that pollution attributed to 66.3 billion US dollars of loss to the Chinese economy; that translated to 3.05% of the Chinese economy (Xiaohua, 2007). Chinese economic growth rate reduction due to environmental damage and depletion of natural resources became politically unacceptable and the 2005 Green GDP report was censored and support for the Green GDP system withdrawn by the Chinese government (Xiaohua, 2007). India has currently embarked on a national activity to estimate Green GDP and expects to release environmentally adjusted GDP figures by 2015, from which it is envisioned that the Green GDP estimates will quantify natural resource consumption, environmental degradation and environmental remediation and mitigation (FE Bureau, 2009).

2.6.3 Benefits and challenges of the Green Gross Domestic Product

Green GDP highlights the impacts of the consumption of products and services on natural resources and the environment (Boyd, 2006). Green GDP allows for the international benchmarking of natural resources and natural resource decline.

The successful implementation of Green GDP is dependent on accurate measurement and reporting of emissions, wastes and other environmental impacts by all organizations (India.CarbonOutlook, 2009). The Green GDP of each organization can then be aggregated to the economic sector's Green GDP and thus to a national Green GDP. Green GDP implementation will lead to reduced GDP (as demonstrated by the Chinese 2004 Green GDP results), which has curtailed many developing countries from measuring and accounting for environmental impacts as lower GDPs implies lower economic growth and development, which governments are reluctant to publicize to international economic markets.

The lack of agreement amongst researchers on what environmental related components should be included in Green GDP contributes to the difficulty in establishing Green GDP. There is also no consensus on the methodology to evaluate/monetize environmental effects such as biodiversity losses and climate change effects, environmental degradation and environmental remediation (Liu and Guo, 2005). The lack of data regarding the quantity and quality of natural resources and the difficulty in pricing natural resources such as forests, mineral resources and fossil fuels, makes Green GDP statistics ambiguous and difficult to entrench (Liu and Guo, 2005).

2.6.4 Calculation of the Green Gross Domestic Product

The three methods to theoretically calculate the Green GDP are Green GDP based on resources depletion, environment degradation and expenditure for environmental protection (Liu and Guo, 2005). Green GDP based on environment degradation is complex because of problems in obtaining data and Green GDP based on expenditure for pollution control is based on end-of-pipe policies; whereas calculating Green GDP based on resources depletion is the simplest and is expressed by Liu and Guo (2005) as:

Green GDP = GDP - natural resources depletion - pollution costs　　Equation [1]

Zhishen (n.d) further simplifies this to:

Green GDP = conventional GDP - environmental cost　　Equation [2] where environmental cost includes environmental degradation prevention costs, resource depletion costs, environmental remediation and restoration costs and environmental resource maintenance costs (Zhishen, n.d.). GDP already includes some of the natural resources costs such as raw materials used in the manufacture of products or in delivering a service.

2.6.5 Alternate measurement indices

The Genuine Progress Indicator (GPI) is an alternate system that can be used to complement GDP as a measurement of economic growth that differentiates between economic and uneconomic growth (Hamilton, 1997). Similar to Gross Domestic Product, the GPI measures the population's consumption of goods and services; however, consumption is amended to include variations in population income; social welfare aspects that traditionally do not have market value such as household tasks, voluntary work, post schooling education, cost of crime, pollution prevention activities undertaken by individuals, commuting time and accidents; as well as environmental costs such as cost of pollution, ecosystem loss, cost of climate change and non-renewable resources depletion (Costanza, 2008; New Economics Institute, 2012). However, the GPI does not consider the money spent by government, the cost of non-renewable minerals and the cost of some renewable resources such as fish and the forests (Haggart, 2000).

2.7 Environmental legislature, standards and codes of practice in the chemical manufacturing sector

2.7.1 Overview of the South African chemical manufacturing sector

Established in the late 1800's, the South African chemical industry's primary function was to supply chemicals and explosives to support the mining industry. The petrochemical industry was founded in the 1950s by the South African Synthetic Oil Liquid (Sasol) company to convert coal to oil (DEAT, 2006a). Prior to 1994, the isolationism of apartheid led to the construction of small chemical plants catering only for local demand. Post 1994, the chemical industry in South Africa has expanded into international markets and is transforming its organizations to meet international standards (DEAT, 2006a). The South African chemical industry is an important part of the manufacturing sector in South Africa. It has a significant influence on the country's economy and employs approximately 200000 people contributing approximately 5% to the national gross domestic product (GDP) and comprising of approximately 25% of the manufacturing sector sales (Brand South Africa, 2008b).

The chemical manufacturing sector consists of four sub-sectors as described by the Department of Environmental Affairs and Tourism (2006a):-

- Base chemicals; consisting of the petrochemical basic chemical compounds such as ethylene and propylene and inorganic base chemicals such as caustic soda, ammonia, sulphuric acid and chlorine;
- Intermediate chemicals; that incorporate waxes, phenols, ammonia, solvents, tars, plastics and rubbers;
- Chemical end products; that include explosives, fertilizers, paints, plastics and
- Specialty end products; for example pharmaceuticals, agrochemicals, bio-chemicals, food and fuel additives.

Whilst there are a limited number of case studies on environmental management accounting in the mining sector of South Africa and triple bottom line accounting case studies for the mining sector in Australia, no case studies of the implementation of the triple bottom line accounting in the chemical manufacturing sector of South Africa could be sourced. The Australian case study of the mining sector utilized input-output analysis to assess the principle of the triple bottom line (Lenzen et al, 2006). Life cycle assessments were employed to quantify the environmental costs associated with the products (Lenzen et al, 2006). Triple bottom line indicators developed during the study were the financial indicators of gross operating surplus, exports and imports (Lenzen et al, 2006). The social indicators developed were employment, income and government revenue and the environmental indicators developed were greenhouse gas emissions, water usage, land disturbance and primary energy (Lenzen et al, 2006).

Traditionally and currently environmental accounting in the chemical manufacturing sector of South Africa has been incorporated into the organization's financial and management accounting tools. Environmental costs and revenues are not accounted for separately.

2.7.2 Legislative framework of the South African chemical manufacturing sector

According to the Department of Environmental Affairs and Tourism (2006a) legislative management of the chemical manufacturing industry in South Africa is characterized by a fragmented regulatory framework resulting in a huge challenge in chemical management safety. The overarching regulatory framework that governs the South African chemical industry lies in the Constitution of South Africa Act 108 of 1996 and legislation governing the chemical industry is distributed over several government departments. The regulations and legislature governing the South African chemical manufacturing sector is given in Appendix 9.

2.7.3 Key legislature governing the chemical industry in South Africa

2.7.3.1 Constitution of the Republic of South Africa

The Bill of Rights included in the Constitution of South Africa is the foundation of democracy in South Africa, protecting the rights of all people in South Africa to the democratic entitlement of human dignity, equality and freedom. It is a basic entitlement to live in an environment that will not adversely affect one's welfare and it is government's duty to ensure that the economic, environmental and social right of every South African is met (South Africa, 1996: Section 24).

2.7.3.2 National Environmental Management Act 107 of 1998

The cornerstone of the National Environmental Management Act 107 of 1998 is that all development in South Africa must be economically, environmentally and socially sustainable. The Act encompasses the avoidance, minimization and/or remediation of environmental pollution, damage to cultural heritage and environmental degradation to ecosystems; the recycle, re-use and disposal of waste; the sustainable use of renewable and non-renewable resources; the integration of environmental management into all aspects of development; environmental justice; participation of all interested and affected parties in transparent environmental decision making; the promotion of environmental education; the protection of workers' rights in terms of health and environmental hazards and the application of the Polluter Pays principle (South Africa, 1998a).

2.7.3.3 National Water Act 36 of 1998

The National Water Act 36 of 1998 ensures the protection of water quality, advocates access to clean water and promotes sustainable development in South Africa (South Africa, 1998b). The National Water Act governs the management of wastewater in South Africa and also provides for the prevention of pollution of water resources by prohibition of the discharge of industrial wastewater, sewage and leakages from chemical and oil storage facilities into storm water systems, surface water or groundwater systems; the separation of storm water systems and sewer systems; permit requirements for the discharge of industrial wastewater into sewer systems; the prohibition of ground or surface water pollution and the application of the Polluter Pays principle (South Africa, 1998b).

2.7.3.4 Environmental Management Air Quality Act No. 39 of 2004

The National Environmental Management Air Quality Act, Section 28 specifies that pollution or degradation of the environment due to industrial activities must be prevented or minimized (South Africa, 2010). The Air Quality Act regulates the prevention of offensive odorous emissions from industrial activity by the compliance to emission measurements and measurement reporting; compliance to controlled emitter emission standards; compliance to fuel usage and fuel production regulations; provision of pollution prevention plans for priority air pollutants; submission of atmospheric impact reports; application for atmospheric emissions licenses (AEL) and the compliance thereto as well as compliance to regulator minimum emission standards (South Africa, 2010). The minimum emission standards applicable to organizations studied within the chemical manufacturing sector of South Africa for various listed activities is detailed in Appendices 10a and 10b.

2.7.4 Environmental management systems

An essential management tool for the chemical industry is the compliance with accreditation and certification schemes. An environmental management system provides structure and support to an organizations environmental policy, programmes and objectives. It influences continuous improvement in the organizations ability to provide an environmentally friendly, high quality product to the customer. Environmental management systems compels an organization to identify, measure, monitor, address, audit, review and evaluate environmental impacts of the organizations activities, processes and products on the environment (Hortensius and Barthel, 1997). ISO14000 stipulates the requirements for an environmental management system and prescribes the key elements of the ISO14000 family of standards.

Additionally, Responsible Care is an international voluntary tool developed by the chemical industry and first introduced in Canada in 1985 (International Council of Chemical Associations, 2013). The South African Chemical and Allied Industries' Association implemented Responsible Care in 1994 in response to public concern over chemical industrial activity and aims to improve environmental aspects related to the industry (Chemical and Allied Industries Association, 2013). The Responsible Container Management Association of Southern Africa, founded in 2001, aims to promote the environmentally safe production, handling, re-use and disposal of containers used in industry (containers refer to industrial steel containers and plastic drums and containers with a maximum of one cubic meter capacity) (Responsible Packaging Management Association of Southern Arica, 2012).

CHAPTER 3 RESULTS

3.1 The Durban Chemicals Cluster

The Durban Chemicals Cluster was established in 2008 to promote the development of the chemicals manufacturing sector in Durban and its surrounding areas and currently is an association of twenty seven chemical companies (Durban Chemicals Cluster, 2012). The Durban Chemicals Cluster membership consists of the following organizations:

- Air Liquide
- Arkema
- BASF
- Buckman Laboratories
- ChemSpec Paint
- Dow Advanced Materials
- Gold-Reef Chemicals
- H&R South Africa
- Hosaf
- Huntsman Tioxide
- Isegen SA
- Improchem
- Isncomo Trading Enterprise
- KZN Oils
- Lungelo General Dealers
- Melton Adhesives
- NCS Resins
- Paperkem
- Protea Chemicals
- Qolotha Cleaning and Manufacturing
- Sancryl Chemicals
- Scott Bader
- SI Group
- SIKA South Africa
- Synthomer
- Steritech
- Vopak Terminal Durban

Four voluntary organizations within the chemical manufacturing sector and specifically the Durban Chemicals Cluster (DCC) were utilized to evaluate the organizations' internal environmental costs; through the introduction of an environmental management accounting system into each organization. External environmental and social costs of the organizations as well as their contribution to Green GDP were estimated. Due to the competitive business and legislative environment in which the participating organizations operate, the anonymity of the participating organizations was assured by non-disclosure of the following essential information:

- Organization name;
- Process operating conditions such as temperature, pressure, reaction time;
- Raw material chemical composition and brand name;
- Auxiliary material chemical composition and brand name;
- Operating material chemical composition and brand name and
- Company specific product brand names.

The organizations from the Durban Chemicals Cluster participating in this study are herein referred to as Company A, Company B, Company C and Company D.

3.1.1 Company profiles

3.1.1.1 Company A

Company A produces coating structural resins as well as various additives. Resins are produced by the reaction of various organic acids and alcohols at controlled process parameters in reaction vessels. The intermediate products from the reactors are then diluted and blended with various solvents. Chemical raw materials are received on site *via* road tankers, drums or flow bins. Products are also dispatched in drums, flow bins and road tankers. Company A is classified as a major hazard installation due to the hazardous raw materials/chemicals that are stored on site that present risks to the health and safety of employees and the surrounding communities. Figure 5 illustrates the organization's manufacturing process flow path. Figures 6 and 7 are schematic and photographic presentations of the organization's effluent/waste water facilities. Table 3.1 is an analysis of Company A's manufacturing inputs and outputs.

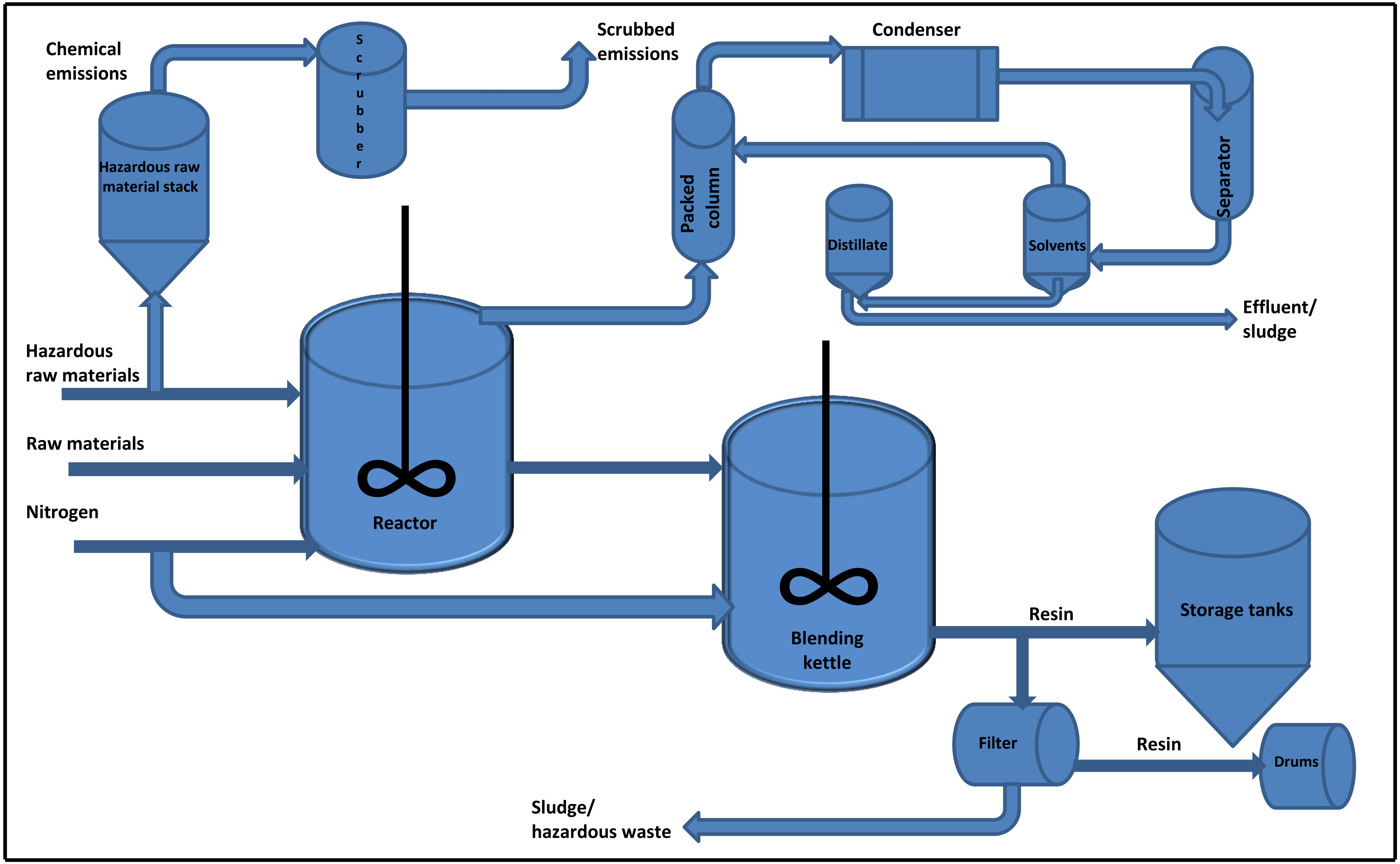


Figure 5: Company A's process flow diagram

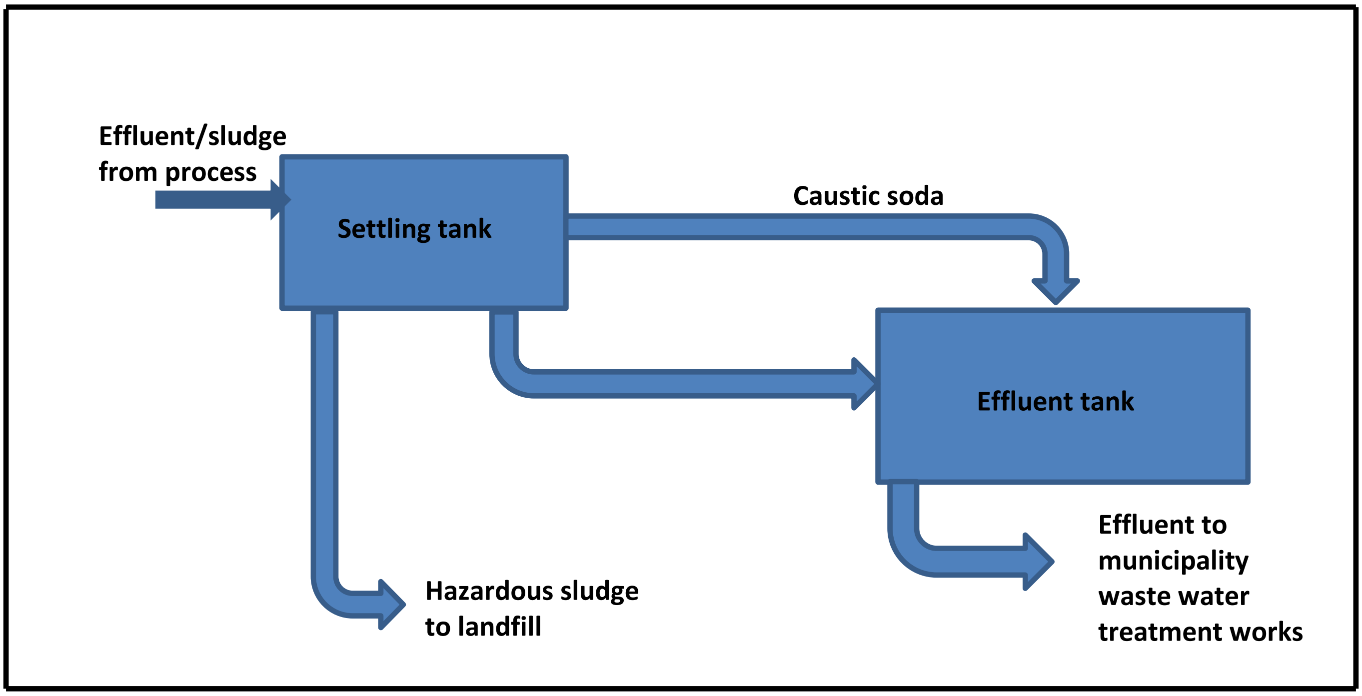


Figure 6: Company A's effluent plant process flow diagram

Figure 7: Company A's effluent tanks

Table 3.1 Inputs and outputs analysis for Company A

INPUTS	OUTPUTS
Raw materials/auxiliary materials	**Products**
Chemical compounds	Coating products
	Structural products
Packaging	
Drums	**Waste**
Flowbins	**Recycled waste**
Metal kegs	Cardboard
Bulk bags	Office paper
Intermediate bulk containers	Plastic such as shrink-wrap and packaging
Paper bags	Plastic bottles
Labels	Bulk bags
	Cans
Operating materials	Printer cartridges
Housekeeping disinfectants	Metal drums and kegs
Oils/lubricants	Plastic drums and kegs
Repairs and maintenance materials	Scrap metals
Office materials	Wooden pallets
Laboratory materials	Solvents/caustic solution
Caustic	Resin waste
Nitrogen	Pallets
Refrigerants	Electronic waste
Compressed air	
	Hazardous waste to landfill
Energy	Hazardous general waste
Externally produced electricity	Hazardous liquid/sludge waste
Steam	Solvents
Methane rich gas	Destructed material
Diesel	Fluorescent tubes
	Asbestos
Water	
Municipal water	**Hazardous waste resold**
	Solvents
	Waste water
	Effluent
	Air emissions
	Burner stack emissions
	Waste gas treatment scrubber emissions
	Raw material/product storage tank vents and fugitive emissions

3.1.1.2 Company B

Company B manufactures industrial chemicals mainly for the pulp and paper, leather and water treatment industries by combining various chemical raw materials in reactors at specified process conditions. Liquid raw materials are received in flow bins and tankers and powders are received in bags. Drums and bags are both recycled. Products are dispatched *via* containers or road tankers. Two boilers provide steam for the process to occur. Company B has an onsite water recovery plant in which effluent is boiled off to produce a distillate that is re-used in the manufacturing process. Figure 8 is a process flow diagram depicting the organization's production stream and Figure 9 is a process flow drawing of the organization's water recovery plant. Photographs of the effluent pits, waste water recovery plant and emission scrubbers are presented in Figures 10 and 11. Table 3.2 tabulates the analysis of the organization's inputs and outputs.

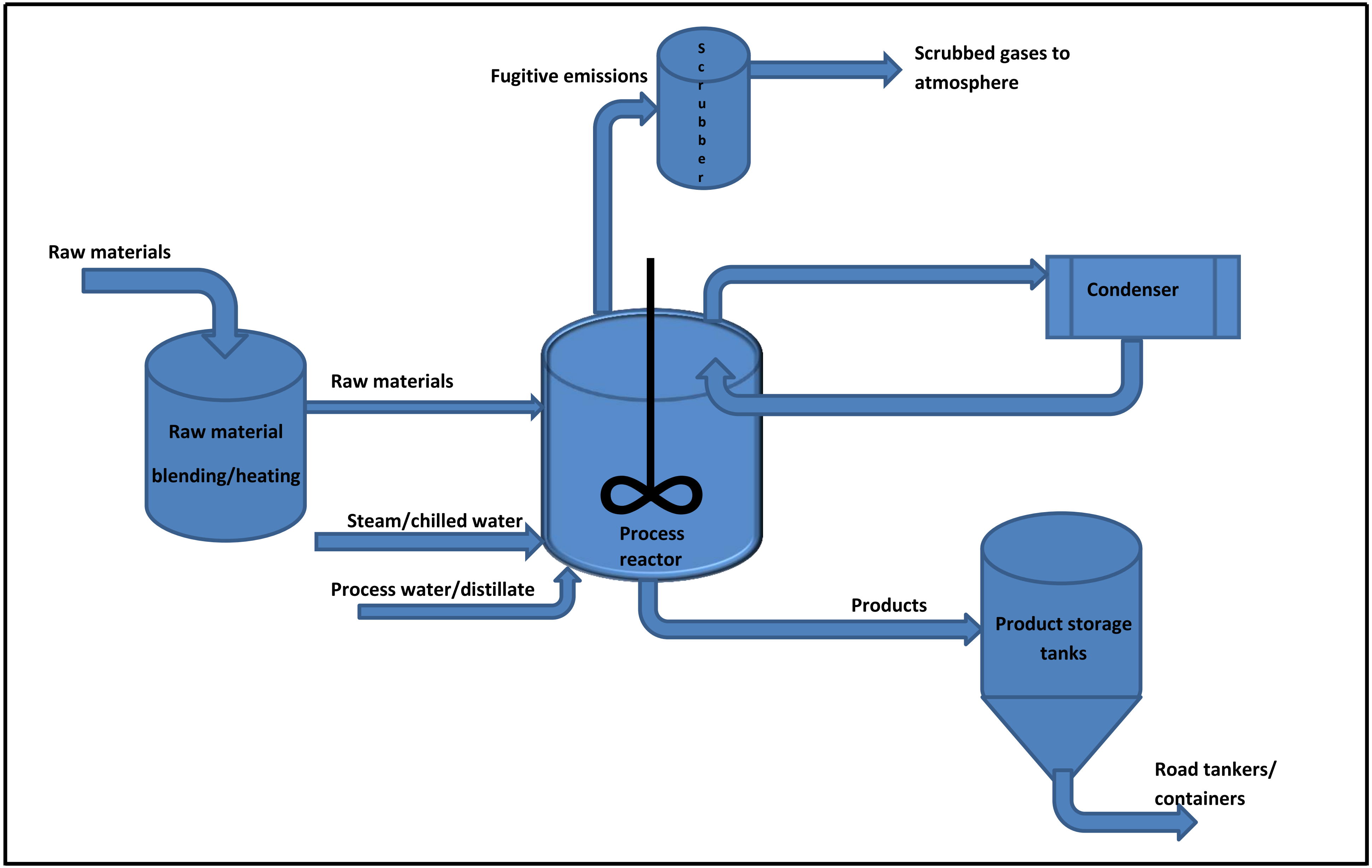


Figure 8: Company B's process flow diagram

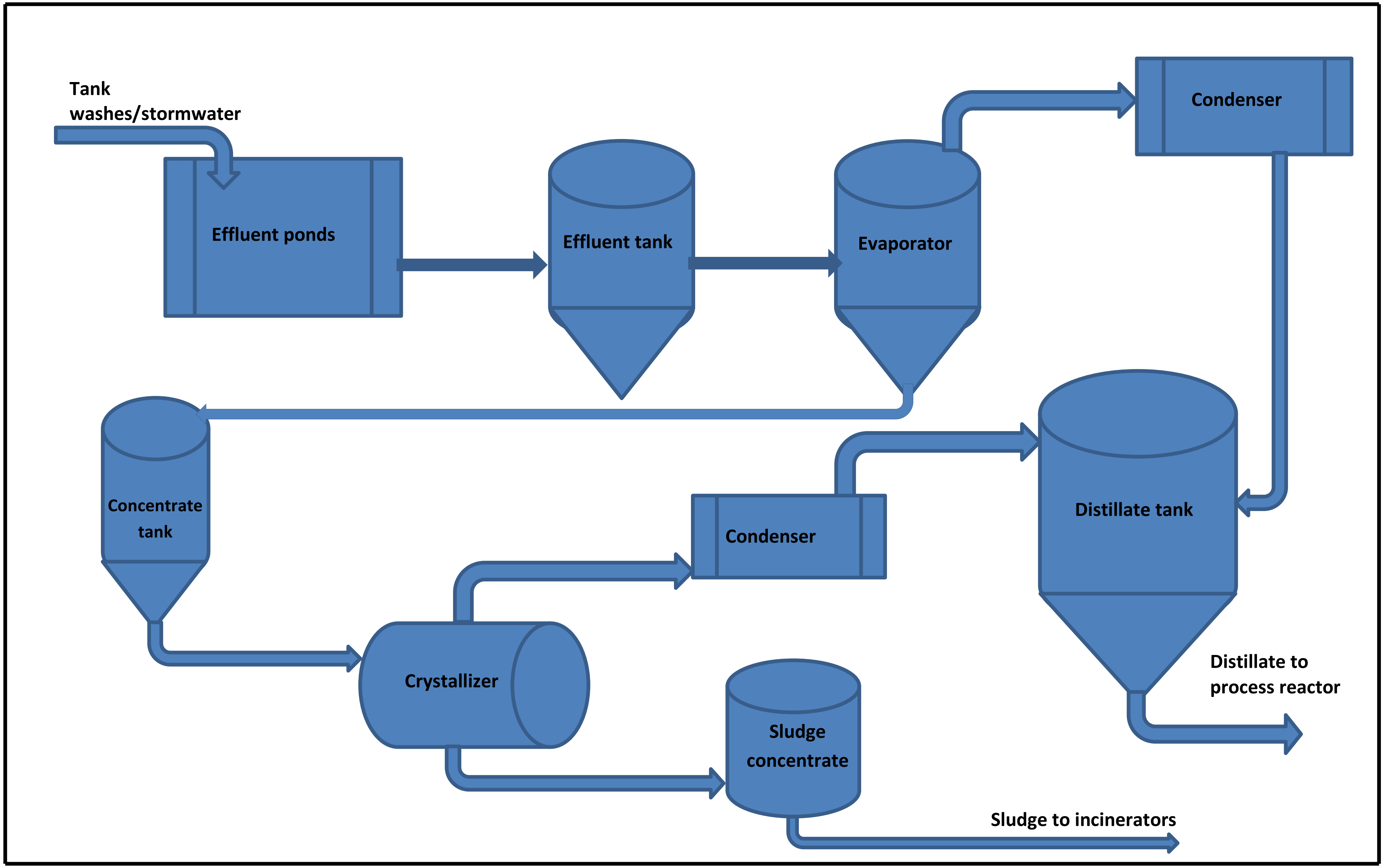


Figure 9: Company B's waste water recovery plant process flow diagram

Figure 10: Company B's effluent pits and waste water recovery plant

Figure 11: Company B's emission scrubbers

Table 3.2 Inputs and outputs analysis for Company B

INPUTS	OUTPUTS
Raw materials/auxiliary materials	**Products**
Chemical compounds	Biocides
	Scale inhibitors
Packaging	Sizing agents
Bulk bags	Wet/dry strength polymers
Wooden pallets	Defoamers
Intermediate bulk containers	Flocculants
Plastic wrapping	Dispersants
Labels	Re-pulping and de-inking agents
Drums	Enzymes
Operating materials	**Waste**
Housekeeping disinfectants	**Recycled waste**
Oils/lubricants	Bulk bags
Repairs and maintenance materials	Drums
Office materials	Intermediate bulk containers
Laboratory materials	Metallic scrap
Nitrogen	Paper
Compressed air	Cardboard
	Plastic wrapping
Energy	
Externally produced electricity	**Hazardous waste for incineration**
Steam	Sludge concentrate from waste water recovery plant
Diesel	
Kerosene	**Waste water**
Refrigerants	None
Water	**Air emissions**
Municipal water	Boiler/burner stack emissions
Distillate (recovered water)	Emissions from raw materials/product tank vents and fugitive emissions

3.1.1.3 Company C

Company C produces emulsion binders and specialized polymers through the polymerization of acrylic and vinyl acetate co-polymers and homo-polymers. Emulsion polymers are manufactured and supplied to the surface coating industry, adhesive industry and the textile and carpet industry. Additives are produced for the coatings and water treatment industry. Liquid raw materials that consist of organic chemicals are received in drums, intermediate bulk containers and road tankers and are stored in underground tanks or in ground level bunded storage areas. Raw material powders are received in bags. The plant is designated as a Zone 1 chemical plant which indicates that the plant is extremely flammable. Bulk monomers and catalysts are combined in a reactor and heated until the emulsion polymerization process is complete. Steam is used as the heating medium for the chemical reaction to occur. Steam is not produced by Company C but is generated and purchased from a neighbouring organization. However, a 500kW standby boiler is available on site for emergency supply requirements. Acidic effluent or waste water is collected and treated for pH using caustic soda. Effluent from Company C is pumped to the neighbouring organization's larger effluent pits for transfer to the Durban municipality's waste water treatment works.

Company C's manufacturing process is depicted by Figure 12 and Figure 13 is the process flow diagram of Company C's effluent system. Figures 14 and 15 are photographic depictions of the effluent pit and the emission scrubbers. Table 3.3 is an analysis of the inputs and outputs of Company C's manufacturing process.

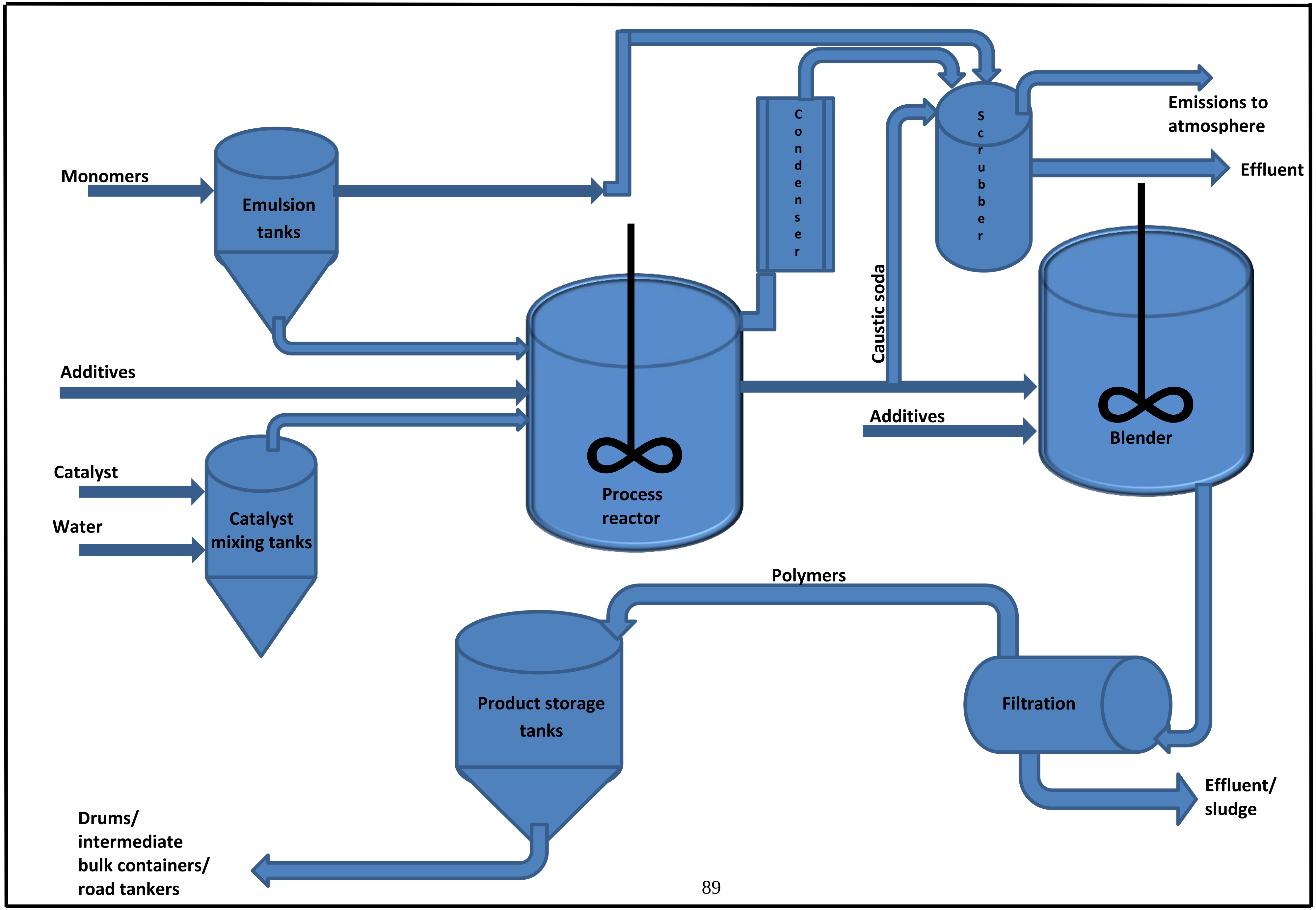


Figure 12: Company C's process flow diagram

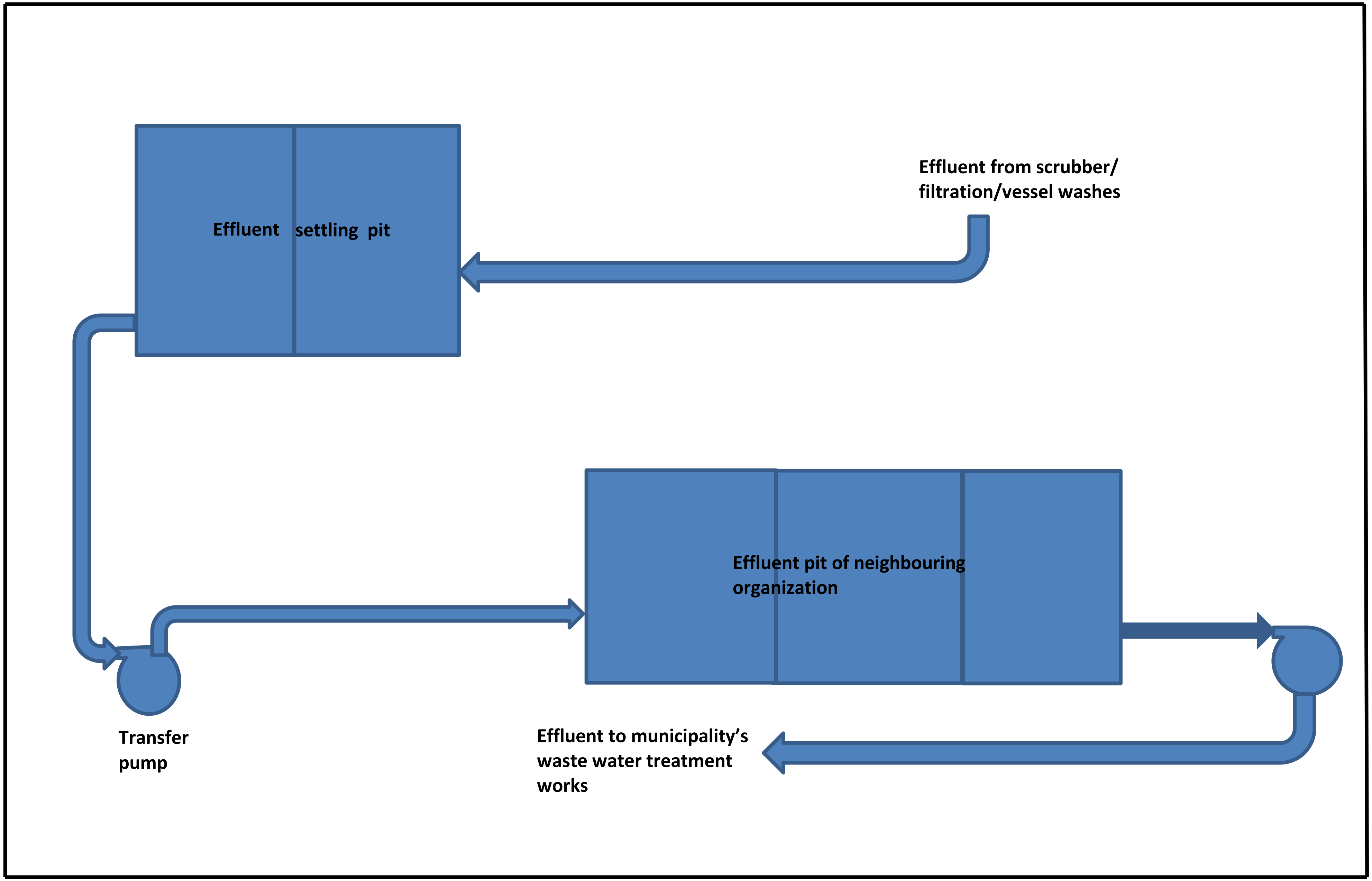


Figure 13: Company C's effluent system process flow diagram

Figure 14: Top view of Company C's effluent tank which is located below the grid (the tank dimensions are 6m in length, 3m in width and 3 m in height)

Figure 15: Company C's emission scrubbing plant

Table 3.3 Input and output analysis for Company C

INPUTS	OUTPUTS
Raw materials/auxiliary materials	**Products**
Chemical compounds	Emulsion polymers for the surface coating industry
Additives	Emulsion polymers for the adhesive industry
Catalysts	Emulsion polymers for the textile/carpet industry
	Additives for the coatings industry
Packaging	Additives for the water treatment industry
Intermediate bulk containers	
Wooden pallets	**Waste**
Drums	**Recycled waste**
Labels	Intermediate bulk containers
	Wooden pallets
Operating materials	Drums
Housekeeping disinfectants	Paper
Oils/lubricants	Metallic scrap
Repairs and maintenance materials	
Office materials	**Hazardous waste to landfill**
Laboratory materials	Polymer grit/process sludge
Caustic	
Production consumables for filters	**Waste water**
Nitrogen gas	Effluent
Oxygen acetylene gas for welding	
Compressed air	**Air emissions**
	Burner stack emissions
Energy	Waste gas treatment scrubber emissions
Externally produced electricity	Raw material/product storage tank vents and fugitive emissions
Externally produced steam	
Internally produced steam	
Diesel	
Paraffin	
Water	
Municipal water	
Demineralized water	
Chilled water	

3.1.1.4 Company D

Company D produces polyethylene terephthalate (PET) resin for the bottling and packaging industries. PET is a type of plastic produced by reacting ethylene glycol and terephthalic acid with a catalyst in an esterification process to produce an ester and water. Esterification links numerous small molecules together into a long chain. Polymerization follows esterification during which the intermediate polymer pellet products are heated through purging with nitrogen. Polymerization lengthens the chains and produces water as a byproduct. The final product is heated and molded into plastic bottles, films and other PET products. Company D's wastewater is collected in an effluent tank that is treated with caustic soda to neutralize its acidity and then pumped to the municipality's waste water treatment facility.

The process flow diagram of Company D's continuous polymerization plant is illustrated in Figure 16 and the solid state polymerization plant's process flow diagram is illustrated in Figure 17. Photographic presentations of the effluent pit and the emission scrubbers are shown in Figures 18 and 19. Table 3.4 tabulates the inputs and outputs analysis for Company D.

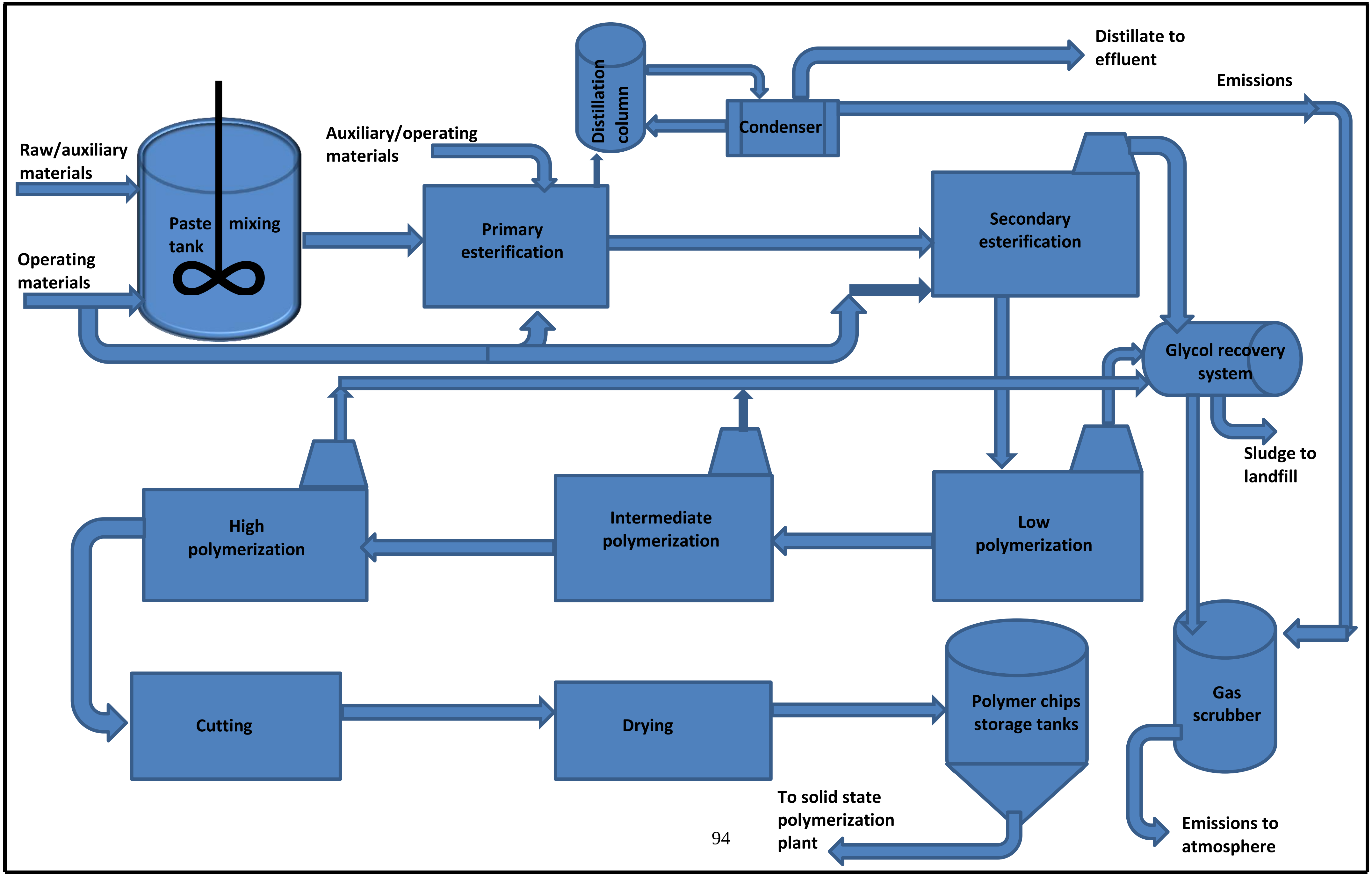


Figure 16: Company D's continuous polymerization plant process flow diagram

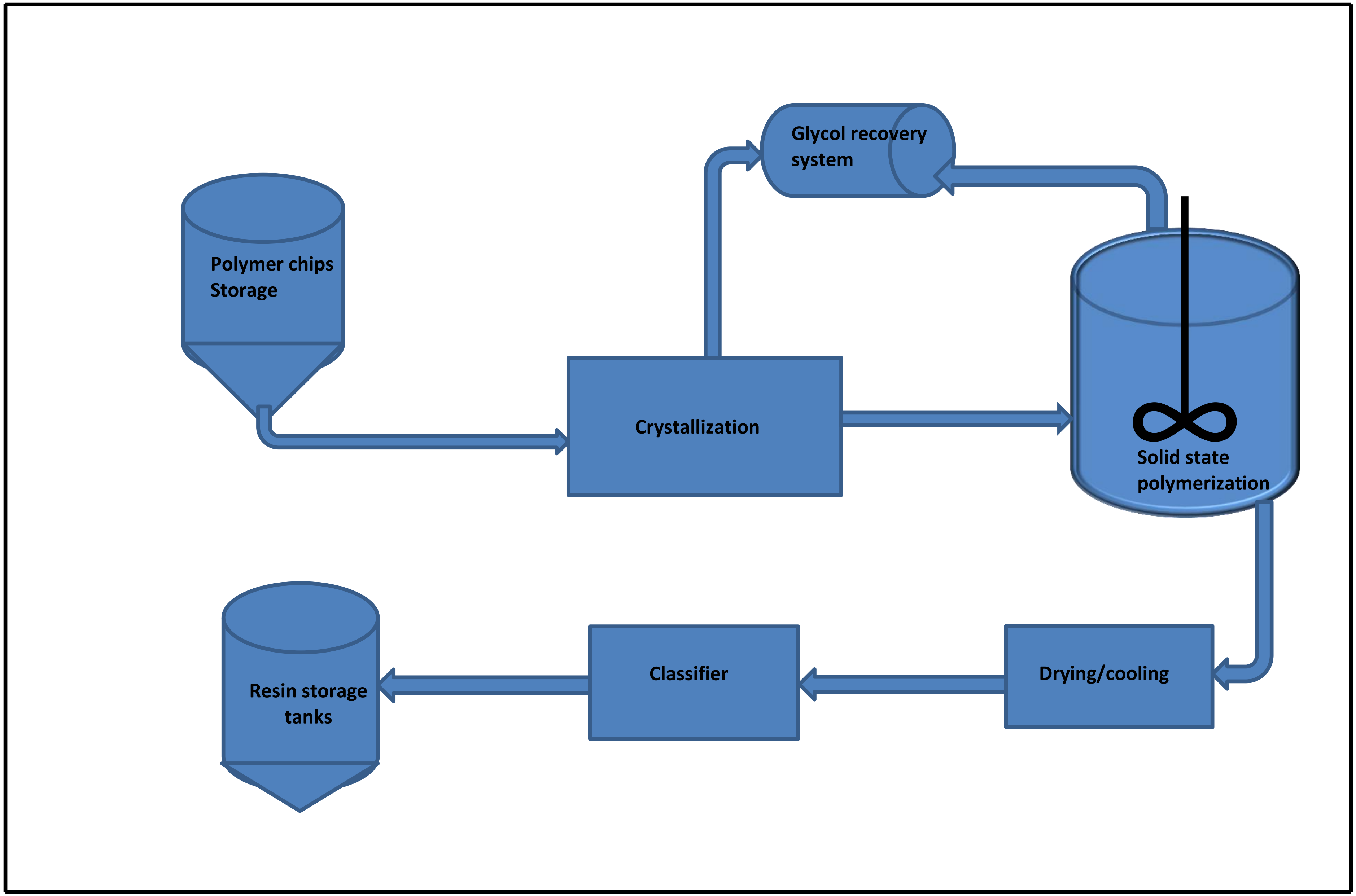


Figure 17: Company D's solid state polymerization plant process flow diagram

Figure 18: Company D’s effluent pit

Figure 19: Company D’s emission scrubbers

Table 3.4 Input and output analysis for Company D

INPUTS	OUTPUTS
Raw materials/auxiliary materials	**Products**
Chemical compounds	Polyethylene terephthalate (PET) resin
Packaging	**By-products**
Bulk bags	Water/distillate
Wooden pallets	Resin dust
Timber from containers	Process sludge
Cardboard	
Paper	**Waste**
Drums	**Recycled waste**
Labels	Bulk bags
Plastics (low density polyethylene (LDPE), polypropylene (PP))	Wooden pallets
	Timber from containers
Operating materials	Cardboard
Housekeeping disinfectants	Paper
Oils/lubricants	Drums
Repairs and maintenance materials	Metallic scrap
Office materials	Oils/lubricants
Laboratory materials	Plastics (LDPE, PP)
Caustic	
Nitrogen	**Hazardous waste to landfill**
Refrigerants	Process sludge
Compressed air	
	Waste water
Energy	Effluent
Externally produced electricity	
Steam	**Air emissions**
Methane rich gas	Burner stack emissions
Kerosene	Waste gas treatment scrubber emissions
Dowtherm thermal oil	Raw material/product storage tank vents and fugitive emissions
Water	
Municipal water	

3.1.2 Environmental information of the participating organizations within the Durban Chemicals Cluster

General environmental information of the four Durban Chemicals Cluster organizations obtained *via* a preliminary general questionnaire (Appendix 6) is tabulated below. All participating organizations had environmental management systems in place and embraced their environmental stewardship responsibilities.

Table 3.5 General environmental information of the participating organizations within the Durban Chemicals Cluster

Description	Company A	Company B	Company C	Company D
Annual income	R250-R500 million	R50-R100 million	R100-R250million	R500 million – R1 billion
Number of employees	51-100	151-200	51-100	151 - 200
Environmental policy	Yes	Yes	Yes	Yes
Environmental management system	Yes	Yes	Yes	Yes
ISO 14001 certification	Yes	Yes	In progress	No
Environmental audits	Yes	Yes	Yes	Yes
Annual environmental report publication	No	Yes	No	Yes
Environmental section in annual report	No	Yes	Yes	Yes
Environmental stewardship/manager	Yes	Yes	Yes	Yes
Compliance with environmental legislation	Yes	Yes	Yes	Yes
Environmental impact assessment done	Yes	Yes	Yes	Yes
Total organizational risk analysis done	Yes	Yes	Yes	Yes
Impact/risk assessments and/or hazard studies for new raw materials/products/projects/ modifications	Yes	Yes	Yes	Yes
Employee training with regard to risks and environmental issues	Yes	Yes	Yes	Yes

3.1.3 Environmental impact assessment of the participating organizations within the Durban Chemicals Cluster

The environmental impacts assessments of the four participating organizations within the Durban Chemicals Cluster; Companies A, B, C and D were consolidated into a single assessment (Appendix 11), as many of the impacts were similar across the organizations.

The four participating companies contribute to air pollution *via* the release of emissions, vapors and spillages thereby potentially impacting global warming and climate change, reducing fossil fuel resources and affecting the health of employees and the surrounding communities. Air pollution also occurs as a result of hazardous and non-hazardous dust creation and the dispersion of fine solids during operational activities. Groundwater pollution *via* chemical spillages and the contamination of effluent and stormwater *via* chemical and product spillages result in organic and inorganic compounds penetrating water ecosystems and degrading potable water resources.

Soil contamination occurs as a result of chemical spillages, hazardous and non-hazardous liquid, semi-solid and solid waste generation at the operational sites and leachate contamination at landfill sites resulting in surface and sub-soil contamination. The participating organizations contribute to the depletion of natural resources by consuming large quantities of potable water and non-renewable energy resources resulting in the release of greenhouse gases that contribute to global warming and climate change. Noise creation by the organizations within the DCC emanating from production equipment and activities poses a health hazard to employees and the neighboring communities. All four organizations recycle certain waste material such as containers and packaging resulting in some conservation of raw materials and energy and a reduction in landfill loading.

3.2 Internal environmental costs

The environmental management accounting system implemented in the participating organizations within the Durban Chemical Cluster were limited to internal, direct costs within the boundary of the organization and did not consider indirect or external costs as these costs were not quantified by the organizations. All costs and revenues excluded value added tax. There were several occurrences in the data where quantities and costs of certain categories in a month did not correlate to each other due to invoices that were received and captured in different months. Costs were not allocated to the different environmental media; i.e. air/climate, wastewater, waste, soil/groundwater, noise/vibration, biodiversity/landscape, radiation and other; as developed by the United Nations Division of Sustainable Development (2001). To do this would have introduced the complication of apportioning and allocating a single available cost such as internal personnel cost for general environmental management activities into various partial costs for the environmental media categories.

Analysis of variance (ANOVA) was performed for the cost categories, total environmental cost and environmental revenue of the four participating organizations using the Microsoft Excel®Analysis ToolPak.

3.2.1 Internal environmental costs of Company A

The environmental management accounting results detailing the environmental costs and revenue data of Company A for the calendar years 2012 and 2013 is outlined in Appendix 12. Table 3.6 and Table 3.7 are summaries of the environmental cost and revenue categories for each month for 2012 and 2013. Company A’s 2012 internal environmental costs amounted to R4 229 644 and the recycling of cardboard, plastic, paper, bulk bags, scrap metal, pallets and drums resulted in environmental revenue of R400 911. Environmental costs in 2013 decreased slightly to R3 956 949 and recycling initiatives realized an environmental revenue of R401 174. The four categories of environmental costs are presented graphically in Figures 20, 21, 22 and 23 for 2012 and 2013.

Table 3.6 Company A's monthly environmental costs for 2012

Company A	Monthly costs for 2012 in Rands														
Environmental cost category	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Mean	Standard deviation
Waste and emission treatment	132 979	154 250	142 205	129 741	130 848	188 164	175 449	167 456	118 010	140 038	185 419	118 587	1 783 146	148 596	25 036
Prevention and environmental management	82 015	98 000	79 425	92 224	95 344	107 631	179 266	190 594	130 146	86 448	91 370	78 600	1 311 063	109 255	38 113
Material purchase value of nonproduct output	0	0	291 943	0	23 812	64 840	50 991	355 233	150 959	27 849	3 297	0	968 924	80 744	122 152
Processing costs of nonproduct output	23 548	3 675	21 894	2 533	6 797	13 950	9 979	25 373	17 518	9 114	18 223	13 907	166 511	13 876	7 645
Total environmental expenditure	238 542	255 925	535 467	224 498	256 801	374 584	415 685	738 656	416 633	263 449	298 310	211 094	4 229 644	352 470	156 642
Environmental revenue	1 057	471	14 330	24 329	41 899	46 925	54 458	32 052	38 420	58 959	60 338	27 673	400 911	33 409	20 701

Table 3.7 Company A's monthly environmental costs for 2013

Company A	Monthly costs for 2013 in Rands														
Environmental cost category	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Mean	Standard deviation
Waste and emission treatment	135 248	132 487	125 094	142 965	163 709	122 870	150 859	124 375	158 915	139 617	84 016	186 400	1 666 555	138 880	25 509
Prevention and environmental management	140 362	96 044	105 165	79 223	69 225	161 091	93 475	87 820	93 965	128 572	81 875	384 260	1 521 077	126 756	85 476
Material purchase value of nonproduct output	0	6 635	74 362	448 913	28 038	15 957	0	14 689	0	362	0	0	588 956	49 080	127 724
Processing costs of nonproduct output	5 640	4 663	39 489	37 954	15 142	5 379	20 386	7 506	14 608	11 560	9 379	8 656	180 361	15 030	11 995
Total environmental expenditure	281 250	239 829	344 110	709 055	276 114	305 297	264 720	234 390	267 488	280 111	175 270	579 316	3 956 949	329 746	154 861
Environmental revenue	28 208	27 825	44 061	53 985	37 974	55 500	44 731	31 966	29 501	29 355	12 340	5 728	401 174	33 431	15 003

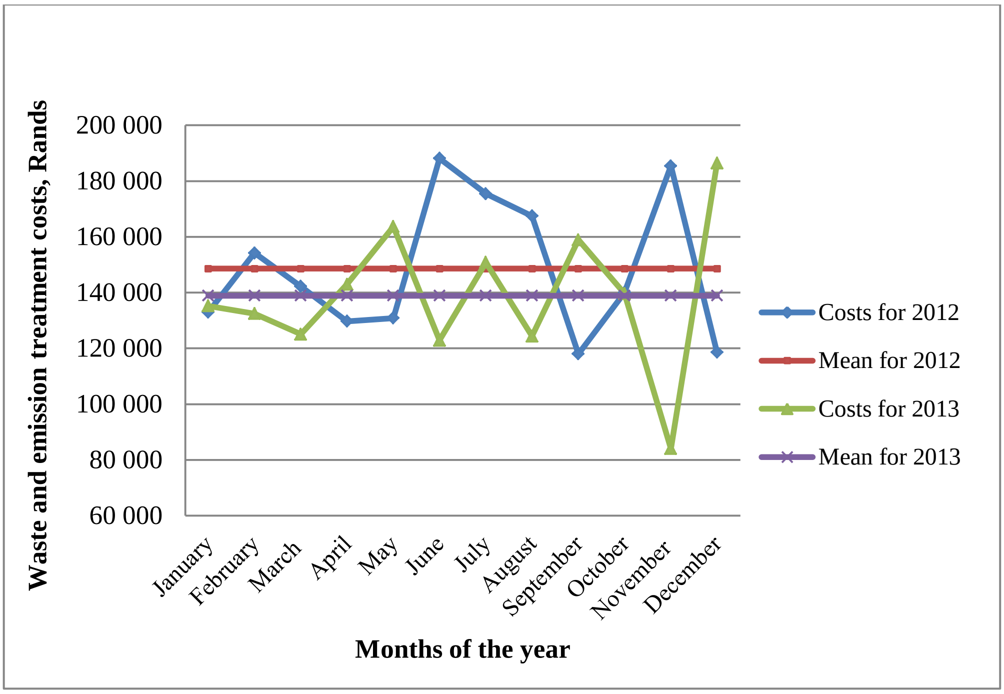


Figure 20: 2012 and 2013 waste and emission treatment costs for Company A

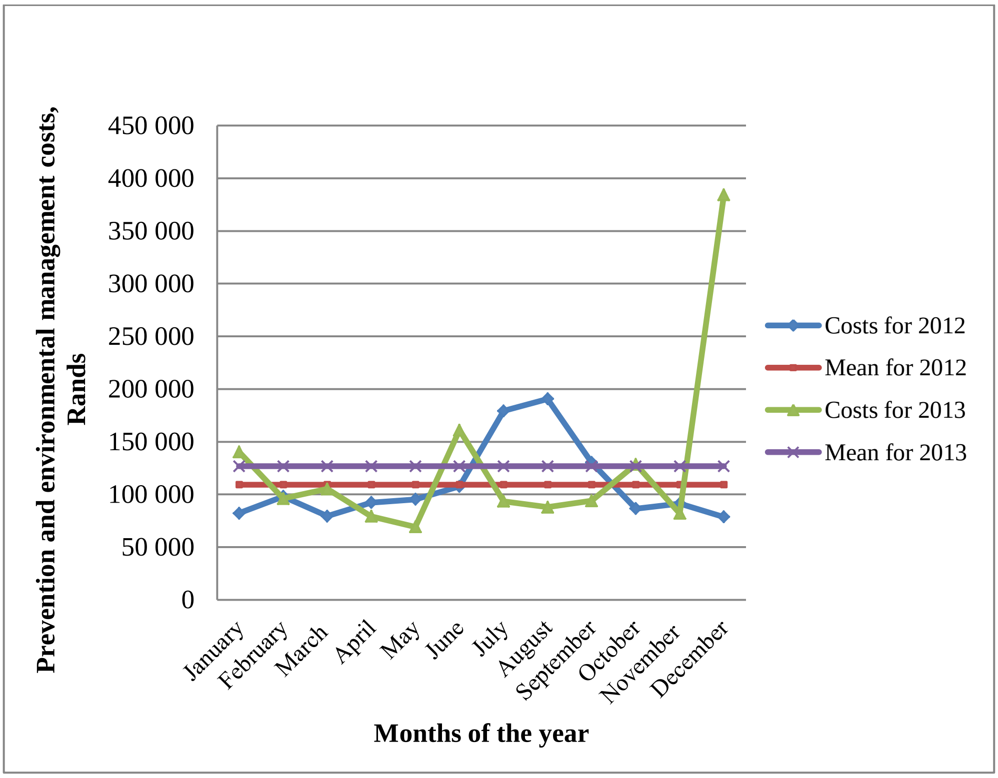


Figure 21: 2012 and 2013 prevention and environmental management costs for Company A

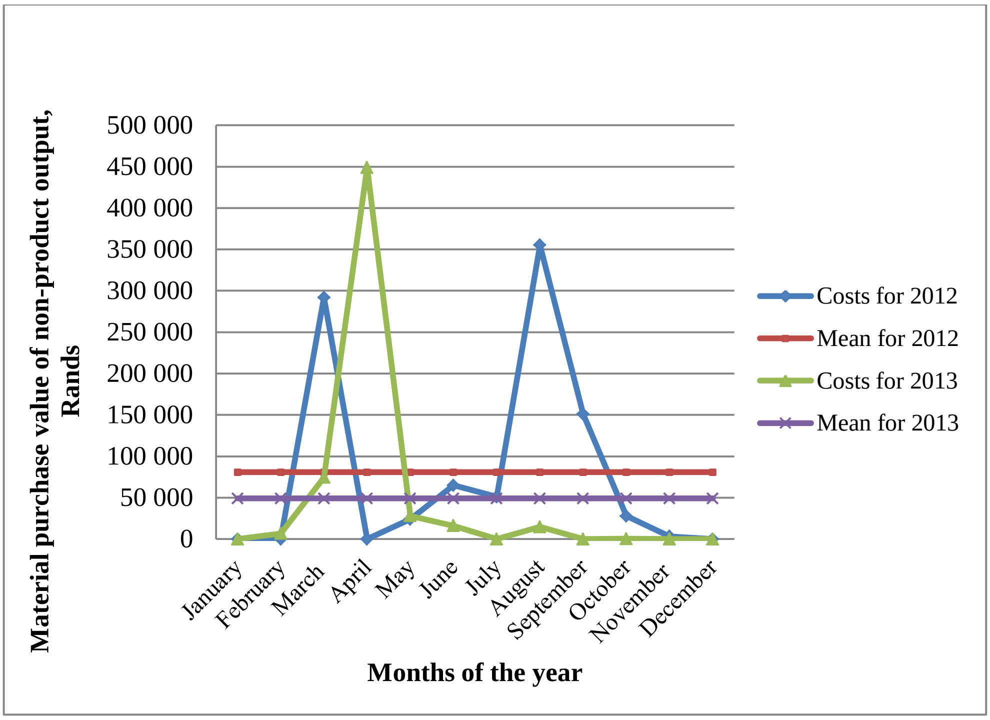


Figure 22: 2012 and 2013 material purchase value of non-product output for Company A

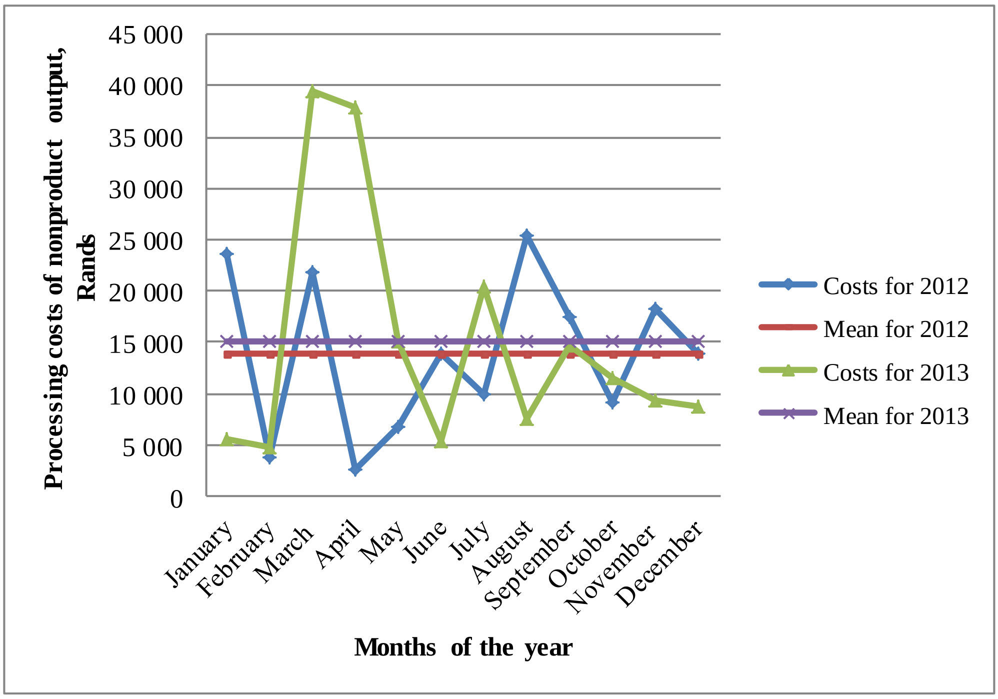


Figure 23: 2012 and 2013 processing costs of non-product output for Company A

Table 3.8 is a summary of Company A's cost and revenue categories as a percentage of the total environmental costs.

Table 3.8 Company A's cost and revenue categories as a percentage of the total environmental costs

Company A	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total environmental expenditure	2013 Percentage of total environmental expenditure
Waste and emission treatment	1 783 146	1 666 555	42.16	42.12
Prevention and environmental management	1 311 063	1 521 077	31.00	38.44
Material purchase value of nonproduct output	968 924	588 956	22.91	14.88
Processing costs of nonproduct output	166 511	180 361	3.94	4.56
Total environmental expenditure	4 229 644	3 956 949		
Environmental revenue	400 911	401 174	9.48	10.14

3.2.1.1 Company A's waste and emission costs

Table 3.9 Subcategories of the waste and emission treatment costs

Company A	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total waste and emission treatment costs	2013 Percentage of total waste and emission treatment costs
Waste and emission treatment:	**1 783 146**	**1 666 555**		
Depreciation for related equipment	4 270	7 320	0.24	0.44
Maintenance and operating materials and services	57 526	72 200	3.23	4.33
Related personnel	25 330	24 480	1.42	1.47
Fees, taxes, charges	1 664 940	1 528 187	93.37	91.70
Fines and penalties	0	0	0.00	0.00
Insurance	31 080	34 368	1.74	2.06
Provisions for clean up costs, remediation	0	0	0.00	0.00

Table 3.10 Breakdown of fees, taxes and charges incorporated in waste and emission treatment costs

Company A	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total fees, taxes and charges	2013 Percentage of total fees, taxes and charges
Fees, taxes, charges:	**1 664 940**	**1 528 187**		
Trade effluent charges	175 366	145 074	10.53	9.49
Hazardous waste collection, transportation and disposal charges	1 489 574	1 383 113	89.47	90.51

Waste and emission treatment costs in 2012 and 2013 amounted to 42.16% and 42.12% respectively of the total environmental costs with fees, taxes and charges comprising 93.37% and 91.70% respectively of this cost. Fees, taxes and charges were incurred for the disposal of waste water to municipality waste water treatment works and the disposal of hazardous and non-hazardous waste to landfill sites. Effluent charges consisted of 10.53% and 9.49% of these costs and hazardous waste collection, transportation and disposal charges 89.47% and 90.51% of the fees, taxes and charges costs for 2012 and 2013 respectively. Hazardous general waste included contaminated packaging as well as hazardous liquid waste such as resin, sludge distillate and caustic. Hazardous waste disposal comprised 83.54% of 2012's and 82.99% of 2013's waste and emission charges at R1 489 574 and R1 383 113 respectively. Maintenance and operating materials and services accounted for 3.23% and 4.33% of the waste and emission treatment costs for 2012 and 2013 at R57 526 and R72 200 respectively. Depreciation, personnel costs and insurance had a negligible influence over the total waste and emission treatment costs. There were no fines or penalties for non-compliance for air emissions and effluent quality that was paid by the organization to the local municipality as these penalties for non-compliance to environmental legislature has not yet been implemented by the South African government.

3.2.1.2 Company A's prevention and environmental management costs

Table 3.11 Subcategories of the prevention and environmental management costs

Company A	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total prevention and environmental management costs	2013 Percentage of total prevention and environmental management costs
Prevention and environmental management:	**1 311 063**	**1 521 077**		
External services for environmental management	560 115	541 642	42.72	35.61
Costs of internal personnel for general environmental management activities	611 200	669 600	46.62	44.02
Research and development	0	0	0.00	0.00
Extra expenditure for cleaner technologies	109 748	279 835	8.37	18.40
Other environmental management costs	30 000	30 000	2.29	1.97

Prevention and environmental management costs made up 31.00% of the total environmental costs for 2012 and 38.44% of the total environmental costs for 2013. Costs of internal personnel for general environmental management activities accounted for the majority of these costs, at 46.62% and 44.02% for 2012 and 2013 respectively. Company A spent 42.72% of the costs in the prevention and environmental management category in 2012 which equates to R560 115 and 35.61% or R541 642 in 2013 on groundwater remediation and product abstraction and emission analysis. Whilst there was money spent on cleaner technology such as improved ventilation systems, improved energy efficiency and effluent dosing systems during 2012 and 2013; no focus was placed on environmental related research and development. R30 000 per annum was spent in 2012 and 2013 on internal printing costs for environmental reports and communication that was recorded under the 'other environmental management costs' sub-category.

3.2.1.3 Company A's material purchase value of non-product output

Table 3.12 Subcategories of the material purchase value of non-product output costs

Company A	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total material purchase value of nonproduct output	2013 Percentage of total material purchase value of nonproduct output
Material purchase value of nonproduct output:	**968 924**	**588 956**		
Raw materials including packaging	921 176	567 657	95.07	96.38
Operating materials	23 877	10 897	2.46	1.85
Energy	23 383	10 094	2.41	1.71
Water	487	308	0.05	0.05

Material purchase value of non-product output consisted of 22.91% of the total environmental costs for 2012 and 14.88% of the total environmental costs for 2013. 95.07% of these costs comprised of wasted raw materials and wasted packaging, translating to R921 176 in 2012 and 96.38% or R567 657 in 2013 due to a reduction in process inefficiencies in 2013. Operating materials, energy and water costs equated to 4.92% and 3.61% of the total material purchase value of non-product output costs for 2012 and 2013 respectively.

3.2.1.4 Company A's processing costs of non-product output

Table 3.13 Subcategories of the processing costs of non-product output costs

Company A	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total processing costs of nonproduct output	2013 Percentage of total processing costs of nonproduct output
Processing costs of nonproduct output:	**166 511**	**180 361**		
Labour costs for discarded product (salaries,wages,contractors)	54 592	33 529	32.79	18.59
Labour costs for reworked out of specification product	111 919	146 832	67.21	81.41

Processing costs of non-product output that comprised of the wasted personnel costs to produce and discard non-product output and to rework out of specification product back into production, accounted for 3.94% of the total environmental costs for 2012 and 4.56% of the total environmental costs for 2013. 67.21% and 81.41% of these costs in 2012 and 2013 were due to the reworking of out of specification product that equated to R111 919 in 2012 and R146 832 in 2013.

3.2.1.5 Company A’s relative environmental costs

Company A’s environmental costs in relation to total production cost is shown in Table 3.14. Environmental costs comprised of 0.524% of total production costs in 2012 and 0.004% of total production costs in 2013; which, whilst a relatively small percentage of total production costs, in monetary terms this percentage equated to R4 229 664 and R3 956 949 respectively.

Table 3.14 Relative environmental costs

Company A	**2012 Annual cost, Rands**	**2013 Annual cost, Rands**
Total production costs	807 947 740	888 969 506
Total environmental costs	4 229 644	3 956 949
Environmental costs as a percentage of production costs	0.524	0.004

3.2.1.6 Company A’s environmental key performance indicators

Company A recorded and monitored environmental aspects and indicators such as raw material usage, direct energy consumption, total site wide water consumption, effluent discharged to municipality and solid waste disposal as recommended by the GRI sustainability reporting system (GRI, 2002). However environmental costs that contributed significantly to the external environmental cost of society such as effluent costs, hazardous waste costs, destructed material costs and reworked material costs were not compressed into key environmental performance indicators that could be measured, monitored and improved upon.

Table 3.15 presents the calculation for the cost of the key performance indicators for Company A relative to a kilogram of product manufactured.

Table 3.15 Recommended key environmental performance indicators for Company A

Company A key environmental performance indicators	2012 costs in Rands/kg of product	2013 costs in Rands/kg of product	Mean (Projected 2014 cost in Rands/kg of product)	Standard deviation
Total production volume (kg)	27 333 623	25 509 516		
Effluent	0.64	0.57	0.61	0.05
Hazardous waste	5.45	5.42	5.44	0.02
Destructed material	3.64	2.08	2.86	1.11
Reworked product	0.61	0.71	0.66	0.07

The cost of each recommended key environmental performance indicator was divided by the annual production volume and multiplied by 100 to obtain the costs of the effluent discarded, hazardous waste disposed, non-product material discarded (destructed material) and the cost of reworking non-standard product for each kilogram of product manufactured. Due to variances in production performances and activities, the cost of effluent, hazardous waste and destructed material decreased from 2012 to 2013. Therefore it is inconsistent to utilize the consumer price index and inflation figures to determine the cost of these factors for 2014. The use of the average costs of these indicators for 2012 and 2013 are however effective indicators of the projected or budgets cost for 2014 for these environmental performance indicators.

3.2.2 Internal environmental costs of Company B

The environmental management accounting results detailing the environmental costs and revenue data for Company B for the calendar years 2012 and 2013 is outlined in Appendix 13. The environmental cost and revenue categories for each month for 2012 and 2013 are summarized in Tables 3.16 and 3.17. Company B spent R18 263 783 on internal environmental costs in 2012 and R9 086 973 in 2013 whilst receiving R114 214 in 2012 and R250 470 in 2013 for the recycling of cardboard, plastic, paper, bulk bags, scrap metal, pallets and drums. Even through the utilisation of graphical trends to display the categories of environmental costs for 2012 and 2013 as presented in Figures 24, 25, 26 and 27; it was difficult to determine whether certain costs were incurred during certain periods of the year; for example, whilst waste and emission treatment costs were high during the summer months between November to March 2012, these costs were low during the same months of 2013.

Table 3.16 Company B's monthly environmental costs for 2012

Company B	Monthly costs fior 2012 in Rands														
Environmental cost category	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Mean	Standard deviation
Waste and emission treatment	434 323	1 095 953	1 071 343	368 083	556 363	537 223	344 323	512 363	428 063	588 283	945 666	932 770	7 814 750	651 229	279 072
Prevention and environmental management	380 464	341 459	324 903	327 099	348 699	346 397	364 541	325 260	335 482	336 367	6 064 477	326 575	9 821 722	818 477	1 652 148
Material purchase value of nonproduct output	0	0	31 316	0	0	19 488	0	8 235	9 162	194 570	123 159	186 164	572 094	47 674	75 028
Processing costs of nonproduct output	5	4	2 448	3	0	1 714	0	775	834	18 688	12 158	18 588	55 217	4 601	7 378
Total environmental expenditure	814 791	1 437 416	1 430 010	695 184	905 062	904 821	708 864	846 632	773 540	1 137 908	7 145 459	1 464 097	18 263 783	1 521 982	1 794 248
Environmental revenue	13 685	7 522	10 745	4 435	3 800	9 733	11 200	4 815	759	654	17 104	29 762	114 214	9 518	8 141

Table 3.17 Company B's monthly environmental costs for 2013

Company B	Monthly costs fior 2013 in Rands														
Environmental cost category	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Mean	Standard deviation
Waste and emission treatment	426 703	323 014	424 462	334 875	351 412	348 967	357 710	552 116	386 684	656 655	410 473	426 364	4 999 433	416 619	97 660
Prevention and environmental management	327 984	327 460	369 377	327 610	333 916	332 850	351 691	327 930	327 430	341 055	329 755	358 114	4 055 173	337 931	14 237
Material purchase value of nonproduct output	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Processing costs of nonproduct output	8	12	4	3	6	3	4	0	29 703	2 624	0	0	32 367	2 697	8 538
Total environmental expenditure	754 695	650 486	793 844	662 488	685 334	681 820	709 405	880 046	743 817	1 000 334	740 228	784 478	9 086 973	757 248	100 116
Environmental revenue	35 375	28 875	21 030	16 665	13 710	0	22 520	25 490	21 735	25 565	14 820	24 685	250 470	20 873	8 929

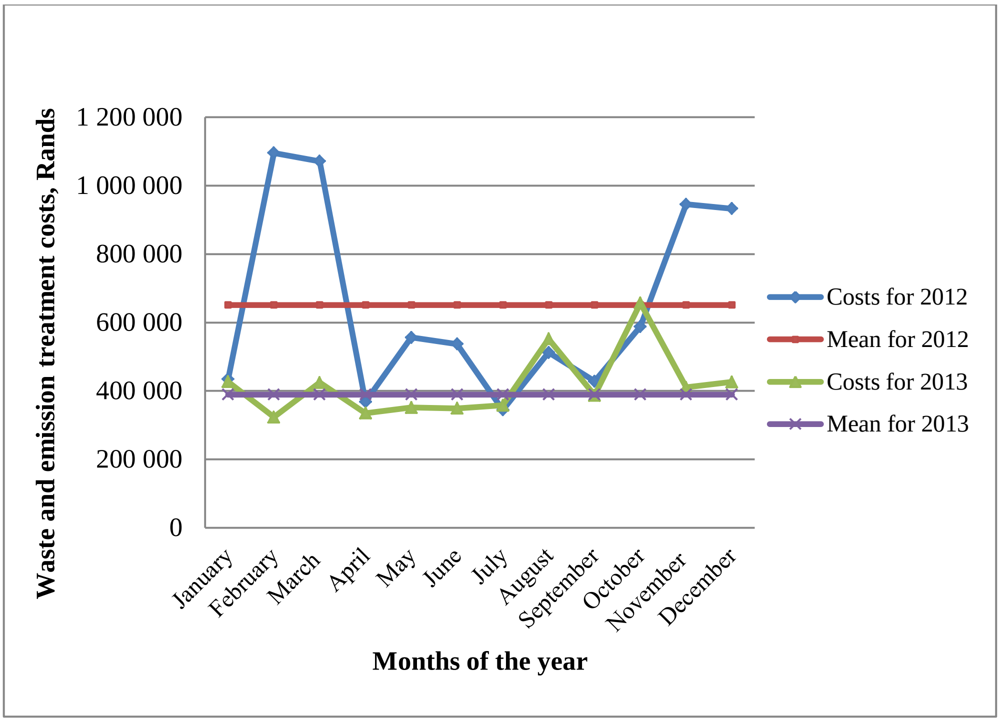


Figure 24: 2012 and 2013 waste and emission treatment costs for Company B

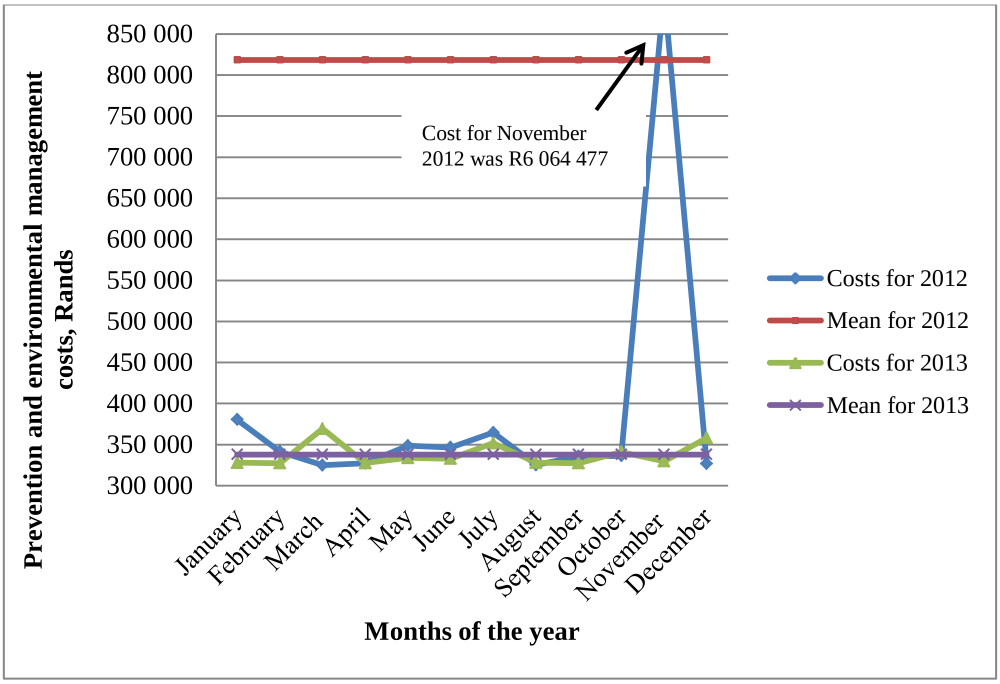


Figure 25: 2012 and 2013 prevention and environmental management costs for Company B

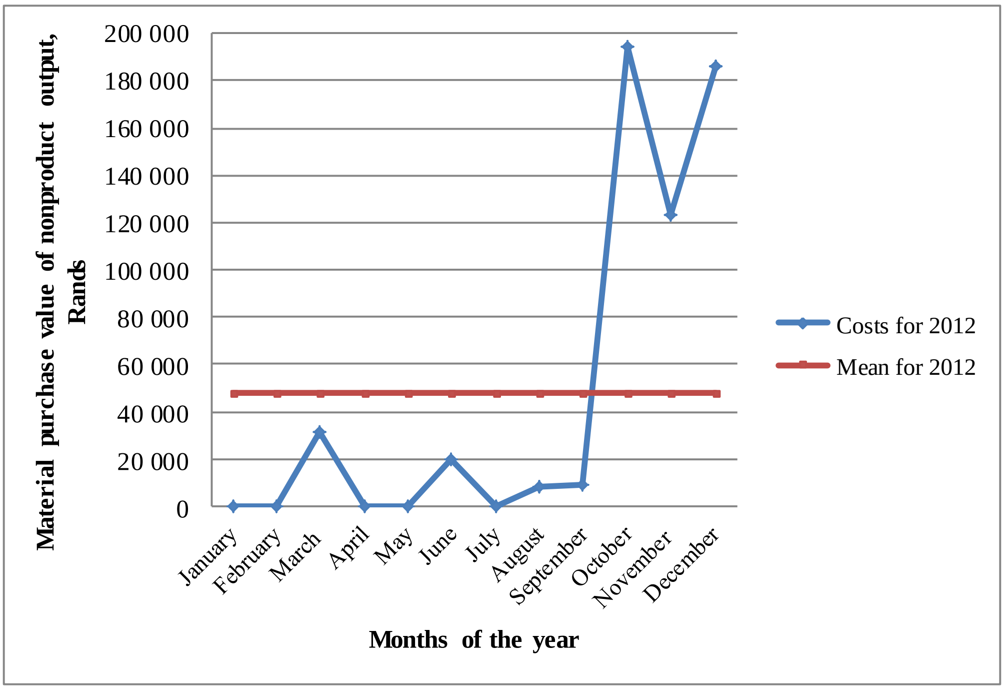


Figure 26: 2012 material purchase value of non-product output for Company B

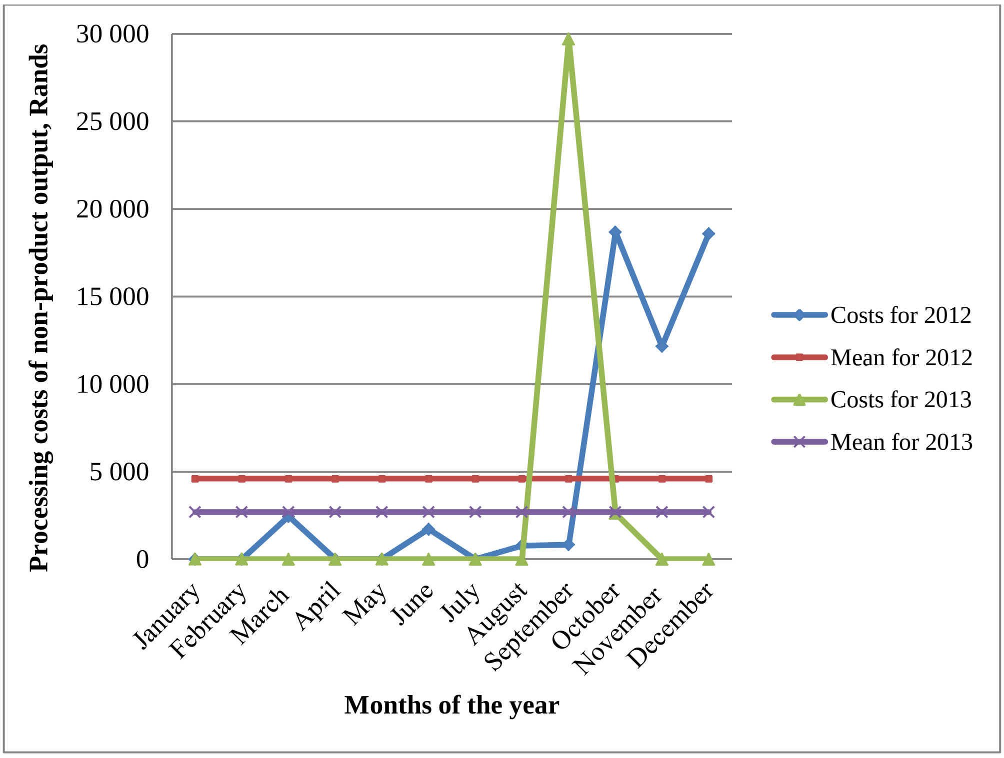


Figure 27: 2012 and 2013 processing costs of non-product output for Company B

A summary of the cost and revenue categories as a percentage of the total environmental costs is depicted in Table 3.18 below.

Table 3.18 Company B's cost and revenue categories as a percentage of the total environmental costs

Company B	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total environmental expenditure	2013 Percentage of total environmental expenditure
Waste and emission treatment	7 814 750	4 999 433	42.79	55.02
Prevention and environmental management	9 821 722	4 055 173	53.78	44.63
Material purchase value of nonproduct output	572 094	0	3.13	0.00
Processing costs of nonproduct output	55 217	32 367	0.30	0.36
Total environmental expenditure	18 263 783	9 086 973		
Environmental revenue	114 214	250 470	0.63	2.76

3.2.2.1 Company B's waste and emission costs

Table 3.19 Subcategories of waste and emission treatment costs

Company B	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total waste and emission treatment costs	2013 Percentage of total waste and emission treatment costs
Waste and emission treatment:	**7 814 750**	**4 999 433**		
Depreciation for related equipment	930 967	1 007 880	11.91	20.16
Maintenance and operating materials and services	689 704	395 266	8.83	7.91
Related personnel	862 593	884 530	11.04	17.69
Fees, taxes, charges	3 261 486	984 479	41.74	19.69
Insurance	2 070 000	1 727 279	26.49	34.55

Table 3.20 Breakdown of the fees, taxes and charges encompassed in waste and emission treatment costs

Company B	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total fees, taxes and charges	2013 Percentage of total fees, taxes and charges
Fees, taxes, charges:	**3 261 486**	**984 479**		
Incineration charges	2 977 676	837 065	91.30	85.03
Cost of transporting hazardous waste to incinerators	142 560	111 882	4.37	11.36
General non-hazardous waste collection, transportation and disposal charges	141 250	35 532	4.33	3.61

Waste and emission treatment costs consisted of 42.79% of 2012 environmental costs or R7 814 750 and 55.02% of 2013 environmental costs or R4 999 433. Company B incinerated its hazardous waste and the incineration costs including transportation to the incinerating company amounted to 39.93% of the total waste and emission costs and 95.67% (91.30% + 4.37%) of the fees, taxes and charges costs for 2012. Company B's hazardous waste incineration costs decreased to 18.98% of the waste and emission costs for 2013, a reduction in cost of R2 171 289. This was due to redundant stock from 2011 that was incinerated in 2012, increased processing in 2012 due to increased holding time at the incineration company and the incineration company not being operational for about four months in 2013 due to a fire that was experienced at their site.

Depreciation for the waste water recovery plant and scrubber contributed to 11.91% and 20.16% of the total waste and emission treatment costs of 2012 and 2013 respectively. Maintenance and operating materials and services accounted for 8.83% and 7.91% of the waste and emission treatment costs for 2012 and 2013 respectively. Personnel costs for waste and emission treatment costs amounted to an average cost of R870 000 per annum. Total insurance for Company B amounted to 26.49% and 34.55% of the 2012 and 2013 waste and emission treatment cost at R2 070 000 and R1 727 279 respectively.

3.2.2.2 Company B's prevention and environmental management costs

Table 3.21 Subcategories of the prevention and environmental management costs

Company B	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total prevention and environmental management costs	2013 Percentage of total prevention and environmental management costs
Prevention and environmental management:	**9 821 722**	**4 055 173**		
External services for environmental management	52 100	0	0.53	0.00
Costs of internal personnel for general environmental management activities	1 080 000	951 600	11.00	23.47
Research and development	2 809 000	2 935 140	28.60	72.38
Extra expenditure for cleaner technologies	5 753 000	0	58.57	0.00
Other environmental management costs	127 622	168 433	1.30	4.15

Prevention and environmental management costs made up 53.78% of the total environmental costs for 2012 and 44.63% of the total environmental costs for 2013. In 2012 Company B spent R8 562 000 on a new scrubber plant (R5 753 000) as well as environmental research and development (R2 809 000) which consisted of 87.17% of the total prevention and environmental management costs. Whilst no environmentally beneficially projects were undertaken in 2013, Company B spent R2 935 140 on research and development that accounted for 72.38% of the total prevention and environmental management costs for 2013. R52 100 was spent in 2012 for external consultants to perform the baseline emission monitoring required for the application of the atmospheric emissions license. Other environmental management costs of R127 622 in 2012 and R168 433 in 2013 were incurred due to sponsoring of environmental community projects.

3.2.2.3 Company B's material purchase value of non-product output

Table 3.22 Subcategories of the material purchase value of non-product output

Company B	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total material purchase value of nonproduct output	2013 Percentage of total material purchase value of nonproduct output
Material purchase value of nonproduct output:	**572 094**	**0**		
Raw materials including packaging	564 007	0	98.59	0.00
Operating materials	678	0	0.12	0.00
Energy	6 731	0	1.18	0.00
Water	677	0	0.12	0.00

Material purchase value of non-product output consisted of 3.13% of the total environmental costs for 2012 and there was no discarded out of specification products for 2013. 98.59% of these costs consisted of wasted raw materials and wasted packaging for 2012, translating to R564 007. Operating materials, energy and water costs were negligible at R8 086.

3.2.2.4 Company B's processing costs of non-product output

Table 3.23 Subcategories of the processing costs of non-product output

Company B	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total processing costs of nonproduct output	2013 Percentage of total processing costs of nonproduct output
Processing costs of nonproduct output:	**55 217**	**32 367**		
Labour costs for discarded product (salaries,wages,contractors)	55 175	0	99.92	0.00
Labour costs for reworked out of specification product	42	32 367	0.08	100.00

Processing costs of non-product output made up 0.30% of the total environmental costs for 2012 and 0.36% of the total environmental costs for 2013 at R55 217 and R32 367 respectively.

3.2.2.5 Company B's relative environmental costs

Company B's environmental costs in relation to total production cost is presented in Table 3.24. Environmental costs consisted of 8.69% of total production costs in 2012 and 4.46% of total production costs for 2013 equating to R18 263 783 and R9 086 973 in 2012 and 2013 respectively.

Table 3.24 Relative environmental costs

Company B	2012 Annual cost, Rands	2013 Annual cost, Rands
Total production costs	210 080 618	203 924 173
Total environmental costs	18 263 783	9 086 973
Environmental costs as a percentage of production costs	8.69	4.46

3.2.2.6 Company B's environmental key performance indicators

As recommended by the GRI sustainability reporting system (GRI, 2002) environmental aspects that have large financial impacts such as raw materials, energy and water and hazardous waste costs were accounted for by Company B. However, key environmental costs that contributed considerably to the external environmental costs of society were not condensed into key environmental performance indicators that were recorded and examined for optimization opportunities. The water in the effluent produced by Company B is recovered by an onsite water recovery plant in which the boiling off of effluent produces a distillate that is re-used in the manufacturing process. The remaining semi-solid sludge or hazardous waste was transported by road to an incineration company in Gauteng for incineration. The use of environmental performance indicators such as incineration costs of hazardous waste, destructed material cost and reworked material cost are recommended for Company B. These costs are divided by the annual production volumes to obtain the cost of each indicator per kilogram of product manufactured.

Table 3.25 displays the calculation for the cost of the key performance indicators for Company B relative to a kilogram of product produced.

Table 3.25 Recommended key performance indicators for Company B

Company B key environmental performance indicators	2012 costs in Rands/kg of product	2013 costs in Rands/kg of product	Mean (Projected 2014 cost in Rands/kg of product)	Standard deviation
Total production volume (kg)	17 934 206	16 801 053		
Effluent	0	0	0	
Incineration of hazardous waste	17.40	5.65	11.52	8.31
Destructed material	5.41	0.00	2.70	3.82
Reworked product	3.69	1.89	2.79	1.27

Due to variances in production performances and incineration activities, the cost of hazardous waste incineration, destructed material and reworked product decreased from 2012 to 2013. The utilization of the average costs for 2012 and 2013 however provides a good indication of projected or budgets costs for 2014 for these environmental performance indicators.

3.2.3 Internal environmental costs of Company C

The environmental management accounting results detailing the environmental costs and revenue data for Company C for the calendar years 2012 and 2013 is outlined in Appendix 14. Tables 3.26 and Table 3.27 are a summary of the environmental cost and revenue categories for each month for 2012 and 2013. R2 088 572 was spent by Company C on internal environmental costs in 2012 and R1 080 142 in 2013. Environmental revenue from the sale of scrap metal and steel amounted to R28 960 in 2012 and decreased to R10 022 in 2013. Graphical representations of the cost categories as presented in Figures 28, 29 and 30 provide no cost recurrences due to seasonal aspects.

Table 3.26 Company C's monthly environmental costs for 2012

Company C	Monthly costs for 2012 in Rands													
Environmental cost category	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Mean	Standard deviation
Waste and emission treatment	59 070	75 754	61 763	65 863	58 774	66 638	56 655	62 365	69 841	63 198	82 577	60 968	783 466	65 289	7 574
Prevention and environmental management	11 395	19 395	12 895	81 452	8 895	32 866	18 143	474 482	283 793	243 671	72 396	9 950	1 269 333	105 778	149 215
Material purchase value of nonproduct output	3 965	0	0	0	0	0	0	0	0	0	0	0	3 965	330	1 145
Processing costs of nonproduct output	4 474	3 544	5 076	0	0	5 224	2 699	4 298	0	4 526	1 966	0	31 807	2 651	2 162
Total environmental expenditure	78 905	98 693	79 734	147 315	67 669	104 728	77 497	541 145	353 634	311 395	156 939	70 918	2 088 572	174 048	149 723
Environmental revenue	11 488	1 440	0	0	3 200	0	5 600	0	2 048	3 584	0	1 600	28 960	2 413	3 376

Table 3.27 Company C's monthly environmental costs for 2013

Company C	Monthly costs for 2013 in Rands														
Environmental cost category	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Mean	Standard deviation
Waste and emission treatment	67 975	71 821	76 079	72 599	68 340	84 570	75 990	81 672	69 720	75 129	73 824	73 137	890 856	74 238	4 987
Prevention and environmental management	9 883	51 789	12 113	9 883	9 883	9 883	14 343	9 883	13 338	9 883	11 418	9 883	172 182	14 349	11 893
Material purchase value of nonproduct output	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Processing costs of nonproduct output	12 890	148	330	413	292	2 736	296	0	0	0	0	0	17 104	1 425	3 690
Total environmental expenditure	90 748	123 758	88 522	82 895	78 515	97 189	90 629	91 555	83 058	85 012	85 242	83 020	1 080 142	90 012	11 769
Environmental revenue	0	3 136	0	0	0	0	0	0	2 736	4 150	0	0	10 022	835	1 543

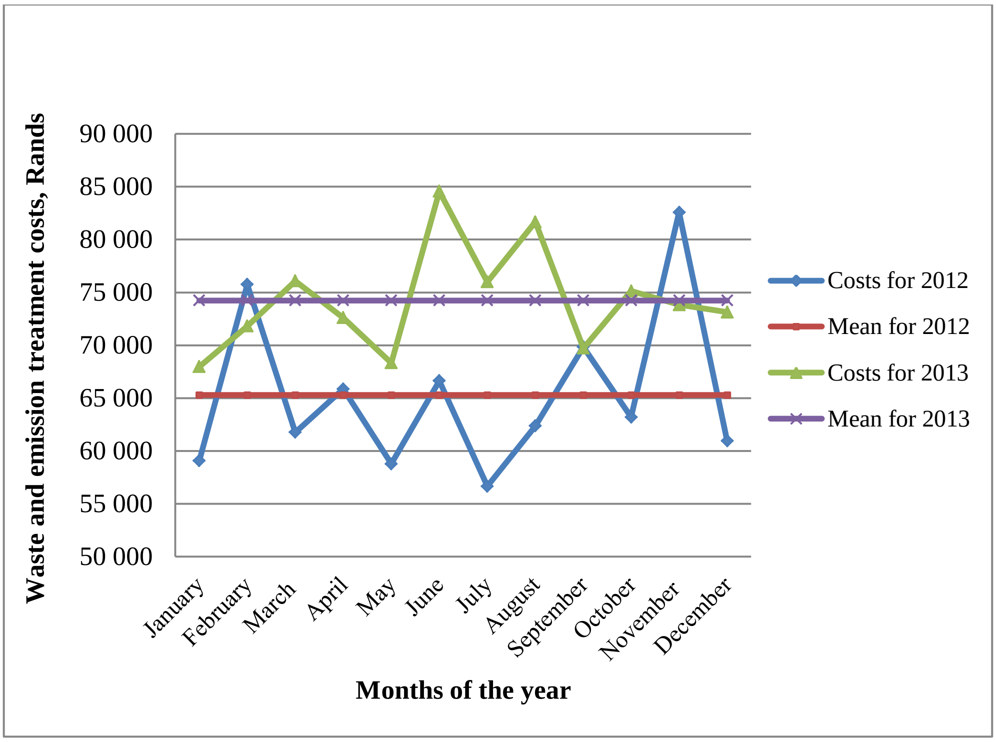


Figure 28: 2012 and 2013 waste and emission treatment costs for Company C

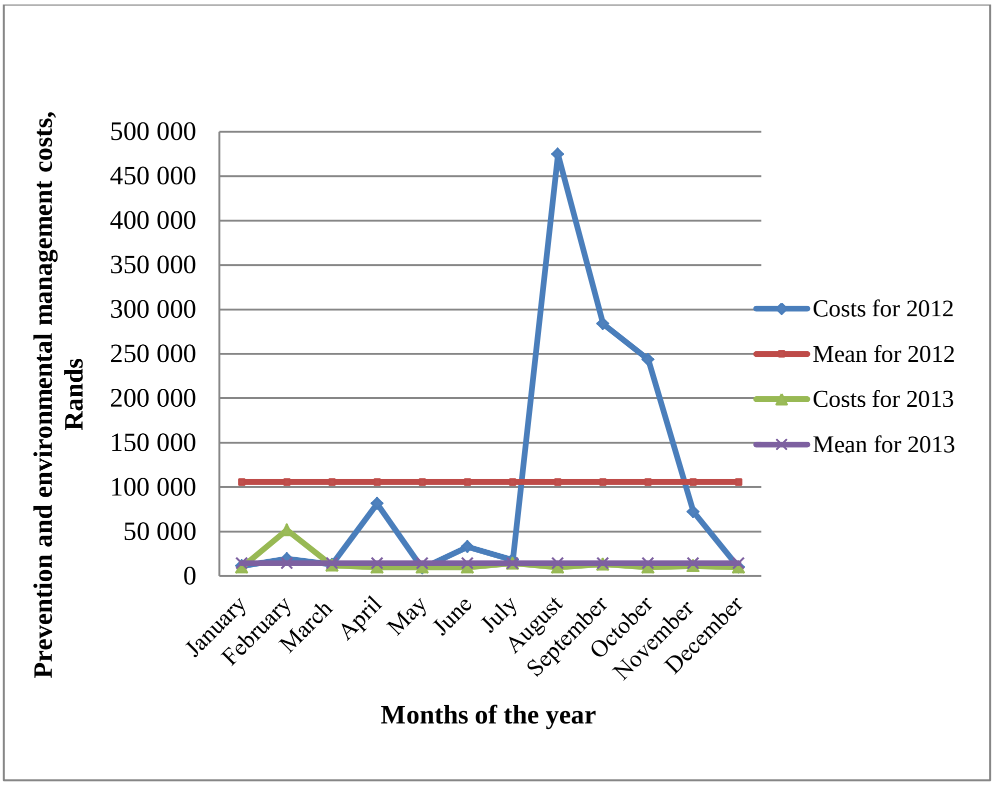


Figure 29: 2012 and 2013 prevention and environmental management costs for Company C

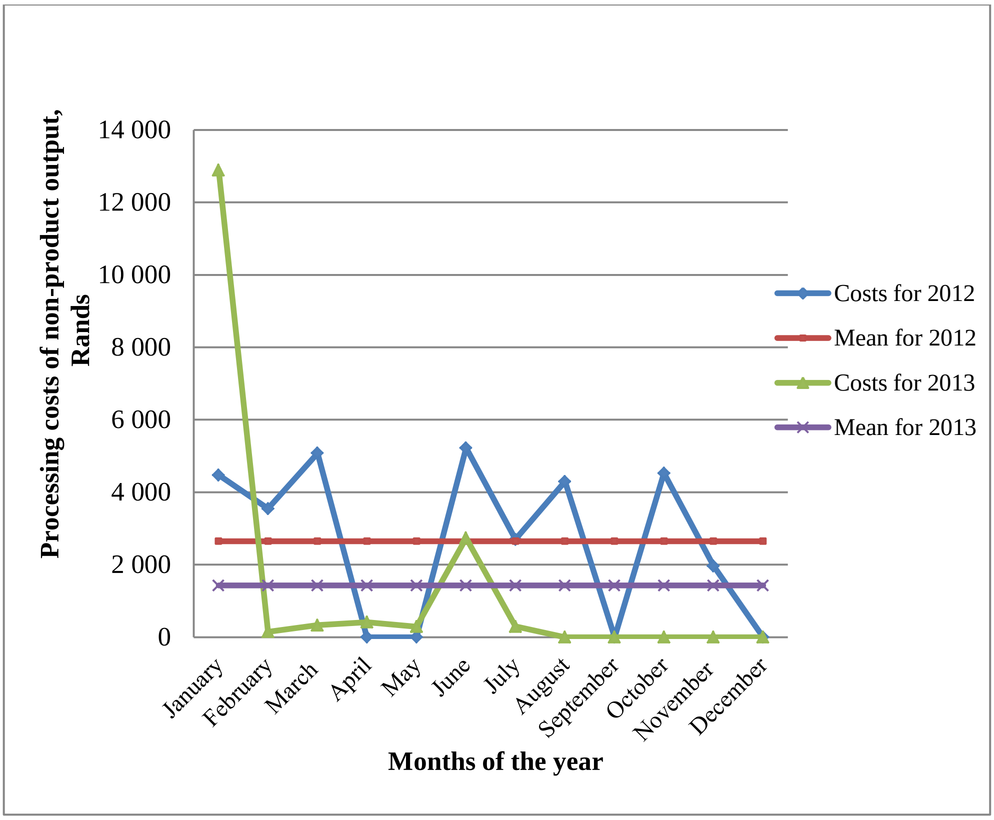


Figure 30: 2012 and 2013 processing costs of non-product output for Company C

Table 3.28 is a summary of Company C's cost and revenue categories as a percentage of the total environmental costs.

Table 3.28 Company C's cost and revenue categories as a percentage of the total environmental costs

Company C	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total environmental expenditure	2013 Percentage of total environmental expenditure
Waste and emission treatment	783 466	890 856	37.51	82.48
Prevention and environmental management	1 269 333	172 182	60.78	15.94
Material purchase value of nonproduct output	3 965	0	0.19	0.00
Processing costs of nonproduct output	31 807	17 104	1.52	1.58
Total environmental expenditure	2 088 572	1 080 142		
Environmental revenue	28 960	10 022	1.39	0.93

3.2.3.1 Company C's waste and emission costs

Table 3.29 Subcategories of the waste and emission treatment costs

Company C	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total waste and emission treatment costs	2013 Percentage of total waste and emission treatment costs
Waste and emission treatment:	**783 466**	**890 856**		
Depreciation for related equipment	21 578	107 257	2.75	12.04
Maintenance and operating materials and services	38 850	29 400	4.96	3.30
Related personnel	163 464	181 632	20.86	20.39
Fees, taxes, charges	175 034	166 403	22.34	18.68
Insurance	384 540	406 164	49.08	45.59

Table 3.30 Breakdown of the fees, taxes and charges incorporated in waste and emission treatment costs

Company C	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total fees, taxes and charges	2013 Percentage of total fees, taxes and charges
Fees, taxes, charges:	**175 034**	**166 403**		
Effluent charges	71 670	71 688	40.95	43.08
Hazardous waste collection, transportation and disposal charges	98 430	94 715	56.23	56.92
Non-hazardous/General waste collection, transportation and disposal charges	4 934	0	2.82	0.00

37.51% or R783 466 of the total environmental costs for 2012 consisted of waste and emission treatment costs and 82.48% or R890 856 of 2013 environmental costs was made up of waste and emission treatment costs. Insurance costs accounted for 49.08% and 45.59% of the waste and emission treatment costs for 2012 and 2013 respectively. Costs for the disposal of effluent to the municipality's waste water treatment facilities and hazardous waste disposal costs consisted of 22.34% of the waste and emission treatment costs for 2012 and 18.68% for 2013. The cost of personnel involved in waste and emission treatment activities accounted for 20.86% and 20.39% of the waste and emission treatment costs for 2012 and 2013 respectively. Operating material in the form of caustic usage for the effluent plant and scrubber were minimal at R38 850 for 2012 and R29 400 for 2013.

3.2.3.2 Company C's prevention and environmental management costs

Table 3.31 Subcategories of the prevention and environmental management costs

Company C	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total prevention and environmental management costs	2013 Percentage of total prevention and environmental management costs
Prevention and environmental management:	**1 269 333**	**172 182**		
External services for environmental management	49 936	11 680	3.93	6.78
Costs of internal personnel for general environmental management activities	106 740	118 596	8.41	68.88
Research and development	0	0	0.00	0.00
Extra expenditure for cleaner technologies	1 112 657	41 906	87.66	24.34
Other environmental management costs	0	0	0.00	0.00

Prevention and environmental management costs consisted of 60.78% of the total environmental costs for 2012 at R1 269 333 and 15.94% of the total environmental costs for 2013 at R172 182. Company C's 2012 capital expenditure on environmental projects consisted of R480 838 on the installation of three new scrubbers and R600 770 on bunding of the product tanks and skip storage compliance for the stores expansion. Only R41 906 was spent in 2013 for cleaner technology activities, accounting for the 63.32% decrease in these costs from 2012 to 2013.

3.2.3.3 Company C's material purchase value of non-product output

Table 3.32 Subcategories of the material purchase value of non-product output

Company C	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total material purchase value of nonproduct output	2013 Percentage of total material purchase value of nonproduct output
Material purchase value of nonproduct output:	**3 965**	**0**		
Raw materials including packaging	3 773	0	95.14	0.00
Operating materials	89	0	2.24	0.00
Energy	98	0	2.46	0.00
Water	6	0	0.16	0.00

Material purchase value of non-product output was negligible and made up 0.19% or R3 965 of the total environmental costs for 2012. There were no discarded products in 2013.

3.2.3.4 Company C's processing costs of non-product output

Table 3.33 Subcategories of the processing costs of non-product output

Company C	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total processing costs of nonproduct output	2013 Percentage of total processing costs of nonproduct output
Processing costs of nonproduct output:	**31 807**	**17 104**		
Labour costs for discarded product (salaries,wages,contractors)	575	0	1.81	0.00
Labour costs for reworked out of specification product	31 232	17 104	98.19	100.00

Processing costs of non-product output made up 1.52% of the total environmental costs for 2012 and 1.58% of the total environmental costs for 2013 at R31 807 and R17 104 respectively, consisting primarily of the blending of out of specification product into product batches.

3.2.3.5 Company C's relative environmental costs

Company C's environmental costs in relation to total production cost is presented in Table 3.34. Environmental costs consisted of 2.44% of total production costs in 2012 and decreased by more than 50% to 1.10% of total production costs for 2013.

Table 3.34 Relative environmental costs

Company C	2012 Annual cost, Rands	2013 Annual cost, Rands
Total production costs	85 725 614	98 395 612
Total environmental costs	2 088 572	1 080 142
Environmental costs as a percentage of production costs	2.44	1.10

3.2.3.6 Company C's environmental key performance indicators

Key commercial environmental aspects were recorded and monitored by Company C as part of its financial accounting system. Raw material consumption, energy and water utilization, effluent and hazardous waste were accounted for. The existence of key environmental performance indicators such as effluent costs, hazardous waste cost, destructed material cost and reworked material cost that contribute negatively towards the external costs placed on the environment were not in place and the benefits of utilizing these indicators to measure and improve upon these costs were therefore not realized.

Table 3.35 presents the calculation for the cost of the key performance indicators for Company C relative to a kilogram of product manufactured.

Table 3.35 Recommended key performance indicators for Company C

Company C key environmental performance indicators	2012 costs in Rands/kg of product	2013 costs in Rands/kg of product	Mean (Projected 2014 cost in Rands/kg of product)	Standard deviation
Total production volume (kg)	13 412 000	14 426 000		
Effluent	0.53	0.50	0.52	0.03
Hazardous waste	0.73	0.66	0.70	0.05
Destructed material	0.06	0.00	0.03	0.04
Reworked product	2.68	0.11	1.39	1.82

Production performance variances and price fluctuations resulted in a decrease in effluent, hazardous waste, destructed material and reworked product costs from 2012 to 2013. Whilst it is inconsistent to use the consumer price index and inflation figures to determine the costs of these factors for 2014, the average costs of 2012 and 2013 are a valuable indication of the projected budgets costs for 2014 for these environmental performance indicators.

3.2.4 Internal environmental costs for Company D

The environmental management accounting results detailing the environmental costs and revenue data for Company D for the calendar years 2012 and 2013 is outlined in Appendix 15. Tables 3.36 and Table 3.37 are a summary of the environmental cost and revenue categories for each month for 2012 and 2013. Company D spent R36 735 393 on internal environmental costs in 2012 and R38 671 529 in 2013. Company D realized environmental revenue of R351 666 in 2012 and R746 700 in 2013 from the sale of bulk bags, plastics, drums, timber from containers, cardboard and metallic scrap.

Graphical representations of the four categories of environmental costs during 2012 and 2013 as shown in Figures 31, 32 and 33 reveal no apparent monthly cost changes.

Table 3.36 Company D’s monthly environmental costs for 2012

Company D	Monthly costs for 2012 in Rands													
Environmental cost category	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Mean	Standard deviation
Waste and emission treatment	434 957	441 774	466 603	416 508	456 129	479 760	423 915	345 732	552 913	495 626	472 197	478 233	5 464 347	455 362	50 258
Prevention and environmental management including PETCO contribution	3 006 977	2 399 048	3 252 288	1 301 523	2 185 215	2 846 091	2 860 015	1 699 074	1 859 492	2 787 575	3 221 466	3 464 960	30 883 724	2 573 644	683 507
Prevention and environmental management costs excluding PETCO contribution	110 000	110 000	110 000	110 000	110 000	110 000	110 000	110 000	110 000	110 000	110 000	110 000	1 320 000	110 000	0
Material purchase value of nonproduct output	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Processing costs of nonproduct output	0	0	0	0	0	62 260	79 801	63 059	71 151	70 872	32 088	8 092	387 322	32 277	34 245
Total environmental expenditure including PETCO contribution	3 441 934	2 840 822	3 718 891	1 718 031	2 641 344	3 388 111	3 363 731	2 107 865	2 483 556	3 354 073	3 725 751	3 951 284	36 735 393	3 061 283	698 507
Total environmental expenditure excluding PETCO contribution	544 957	551 774	576 603	526 508	566 129	652 020	613 716	518 791	734 064	676 498	614 285	596 324	7 171 669	597 639	64 608
Environmental revenue	24 255	24 255	24 255	24 255	24 255	24 255	34 356	34 356	34 356	34 356	34 356	34 356	351 666	29 306	5 275

Table 3.37 Company D’s monthly environmental costs for 2013

Company D	Monthly costs for 2013 in Rands														
Environmental cost category	January	February	March	April	May	June	July	August	September	October	November	December	Annual	Mean	Standard deviation
Waste and emission treatment	522 207	427 005	417 790	448 351	576 353	439 822	396 693	435 825	434 072	415 022	415 022	415 022	5 343 184	445 265	51 830
Prevention and environmental management including PETCO contribution	2 700 164	2 453 867	3 053 916	2 526 739	2 572 056	3 481 160	2 151 014	2 730 067	2 743 159	2 743 159	2 743 159	2 743 159	32 641 619	2 720 135	322 957
Prevention and environmental management costs excluding PETCO contribution	120 000	120 000	120 000	133 000	120 000	120 000	120 000	120 000	120 000	120 000	120 000	120 000	1 453 000	121 083	3 753
Material purchase value of nonproduct output	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Processing costs of nonproduct output	69 816	70 742	61 166	60 239	16 373	132 526	179 482	96 383	0	0	0	0	686 726	57 227	58 219
Total environmental expenditure including PETCO contribution	3 292 187	2 951 615	3 532 872	3 035 329	3 164 782	4 053 508	2 727 189	3 262 274	3 177 231	3 158 181	3 158 181	3 158 181	38 671 529	3 222 627	325 420
Total environmental expenditure excluding PETCO contribution	712 023	617 748	598 956	641 590	712 726	692 348	696 175	652 207	554 072	535 022	535 022	535 022	7 482 910	623 576	71 294
Environmental revenue	34 356	34 356	34 356	34 356	34 356	34 356	60 296	109 968	153 578	96 914	103 660	16 148	746 700	62 225	42 992

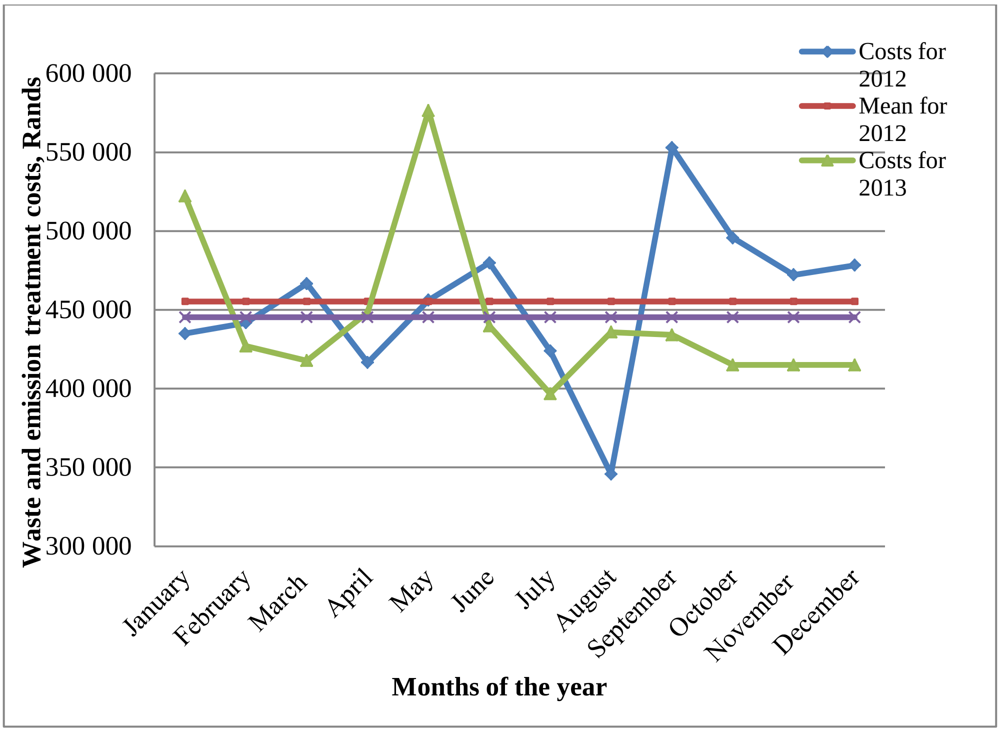


Figure 31: 2012 and 2013 waste and emission treatment costs for Company D

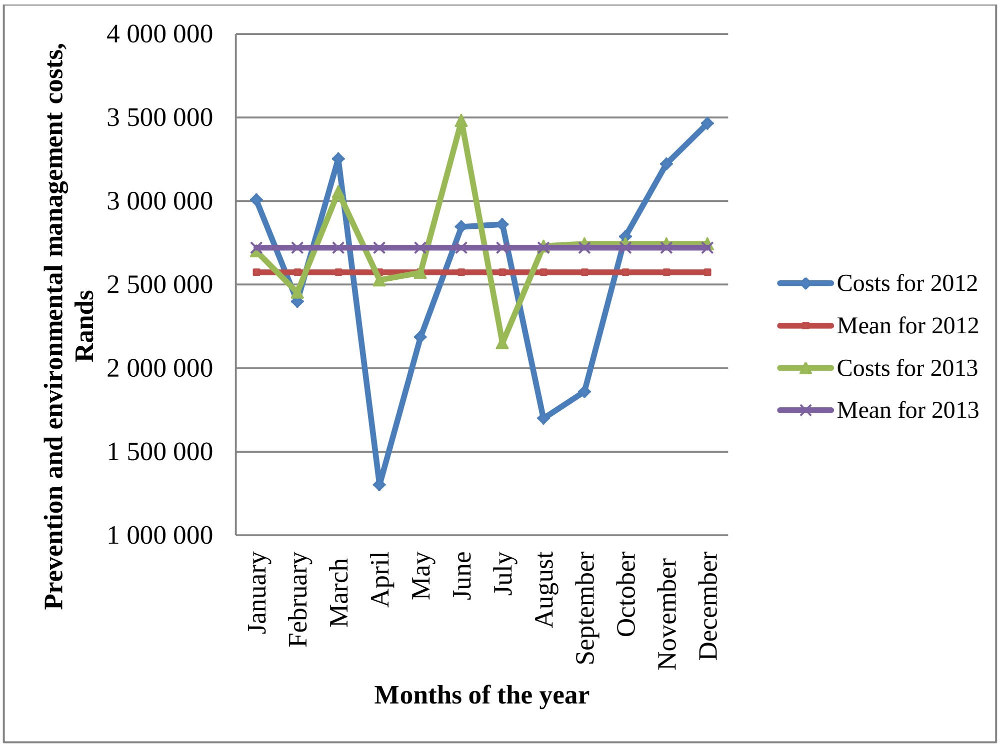


Figure 32: 2012 and 2013 prevention and environmental management costs for Company D (including PETCO contribution)

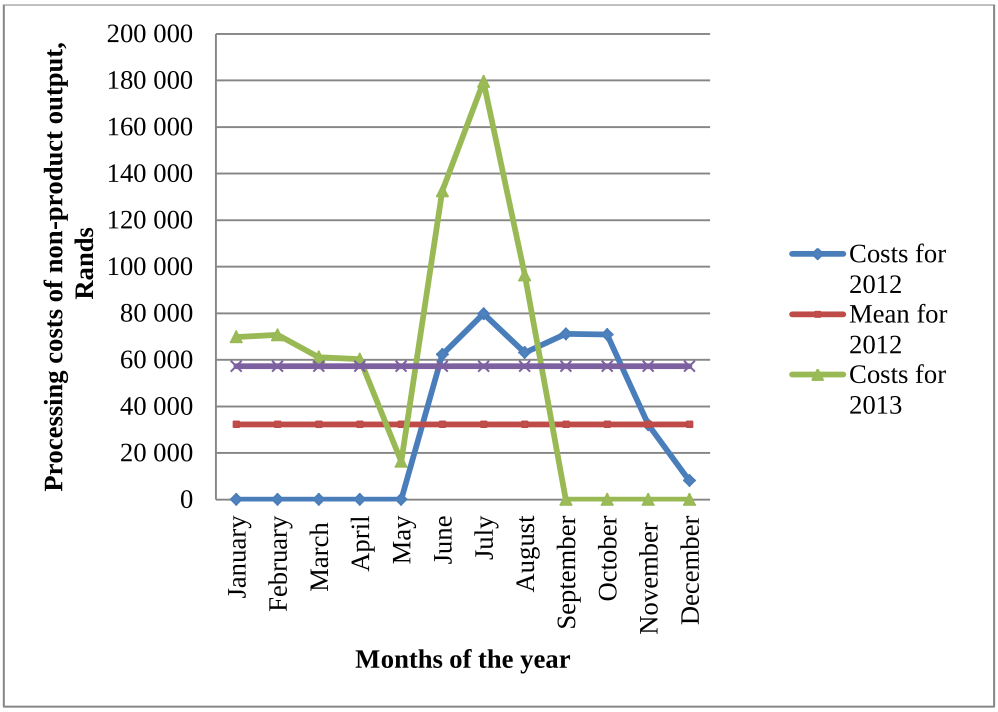


Figure 33: 2012 and 2013 processing costs of non-product output for Company D

Table 3.38 is a summary of the cost and revenue categories as a percentage of the total environmental costs.

Table 3.38 Company D's cost and revenue categories as a percentage of the total environmental costs

Company D	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total environmental expenditure	2013 Percentage of total environmental expenditure
Waste and emission treatment	5 464 347	5 343 184	14.87	13.82
Prevention and environmental management including PETCO contribution	30 883 724	32 641 619	84.07	84.41
Material purchase value of nonproduct output	0	0	0.00	0.00
Processing costs of nonproduct output	387 322	686 726	1.05	1.78
Total environmental expenditure including PETCO contribution	36 735 393	38 671 529		
Environmental revenue	351 666	746 700	0.96	1.93

3.2.4.1 Company D's waste and emission costs

Table 3.39 Subcategories of the waste and emission treatment costs

Company D	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total waste and emission treatment costs	2013 Percentage of total waste and emission treatment costs
Waste and emission treatment:	**5 464 347**	**5 343 184**		
Depreciation for related equipment	0	0	0.00	0.00
Maintenance and operating materials and services	249 920	291 785	4.57	5.46
Related personnel	336 000	351 000	6.15	6.57
Fees, taxes, charges	1 428 433	1 500 407	26.14	28.08
Insurance	3 449 994	3 199 992	63.14	59.89

Table 3.40 Breakdown of the fees, taxes and charges encompassed in waste and emission treatment costs

Company D	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total fees, taxes and charges	2013 Percentage of total fees, taxes and charges
Fees, taxes, charges:	**1 428 433**	**1 500 407**		
Effluent charges	1 330 462	1 380 276	93.14	91.99
Hazardous waste collection, transportation and disposal charges	54 129	76 091	3.79	5.07
Non-hazardous/General waste collection, transportation and disposal charges	43 842	44 040	3.07	2.94

Company D spent 14.87% or R5 464 347 of the total environmental costs for 2012 on waste and emission treatment and 13.82% or R5 343 184 of 2013 environmental costs on waste and emission treatment. Insurance contributed to 63.14% and 59.89% of these costs for these 2012 and 2013 respectively. 26.14% of the 2012 waste and emission treatment costs or R1 428 433 and 28.08% or R1 500 407 of the 2013 waste and emission treatment costs consisted of the disposal costs of effluent and hazardous and non-hazardous waste to the municipality waste water treatment plant and landfill site. 4.57% and 5.46% of the 2012 and 2013 waste and emission treatment costs were made up of maintenance and operating costs respectively.

3.2.4.2 Company D's prevention and environmental management costs

Table 3.41 Subcategories of the prevention and environmental management costs including PETCO contribution

Company D	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total prevention and environmental management costs	2013 Percentage of total prevention and environmental management costs
Prevention and environmental management costs including PETCO contribution	**30 883 724**	**32 641 619**		
External services for environmental management	0	13 000	0.00	0.04
Costs of internal personnel for general environmental management activities	1 200 000	1 320 000	3.89	4.04
Research and development	120 000	120 000	0.39	0.37
Extra expenditure for cleaner technologies	0	0	0.00	0.00
Other environmental management costs	29 563 724	31 188 619	95.73	95.55

Table 3.42 Subcategories of the prevention and environmental management costs excluding PETCO contribution

Company D	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total prevention and environmental management costs	2013 Percentage of total prevention and environmental management costs
Prevention and environmental management excluding PETCO contribution:	**1 320 000**	**1 453 000**		
External services for environmental management	0	13 000	0.00	0.89
Costs of internal personnel for general environmental management activities	1 200 000	1 320 000	90.91	90.85
Research and development	120 000	120 000	9.09	8.26
Extra expenditure for cleaner technologies	0	0	0.00	0.00
Other environmental management costs	0	0	0.00	0.00

PETCO is a recycling company specializing in the recycling of polyethylene terephthalate (PET) bottles and products. One percent of all Company D's sales is donated to PETCO and used for environmental projects and initiatives. Due to this amount being in the region of R30 million per annum or 95.64% of Company D's prevention and environmental management costs; the costs were analyzed including and excluding the PETCO contribution. Excluding Company D's contribution to PETCO, an average of 90.88% of the prevention and environmental costs consisted of general environmental management activities by internal personnel. R120 000 per year was spent in 2012 and

2013 for environmental research and development into the reduction of the organization's effluent chemical oxygen demand loading.

3.2.4.3 Company D's processing costs of non-product output

Table 3.43 Subcategories of the processing costs of non-product output

Company D	2012 Annual cost, Rands	2013 Annual cost, Rands	2012 Percentage of total processing costs of nonproduct output	2013 Percentage of total processing costs of nonproduct output
Processing costs of nonproduct output:	**387 322**	**686 726**		
Labour costs for discarded product (salaries,wages,contractors)	0	0	0.00	0.00
Labour costs for reworked out of specification product	387 322	686 726	100.00	100.00

Company D did not manufacture any products that could not be reworked into the final product. Processing costs of non-product output made up 1.05% of the total environmental costs for 2012 and 1.78% of the total environmental costs for 2013 at R387 322 and R686 726 respectively, consisting only of labour costs to rework out of specification product back into the product batches.

3.2.4.4 Company D's relative environmental costs

Company D's environmental costs in relation to total production cost is shown in Table 3.44. Environmental costs including PETCO contribution made up 1.28 % of total production costs in 2012 and 1.20% of total production costs for 2013.

Table 3.44 Relative environmental costs

Company D	2012 Annual cost, Rands	2013 Annual cost, Rands
Total production costs	2 871 308 494	3 231 427 448
Total environmental costs including PETCO contribution	36 735 393	38 671 529
Environmental costs including PETCO contribution as a percentage of production costs	1.28	1.20
Total environmental costs excluding PETCO contribution	7 171 669	7 482 910
Environmental costs excluding PETCO contribution as a percentage of production costs	0.25	0.23

3.2.4.5 Company D's environmental key performance indicators

Raw material, energy, water, effluent and hazardous waste costs were recorded and monitored by Company A in accordance with the GRI sustainability reporting system (GRI, 2002) recommendations. Similarly to the other three organizations participating in this research study environmental costs that contributed significantly to the external environmental costs of society such as effluent costs, hazardous waste cost, destructed material cost and reworked material cost were not compressed into key environmental performance indicators that could be measured, monitored and improved upon. The benefits of these performance indicators as benchmarking and optimization tools were therefore not realized.

Table 3.45 presents the calculation for the cost of the key performance indicators for Company D relative to a kilogram of product manufactured.

Table 3.45 Recommended key performance indicators for Company D

Company D key environmental performance indicators	2012 costs in Rands/kg of product	2013 costs in Rands/kg of product	Mean (Projected 2014 cost in Rands/kg of product)	Standard deviation
Total production volume (kg)	120 114 000	120 420 000		
Effluent	1.11	1.15	1.13	0.03
Hazardous waste	0.05	0.06	0.05	0.01
Destructed material	0.00	0.00	0.00	0.00
Reworked product	0.05	0.08	0.06	0.02

Unlike the other three organizations participating in this research study, effluent, hazardous waste and reworked product costs for Company D increased from 2012 to 2013. The average costs of 2012 and 2013 are a valuable indication of the projected budgets cost for 2014 for these environmental performance indicators.

3.2.5 Comparison of environmental costs between the organizations

3.2.5.1 Comparison of the environmental cost categories and environmental revenue between organizations

The costs of the four organizations for the four environmental cost categories as well as the environmental revenue realized for 2012 and 2013 is presented in Table 3.46. There were large differences in environmental costs in all four environmental cost categories amongst the four organizations. Company D contributed one percent of its total annual sales to PETCO resulting in the prevention and environmental management costs of this company being much higher than the costs of the other three organizations. This contribution also resulted in the total environmental costs of

Company D being much higher than the other organizations. This cost is an anomaly that only applies to Company D and a comparison of the environmental cost categories excluding this cost is presented in Figures 34 and 35 for 2012 and 2013.

Table 3.46 Comparison of environmental cost categories for the four organizations

Environmental cost category	Cost for 2012, Rands				Cost for 2013, Rands			
	Company A	Company B	Company C	Company D(including PETCO contribution)	Company A	Company B	Company C	Company D(including PETCO contribution)
Waste and emission treatment	1 783 146	7 814 750	783 466	5 464 347	1 666 555	4 999 433	890 856	5 343 184
Prevention and environmental management	1 311 063	9 821 722	1 269 333	30 883 724	1 521 077	4 055 173	172 182	32 641 619
Material purchase value of nonproduct output costs	968 924	572 094	3 965	0	588 956	0	0	0
Processing costs of nonproduct output costs	166 511	55 217	31 807	387 322	180 361	32 367	17 104	686 726
Total environmental expenditure	4 229 644	18 263 783	2 088 572	36 735 393	3 956 949	9 086 973	1 080 142	38 671 529
Environmental revenues	400 911	114 214	28 960	351 666	401 174	250 470	10 022	746 700
Environmental costs as a percentage of production costs	0.52	8.69	2.44	1.28	0.0045	4.46	1.10	1.20

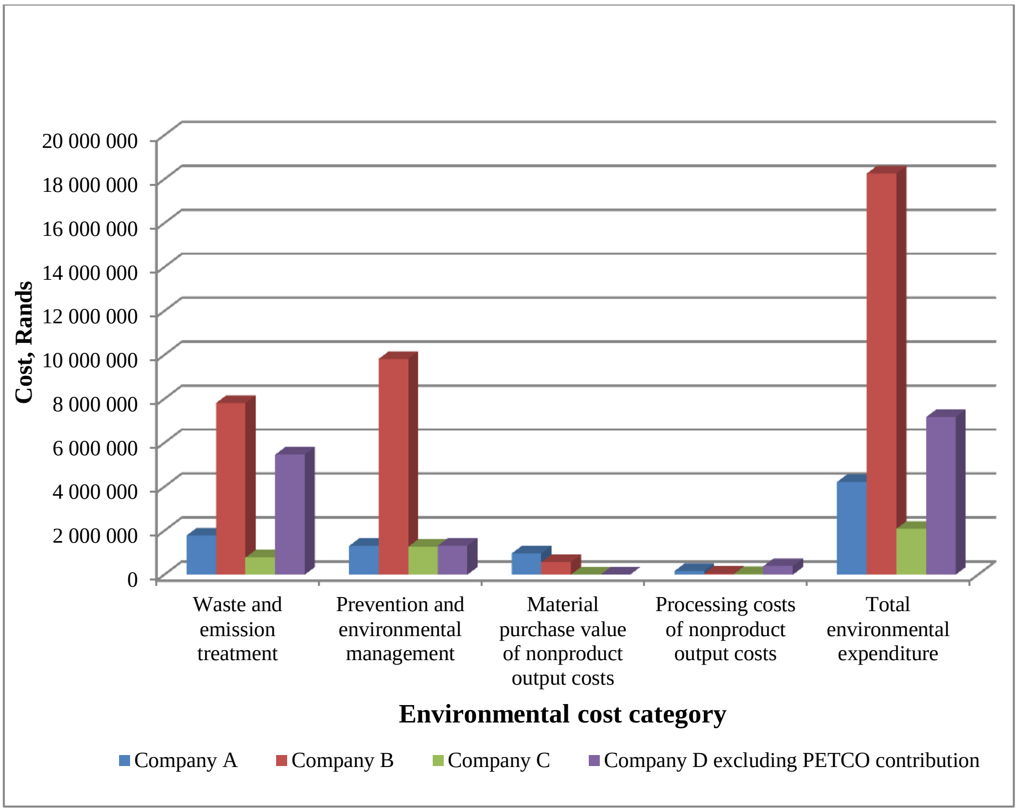


Figure 34: Comparison of 2012 environmental cost categories between organisations excluding Company D's PETCO contribution

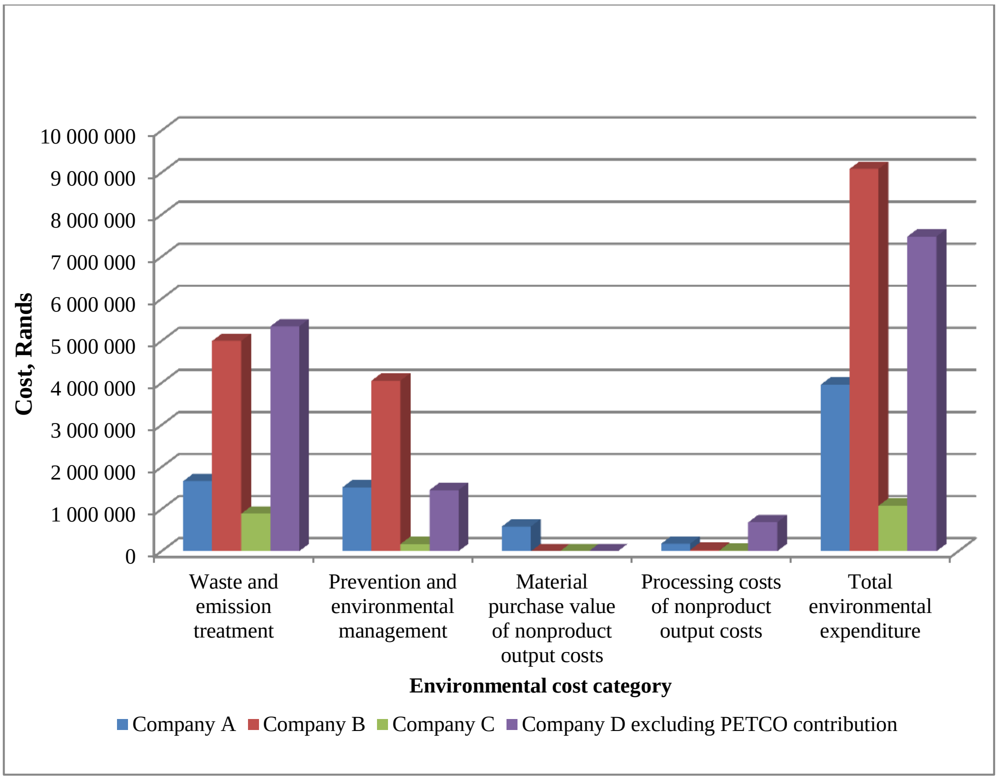


Figure 35: Comparison of 2013 environmental cost categories between organisations excluding Company D's PETCO contribution

Excluding Company D's PETCO contribution, it is evident that Company B incurred the most cost on prevention and environmental management for both 2012 and 2013; as well as having spent the most money on total environmental costs.

The cost categories for each company as a percentage of the total environmental costs are depicted in Figures 36 and 37. Company D's PETCO contribution is included in this data. It is evident that waste and emission treatment costs and prevention and environmental management costs in all organizations for both years contribute the most to the organizations total environmental costs.

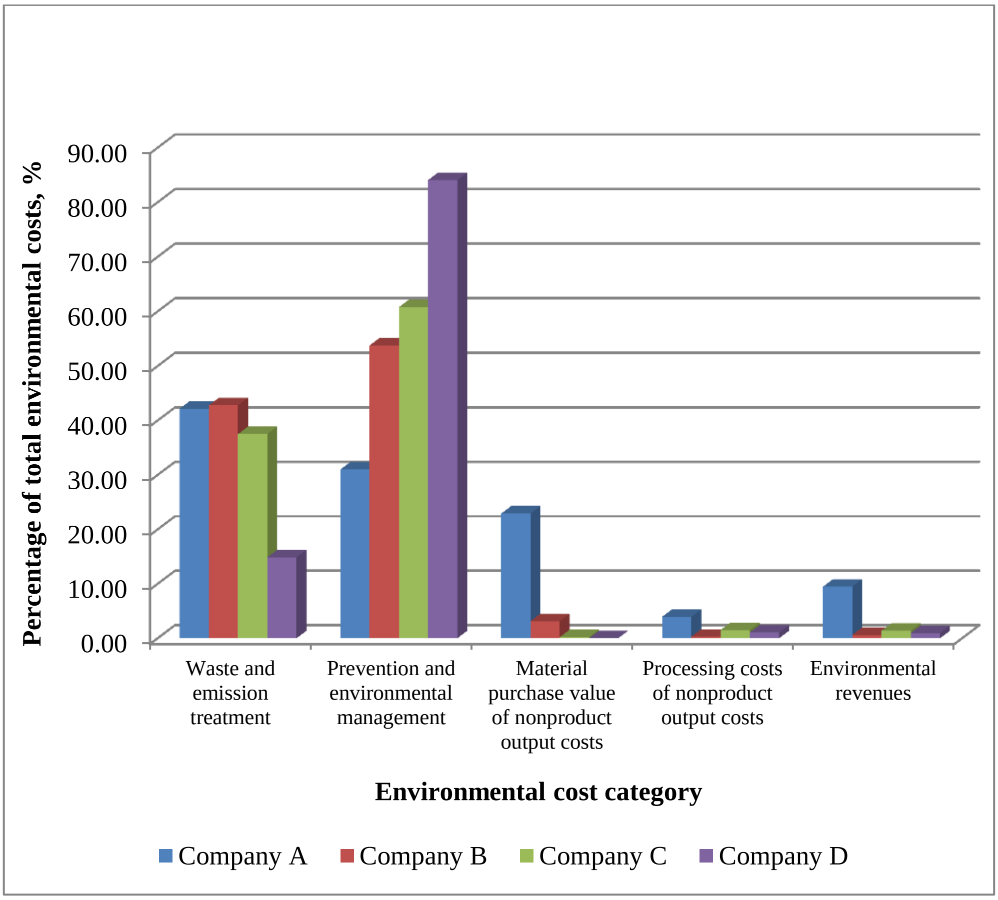


Figure 36: Comparison of 2012 environmental cost categories as a percentage of total environmental costs between organizations

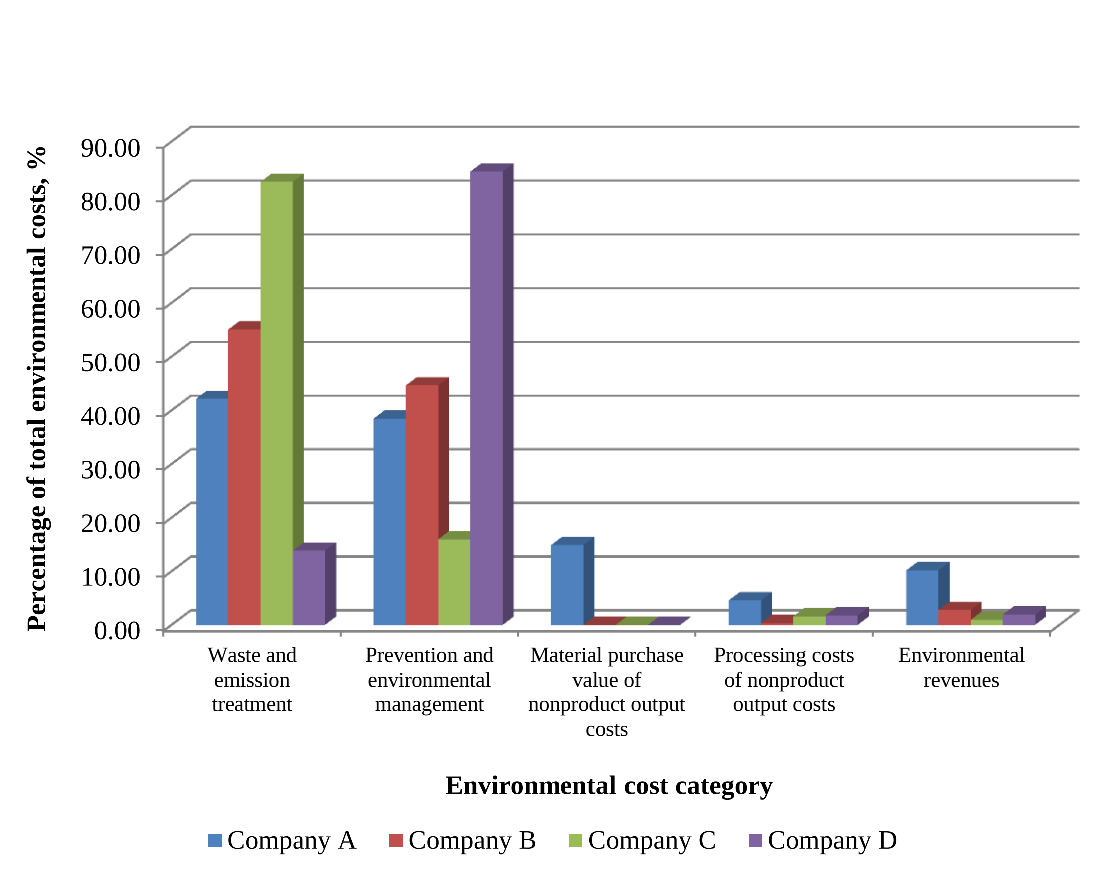


Figure 37: Comparison of 2013 environmental cost categories as a percentage of total environmental costs between organizations

3.2.5.2 Comparison of the environmental costs as a percentage of production costs between the organizations

Environmental costs as a percentage of the company's production costs between the four companies are shown in Figure 38. Company B's environmental cost contributed to 8.69% of its total production costs in 2012 and 4.46% in 2013; which is well above the percentages of the other organizations studied. Company C's environmental cost as a percentage of production costs decreased by more than half the amount from 2.44% in 2012 to 1.10% in 2013. Company D's environmental costs including PETCO contribution averaged 1.24% of the production costs for both years while Company A's environmental costs as a percentage of its production costs decreased from 0.524% in 2012 to 0.004% in 2013.

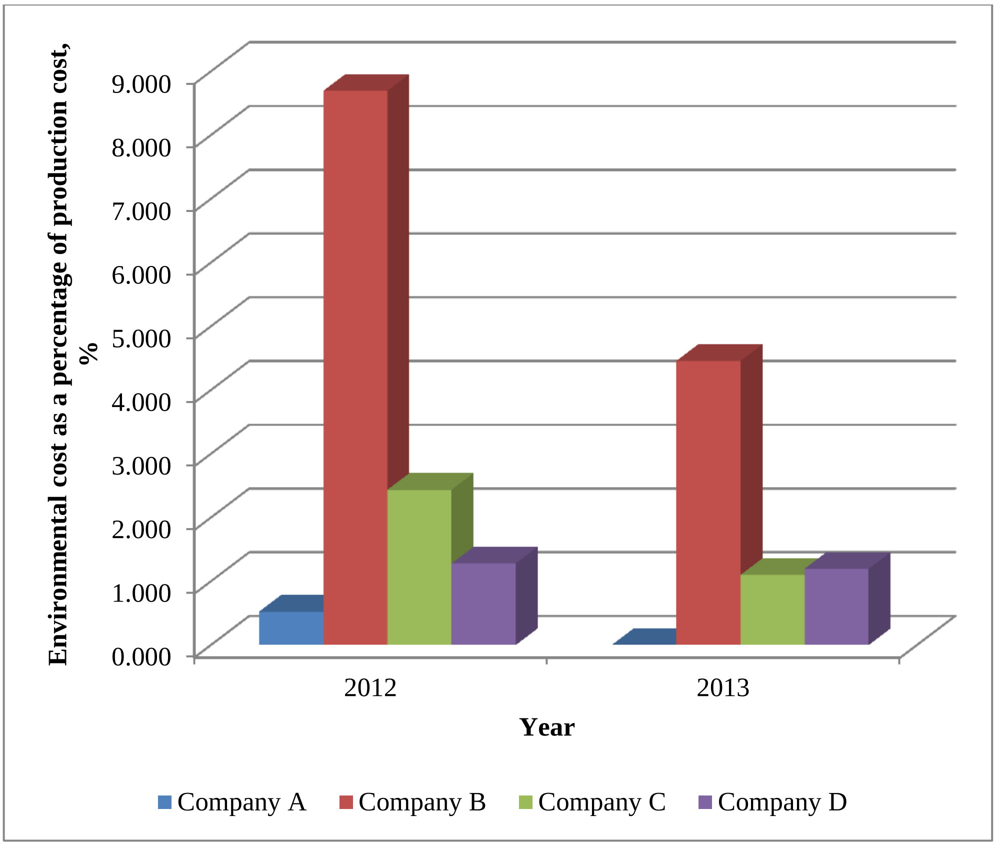


Figure 38: Comparison of the environmental costs as a percentage of production costs between organizations

3.2.5.3 Comparison of the recommended key environmental performance indicators between organizations

It is recommended that environmental costs that contribute significantly to the external environmental cost of society such as effluent costs, hazardous waste cost, destructed material cost and reworked material cost be compressed into key environmental performance indicators that can be measured, monitored and improved upon. A comparison of these average environmental performance indicators for 2012 and 2013 between the four companies is presented in Figure 39. Hazardous waste costs and destructed material costs for Companies A and B were the highest of the four organizations.

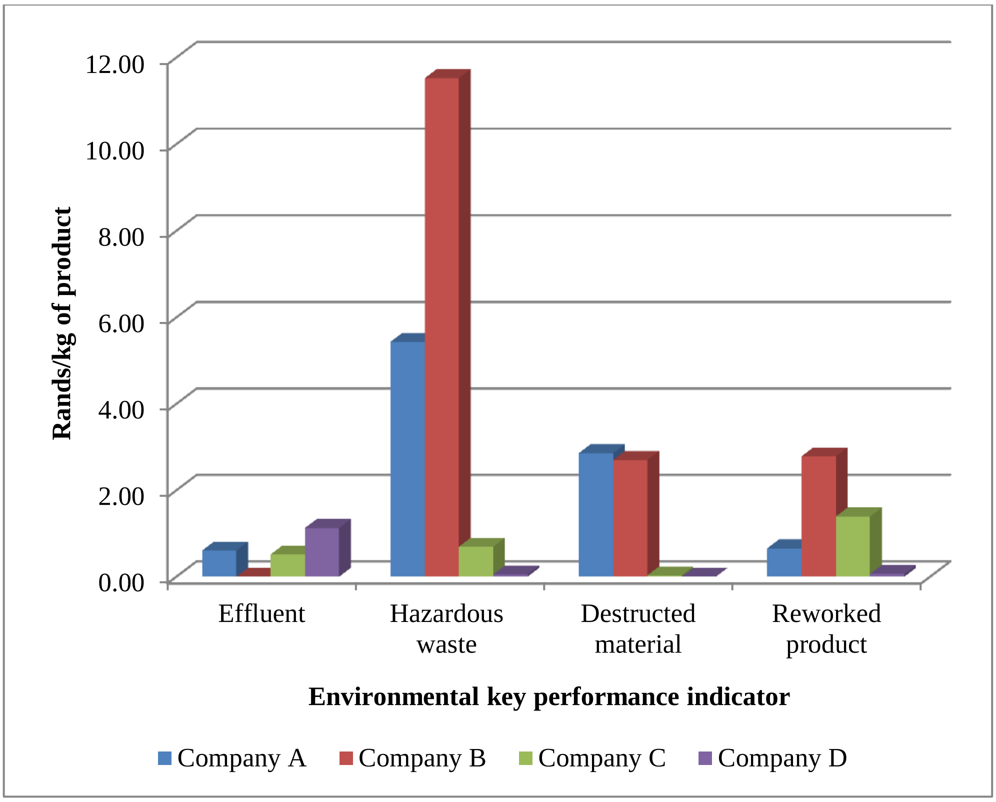


Figure 39: Environmental key performance indicators for the four organizations in rands per kilogram of product manufactured

3.2.5.4 Comparison of the differences in means or analysis of variance between organizations

Analysis of variance (ANOVA) results obtained from the use of the Microsoft Excel® Analysis ToolPak and as outlined in Appendix 16, showed statistically significant differences in means between the organizations for waste and emission treatment costs, prevention and environmental management costs and processing costs of non-product output for both 2012 and 2013 ($p < 0.05$). Analysis of variance showed no significant difference for the cost of material purchase value of non-product output across the four organizations as the P-value was greater the 0.05 at a P-value of 0.02 for the 2012 costs and a P-value of 0.17 for the 2013 costs. The means of the total environmental expenditure and environmental revenue across the organizations differed greatly with a P-value of less than 0.05.

3.3 External environmental costs

The effect of pollution and waste disposal as a result of chemical manufacturing activities on society and the environment is not evaluated and accounted for. These external costs are borne by the community in which the organization operates who suffer the consequences of poor health, air and water quality. Environmental taxes such as effluent or waste water taxes, emissions taxes and solid waste taxes as methods of internalizing external costs that force organizations to pay for the impacts of their activities have not been introduced by the South African government unlike many of their

European counterparts. Europe is the leading implementer of environmental taxation and emission trading schemes (Winkler and Marquard, 2011). In comparison to the United States of America, the level of European environmental taxation is much more advanced due to the significant usage of taxation as an environmental policy instrument and the greater acceptance of taxation by the public sector (Sterner and Köhlin, n.d.). European environmental tax reforms have shown drastic reduction in greenhouse gas emissions and solid waste generation as well as improved waste water quality (Sterner and Köhlin, n.d.). Their extensive experience in environmental taxation enables European countries to continually optimise these instruments to order to increase their effectiveness (Milne, 2007). Due to the longevity of their taxation programmes, decreased pollution and natural resource consumption is evident (Milne, 2007). These proven European environmental taxation methodologies can be utilized as a basis for the implementation of environmental taxation in South Africa. South Africa and Europe share similar environmental challenges such as air pollution, biodiversity loss, solid waste generation and disposal, waste water quality and water scarcity (Milne, 2007). Economic valuation of natural resources in South Africa has not been extensively considered. European valuations of these entities can be used as a yardstick against which to measure South African resources.

External factors considered in this study are air emissions, waste water quality and solid waste. The scarcity of and impacts to non-renewable resources are not considered in this study as it is assumed that these factors are included in the purchase price of these raw materials (European Commission, 2003). Company A stores hazardous raw materials in underground storage tanks as well as above ground storage tanks resulting in groundwater contamination *via* leakages and spillages as outlined in the environmental impact assessment of the organizations studied and outlined in Appendix 11. However the external costs of groundwater contamination was not calculated for Company A as this cost is internalised by the organization *via* the costs incurred in continuous groundwater remediation and product abstraction activities.

3.3.1 External costs of the organizations waste water discharge

Similar to the European application of waste water taxes, this tax should vary depending on the waste water quality standards. Waste water that meets the environmental standards set out by legislature should be taxed at a lower rate than that contravening these standards. Of all the damage units upon which the European waste water tax amounts are based as discussed in Chapter 2, chemical oxygen demand (COD) is the only water quality parameter that was measured by all the organizations in this study. The South African waste water COD discharge limit as per the National Water Act (South Africa, 1998b) is 75 mg/l. As shown in Table 3.47 the COD measurements of all the organizations are well above this limit. Using the COD measurements, the quantity of waste water discharged per annum by each organization for the period of the study (2012 and 2013) and the German waste water taxes (Ecotec, 2013), the external costs of waste water discharged into the rivers and sea was determined as presented in Table 3.47 below. Company B does not discharge any waste water due to the installation of a waste water recovery plant that treats and re-uses the clean distillate in the process. Company A's 2013 values were assumed to be the same as 2012 as no analysis was performed in 2013.

Table 3.47 Calculation of waste water taxes for Companies A, C and D

Determinant	2012			2013		
	Company A	Company C	Company D	Company A	Company C	Company D
COD, mg/l	15 773	6 745	7 560	15 773	4 509	3 790
Waste water discharge per annum, kl	2 175	13 427	64 311	1 885	11 188	45 714
COD per annum, kg	34 306	90 565	486 191	29 732	50 447	173 256
Annual equivalent German waste water tax, Rands	343 063	905 651	4 861 912	386 517	655 807	2 252 329

The annual equivalent German waste water tax is the amount of waste water tax that Companies A, C and D would have paid in 2012 and 2013 for the quantity of waste water at the measured COD levels. This is an indication of the external cost of discharging waste water into a water medium by each of these organizations. The tax amounts have been adjusted for inflation using the consumer price index and the 2012 and 2013 Euro/Rand exchange rate, as shown in Appendix 17. Company D spent a large amount of resources in reducing the COD loading and the quantity of the waste water in 2013, effectively reducing its external effects on the environment by more than half the amount. Plans are underway to install a waste water treatment plant that will further reduce COD levels and waste water quantity at Company D.

3.3.2 External costs of the organizations emissions discharge

Carbon taxes as a tool to internalize the external cost of greenhouse gas emissions will only be introduced in South Africa in 2015 (Urban Earth, 2013). External emission costs was calculated for the four companies using external cost studies as discussed in the literature survey. The external cost study values utilised to monetize environmental impacts included the European Commission's study (European Commission, 2003), Spadaro and Rabl's economic valuations costs (Spadaro and Rabl, 1999; European Commission, 2003), RDC Environment and Pira International's monetary external cost evaluation (RDC Environment and Pira International, 2001; European Commission, 2003), monetary value of natural resources and pollution treatment in China (Liu and Guo, 2005) and the Climate Care's external emission costs (Forum for the future for the SIGMA Project, 2003). 'NR' in the tables that follow indicates that no result was obtained from the organization for that analysis.

The emission data used for the calculation of the external costs was obtained from the four organizations and is shown in Table 3.48.

Table 3.48 Companies A, B, C and D emission analysis data

Analysis/Pollutant	Company A	Company B	Company C	Company D
Sampling year	2010-2012	2012	2012	2007/2011
Dry standard emission flow (dsm^3/hr)	2452	NR	720	NR
Volatile organic compounds (VOCs), average concentration mg/m^3	2.65	NR	12.09	
VOCs, kg/hr	$4.43x10^{-11}$	NR	0.0000725	0.0009612
Dry standard particulate concentration (mg/dsm^3)	10.36	NR	NR	NR
Dry standard particulate concentration (kg/hr)	0.032	NR	NR	NR
CO (mg/dsm^3)	40.56	NR	19.71	NR
CO (kg/hr)	0.09	NR	0.0142	NR
NO_x (mg/dsm^3)	56.156	NR	113.082	NR
NO_x (kg/hr)	0.150	0	0.0814	NR
SO_2 (mg/dsm^3)	<5	NR	48.5	NR
SO_2 (kg/hr)	0.01	0.01	0.021791	NR
CO_2 (mg/m^3)	33719	NR	67049	NR
CO_2 (kg/hr)	76.879	31.706	48.275	0.0001368

Company A, B, C and D's external cost due to greenhouse gas emissions was determined using the European Commission's average external cost factors considered to monetize environmental impacts and is presented in Table 3.49. The use of Spadaro and Rabl's economic valuations of external costs for the four organizations is shown in Table 3.50. RDC Environment and Pira International's monetary external cost evaluation is presented in Table 3.51. The monetary value of pollution treatment for emission release was calculated using the Chinese pollution treatment price and is shown in Table 3.52. Climate Care's external costs to determine the companies' external emission costs are presented in Table 3.53.

Table 3.49 External emission costs as determined using the European Commission's study

Pollutant	Impact	External cost (Euros/g pollutant) (European Commission, 2003)	Euros/hour				Costs adjusted for CPI from 2003 to 2012 and converted to Rands as at the 2012 Euro/Rand exchange rate in Rands/hour				Costs adjusted for CPI from 2003 to 2013 and converted to Rands as at the 2013 Euro/Rand exchange rate in Rands/hour			
			Company A	Company B	Company C	Company D	Company A	Company B	Company C	Company D	Company A	Company B	Company C	Company D
SO_2	Air acidification	0.00224	0.022350	0.022350	0.048703	NR	0.284768	0.284768	0.620538	NR	0.349563	0.349563	0.761733	NR
CO_2	Greenhouse effect (direct, 100 years)/Global warming potential	0.0000335	2.575447	1.062151	1.617213	0.000005	32.814536	13.533185	20.605390	0.000058	40.281013	16.612467	25.293850	0.000072
NO_x as NO_2	Photochemical oxidation	0.00195	0.292500	0.000000	0.158730	NR	3.726830	0.000000	2.022427	NR	4.574817	0.000000	2.482601	NR
Particulates, PM_{10}	Human health effects caused by dusts	0.03035	0.971200	NR	NR	NR	12.374351	NR	NR	NR	15.189956	NR	NR	NR

Table 3.50 External emission costs as determined using Spadaro and Rabl's economic valuations of external costs

Pollutant	Impact	External cost (Euros/kg of pollutant)(Spadaro and Rabl, 1999; European Commission, 2003)	Euros/hour				Costs adjusted for CPI from 1999 to 2012 and converted to Rands as at the 2012 Euro/Rand exchange rate in Rands/hour				Costs adjusted for CPI from 1999 to 2013 and converted to Rands as at the 2013 Euro/Rand exchange rate in Rands/hour			
			Company A	Company B	Company C	Company D	Company A	Company B	Company C	Company D	Company A	Company B	Company C	Company D
Particulates, PM_{10}	Mortality and morbidity	15.4	0.492800	NR	NR	NR	6.849723	NR	NR	NR	8.395981	NR	NR	NR
SO_2	Crops and material	0.3	0.003000	0.000030	0.000065	NR	0.041699	0.000417	0.000909	NR	0.051112	0.000511	0.001114	NR
SO_2	Mortality and morbidity	0.3	0.003000	0.000030	0.000065	NR	0.041699	0.000417	0.000909	NR	0.051112	0.000511	0.001114	NR
Carbon monoxide (CO)	Morbidity	0.002	0.000180	NR	0.000028	NR	0.002502	NR	0.000037	NR	0.003067	NR	0.000484	NR
CO_2	Global warming	0.029	2.229491	0.919474	1.399975	0.000004	30.989033	12.780321	19.459093	0.000055	37.984507	15.665354	23.851794	0.000068

Table 3.51 External emission costs as determined using RDC Environment and Pira International's monetary external cost evaluation

Pollutant	Impact	External cost (Euros/kg of pollutant)(RDC Environment and Pira International, 2001; European Commission, 2003)	Euros/hour				Costs adjusted for CPI from 2001 to 2012 and converted to Rands as at the 2012 Euro/Rand exchange rate in Rands/hour				Costs adjusted for CPI from 2001 to 2013 and converted to Rands as at the 2013 Euro/Rand exchange rate in Rands/hour			
			Company A	Company B	Company C	Company D	Company A	Company B	Company C	Company D	Company A	Company B	Company C	Company D
CO2	Global warming potential	0.01344	1.033254	0.426129	0.648816	0.000002	13.709004	5.653790	8.608361	0.000024	16.942055	6.987146	10.638506	0.000030
SO_2	Toxicity gaseous non carcinogens	1	0.010000	0.010000	0.021791	NR	0.132678	0.132678	0.289119	NR	0.163968	0.163968	0.357303	NR
Particulates, PM_{10}	Toxicity particulates and aerosols	24	0.768000	NR	NR	NR	10.189670	NR	NR	NR	12.592742	NR	NR	NR
VOCs	Smog (ethylene equivalent)	0.73	0.00000	NR	0.000053	0.000702	0.000000	NR	0.000702	0.009310	0.000000	NR	0.000868	0.011505

Table 3.52 External emission costs as determined using the pollution treatment price in China

Pollutant	Pollution treatment price (Chinese RMB/m³) (Liu and Guo, 2005)	RMB/hour				Costs adjusted for CPI from 2005 to 2012 and converted to Rands as at the 2012 RMB/Rand exchange rate in Rands/hour				Costs adjusted for CPI from 2005 to 2013 and converted to Rands as at the 2013 RMB/Rand exchange rate in Rands/hour			
		Company A	Company B	Company C	Company D	Company A	Company B	Company C	Company D	Company A	Company B	Company C	Company D
Emissions	0.000221	0.541892	NR	0.159120	NR	0.892605	NR	0.262102	NR	1.020762	NR	0.299734	NR

Table 3.53 External emission costs as determined using the Climate Care's external costs

Pollutant	External cost (Pounds/kg)(Forum for the future for the SIGMA Project, 2003)	Pounds/hour				Costs adjusted for CPI from 2003 to 2012 and converted to Rands as at the 2012 Pounds/Rand exchange rate in Rands/hour				Costs adjusted for CPI from 2003 to 2013 and converted to Rands as at the 2013 Pounds/Rand exchange rate in Rands/hour			
		Company A	Company B	Company C	Company D	Company A	Company B	Company C	Company D	Company A	Company B	Company C	Company D
CO_2	0.00545	0.418991	0.172798	0.263099	0.000001	6.595791	2.720199	4.141727	0.000012	7.713532	3.181171	4.843595	0.000014
NO_x	1.4	0.210000	0.000000	0.113960	NR	3.305841	0.000000	1.793970	NR	3.866058	0.000000	2.097981	NR
SO_2	2.4	0.024000	0.024000	0.052298	NR	0.377810	0.377810	0.823287	NR	0.441835	0.441835	0.962803	NR

External emissions costs as calculated by the European and Chinese methods in Tables 3.49 to 3.53 are summarized by pollutant and averaged for the different external cost studies employed and presented in Table 3.54. These average costs provide an indication of the costs that these emissions place on the environment and society. All four organizations operate five days a week, twenty four hours a day. Assuming that the plants were not operational two days a month due to maintenance and process shutdowns, all four companies operated their plants for a total of 5 880 hours per year each. The annual total emissions cost per pollutant was calculated using the latter total annual operational hours.

Company C's activities resulted in almost double the SO_2 emissions cost to the environment for both 2012 and 2013 compared to the other organizations. Company A contributed the most to CO_2 emissions at an external cost of R123 639 for the 2012 year and R151 294 for the 2013 year. Company D's activities produced negligible quantities of CO_2 emissions. Only Company A's results for particulate matter from its stack emissions were available which equated to an external cost of R57 651 for 2012 and R70 910 for 2013. Company B did not emit NO_2 into the atmosphere. CO and VOC emissions by all organizations had negligible external environmental impacts. Company A had the highest total external emission costs for both 2012 and 2013.

Table 3.54 Average external emission costs as calculated from literature studies

External cost study	2012 External emissions costs, Rands/hour				2013 External emissions costs, Rands/hour			
Pollutant: SO_2	**Company A**	**Company B**	**Company C**	**Company D**	**Company A**	**Company B**	**Company C**	**Company D**
European Commission, 2003	0.284768	0.284768	0.620538	NR	0.349563	0.349563	0.761733	NR
Spadaro and Rabl, 1999; European Commission, 2003: 144	0.041699	0.000417	0.000909	NR	0.051112	0.000511	0.001114	NR
Average SO_2 cost	**0.163233**	**0.142593**	**0.310723**	**NR**	**0.200337**	**0.175037**	**0.381423**	**NR**
SO_2 costs, Rands/annum	**959.81**	**838.44**	**1 827.05**	**NR**	**1 177.98**	**1 029.22**	**2 242.77**	**NR**
Pollutant: CO_2								
European Commission, 2003	32.814536	13.533185	20.605390	0.000058	40.281013	16.612467	25.293850	0.000072
Spadaro and Rabl, 1999; European Commission, 2003: 144	30.989033	12.780321	19.459093	0.000055	37.984507	15.665354	23.851794	0.000068
RDC Environment and Pira International, 2001; European Commission, 2003:144	13.709004	5.653790	8.608361	0.000024	16.942055	6.987146	10.638506	0.000030
Forum for the future for the SIGMA Project, 2003	6.595791	2.720199	4.141727	0.000012	7.713532	3.181171	4.843595	0.000014
Average CO_2 cost	**21.027091**	**8.671873**	**13.203642**	**0.000037**	**25.730277**	**10.611535**	**16.156937**	**0.000046**
CO_2 costs, Rands/annum	**123 639.30**	**50 990.62**	**77 637.42**	**0.22**	**151 294.03**	**62 395.82**	**95 002.79**	**0.27**
Pollutant: Particulates, PM_{10}								
European Commission, 2003	12.374351	NR	NR	NR	15.189956	NR	NR	NR
Spadaro and Rabl, 1999; European Commission, 2003: 144	6.849723	NR	NR	NR	8.395981	NR	NR	NR
RDC Environment and Pira International, 2001; European Commission, 2003:144	10.189670	NR	NR	NR	12.592742	NR	NR	NR
Average PM_{10} cost	**9.804581**	**NR**	**NR**	**NR**	**12.059560**	**NR**	**NR**	**NR**
PM_{10} costs, Rands/annum	**57 650.94**	**NR**	**NR**	**NR**	**70 910.21**	**NR**	**NR**	**NR**
Pollutant: NO_x as NO_2								
European Commission, 2003	3.726830	0.000000	2.022427	NR	4.574817	0.000000	2.482601	NR
Forum for the future for the SIGMA Project, 2003	3.305841	0.000000	1.793970	NR	3.866058	0.000000	2.097981	NR
Average NO_x as NO_2 cost	**3.516336**	**0.000000**	**1.908198**	**NR**	**4.220438**	**0.000000**	**2.290291**	**NR**
NO_x as NO_2 costs, Rands/annum	**20 676.05**	**0.00**	**11 220.21**	**NR**	**24 816.17**	**0.00**	**13 466.91**	**NR**
Pollutant: Carbon monoxide (CO)								
Spadaro and Rabl, 1999; European Commission, 2003: 144	0.002502	NR	0.000037	NR	0.003067	NR	0.000484	NR
CO costs, Rands/annum	**14.71**	**NR**	**0.22**	**NR**	**18.03**	**NR**	**2.85**	**NR**
Pollutant: VOCs								
RDC Environment and Pira International, 2001; European Commission, 2003:144	0.000000	NR	0.000702	0.009310	0.000000	NR	0.000868	0.011505
VOCs costs, Rands/annum	**0.00**	**NR**	**4.13**	**54.74**	**0.00**	**NR**	**5.10**	**67.65**
Annual total emissions cost, Rands/annum	**202 940.81**	**51 829.06**	**90 689.03**	**54.96**	**248 216.43**	**63 425.04**	**110 720.41**	**67.92**

3.3.3 External costs of the organizations solid/semi-solid waste discharge

3.3.3.1. External costs of the organizations solid/semi-solid waste discharge at landfills

Companies A, C and D disposed of their hazardous and non-hazardous waste at the Shongweni landfill site where leachate contamination has been reported (Baldwin, 2009), whilst Company B incinerated its hazardous waste through an incineration operator in the Gauteng region and sent its non-hazardous general waste to the landfill site. The costs of the impacts of landfill sites are internalized by many governments through the use of landfill taxes. South Africa has not yet introduced landfill taxes. The external cost of hazardous and non-hazardous waste discharged to landfill sites was calculated for Companies A, B, C and D using the average landfill taxes for the European countries discussed in the literature survey and is presented in Tables 3.55, 3.56 and 3.57.

Table 3.55 Average European landfill taxes for hazardous waste (Adapted from: Revise Sustainability, 2013; Fischer et al, 2012)

Country	Tax year	Tax amount in Euros/ton	Tax amount, Rands/ton for 2012 (Adjusted for CPI and exchange rate)	Tax amount, Rands/ton for 2013 (Adjusted for CPI and exchange rate)
Austria	2012	29.8	313.79	446.63
Belgium-Flanders region	2011	79.56	971.81	1192.42
Belgium- Wallonia	2010	65	793.96	974.20
Czech Republic	2011	248	3029.27	3716.95
Denmark	2012	21.3	21.30	319.24
Estonia	2010	12	146.58	179.85
Finland	2013	50	437.00	640.50
Italy	2012	18.83	18.83	282.22
Latvia	2012	21.34	21.34	319.84
United Kingdom	2013	72	629.27	922.32
Average tax			**638.32**	**899.42**

Table 3.56 Average European landfill taxes for non-hazardous waste (Adapted from: Revise Sustainability, 2013; Fischer et al, 2012)

Country	Tax year	Tax amount in Euros/ton	Tax amount, Rands/ton for 2012 (Adjusted for CPI and exchange rate)	Tax amount, Rands/ton for 2013 (Adjusted for CPI and exchange rate)
Austria	2012	87	916.11	1303.93
Belgium- Wallonia	2010	60	732.89	899.26
Czech Republic	2011	20	244.30	299.75
Denmark	2011	63.3	773.20	948.72
Estonia	2010	12	146.58	179.85
Finland	2013	50	437.00	640.50
France	2013	30	262.20	384.30
Ireland	2012	75	789.75	1124.08
Italy	2012	18.83	198.28	282.22
Latvia	2012	9.96	104.88	149.28
Netherlands	2012	127	1337.31	1903.44
Poland	2012	26.6	280.10	398.67
United Kingdom	2013	72	629.27	922.32
Average tax			**527.07**	**725.87**

Table 3.57 Equivalent average European landfill taxes for Companies A, B, C and D

	2012				2013			
Non-hazardous waste:	**Company A**	**Company B**	**Company C**	**Company D**	**Company A**	**Company B**	**Company C**	**Company D**
Landfill quantity, tons	0	144.23	0	116.10	0	36.28	0	121.20
Equivalent European landfill taxes, Rands/ton	**0**	**76 019**	**0**	**61 192**	**0**	**26 335**	**0**	**87 976**
Hazardous waste:								
Landfill quantity, tons	1 286	0	87.82	17.81	1 093	0	100	30.79
Equivalent European landfill taxes, Rands/ton	**820 873**	**0**	**56 057**	**11 370**	**983 063**	**0**	**89 969**	**27 689**

The equivalent European landfill tax for each organization was calculated by multiplying the average hazardous and non-hazardous waste European tax with the quantity of waste discharged by each organization. Company A had a very large external cost on society and the environment as a result of hazardous waste disposal as compared to Companies C and D.

3.3.3.2. External costs of Company B's semi-solid waste incineration

As reviewed in the literature survey incineration has a higher social cost than landfilling (Edwards, 2012). However, very few countries have implemented incineration taxes and the incineration taxes for both Austria and France are much lower than the average landfill taxes charged by all European countries. The external cost of incineration for Company B was determined by utilizing the incineration taxes of those European countries that have implemented these taxes and are presented in Tables 3.58 and 3.59.

Table 3.58 European incineration taxes (Adapted from: Revise Sustainability, 2013; Fischer et al, 2012)

European country	Landfill tax amount for the year	Tax amount in Euros/ton	Tax amount in Rands/ton
Austria	2012	8	88
France	2013	14	196

Table 3.59 Equivalent European incineration tax for Company B

	Hazardous waste quantity to incinerators for 2012, tons	Hazardous waste quantity to incinerators for 2013, tons	Hazardous waste incineration tax for 2012, Rands	European landfill taxes for hazardous waste, Rands
Company B	146	51	12 859	9 943

3.3.4 Total external costs of all organizations

The total external costs of the four organizations was determined by totalling the waste water taxes, emissions costs, landfill taxes and incineration taxes of the organizations and is presented in Figure 40. Company D contributed the most to the external cost on society and the environment due to its large waste water tax that decreased by more than a half in 2013 due to improved processes. Company B's external costs were negligible in comparison to the other organizations. Company C's external costs as a percentage of production costs were the highest amongst all the organizations at 1.23% for 2012 and 0.87% for 2013 (Figure 41). In monetary terms however these costs are much less than the environmental costs of Company D. The average external cost of all four organizations as a percentage of production costs was 0.40% for 2012 and 0.35% for 2013.

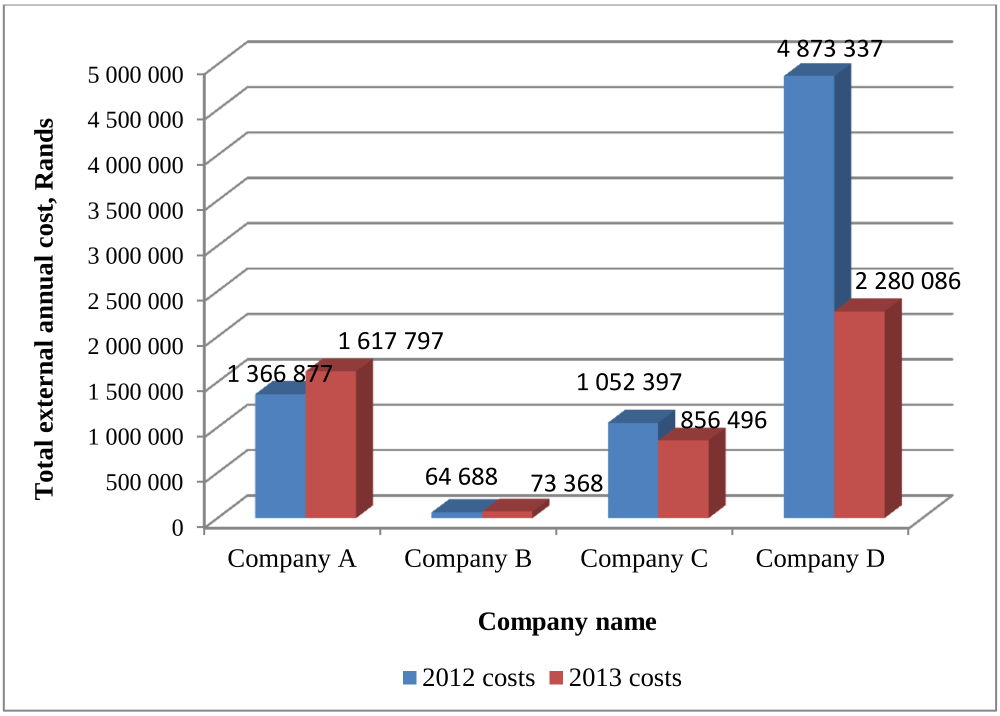


Figure 40: Total external costs of Companies A, B, C and D

3.3.4.1 Total external costs of Companies A, B, C and D as a percentage of production costs

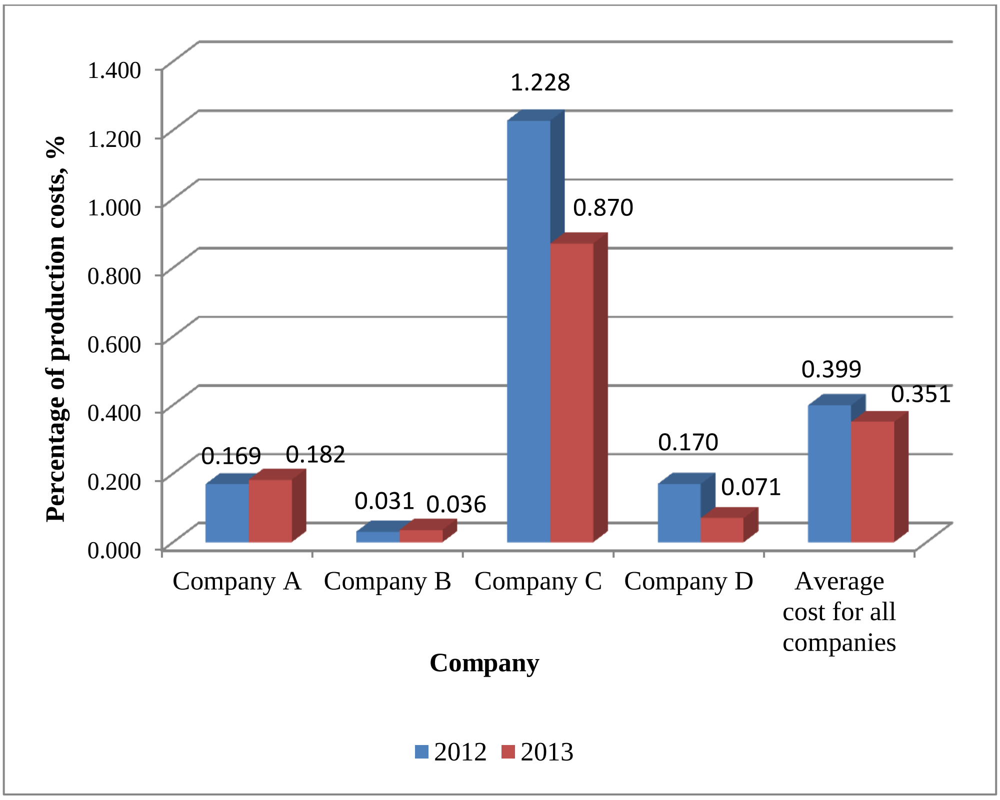


Figure 41: Total external costs as a percentage of production costs

3.4 Green Gross Domestic Product calculation for the chemical manufacturing sector of South Africa

Green Gross Domestic Product (Green GDP) allows economic activities to include both environmental issues and social aspects and adjusts the conventional Gross Domestic Product (GDP) accordingly (Jieyan, 2005). Simplifying the production or output approach in determining GDP by using the market value of final goods produced for a year, allows for the determination of the effect of external environmental costs on the chemical manufacturing sectors GDP. The manufacturing sector of South Africa into which the chemical manufacturing sector falls contributed 15.20% to South Africa's GDP in 2013 and 15.30% in 2012, making it the third-largest contributor to the South African economy (Statistics South Africa, 2014a and 2014b). The estimated sales and percentage contribution to GDP of the chemical manufacturing sector in South Africa as noted by Statistics South Africa (2014a and 2014b) is presented in Table 3.60 below.

Table 3.60 Estimated sales and percentage contribution to GDP of the chemical manufacturing sector in South Africa (Adapted from: Statistics South Africa, 2014a and 2014b)

Subdivision of manufacturing sector	2012		2013	
	2012 Sales, Rands	Percentage contribution to GDP	2013 Sales, Rands	Percentage contribution to GDP
Petroleum, chemical products, rubber and plastic products	**376 486 756 000**	**3.76**	**420 195 429 000**	**3.85**
Coke, petroleum products and nuclear fuel	158 106 980 000	1.58	180 117 559 000	1.65
Basic chemicals	76 438 686 000	0.76	85 217 409 000	0.78
Other chemical products	79 423 187 000	0.79	89 191 428 000	0.82
Total of basic chemicals and other chemical products	**155 861 873 000**	**1.555**	**174 408 837 000**	**1.596**
Rubber products	15 263 719 000	0.15	15 681 997 000	0.14
Plastic products	47 254 184 000	0.47	49 987 036 000	0.46
			1 014 799 695 000	
Total estimated sales of the manufacturing sector	1 533 076 572 000	15.3	1 660 563 697 000	15.2

The basic chemicals and other chemical products subsection of the manufacturing sector of South Africa contributed 1.56% (0.76% + 0.79%) or R155 861 873 000 to the GDP in 2012 and 1.60% (0.78% + 0.82%) or R174 408 837 000 in 2013 (Statistics South Africa, 2014a and 2014b). For simplicity in calculations it is assumed that the estimated sales for the various subsectors are an indication of the GDP of the subsector for the annual year.

Using the environmental cost method to calculate Green GDP or Equation [2]:

Green GDP = conventional GDP - environmental cost (Zhishen, n.d.);

provides an indication of the effect of external environmental costs on the GDP of the chemical manufacturing sector of South Africa. Internal environmental costs and certain natural resource depletion costs are already included in the market price of the chemical products and therefore in the GDP. The average external cost as a percentage of production costs of the four organizations studied is assumed to be the same as the external cost as a percentage of estimated sales for this subsector and is used as the environmental cost to determine the Green GDP of the basic chemical and other chemical products subsector of the manufacturing sector of South Africa as outlined in Table 3.61.

Table 3.61 Calculation of Green GDP using the external costs of the companies

	2012	**2013**
Total estimated sales of the basic chemicals and other chemical products subsector (GDP), Rands	155 861 873 000	174 408 837 000
Percentage contribution to GDP	1.555	1.596
Average external costs as a percentage of production costs for the four companies	0.399	0.351
External cost of estimated sales of the basic chemicals and other chemical products subsector, Rands	621 888 873	612 175 018
Green GDP, Rands	155 239 984 127	173 796 661 982
Green GDP percentage contribution to GDP	1.549	1.590
Percentage difference in GDP and Green GDP	0.006	0.006

The external costs of estimated sales of the basic chemicals and other chemical products subsector for each year was determined by multiplying the total estimated sales of the basic chemicals and other chemical products subsector by the average external cost as a percentage of production costs for the four companies. The Green GDP was obtained by subtracting the external costs from the total estimated sales of the basic chemicals and other chemical products subsector. Although the average external costs as a percentage of production costs appears to have a negligible effect on the GDP, in terms of monetary value it equates to R621 888 873 for 2012 and R612 175 018 for 2013 which reduces the GDP by 0.006% for both these years. This is a good indication of the effect of external costs of the chemical manufacturing sector on the economy of the country.

3.5 Social performance indicators

The impacts of the organization's activities on the community in which it operates and on society as a whole is measured and monitored through social performance indicators (GRI, 2011). Social sustainability aspects of the four organizations were analyzed for labour practices and community contribution and are presented in Table 3.62. NR indicates that no result was obtained for a particular aspect.

Table 3.62 Social sustainability aspects of the four organizations

Social Sustainability Aspects	2012				2013			
	Company A	Company B	Company C	Company D	Company A	Company B	Company C	Company D
1. Labour practices								
1.1. Breakdown of labour force								
Total number of permanent staff	88	190	57	156	89	183	62	112
Employment Equity:								
Number of men	75	145	49	134	73	141	52	99
Number of women	13	45	8	22	16	43	10	13
Number of senior executives who are women	1	1	0	1	1	1	0	1
Number of white employees	8	71	1	18	5	65	1	11
Number of non- white employees	80	119	56	138	85	119	61	101
Number of employees with disabiliites	1	4	3	2	1	2	3	1
1.2. Number of employees represented by independent trade union organisations	42	21	21	NR	45	30	22	NR
1.3. Training and Education								
Employee educational training costs	271 064	1 520 337	233 808	550 000	57 650	2 550 972	305 000	660 000
Average hours of training/employee	1	4	NR	NR	0	5		NR
1.4. Health and Safety (Permanent and Contractual employees)								
Number of injuries on duty(excluding disabling injuries)	6	1	4	4	4	0	3	6
Number of disabling injuries	0	0	0	0	0	0	0	0
Number of lost/restricted workdays due to on-site injury	0	14	0		0	0	0	NR
Number of employees benefitting from organisational health care/health education programmes	88	190	57	156	89	183	62	112
2. Community Focus								
Donations to the community in monetary terms	0	114 180	64 726	64 883	0	168 433	50 000	204 874
Number of hours of involvement to projects with value to the greater community	0	636	8	50	0	324	24	60
Other monetary charitable contributions	48 740	13 442	8	0	99 990	0	0	0
Number of in-service trainees	5	0		5	7	1	8	6

3.6 Conclusion

Environmental management accounting was successfully implemented into four organizations within the Durban Chemicals Cluster. This was achieved by the successful extraction of environmental cost and revenue data from the various financial and management accounting systems within the organizations studied. The absolute cost amounts for each of the environmental categories of waste disposal and emission treatment costs, prevention and environmental management costs, material purchase value of non-product output, processing costs of non-product output and environmental revenues were established for the four organizations. Based on the results of this study, environmental key performance indicators recommended for the organizations within the Durban Chemicals Cluster were:

- Effluent/waste water cost per kilogram of product manufactured;
- Hazardous waste cost per kilogram of product manufactured;
- Destructed material cost per kilogram of product manufactured and
- Reworked material cost per kilogram of product manufactured.

The external costs or external impacts of the organizations that participated in this study were calculated using European tax evaluation methods resulting in an indication of the Green Gross Domestic Product for the chemical manufacturing sector of South Africa. The calculation of the Green Gross Domestic Product indicated that the Gross Domestic Product of the chemical manufacturing sector and consequently South Africa's Gross Domestic Product, significantly decreased as a result of the external costs imposed by the activities of chemical manufacturing organizations in South Africa. Finally the social sustainability aspect of sustainable development was quantified for the aspects of labour practices and community contribution in order to quantify the three aspects of sustainable development and promote triple bottom line accounting in the organizations studied. The analysis of social sustainability practices highlighted gender discrimination issues in the chemical manufacturing sector as well as a skills deficiency in the female population of South Africa. Social performance indicators such as employee training, health and safety and community focus was generally well entrenched amongst the organizations within the chemical manufacturing sector of South Africa.

CHAPTER 4 DISCUSSION

This chapter presents a discussion of the implementation of the environmental management accounting system into each of the four organizations of the Durban Chemicals Cluster by environmental cost categories and environmental revenue. The discussion is structured in accordance with the categorization of environmental costs by the United Nations Division for Sustainable Development (2001) into waste disposal and emission treatment costs, prevention and environmental management costs, material purchase value of non-product output, processing costs of non-product output and environmental revenues. These environmental cost categories are discussed as a series of sub-categories that contribute to the total costs of these categories. The results of the calculation of the external costs as determined *via* the utilization of environmental taxes and external studies and the estimation of the Green Gross Domestic Product for the chemical manufacturing sector are evaluated and discussed. This chapter concludes with a discussion of social sustainability within the Durban Chemicals Cluster and the effect that environmental and social costs have on the triple bottom line of the organizations within the chemical manufacturing sector of South Africa.

4.1 Internal environmental costs

4.1.1 Waste and emission treatment

Company B incurred the largest cost in 2012 for the category of environmental waste and emission treatment costs, spending 77.18% more than Company A; 89.97% more than Company C and 30.08% more than Company D. In 2013 Company D incurred the largest waste and emission treatment cost, spending 68.81% more than Company A, 6.43% more than Company B and 83.33% more than Company C. Company A's waste and emission treatment costs for 2012 and 2013 amounted to 42.16% and 42.12% of its total environmental expenditure at R1 783 146 and R1 666 555 respectively. Company B's waste and emission treatment costs amounted to 42.79% of its 2012 total environmental costs at R7 814 750 and 55.02% of its 2013 total environmental costs at R4 999 433. Waste and emission treatment costs for Company C made up 37.51% or R783 466 of the total environmental costs for 2012 and 82.48% or R890 856 of its 2013 environmental costs. Company D's waste and emission treatment activities cost 14.87% or R5 464 347 of the total environmental costs for 2012 and 13.82% or R5 343 184 of its 2013 environmental costs.

The large waste and emission treatment costs incurred by the Durban Chemicals Cluster organizations is an indication of the significant sustainable development challenges imposed by the chemical manufacturing sector on the wellbeing of the country. The eco- efficiency of the organizations studied was not at an optimal point as further process improvement opportunities needed to be identified and exploited to ensure the maximum conversion of raw material to products with minimal waste production.

South Africa is faced with numerous waste management challenges as discussed in Chapter 2. It was evident that organizations within the Durban Chemicals Cluster abdicated all responsibility of their waste to the waste management companies contracted to dispose of their waste. Companies can assist the South African government in enforcing waste management policies by ensuring that landfill operators such as Enviroserv Waste Management (Pty) Ltd adhere to waste management policies and legislature. Landfill operators should be held accountable for the monitoring and remediation of groundwater and soil contamination and should provide evidence of these activities. This evidence should be provided to both the organization contracting Enviroserv Waste Management (Pty) Ltd to dispose of their waste as well as the South African government.

The development of the chemical manufacturing sector in South Africa has resulted in an increase in water usage and waste water generation as production volumes increase in the quest for greater profits. This was evident in the large fees paid to the municipality by the organizations studied within the Durban Chemicals Cluster to dispose of their waste water. With the threat that water demand will exceed availability in South Africa by 2025 (DWA, 2012b), it is imperative that organizations in the chemical manufacturing sector strive to reduce their water usage. Recycling and re-use of their waste water as achieved by Company B will reduce both fresh water consumption and the negative effects of waste water disposal into water systems such as rivers and seas.

All four organizations studied within the Durban Chemicals Cluster have boilers and processes that generate gaseous waste emissions. During the course of the study organizations were not charged or taxed for the emissions released as a result of their manufacturing activities. South Africa's manufacturing and industrial sectors are the major contributors to climate change in the African continent prompting the introduction of carbon taxation in South Africa from the 1st of January 2015 in order to control and mitigate these emissions. In view of this pending environmental cost it is beneficial to all organizations to not only improve the efficiencies of their emissions scrubbing equipment but to consider and introduce process technology that will reduce or eliminate emissions at the source of production. Liquefied petroleum gas was utilized as the boiler energy source by all four organizations studied resulting in the generation of lower greenhouse gas emissions in comparison with the use of fuels such as coal and petrol. Whilst all four organizations measured the concentrations of volatile organic compounds at their sites, research and implementation of alternate raw materials that will reduce volatile organic compound concentrations still has to be pursued by all the organizations.

The sub-categories of waste and emission treatment costs are discussed in sections 4.1.1.1 to 4.1.1.5.

4.1.1.1 Depreciation for related equipment

Depreciation for environmental equipment that is used to reduce the impact of water, air or soil pollution is incorporated into waste and emission treatment costs. Depreciation was calculated by all four organizations studied by extending the environmental equipment investment cost over the expected life time of the equipment, assumed to be ten years. Company A's depreciation costs during the course of the study included the installation of ventilation systems to reduce the impact of air pollution on employee health, the installation of variable speed drives on motors to reduce the energy consumption of these pieces of equipment and the automation of the dosing of caustic soda into the effluent to regulate the pH of the waste water going to the municipality waste water works. Company B installed new scrubbers to reduce the concentrations of emissions being discharged into the atmosphere and undertook an energy audit to identify and improve upon energy consumption activities. Company B incurred depreciation costs for the installation of the waste water recovery plant that was commissioned before the commencement of the study. Company C incurred depreciation costs as a result of the installation of scrubbers, extraction fans and ducting and the enclosure of product and storage tanks to eliminate the possibility of soil and water contamination as a result of product and raw material leakages. Company D did not incur any depreciation costs during the period of study. Company B incurred the highest costs for depreciation for both 2012 and 2013 spending 99.54% and 99.27% more than Company A on depreciation costs and 97.68% and 89.36% more than Company C for these respective years.

Company A's depreciation of environmental equipment amounted to 0.10% and 0.19% of its total environmental expenditure for 2012 and 2013 respectively. Company B's depreciation contributed to 5.10% of its total environmental cost for 2012 and more than doubled to 11.09% of its total environmental cost in 2013 due to the total environmental cost in 2013 having decreased by approximately half the amount of the total 2012 environmental expenditure while the depreciation costs remained approximately the same. Company C's depreciation costs made up 1.03% of the company's total environmental cost in 2012 and 9.93% of the organization's total environmental cost in 2013 due to the increase in depreciation costs in 2013 as a result of the installation of environmental equipment in 2012 that depreciated in 2013.

All four participating organizations utilized the traditional end of pipe equipment at the end of their processes to clean up the waste streams being released into the environment. End of pipe technology included scrubbers to clean up the emissions released into the atmosphere, wastewater treatment facilities and solid or semi-solid waste separation equipment. End of pipe technologies are temporary solutions that do not result in the long term reduction of raw material, water and energy usage or reductions in emissions, solid waste and effluent. The installation and utilization of scrubbers by companies studied within the Durban Chemicals Cluster to clean the emissions going into the atmosphere implies that these companies are not motivated to eliminate emission generation at the source of production. Emission reduction strategies at the project or plant conception phase were not evident mainly due to existing plant and equipment having been installed many decades ago when pollution reduction and prevention was not a priority. There was very little or no evidence of environmental impact assessments or hazard and operability studies conducted for new pieces of plant and machinery that would result in technology implementation that effectively reduced or eliminated the source of emissions.

The capital investment and depreciation costs of Company B's waste water recovery and reuse plant is an excellent example of the way forward for waste water treatment technology that needs to be implemented by all organizations within the Durban Chemicals Cluster. This plant eliminates the discharge of wastewater into the municipality waste water systems that results in river and sea pollution. The re-use of wastewater from this plant reduces freshwater consumption at this plant, significantly contributing to the conservation of this valuable and scarce resource. A reduction in the depreciation costs of end of pipe equipment is required by the chemical manufacturing sector as organizations need to implement plant and equipment that will eliminate emissions, waste water and solid waste generation during the production processes and not merely treat these wastes at the end of production activities.

4.1.1.2 Maintenance and operating material and services

The largest cost for environmental maintenance and operating materials and services cost was incurred by Company B. These costs consisted of energy usage and maintenance costs for the waste water recovery plant as well as acid and alkali usage and maintenance costs for the scrubber. Company B spent 91.66% and 81.73% more than Company A's expenditure on environmental maintenance and operating materials and services for 2012 and 2013 respectively. Company A's maintenance costs included the replacement of the pH probe in the effluent plant and the cleaning of the settling tanks, as well as the cleaning of the emission treatment scrubbers. Operating material costs included caustic usage for the effluent and emissions treatment plants and materials and chemicals used for laboratory effluent analysis. Company C spent the least amount of money on maintenance and operating materials and services during both 2012 and 2013. Company C's maintenance costs for the effluent plant and scrubber were absorbed into the overhead maintenance costs and could not be quantified thereby resulting in the low cost for this sub-category for this company. Company B spent 94.37% and 92.56% more on maintenance and operating materials and services in 2012 and 2013 than Company C and 63.76% and 26.18% more than Company D for these years.

Company A's environmental maintenance and operating materials and services costs amounted to 1.36% and 1.82% of its total environmental expenditure for 2012 and 2013 respectively. Company B's environmental maintenance and operating materials and services costs contributed to 3.78% of its total environmental cost for 2012 and 4.36% of its total environmental cost in 2013. Company C's costs for this sub-category made up 1.86% of the company's total environmental cost in 2012 and 2.72% of the organization's total environmental cost in 2013 while Company D's environmental maintenance and operating materials and services costs were 0.68% and 0.75% of the total environmental expenditure for the company for 2012 and 2013 respectively.

It is crucial that environmental equipment be adequately maintained and operated as ineffectively operating equipment will reduce the efficiencies of these equipment resulting in greater concentrations of gaseous pollutants reaching the atmosphere, incorrect acidity or alkalinity of waste water streams and increased COD and BOD loading in waste water streams. As evident from the costs incurred for this sub-category of environmental waste and emission treatment costs, organizations within the Durban Chemicals Cluster were paying adequate attention to the maintenance, operation and replacement of their environmental equipment ensuring that pollution impacts were reduced by the optimal utilization of their end of pipe technologies.

4.1.1.3 Related personnel

Company B incurred the highest cost of the four organizations on salaries and wages for personnel to operate waste and emission treatment and collection processes. Company B spent 97.06% and 97.23% more than Company A, 81.05% and 79.47% more than Company C and 61.05% and 60.32% more than Company D on personnel costs for 2012 and 2013 respectively. The personnel costs for waste and emission treatment activities as a percentage of its total environmental expenditure for 2012 and 2013 amounted to 0.60% and 0.62% for Company A, 4.72% and 9.73% for Company B, 7.83% and 16.82% for Company C and 0.91% for both years for Company D.

Companies within the Durban Chemicals Cluster employed personnel who were committed to the operation of environmental equipment and waste collection and disposal strategies as part of their daily work activities. Monetary incentives to optimise the productivity and reactivity of these personnel to further optimise pollution reduction were not evident from these costs and should be considered by all organizations within the chemical manufacturing sector.

4.1.1.4 Fees, taxes, charges

The fees, taxes and charges associated with waste and emission treatment encompassed effluent disposal costs to municipality waste water treatment facilities and the cost to transport and dispose of hazardous and general waste. Company C incurred the least costs for these activities while Company

B incurred the highest cost under this sub-category for 2012. Company B spent 48.95%, 94.63% and 56.20% more than Companies A, C and D in 2012 respectively. Company A's cost for fees, taxes and charges was slightly higher than Company D (1.82% more) and 35.58% and 89.11% more than Companies B and C respectively for 2013. Company A's fees, taxes and charges amounted to 39.63% and 38.62% of its total environmental expenditure for 2012 and 2013 respectively. Company B's costs for this sub-category contributed to 17.86% of its total environmental cost for 2012 and 10.83% of its total environmental cost in 2013. Company C's costs for fees, taxes and charges made up 8.38% of the company's total environmental cost in 2012 and 15.41% of the organization's total environmental cost in 2013 while Company D's costs amounted to 3.89% and 3.88% of the total environmental expenditure for 2012 and 2013 respectively.

As evidenced from the costs for this sub-category all companies within the Durban Chemicals Cluster contributed significantly to the impacts of solid and semi-solid waste disposal at the Shongweni landfill site. These impacts included the degradation of ecosystems at the Shongweni landfill site, the generation of methane and carbon dioxide emissions and the contamination of soil, surface water and groundwater through leachate generation. The incineration cost of solid waste by Company B indicated that Company B contributed to the generation of incineration emissions such as furans and persistent dioxins that has severe health and environmental consequences. Three of the companies studied discharged their waste water through the municipalities into rivers and seas contributing to the contamination of these water systems. The South African COD discharge limit as per the National Water Act (South Africa, 1998b) is set at 75mg/l. Waste water COD levels for the three organizations discharging waste water into the water systems were significantly over this limit. Company A's average COD measurement for 2012 and 2013 was 15 773mg/l, Company C's average COD measurement for 2012 and 2013 was 5 627mg/l and Company D's average COD measurement for 2012 and 2013 was 5 675mg/l. These companies contributed significantly to the introduction of organic, inorganic and biological pollutants into KwaZulu-Natal's water systems.

Reduction in solid waste and waste water generation will greatly improve the quality of groundwater and surface water systems in KwaZulu-Natal and will contribute to the eradication of water borne diseases in poorer communities that utilize these water sources for domestic purposes. Reduction in costs incurred in this sub-category will substantially reduce the organization's environmental costs and increase profits.

4.1.1.5 Insurance for environmental liability

All four organizations insured themselves against damage to persons, property and the environment due to their business activities. Company D spent 99.10% more than Company A, 40.00% more than Company B and 88.85% more than Company C on insurance premiums in 2012. This pattern was repeated in 2013 when Company D spent 98.93% more than Company A, 46.02% more than Company B and 87.31% more than Company C on insurance premiums. The organizations did not budget for environmental remediation and compensation as this aspect was covered by the insurance premiums. Insurance costs amounted to 0.73% and 0.87% of its total environmental expenditure for Company A, 11.33% and 19.01% for Company B, 18.41% and 37.60% for Company C and 9.39% and 8.27% for Company D for 2012 and 2013 respectively

Insurance payments by the companies of the Durban Chemicals Cluster contribute significantly to the overall waste and emission treatment costs of these organizations. The comprehensive insurance contracts entered into by the organizations within the Durban Chemicals Cluster demonstrates the organizations commitment to ensuring the safety of persons, property and the environment and the mitigation and remediation of any unforeseen events due to business activities.

4.1.2 Prevention and environmental management

For the category of prevention and environmental management costs Company D incurred the largest cost of R30 883 724 in 2012 due to its large contribution to PETCO, spending 95.75% more than Company A, 68.20% more than Company B and 95.89% more than Company C. In 2013 Company D incurred the largest prevention and environmental management cost of R32 641 619, again due to its large donation to PETCO, spending 95.34% more than Company A, 87.58% more than Company B and 99.47% more than Company C on these costs. Company A spent R1 311 063 or 31.00% of its total environmental costs for 2012 and R1 521 077 or 38.44% of the total environmental costs for 2013 on prevention and environmental management costs. Company B's prevention and environmental management costs made up 53.78% of its total environmental costs for 2012 at R9 821 722 of which R5 753 000 was due to the installation of a new emissions scrubber plant. 44.63% or R4 055 173 of Company B's total environmental costs was spent on prevention and environmental management in 2013. Company C's prevention and environmental management costs consisted of 60.78% of its total environmental costs for 2012 at R1 269 333, of which R 1 112 657 was spent on environmental projects. Company C's prevention and environmental management costs made up 15.94% of its total environmental costs for 2013 at R172 182. Company D's prevention and environmental costs including their contribution to PETCO amounted to 84.07% and 84.41% of its total environmental expenditure for 2012 and 2013.

The large amounts of money spent by the organizations within the Durban Chemicals Cluster on prevention and environmental management costs is an indication of the commitment by these organizations to the analysis of waste streams and remediation of contaminated groundwater in the case of Company A, as well as an indication of the sectors commitment towards environmental management strategies and legislative compliance. Environmental research and development and the implementation of cleaner technologies to reduce and eliminate the impacts of manufacturing activities on the environment is an area requiring greater commitment from the chemical manufacturing sector of South Africa.

Sections 4.1.2.1 to 4.1.2.5 discusses the sub-categories of prevention and environmental management costs.

4.1.2.1 External services for environmental management

External services that included the employment of environmental management consultants for groundwater remediation, product abstraction and emission analysis were undertaken most frequently and at the largest cost by Company A. Company A spent an average of 93.93% more than the other three organizations in 2012 and an average of 98.48% more than Companies B, C and D in 2013 on external environmental consultants. Company A spent 13.24% and 13.69% of its total environmental expenditure for 2012 and 2013 respectively on external services for environmental management activities. Companies B and D's costs for this sub-category was zero or negligible (less than 0.3%) for both years of the study. Company C's external services costs amounted to 2.39% of its 2012 and 1.08% of its 2013 total environmental costs.

Company A spent R281 975 in 2012 and R319 906 in 2013 on groundwater remediation and product abstraction, the only company that contributed to groundwater contamination during the two years of the study. Groundwater is a crucial domestic water resource for many rural communities in South Africa and contaminated groundwater resulting from manufacturing activities will make this resource unusable as groundwater remediation is a costly exercise that cannot guarantee re-usable potable water quality. Research, process and production strategies to prevent groundwater contamination were not evident in the environmental cost data review and plant familiarisation surveys conducted at Company A. Groundwater contamination taxation and/or fines have not yet been addressed by the South African government. Organizations contributing to groundwater contamination would be well advised to remediate contamination and eliminate processes resulting in groundwater contamination before the consideration and implementation of groundwater contamination taxes by the South African government.

4.1.2.2 Personnel for general environmental management activities

Company D incurred the highest cost for the salaries and benefits for both permanent and temporary internal personnel for environmental management activities. These costs were 49.07% higher than the amount spent by Company A, 10.00% higher than Company B's costs and 91.11% more than Company C's costs for internal personnel for 2012. A similar trend resulted in Company D spending 49.27%, 27.91% and 91.02% more than Companies A, B and C respectively for 2013 for internal personnel for environmental management activities. Internal personnel costs for Company A equated to 14.45% and 16.92% of its total environmental management costs for 2012 and 2013 respectively, whilst Company B's costs as a percentage of its total environmental costs increased from 5.91% in 2012 to 10.47% in 2013 due to the increase in total environmental costs from 2012 to 2013. Company C's internal personnel costs for this sub-category doubled from 5.11% in 2012 to 10.98% in 2013 of its total environmental costs. Company D's internal personnel costs remained fairly constant at 3.27% and 3.41% of its total environmental costs in 2012 and 2013 respectively.

All the organizations studied had environmental, safety and health managers committed to ensuring that environmental management strategies and policies were adhered to. All organizations had documented environmental management systems in place and conducted environmental audits. ISO 14001 certification was achieved by all organizations except Company C whose certification was in the process of being obtained during the course of the study. Environmental management activities for which personnel were employed also included activities ensuring compliance with environmental legislation and risk assessments. Organizations within the Durban Chemicals Cluster employed adequate personnel to ensure that general environmental management activities were conducted timeously and effectively.

4.1.2.3 Research and development

Companies A and C did not spend any money on external and/or internal personnel for environmental research and development in 2012 and 2013. Company B spent 96.00% more on this cost than Company D for both 2012 and 2013. Personnel costs for research and development for Company B amounted to 15.38% and 32.30% of its total environmental costs for 2012 and 2013 respectively while Company D spent 0.33% and 0.31% of its total environmental costs for these years on this sub-category.

Companies A, C and D did not consider the employment of personnel for environmental research and development a beneficial business activity that would justify the expenditure spent on personnel resources. This perspective is detrimental to organizations within the Durban Chemicals Cluster as environmental research and development results in the implementation of cleaner technologies and process improvements that benefit both the environment and the organization's bottom line. Innovative environmental research and development could also be shared across the organizations within the Durban Chemicals Cluster resulting in the faster implementation of environmentally sustainable solutions with substantial benefits to the environment, society and the South African economy.

4.1.2.4 Extra expenditure for cleaner technologies

Company D did not implement any environmental projects during the two years of the study. Company B spent 98.09% more than Company A and 80.66% more than Company C in 2012 on the installation of new emission scrubbers and did not implement any environmental projects in 2013. Company A spent 85.02% more on cleaner technology project implementation in 2013 than Company C, the only other organization to incur this cost in 2013. Companies A, B and C spent 2.59%, 31.50% and 53.27% of their total environmental costs in 2012 on environmental projects. Companies A and C spent 7.07% and 3.88% respectively of their total environmental costs on cleaner technology implementation in 2013.

Environmentally beneficial technology increases production efficiencies resulting in the conservation of water and energy and the minimisation of waste production that consequently increases the organization’s bottom line. It is therefore imperative that organizations continuously improve their processes to remain competitive within the chemical manufacturing sector and to comply with environmental legislation and external pressure.

4.1.2.5 Other environmental management costs

Other environmental management costs such as money spent on environmental community projects and internal printing costs for environmental reporting and communication were incurred by Companies A and B for 2012 and 2013. However, these costs were insignificant in comparison to the R29 563 724 and R31 188 619 donated by Company D to PETCO, a recycling company specializing in the recycling of polyethylene terephthalate (PET) bottles and products, for the implementation of environmental initiatives. This amounted to 80.48% and 80.65% of Company D’s total environmental expenditure for 2012 and 2013 respectively. Company A spent 0.71% and 0.76% of its total environmental costs on environmental community projects and internal printing whilst Company B spent 0.70% and 1.85% of its total environmental expenditure on these costs for 2012 and 2013 respectively. Company C did not incur any additional environmental costs in 2012 and 2013.

4.1.3 Material purchase value of non-product output

Non-product outputs such as waste, waste water and emissions resulted in wasted raw material, operating materials, energy and water. For the category of material purchase value of non-product output Company A incurred the largest cost of R968 924 in 2012 and R588 956 in 2013. In 2012 Company A spent 40.96% more than Company B and 99.59% more than Company C on material purchase value of non-product output costs while Company D did not incur any costs due to this category. In 2013 Companies B, C and D did not incur any material purchase value of non-product output costs. Company A’s material purchase value of non-product output amounted to 22.91% and

14.88% of its total environmental costs for 2012 and 2013; whilst this only accounted for 3.13% of Company B's and 0.19% of Company C's total environmental costs for 2012.

Companies B, C and D's process inefficiencies that resulted in the production of out of specification product were maintained at a minimal amount during the course of the study. The cost of non-product output for Company A could be reduced by conducting a detailed time-based input-output analysis of its raw materials and products, as most of the out of specification product occurred as a result of the use of outdated raw materials or the prolonged storage of products at the organization's or customer's site. Improved stock rotation systems will further assist in identifying and implementing cost savings opportunities in reducing and eliminating the manufacture of non-product outputs. Improved production planning strategies would ensure that customer requirements are met without the holding of raw material and/or product stock that cannot be timeously utilised or dispatched.

4.1.3.1 Raw materials and packaging

During 2012 Company A incurred the highest costs due to wasted raw materials including packaging and spent more than 38.77% compared to Company B and 99.35% more than Company C on wasted raw material and packaging for this year. Company D incurred no raw material non-product output costs for 2012 and 2013 as all out of specification products were reworked into final products. For 2013 only Company A incurred costs due to wasted raw materials that could not be blended into final products. Company A's wasted raw materials cost the company 21.78% and 14.35% of its total environmental expenditure in 2012 and 2013 respectively. Companies B and C incurred costs for wasted raw material only in 2012 which cost these companies 3.09% and 0.18% of its total environmental expenditure for this year.

With the exception of Company A, wasted raw materials and packaging as a result of out of specification products were kept to a minimal quantity and cost by Companies B, C and D. Most out of specification product manufactured by these organizations could be reworked and blended into new product batches resulting in additional energy, water, operating materials and personnel costs for the reworking process.

4.1.3.2 Operating materials, energy and water

Wasted operating materials to produce non-product output for Companies B, C and D were either zero or negligible for 2012 and 2013. Company A's wasted operating material amounted to 0.56% and 0.28% of its total environmental expenditure for 2012 and 2013 respectively. Energy used to convert materials to non-product outputs were negligible or zero for Companies C and D for 2012 and 2013. Company A incurred the most costs for energy for this sub-category spending 71.22% more than Company B for 2012 and was the only organization to incur these costs for 2013. Company A's cost of energy utilisation for non-product outputs amounted to 0.55% and 0.26% of its total environmental costs for 2012 and 2013 respectively whilst Company B only incurred this cost in 2012 which amounted to 0.04% of its total environmental expenditure. The costs for water that was wasted due to the production of non-product output was zero or negligible for all companies for both years of study.

4.1.4 Processing costs of non-product output

Processing costs of non-product output included labour costs to produce the discarded products and labour costs to rework out of specification products back into final products. Company D incurred the highest processing costs of non-product output for both 2012 and 2013 at R387 322 and R686 726 respectively for these years. Company D's costs were 57.01% higher than Company A, 85.74% more than Company B and 91.79% higher than Company C for 2012 and 73.74% higher than Company A, 95.29% higher than Company B and 97.51% higher than Company C for 2013.

Company A's processing costs of non-product output accounted for 3.94% of its total environmental costs for 2012 at R166 511 and 4.56% of its total environmental costs for 2013 at R180 361. Processing costs of non-product output made up 0.30% of the total environmental costs for 2012 and 0.36% of the total environmental costs for 2013 at R55 217 and R32 367 respectively for Company B. Company C's processing costs of non-product output made up 1.52% and 1.58% of its total environmental costs for 2012 and 2013 at R31 807 and R17 104 respectively. Processing costs of non-product output made up 1.05% and 1.78% of the total environmental costs for 2012 and 2013 at R387 322 and R686 726 respectively for Company D.

Wasted personnel costs incurred in the production of non-product output and the reworking of out of specification product could be minimized by the reduction and elimination of non-product and out of specification outputs. Quantification of this previously unknown cost allows management to realize the true cost of this activity and provides the motivation to reduce this cost by optimizing production process efficiencies and stock rotation strategies.

4.1.4.1 Labour costs of discarded product

Companies A and B spent approximately the same amount of money on labour for discarded products in 2012 at R54 592 and R55 175 respectively, whilst Company D spent negligible or zero amounts on this sub-category. Company A was the only organization to spend money on labour for discarded products in 2013 at R33 529. Labour costs for discarded product accounted for 1.29% and 0.85% of Company A's total environmental costs for 2012 and 2013, whilst Company B only incurred this cost in 2012 that amounted to 0.30% of its total environmental expenditure. Company C only incurred labour costs for discarded product in 2012 that accounted for 0.03% of its total environmental cost and did not incur any cost for this sub-category in 2013.

4.1.4.2 Labour costs of reworked out of specification product

Company D incurred the highest cost for labour for reworked out of specification products for both years of the study. Company D spent 71.10%, 99.99% and 91.94% more than Companies A, B and C respectively for 2012 and 78.62%, 95.29% and 97.51% more than Companies A, B and C respectively for 2013. Labour costs for reworked out of specification products accounted for 2.65% and 3.71% of Company A's total environmental costs for 2012 and 2013 respectively. Company B spent a negligible amount of R42 on reworking of out of specification product in 2012 and spent 0.36% of its total environmental costs on this sub-category in 2013. Company C's labour costs for reworking products amounted to 1.50% and 1.58% of its environmental expenditure for 2012 and 2013 respectively whilst Company D's percentage of total environmental costs attributed to this category was 1.05% and 1.78% for these years.

4.1.5 Total environmental expenditure

Total environmental expenditure of Company D amounted to R36 735 393 and R38 671 529 for 2012 and 2013 respectively due mainly to the contribution of 1% of all sales to PETCO. In 2012 Company D spent 88.49% more than Company A whose total environmental expenditure amounted to R4 229 644, 50.28% more than Company B who spent R18 263 783 on environmental costs and 94.31% more than Company C who spent R2 088 572 due to environmental expenditure. A similar trend was seen in 2013 with Company B incurring the second highest environmental costs followed by Companies A and C. In 2013 the total environmental expenditure for Companies A, B and C were R3 956 949, R9 086 973 and R1 080 142 respectively.

Company A's total environmental costs comprised of 0.52% of total production costs in 2012 and 0.004% of total production costs in 2013. Company B's environmental costs made up 8.69% of total production costs in 2012 and 4.46% of total production costs for 2013 which is a significant percentage of the total production costs, primarily due to costs incurred for waste and emission treatment and prevention and environmental management activities. Company C's environmental costs consisted of 2.44% of total production costs in 2012 and decreased by more than 50% to 1.10% of total production costs for 2013 due to the decrease in prevention and environmental management costs for this year. Company D's environmental costs including PETCO contributions made up 1.28 % of total production costs in 2012 and 1.20% of total production costs for 2013.

The percentage distribution of environmental costs across the environmental categories allowed the organizations to focus on cost optimization and reduction opportunities in the environmental categories where the most amount of money was spent. The absolute cost amount of each environmental category and sub-category was also important as these amounts were underestimated by all the organizations and enabled managers to understand and appreciate the magnitude of environmental costs in relation to production costs as the organizations financial and management accounting systems did not emphasize these costs. The realization that organizations environmental costs severely erode the bottom line will provide the financial motivation for organizations to embrace and incorporate sustainable development into their business strategies. Environmental costs were successfully extracted from different information systems within the organizations and incorporated into a single system that could be easily utilized and understood by all the departments within the organization.

4.1.6 Total environmental revenue

Total environmental revenue from the recycling of cardboard, plastic, paper, bulk bags, pallets, drums and scrap metal was the highest for Company A in 2012 at R400 911, who received 71.51% more than Company B who earned R114 214, 92.78% more than Company C who earned R28 960 and 12.28% more than Company D who received R351 666 for its recycling efforts. Company D received the highest revenue in 2013 at R746 700 equating to 46.27% more than the R401 174 received by Company A, 66.46% more than Company B who received R250 470 and 98.66% more than Company C who received R10 022. It was evident that recycling activities generated sufficient income for organizations to incorporate these practices into daily business processes.

4.2 Environmental key performance indicators

All the participating organizations recorded and monitored environmental costs, usages and discharges of raw materials, energy, water and hazardous waste as recommended by the GRI sustainability reporting system (GRI, 2002). The use of environmental performance indicators to monitor the usages and costs of the organization’s input and output flows is recommended as reporting and benchmarking tools and is beneficial in analyzing and recognizing environmental and process optimization opportunities as well as cost reduction strategies.

Environmental key performance indicators recommended for all four organizations who participated in the study included the cost of waste water, hazardous waste, destructed/discarded material and reworked product per kilogram of product manufactured. Using the actual costs of these indicators relative to the total production volumes for 2012 and 2013, it was possible to calculate the mean projected cost of each of these indicators for 2014 as presented in Chapter 3. Organizations can utilize these indicators as budgetary tools as well as monitor actual costs against budget costs and react timeously to any non-compliance issues and capitalize on optimization opportunities.

It was calculated that waste water cost was the highest for Company D at a projected cost of R1.13 per kilogram of product manufactured for 2014. This was 46.02% more than Company A’s 2014 projected waste water cost of R0.61/kg of product and 53.98% more than Company C’s projected

2014 cost of R0.52/kg of product. Company B recovered and reused its waste water and did not incur any waste water costs. The projected 2014 cost of disposing of hazardous waste through incineration would cost Company B R11.52/kg of product which was 52.78% more than Company A's cost of hazardous waste disposal through landfilling at R5.44/kg of product. Company B's projected 2014 cost of hazardous waste disposal was 93.92% more than that of Company C's projected cost at R0.70/kg of product and 99.57% more than Company D's cost at R0.05/kg of product. The projected 2014 cost of destructed material was the highest for Company A at R2.86/kg of product, 5.56% higher than Company B's cost of R2.70/kg of product and 98.95% more than Company C's cost of R0.03/kg of product. Company D did not incur any costs due to destructed material. The 2014 projected cost of reworking out of specification product would cost Company B the most at R2.79/kg of product that is 76.34% more than Company A's cost of R0.66/kg of product, 50.18% more than Company C's cost of R1.39/kg of product and 97.85% more than Company D's cost of R0.06/kg of product.

4.3 External environmental costs

External environmental costs are costs that arise out of the activities of the chemical manufacturing sector but are not accounted for and internalized by these companies. These costs are imposed on society who must either suffer the consequences of pollution arising from industrial activities or pay for the clean-up and remediation of this pollution. The cost of air emissions, waste water quality and quantity and solid waste as a result of the activities of the participating organizations were calculated and presented in Chapter 3. These costs were determined utilizing European taxes and external cost studies.

An annual equivalent German waste water tax indication of the external cost of waste water on the environment and society based on waste water quantities and COD levels for 2012 and 2013 revealed that Company D would have incurred costs of R4 861 912 and R2 252 329 due to waste water taxes for these two years respectively. Company C would have realized waste water taxes of R905 651 in 2012 and R655 807 in 2013. Company A's waste water taxes would have remained fairly consistent at R343 063 for 2012 and R386 517 for 2013. Company B recovered and reused it waste water.

External emission costs for the organizations were determined using external cost studies based on the emission pollutant concentrations and quantities as measured and analysed by the organizations. The average annual emissions costs for these organizations revealed that Company A's emissions resulted in the highest external cost to the environment and society at a cost of R202 941 for 2012 and R248 216 for 2013, mostly due to high carbon dioxide and particulate matter emissions. Company B's external emission costs amounted to R51 829 for 2012 and R63 425 for 2013 of which 98.38% of these costs for both these years consisted of the external costs of carbon dioxide emissions. Company C's external emission costs was evaluated at R90 689 for 2012 and R116 720 for 2013 consisting primarily of carbon dioxide emission costs and NO_x as NO_2 emission costs. Company D contributed a negligible amount to external emissions costs at R55 and R68 for 2012 and 2013 respectively.

The external impacts of hazardous and non-hazardous waste disposal at landfill sites by the organizations included leachate contamination of surface water, groundwater systems and soil. The creation of landfill sites also resulted in the degradation of ecosystems and generation of landfill gas emissions. The external costs of waste disposal at landfill sites was determined using average European landfill taxes as discussed in Chapter 3. External costs of general non-hazardous waste disposal at landfill sites was the highest for Company B at R76 019 in 2012 while Company D incurred costs of R61 192 due to this externality. Company A and C did not send any general non-hazardous waste to landfill sites in both 2012 and 2013. In 2013 Company B's external cost due to non-hazardous waste disposal at landfill sites decreased to R26 335 and Company D's cost increased to R87 976. Company A's external costs to society and the environment due to hazardous waste disposal at landfill sites was determined to be the highest of all the organizations at R820 873 for 2012 and R983 063 for 2013. Company C's and D's external costs due to hazardous waste disposal amounted to R56 057 and R11 370 for 2012 and R89 969 and R27 689 for 2013 respectively. Company B incinerated its hazardous waste. European incineration taxes were used to determine Company B's external cost of incineration which equated to R12 859 for 2012 and R9 943 for 2013. European incineration taxes do not adequately reflect the effect of incineration on the environment which as discussed in Chapter 2 has a higher external cost than does landfilling. The incineration taxes calculated for Company B was therefore an under-evaluation of the true cost of incineration on society and the environment.

All external costs i.e. waste water taxes, emissions taxes, landfill and incineration taxes were combined to obtain the total external costs of each of the four organizations. Company D had the largest impact on the environment and society at a cost of R4 873 337 for 2012 and R2 280 086 for 2013. Company D's external costs for 2012 was 71.95% and 78.41% more than Companies A and C respectively. Company A and C also had a significant impact on the environment at a cost of R1 366 877 and R1 617 797 for Company A and R1 052 397 and R856 496 for Company C in 2012 and 2013 respectively. Company B's external cost on society and the environment was minimal in comparison to the other three organizations at a cost of R64 688 for 2012 and R73 368 for 2013.

The implementation of environmental taxes by the South African government will compel organizations to implement cleaner technologies and environmental management strategies that will result in the reduction of environmental costs that will maximize profits while minimizing pollution.

4.4 Green Gross Domestic Product for the chemical manufacturing sector of South Africa

The cost of industrial environmental impacts is not considered in conventional Gross Domestic Product calculations. The Green Gross Domestic Product compensates for the cost of environmental and social issues and adjusts the Gross Domestic Product to reflect these costs. Green GDP was calculated for the four organizations by using the external costs imposed by the organizations as discussed in Chapter 3.

These calculations are an indication that external costs imposed by the chemical manufacturing sector of South Africa had a significant effect on the Gross Domestic Product of this sector, having reduced the GDP by 0.006% for 2012 and 2013 which equated to a reduction in GDP of R 621 888 873 for 2012 and R612 175 018 for 2013. It is therefore evident that to continue building a sustainable South African economy government needs to internalize the external costs imposed by the chemical manufacturing sector of South Africa. More stringent environmental legislation and corresponding taxation will compel South African organizations to reduce environmental costs and subsequently environmental and societal impacts.

4.5 Social performance indicators

Aspects of social performance as recommended by the GRI reporting system (GRI, 2011) were measured and monitored for the period of study as presented in Chapter 3. Social performance aspects monitored included labour practices and societal issues. Gender disproportionality in employment opportunities is evident by the lower number of women employed at the participating organizations. This infers a skills deficiency in scientific, technical and industrial vocations amongst the female population of South Africa that needs to be addressed. Company B's permanent labour force consisted of 31.03% and 30.50% of women for 2012 and 2013 respectively, the highest number of women compared to the other three organizations. Companies A, C and D's permanent labour force consisted of 17.33%, 16.33% and 16.42% of women in 2012 and 21.92%, 19.23% and 13.13% of women in 2013 respectively. The number of senior women executives employed by all organizations was 1 or 0 for both 2012 and 2013 indicating an area requiring focus by all organizations. In alignment with black economic empowerment strategies implemented by the South African government and population demographics the number of white employees employed by all four organizations were lower than the number of non-white employees. The number of employees with disabilities as a percentage of the permanent labour force employed was the highest for Company C at 5.26% and 4.84% for 2012 and 2013 respectively. Companies A, B and C's staff with disabilities consisted of 1.14%, 2.11% and 1.28% of the total permanent workforce for 2012 and 1.12%, 1.09% and 0.89% of the total permanent workforce for 2013 respectively.

Company B spent R1 520 337 in 2012 on employee education training costs, which was 82%, 84% and 64% more than what Companies A, C and D spent respectively. Company B spent R2 550 972 in 2013 on employee education training costs, which was 98%, 88% and 74% more than what Companies A, C and D spent respectively. No disabling injuries were experienced by any of the organizations during the two years of this study. All employees benefited from health care and health education programs provided by all four organizations during 2012 and 2013. All organizations provided monetary donations to the community and endeavoured to employ in-service trainees in order to provide employment skills to the younger generation within the communities in which they operated. Social sustainability practices amongst all the organizations were well entrenched.

4.6 Conclusion

The impact of the organizations environmental costs on the environment and the triple bottom line was discussed in this chapter. A comparison of the environmental costs between the organizations studied was performed. The percentage contribution of each environmental cost sub-category to the total environmental cost as well as the absolute environmental costs and environmental revenue amounts was discussed. The quantification of the recommended environmental key performance indicators was presented and the external environmental costs due to emissions, waste water and solid waste generation evaluated. The Green Gross Domestic Product of the chemical manufacturing sector of South Africa was discussed and the social performance indicators of the participating organizations assessed. Lastly the organizations internal environmental costs, external environmental costs and social performance were holistically evaluated to determine the effect of these dimensions on the triple bottom line of the chemical manufacturing sector of South Africa.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions and key findings of this study

The aim of this research was to implement environmental management accounting systems within four organizations of the Durban Chemicals Cluster in the chemical manufacturing sector of Durban, KwaZulu-Natal, South Africa as well as determine the triple bottom line of the companies by accounting for the external costs that these companies place on society and the environment.

The results of the research indicate that:

- All the organizations studied had an environmental policy and an environmental management system in place; however the adherence to these policies and systems could be improved upon. Management and financial accounting systems did not focus on environmental costs and did not consider the effect that environmental costs and impacts had on the bottom line of the organization;

- Environmental management accounting (EMA) integrated each organization's environmental costs into one central system. This enabled them to realize and appreciate the total environmental expenditure incurred which equated to millions of rands per annum;

- The EMA system adopted identified issues and trends that facilitated decision-making in improving environmental performance in the chemical manufacturing sector of South Africa. For example, the large annual costs of hazardous waste disposal through landfilling or incineration, as well as effluent disposal costs, had propelled organizations to rethink their process activities in order to reduce these costs. Company D's environmental research and development activities during 2012 and 2013 resulted in the planned installation of a waste water treatment plant in 2014 and 2015 that will significantly decrease effluent quantities, COD loading and effluent costs;

- The majority of environmental expenditure incurred by organizations in the Durban Chemicals Cluster was due to prevention and environmental management costs followed by waste and emission treatment costs;

- Most manufactured products that were out of specification and could not be sold to customers could be reworked and blended into new product batches thereby reducing the quantity and costs of non-product outputs;

- Environmental costs as a percentage of the organization's production costs varied between 0.524% and 8.694% for 2012 and 0.004% to 4.456% for 2013, which indicated the significant effect that environmental costs had on the organization's profits. These environmental costs will continue to erode the organization's future profits if not properly managed and optimised;

- Environmental revenue was realized by all the organizations through the recycling and sale of cardboard, plastic, paper, bulk bags, scrap metal, pallets and drums; thereby reducing landfill loading and natural resource depletion;

- The effect of air emissions, waste water quality and solid/semi-solid waste production by the organizations, as determined with the use of European tax evaluation methods disclosed that the external costs borne by society and the environment as a result of chemical manufacturing activities was in the region of millions of rands within organizations in the Durban Chemicals Cluster;

- External costs as a percentage of production costs for all organizations for both 2012 and 2013 averaged 0.375%, which was an indication of the negative effects placed on society and the environment by the chemical manufacturing sector of South Africa;

- The effect of external costs on the Gross Domestic Product or Green Gross Domestic Product resulted in a reduction in the Gross Domestic Product of the chemical manufacturing sector of South Africa by 0.006% which in monetary terms substantially reduced the Gross Domestic Product for 2012 by R621 888 873 and for 2013 by R612 175 018;

- Social sustainability practices amongst all the organizations revealed that men still formed the dominant employee base in the chemical manufacturing sector due to the skills deficiencies of women in the scientific and technical fields. Employee training was well funded, health and safety in the workplace was an area of priority and community focus in terms of manhours and funding could be improved upon.

This study demonstrates that significant internal environmental costs, external costs and social costs incurred by the organizations in the Durban Chemicals Cluster substantially eroded the triple bottom line of these organizations. The chemical manufacturing sector of South Africa has to be held accountable for the impacts of their activities on the environment and society through legislature and external pressure. Management of environmental costs and waste streams will ensure sustainable development as well as increased future profit and growth within this sector.

5.2 Recommendations for triple bottom line accounting for the chemical manufacturing sector of South Africa

Changes in production processes affects the quantity and quality of waste streams (waste water, emissions and solid waste) discharged from the organizations thereby changing the external costs and impacts to the society and the environment in which the organization operates. Environmental costs are consequently affected resulting in changes to the organizations financial performance by either increasing or decreasing the organizations bottom line accordingly. It is therefore evident that changes to one dimension of sustainable development changes the other two dimensions as well, making the economic, environmental and social dimensions of sustainable development interdependent of each other (Brown et al, 2006). Triple bottom line accounting that incorporates environmental and social accounting demonstrates the organizations commitment to the welfare of its employees, community and country. This study attempted to quantify the environmental and social aspects of sustainable development thus enabling triple bottom line accounting and reporting by the organization.

Implementation of the EMA system, determination of the external environmental costs of waste water, emissions and solid wastes as well as identification of social performance indicators in organizations within the Durban Chemicals Cluster allowed the balancing of the organizations' economic analysis with its environmental and social performance analysis thereby integrating triple bottom line accounting into their business activities.

At industry level, the following recommendations are made:

- Environmental costs within the organizations are scattered amongst the different departments and cost centers in each organization. It is recommended that each organization create a new and distinct cost category/center for total environmental expenditure under which each of the sub-categories of waste and emission treatment, prevention and environmental management, material purchase value of non-product output and processing costs of non-product output are allocated their own sub-cost category or sub-cost center. All environmental costs must be linked or allocated to these cost centers to facilitate ease of incorporation into the environmental management accounting system;

- A 'cradle to grave' approach of waste management needs to be adopted by organizations within the chemical manufacturing sector of South Africa. Organizations can play a crucial role in improving waste management in South Africa by ensuring that landfill operators adhere to waste management policies and provide organizations and government with evidence of their compliance to legislation. Landfill operators should also provide evidence of monitoring of groundwater, surface water, soil contamination and emissions and the remediation actions taken to mitigate these contaminations. It is recommended that organizations conduct landfill site audits to ensure compliance by operators to legislation;

- Projects and initiatives to recycle and re-use waste water by the chemical manufacturing sector is critical for the reduction of both fresh water consumption and waste water generation, as water resources are under severe constraint to meet the demands of the domestic and industrial sectors of South Africa;

- Organizations can reduce the cost of non-product outputs by conducting detailed time-based input-output analysis of its raw materials and products, as it was evident from the study that most of the out of specification product occurred as a result of the use of outdated raw materials or the prolonged storage of products at the organization's or customer's site. Improved stock rotation systems will further assist in identifying and implementing cost savings opportunities in reducing and eliminating the manufacture of non-product outputs. Improved production planning strategies would ensure that customer requirements are met without the holding of raw material and product stock that cannot be timeously utilised or dispatched;

- The implementation of key environmental performance indicators within the chemical manufacturing sector as identified in the study includes effluent/waste water cost per kilogram of product manufactured, hazardous waste cost per kilogram of product manufactured, destructed material cost per kilogram of product manufactured and reworked material cost per kilogram of product manufactured. Weekly or monthly tracking of these key environmental performance indicators against budgeted values will allow for the prompt identification and implementation of reduction and optimization opportunities;

- Skills deficiency in the scientific and industrial vocations amongst the female population of South Africa may be inferred by the lower number of women employed by organizations within the Durban Chemicals Cluster. There were also none or a minimal number of senior women executives employed by organizations within the Durban Chemicals Cluster. The chemical manufacturing sector of South Africa need to employ more women at all levels within their organizations and provide more bursaries, scholarships and apprenticeships for women to develop their academic and technical skills in the manufacturing and industrial sectors of South Africa.

At a national policy implementation level, the following recommendations are made:

- The financial, social and environmental benefits due to the implementation of triple bottom line accounting have been adequately demonstrated in this study. Focus on triple bottom line accounting will contribute to improved resource efficiencies and cleaner production in the chemical manufacturing sector of South Africa. The South African government can assist in the implementation of triple bottom line accounting by sponsoring awareness campaigns and incentives in the manufacturing sector of South Africa. It is recommended that the government utilize the Environmental Management Accounting Network (EMAN)-Africa to implement and manage these programmes.

- There is a need for environmental management accounting practices to be incorporated into financial and management accounting practices. This can be driven by financial reporting governance;

- Government can promote the industrial application of environmental management accounting *via* policy instruments such as information-based instruments for example the development of environmental management accounting software and distribution, economic incentive instruments such as taxes or subsidies and fines and penalties, self-regulatory instruments such as voluntary implementation of environmental management accounting, environmental management systems and environmental reporting (Ambe, 2007b);

- The external costs of an organization's activities on the society and the environment in which it operates can be quantified, internalized and integrated into the organization's environmental management accounting system through the implementation of environmental taxes, in accordance with the Polluter Pays principle and as calculated in this study for the organizations within the Durban Chemicals Cluster. As demonstrated in Europe, the implementation of landfill and incineration taxes will reduce waste and increase recycling and other environmentally beneficial waste management activities. Decreased landfill loading will reduce leachate contaminations and methane gas emissions, benefiting both society and the environment. It is recommended that landfill taxes vary according to type (hazardous, non-hazardous, general) of waste and quantity of waste sent to landfill sites as well as the environmental impacts of the waste type on the landfill site, the environment and the community in which the site operates. The tax rate should be significant enough to provide adequate incentive for waste producers to implement recycling and re-use strategies. The tax should be paid by the waste producers to the landfill operator as an additional amount to the fees paid to the landfill operator to collect and dispose of the waste. The landfill operator would then pay these taxes to the local government municipality in which it operates (Fischer et al, 2012). Tax revenues can be utilized for waste management activities such as prevention and remediation of contaminated landfill sites, funding of waste management and waste treatment strategies, research and infrastructure (Fischer et al, 2012). Similarly, waste water and emission taxes that affect the organization's bottom line will force industrial treatment and/or re-use of waste water and emissions thereby reducing the effects and costs of these externalities on society and the environment.

External costs imposed by the chemical manufacturing sector of South Africa significantly reduce the Gross Domestic Product of this sector. To continue building a sustainable South African economy government needs to internalize the external costs imposed by the chemical manufacturing sector of South Africa. More stringent environmental legislation and corresponding taxation will compel South African organizations to reduce environmental costs and subsequently environmental and societal impacts;

- Groundwater is a valuable and under-utilized resource that needs to be managed by government to provide South Africans with an alternate source of potable water. There is currently no evaluation and monitoring of industrial groundwater contamination by government and therefore no consequences related to this environmental externality. It is recommended that groundwater contamination surveys be performed by the Department of Water Affairs in industrial areas and industries be held accountable for groundwater contamination. Regulatory measures that can assist in the prevention, reduction and control of soil and groundwater quality are permits, quality standards and penalties (Zaporozec, 2002). These measures will force industry to enforce good management practices that will prevent soil and groundwater contamination such as above ground installation of chemical storage tanks and offloading areas that are adequately enclosed so as to contain spillages and drainage systems that correctly treat and dispose of spilt chemicals (Zaporozec and Miller, 2000; Hohne, 2004; Government of Alberta, 2010);

- The social sustainability aspect of gender equality must be actively addressed by government. The skills deficiency in scientific and industrial vocations amongst the female population in South Africa must be compensated for by the introduction of education and scholarship programmes that encourage young women to consider these fields of study. Gender equality in employment opportunities must continuously be addressed through stringent employment equity practices and reporting structures.

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APPENDICES

Appendix 1: Environmental management accounting expenditure and revenue template

(Appendix 1 is available to view on the attached disc on the back cover of the thesis)

Appendix 2: Letter of introduction addressed to the managers of the companies within the Durban Chemicals Cluster

<u>Permission to introduce an environmental management accounting system into your organization as a case study for a PhD in Environmental Science</u>

In South Africa, the second King Report on Corporate Governance (King II) acknowledged the shift in emphasis from a mainly financial focus of the past to a wider and more inclusive approach to doing business in the future. This resulted in a shift from the single bottom line (that is, profits only) to a triple bottom line that embraces the economic, environmental and social aspects of a company's activities.

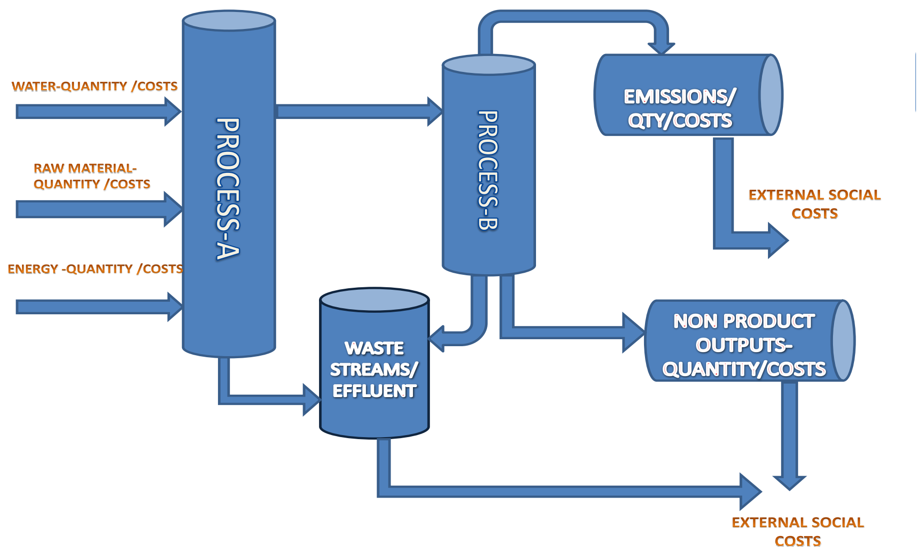
I have a BSc Chemical engineering and have spent the last 15 years in the projects, process and cost optimization field at Sappi Saiccor at Umkomaas and the South African Breweries at Prospecton. My MSc research focused on environmental management and I want to expand that research into looking at "Triple bottom line accounting for the manufacturing sector in South Africa". This study will highlight areas of cost reduction and revenue raising opportunities within your organization. While initially some resources may be required to obtain the data, the long term benefits of identified waste reductions, water and energy savings will more than compensate for this.

Your organization name will remain anonymous, unless you wish otherwise.

Please consider this as an opportunity for an outside consultant to review your processes with the ambition of cost reduction and improving your environmental management systems.

<u>Scope of work</u>

Identify environmental revenue or cost cutting opportunities currently being ignored by quantifying all environmental costs via an environmental management accounting system. Quantify external/social costs.



Appendix 3: Letter including details of study addressed to the managers of the companies within the Durban Chemicals Cluster (Pages 212 – 214)

Permission to introduce an environmental management accounting system into your organisation as a case study for a PhD in Environmental Science

Introduction

"Triple bottom line accounting for the Manufacturing sector in South Africa".

In South Africa, the second King Report on Corporate Governance (King II) acknowledged the shift in emphasis from a mainly financial focus of the past to a wider and more inclusive approach to doing business in the future. This resulted in a shift from the single bottom line (that is, profits only) to a triple bottom line that embraces the economic, environmental and social aspects of a company's activities.

Internal environmental costs as well as the social and external costs occurring as a result of your economic activities will be considered. The previous year's annual data will be used to determine the environmental costs. **The name of your organisation will remain anonymous, but will be reported as an industry in the manufacturing sector of South Africa.**

Triple bottom line accounting is an expansion of the traditional reporting framework to accommodate ecological and social performance as well as financial performance.
A sustainable management accounting system is a management system that concurrently provides economic, environmental and social information.

Environmental management accounting (EMA) incorporates and integrates two of the three building blocks of sustainable development, environment and economics, as they relate to an organization's internal decision-making. External or social costs occur when the economic activities of an organization adversely affect society and the environment, but the adverse impacts are not fully accounted for, or compensated for, by the organization. External or social costs need to be integrated into a sustainable management accounting system, by an internalization of external costs.

Scope of work

Environmental Management Accounting:

Define the boundaries of the proposed system.

Ascertain the organization's environmental impacts.

Determine, how if at all, environmental impacts are being accounted for.

Define environmental costs.

Review existing accounting systems.

Identify environmental revenue or cost cutting opportunities currently being ignored.

Suggest changes to the existing accounting system.

Determine the internal environmental costs of the organization.

External/Social Costs:

Place a value on external/social impacts caused by the organization.

Using physical flow quantities obtained from the EMA system determine the organization's external/ social cost within the manufacturing sector of South Africa.

Green Gross Domestic Product:

Use the external costs obtained to determine the green GDP of the manufacturing sector of South Africa.

The type of information required from the organization

Environmental costs/expenditures for the following:

1. Waste and emission treatment

1.1. Depreciation for related equipment
1.2. Maintenance and operating materials and services
1.3. Related personnel
1.4. Fees, taxes, charges
1.5. Fines and penalties
1.6. Insurance for environmental liabilities
1.7. Provisions for clean-up costs, remediation

2. Prevention and environmental management

2.1. External services for environmental management
2.2. Personnel for general environmental management activities
2.3. Research and development
2.4. Extra expenditure for cleaner technologies
2.5. Other environmental management costs

3. Material purchase value of non-product output

3.1. Raw materials
3.2. Packaging
3.3. Auxiliary materials
3.4. Operating materials
3.5. Energy
3.6. Water

4. Processing costs of non-product output

5. Environmental revenues
5.1. Subsidies, awards
5.2. Other earnings

Data will be collected via the following channels:

- Initial workshops or interviews with the relevant plant personnel will be held to discuss the scope of work and understand the organisation's process flow of physical materials and outline the organisation's material balance.
- A second workshop or interviews with the relevant personnel to understand the current accounting systems and to obtain environmental cost data.
- Environmental and sustainability reporting information from internal company reports will be accessed.
- Liaison with the relevant plant personnel to obtain the data required.

Your assistance in affording me this opportunity would be greatly appreciated.

Yours faithfully

Vasagie Moodley

Appendix 4: Consent and disclosure/non-disclosure agreement (Pages 215 – 219)

Department of Environmental Sciences
University of Kwa-Zulu Natal
Private Bag X 54001, Durban, 4000
Tel.031 260 1111
enquiries@ukzn.ac.za

19 January 2012

Dear Sir/Madam

CONSENT AND DISCLOSURE/NON-DISCLOSURE AGREEMENT TO CONDUCT RESEARCH AT YOUR ORGINISATION

I, Vasagie Moodley, want to pursue a Doctorate in Philosophy at the Department of Environmental Sciences at the University of Kwa-Zulu Natal, under the supervision of Dr Srinivasan Pillay.

My research will investigate "Triple bottom line accounting for the chemical manufacturing sector in South Africa". Triple bottom line accounting is an expansion of the traditional reporting framework to accommodate ecological and social performance as well as financial performance. This study will introduce environmental management accounting into your organization and highlight areas of cost reduction and revenue raising opportunities within your organization. Internal environmental costs as well as the social and external costs occurring as a result of your economic activities will be considered.

I request your consent to utilize your organization as a case study for this research within the Durban Chemicals Cluster. I undertake to maintain the anonymity of the name of your organization, unless you grant me permission to use the name of your organization. Participation in the proposed research is voluntary and you are free to withdraw from the research at any time without any negative or undesirable consequences to yourself or your organization.

Data will be collected via the following channels:

- Workshops or interviews with the relevant plant personnel will be held at the organization to discuss the scope of work and understand the organization's process flow of physical materials and outline the organization's material balance.
- Workshops or interviews with the relevant personnel to understand the current accounting systems and to obtain environmental cost data.
- Environmental and sustainability reporting information from internal company reports will be accessed.
- Liaison with the relevant plant personnel to obtain the data required.

Please note that, by participating in this research no financial benefit or remuneration will accrue to you, however your participation will result in the identification of cost reduction and revenue raising opportunities within your organization.

In order to guarantee the authenticity of the research undertaken and to fulfill the requirements of the attainment of the degree Doctorate of Philosophy; the following disclosure and non-disclosure items are agreed upon:

Table 1: Non-disclosure data

ITEM NO.	NON-DISCLOSURE DATA/INFORMATION	CONSENT GIVEN FOR NON-DISCLOSURE YES/NO
1	Organization name	
2	Process operating conditions such as temperature, pressure, reaction time	
3	Raw material chemical composition and/or brand name	
4	Auxiliary material chemical composition and/or brand name	
5	Operating material chemical composition and/or brand name	
6	Company specific product brand names	

Table 2: Disclosure data

ITEM NO.	DISCLOSURE DATA/INFORMATION	CONSENT GIVEN FOR DISCLOSURE YES/NO
1	Company A is a member organization of the Durban Chemicals Cluster	
2	Company A belongs to the chemical manufacturing sector in Durban and its surrounding areas	
3	Product groups for example polymers, acrylics, resins	
4	Description of the manufacturing processes	
5	Production quantities and/or production rates	
6	Raw materials besides water and energy will be specified as Raw Material A1, B1, C1 for example.	
7	Auxiliary and operating materials besides water and energy will be specified as Raw Material A1, B1, C1 for example.	
8	Raw material quantities	
9	Auxiliary material quantities	
10	Operating material quantities	
11	Packaging materials, for example, cardboard, drums, paper, containers etc. will be specified; but not specific packaging brand names if applicable	
12	Packaging material quantities	
13	Water quantities	
14	Energy quantities for example steam, electricity, refrigerants etc	
15	Waste stream quantities	

ITEM NO.	DISCLOSURE DATA/INFORMATION	CONSENT GIVEN FOR DISCLOSURE YES/NO
16	Chemical composition and physical composition of waste streams	
17	Waste stream discharge methods	
18	Emission quantities	
19	Chemical composition and physical composition of emissions	
20	Emission discharge methods	
21	Water balances which will incorporate flow rates and quantities	
22	Energy balances which will incorporate flow rates and quantities	
23	Raw/auxiliary/operating materials balances specifying quantities	
24	Effluent and waste stream treatment processes without actual chemical names and operating conditions such as temperature, pressure and times. Quantities will be disclosed.	
25	Emission treatment processes without actual chemical names and operating conditions such as temperature, pressure and times. Quantities will be disclosed.	
26	Impacts of the organization's activities on the environment and society	
27	Environmental costs as specified in Table 3; but not wholly inclusive of these specified costs	
28	External environmental costs imposed by the organization	

Table 3: Examples of Environmental Costs									
ENVIRONMENTAL DOMAIN / ENVIRONMENT-RELATED COST CATEGORIES	Air and Climate	Waste Water	Waste	Soil, Surface and Groundwater	Noise and Vibration	Biodiversity and Landscape	Radiation	Other	Total
1a. MATERIALS COSTS OF PRODUCTS									
1.1. Raw and Auxiliary Materials									
1.2. Packaging Materials									
1.3. Merchandise									
1.4. Operating Materials									
1.5. Water									
1.6. Energy									
TOTAL MATERIALS COSTS OF PRODUCTS	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1. MATERIALS COSTS OF NON-PRODUCT OUTPUTS	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
1.1. Raw and Auxiliary Materials									
1.2. Packaging Materials									
1.3. Operating Materials									
1.4. Water									
1.5. Energy									
1.6. Processing Costs									
2. WASTE and EMISSION CONTROL COSTS	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2.1. Equipment Depreciation									
2.2. Operating Materials									
2.3. Water and Energy									
2.4. Internal Personnel									
2.5. External Services									
2.6. Fees, Taxes and Permits									
2.7. Fines									
2.8. Insurance									
2.9. Remediation and Compensation									
3. PREVENTIVE and OTHER ENVIRONMENTAL MANAGEMENT COSTS	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
3.1. Equipment Depreciation									
3.2. Operating Materials, Water, Energy									
3.3. Internal Personnel									
3.4. External Services									
3.5. Other									
4. RESEARCH and DEVELOPMENT COSTS	0	0	0	0	0	0	0	0	0
5. LESS TANGIBLE COSTS	0	0	0	0	0	0	0	0	0
TOTAL ENVIRONMENT-RELATED COSTS (1. + 2. + 3. + 4. + 5.)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
6. ENVIRONMENT-RELATED EARNINGS									
6.1. Other Earnings									
6.2. Subsidies									

Please note that I, the undersigned, am your contact for the duration of the research. You may contact me during office hours, Tel. 031 9101 385/ 082 -9217383
or e-mail: Vasagie.moodley@za.sabmiller.com

Your cooperation is greatly appreciated.

Yours faithfully
Vasagie Moodley (Researcher)

CONSENT TO CONDUCT RESEARCH

ORGANISATION:

I, __________________________; representing ________________________ (organization name), in my

capacity as ________________________ (title) hereby consent to the above research being undertaken

and agree to the disclosure and non- disclosure data as tabled in this document.

Signed on this _____________ day of ___________ (month) ___________ (year)

Signature: _____________________________

RESEARCHER

I, _________________________, the researcher, hereby declare that I have asked

________________________, the participant, if he/she is fully aware of the terms and

conditions of this letter, and that he/she has granted permission to me to conduct the

research as per the disclosures and non-disclosures outlined in this document.

Signed on this _____________ day of ___________ (month) ___________ (year)

Signature:__________________________________

Appendix 5: University of Kwazulu-Natal's confidentiality declaration form

UNIVERSITY OF KWAZULU-NATAL
COLLEGE OF AGRICULTURE, ENGINEERING & SCIENCE

CONFIDENTIALITY DECLARATION FORM FOR RESEARCH TOWARDS MASTERS/DOCTORAL STUDIES

THIS FORM IS TO BE COMPLETED BEFORE ANY AGREEMENT IS SIGNED BETWEEN A SPONSOR AND THE UNIVERSITY OF KWAZULU-NATAL

School / College Agriculture, Engineering and Science
Student Name Vasagie Moodley
Student Number 9035475
Degree PhD Environmental Science
Proposed dissertation title Triple bottom line accounting for the chemical manufacturing sector in South Africa
Supervisor's name Dr Srinivasan Pillay
Proposed sponsor Participating organization name

Nature / extent of confidentiality agreement requested by sponsor

As per the attached Consent and Disclosure/Non-disclosure Agreement; the following items, amongst others, as listed in the attached agreement; will not be disclosed/published:
Organization name
Process operating conditions such as temperature, pressure, reaction time
Raw material chemical composition and/or brand name
Auxiliary material chemical composition and/or brand name
Operating material chemical composition and/or brand name
Company specific product brand names

Reason for such request

Due to the competitive business and legislative environment in which this organization operates, the above non-disclosure items are required to avoid any risks to the business.

Obligations on / action required by the College if agreement accepted

The anonymity of the organizations participating in the study must be maintained at all times. The non-disclosure items agreed upon with the sponsor may not be used in any manner to prejudice the outcome of the study conducted by the student.

Recommendation by Supervisor

____
____
____
____

______________________ _____________________
Signature of Student **Signature of Supervisor**

Recommendation by Dean & HOS / Academic Leader: Research

____
____

__________________________ _____________________
Signature of Dean & HOS / ALR **Date**

Recommendation by College Higher Degrees Committee:

Agreed/Not Agreed
Comments:

____
____

Dean: _______________________ _____________________
Signature **Date**

Sponsor: _______________________ _____________________
Signature of Sponsor's Representative **Date**

Appendix 6: Preliminary general questionnaire

<u>Preliminary General Questionnaire</u>

Organization Pseudonym: _______________________________

Date: _________________________________

Please tick the relevant blocks.

1. What is your position in your organization?

Environmental manager/practitioner	SHEQ manager	Financial practitioner	Production engineer	Other (Specify)

2. What is the approximate annual turnover of your organization?

< R50 million	R50 million – R100 million	R100 million – R250 million	R250 million – R500 million	R500 million – R1 billion

3. What is the approximate number of employees in your organization?

< 20	21 – 50	51 – 100	101 - 150	151 - 200	201 - 250

4. Does your organization have an environmental policy?

Yes	No

5. Does your organization have an environmental management system?

Yes	No

6. Does your organization have ISO 14001 certification?

Yes	No

7. Does your organization perform environmental audits?

Yes	No

8. Does your organization publish an annual environmental report?

Yes	No

9. Does your organization include an environmental section in its annual report?

Yes	No

10. Does your organization have a dedicated person who is responsible for environmental aspects at your organisational site?

Yes	No

11. Does your organization comply with environmental legislation?

Yes	No

12. Has your organization performed a total organisational environmental impact assessment?

Yes	No

13. Has your organization performed a total organisational risk analysis?

Yes	No

14. Does your organization perform impact assessments or hazard and operability studies for new raw materials/products/projects/modifications?

Yes	No

15. Have your employees and contractors received training/information to ensure that they are aware of your organizational risks and environmental issues?

Yes	No

Appendix 7: Air emission standards for the incineration of general and hazardous waste in dedicated incinerators (Source: South Africa, 2010:31)

Description	***"Facilities where general and hazardous waste including health care waste, crematoria, veterinary waste, used oil or sludge from the treatment of used oil are incinerated."***		
Application	***"Facilities with an incinerator capacity of 10kg of waste processed per hour or larger capacity"***		
Substance or mixture of substances	**Chemical symbol**	**Plant status**	**Mg/Nm³ under normal conditions of 10% oxygen and at 273 Kelvin and 101.3 kPa**
Particulate matter	None	New	10
		Existing	25
Carbon monoxide	CO	New	50
		Existing	75
Sulphur dioxide	SO_2	New	50
		Existing	50
Oxides of nitrogen	NO_x expressed as NO_2	New	200
		Existing	200
Hydrogen chloride	HCL	New	10
		Existing	10
Hydrogen fluoride	HF	New	1
		Existing	1
		Existing	10
Sum of lead, arsenic, antimony, chromium, cobalt, copper, manganese, nickel, vanadium	Pb+As+Sb+Cr+Co+Cu+Mn+Ni +V	New	0.5
		Existing	0.5
Mercury	Hg	New	0.05
		Existing	0.05

Substance or mixture of substances	**Chemical symbol**	**Plant status**	**Mg/Nm³ under normal conditions of 10% oxygen and at 273 Kelvin and 101.3 kPa**
Cadmium and Thallium	Cd+Tl	New	0.05
		Existing	0.05
Total organic compounds	TOC	New	10
		Existing	10
Ammonia	NH_3	New	10
		Existing	10
			Ng l-TEC/Nm³ under normal conditions at 10% oxygen and 273 Kelvin and 101.3 kPa
Dioxins and furans	PCDD/PCDF	New	0.1
		Existing	0.1

Appendix 8: Landfill taxes per European country (Source: Revise Sustainability, 2013; Fischer et al, 2012) (Pages 226 – 228)

European country	**Description of waste**	**Year of introduction of tax**	**Landfill tax amount for the year**	**Tax amount in Euros/ton**	**Effects of landfill tax**
Austria	Organic waste	1989	2011	87	Increase in waste recycling and recovery resulting in reduced landfilling. 34% decrease in domestic landfilled waste from 2004 to 2009. 28% decrease in total landfilled waste from 2003 to 2010.
Austria	Hazardous waste	1989	2012	29.80	
Belgium-Flanders region	Flammable waste	1990	2011	79.56	Decrease in landfilling from 1 million tons in 1996, when the landfill tax rate reached 40 Euros/ton to approximately 50000 tons in 2006, when the landfill tax rate reached 63 Euros/ton.
Belgium- Wallonia	Hazardous and non-hazardous waste	1991	2010	65	Belgium's Wallonia region has shown a similar pattern of declining landfill waste volumes as per the Flanders region; from 2004.
Belgium- Wallonia	Non-hazardous industrial waste	1991	2010	60	
Belgium- Wallonia	Hazardous industrial waste	1991	2010	65	

European country	Description of waste	Year of introduction of tax	Landfill tax amount for the year	Tax amount in Euros/ton	Effects of landfill tax
Czech Republic	Municipal and other waste	1992	2011	20	Recycling increased from 12% in 1997 to 32% in 2010 and landfilling decreased from 85% in 1997 to 60% in 2010; as landfill tax rates increased.
Czech Republic	Hazardous waste – basic charge	1992	2011	68	
Czech Republic	Hazardous waste – risk charge	1992	2011	180	
Czech Republic	Total hazardous waste charge	1992	2011	248	
Denmark	Non-hazardous waste	1987	2011	63.3	Landfilling decreased from 39% in 1985 to 6% in 2009.
Denmark	Hazardous waste	1987	2012	21.3	
Estonia	Hazardous, non-hazardous and municipal waste	1990	2010	12	
Finland	All wastes that has the potential to be recovered	1996	2013	50	
France	Non-hazardous waste	1992	2013	30	Landfilling decreased from 45% in 1995 to 32% in 2009 and recycled waste increased from 18% in 1995 to 34% in 2009.

European country	Description of waste	Year of introduction of tax	Landfill tax amount for the year	Tax amount in Euros/ton	Effects of landfill tax
Ireland	Municipal waste	1996	2012	75	Landfilling decreased by 32% from 2001 to 2008.
Italy	Hazardous, non-hazardous and municipal waste	1996	2012	18.83	Landfilling decreased by 27% from 1996 to 2009.
Latvia	Non-hazardous and municipal waste	1991	2012	9.96	Landfill waste quantities did not drastically decrease over the past few years, mainly due to the rapid economic growth in the country. However, non-hazardous waste recovery increased from 10 million tons in 2002 to 590 million tons in 2008.
Latvia	Hazardous waste	1991	2012	21.34	
Netherlands	Inert waste	1995	2012	127	Landfilling decreased from 23% in 1996 to 4% in 2005; mainly due to a ban on new landfills and the expansion of existing landfills since 1995; as well as increasing landfill tax rates.
Poland	Mixed municipal waste	1997	2012	26.6	Recycling and incineration increased from 8% in 2007 to 22% in 2010.
United Kingdom	All active waste	1996	2013	72	Municipal landfilling decreased from 84% in 1998 to 49% in 2009. Recovered waste increased from 16% in 1998 to 51% in 2009.

Appendix 9: Legislature and regulations governing the chemical industry in South Africa (Pages 229 – 231)

(Department of Environmental Affairs and Tourism, 2006b; Ambe, 2007b; Mohr-Swart, 2008)

Legislature/Regulation	**Government department**	**Legislative objective**
Constitution of the Republic of South Africa Act 108 of 1996	Parliament	All business activities must fulfill the obligations as set out in the Constitution; as the concept of equality, freedom and human dignity is entrenched in the Bill of Rights.
National Environmental Management Act No. 107 of 1998	Department of Environmental Affairs and Tourism	Ensures the sustainability of the environment via effective governance and civil responsibility.
National Environmental Management: Air Quality Act, Act No.39 of 2004 (Repealed Atmospheric Pollution Prevention Act, Act No. 45 of 1965)	Department of Environmental Affairs and Tourism	Controls the release of hazardous emissions into the atmosphere and provides measures for pollution prevention and mitigation of ecological degradation. The implementation of emission and pollution control and measurement is endorsed. Development and management of alternative fuels resulting in reduced pollution is promoted.
Environment Conservation Act No. 73 of 1989	Department of Environmental Affairs and Tourism	Environmental conservation is provided for by the control of pollution through waste management systems.
Hazardous Substances Act No. 15 of 1973	National Health and Population Development	Classification of substances as per their hazardous nature. Allows for the prevention and control of hazardous substances due to their physical or chemical nature or composition.

Legislature/Regulation	Government department	Legislative objective
National Water Act No.36 of 1998	Department of Water Affairs and Forestry	Provides for the conservation, protection, control and distribution of water and other related matters.
Compensation for Occupational Injuries and Disease Act No 130 of 1993	Department of Labour	Provides compensation for disablement or death as a consequence of occupational injuries or disease or employment.
Conservation of Agricultural Resources, Act No 43 of 1983	Agricultural Research Council	Provides for the prevention of the damage of land and water resources on agricultural properties.
Dumping at Sea Control Act 73 of 1980	Department of Environmental Affairs and Tourism	Prevents pollution of the marine system by prohibiting the dumping of specified material into the sea from any type of vessel, equipment or pipeline.
Explosives Act No 26 of 1956	South African National Defence Force, South African Police Service	Reinforces the laws governing the production, distribution and usage of explosives.
Foodstuffs, Cosmetic and Disinfectant Act 54 of 1972 and relevant regulations	Department of Health	Protects consumers against detrimental effects of pesticides, metals and chemicals found in products.
Marine Pollution (Control and Civil Liability) Act 6 of 1981	Department of Transportation and DEAT	Prohibits and regulates the dumping, spilling or leaking of any detrimental substance into the sea.

Legislature/Regulation	Government department	Legislative objective
Minerals Act 50 of 1991	Department of Minerals and Energy	Provides for the regulation of the extraction, processing and use of minerals. Ensures that all exploited land is rehabilitated.
Guidelines for the Minimum Requirement for Water Monitoring at Waste Management Facilities	Department of Water Affairs and Forestry	These guidelines aim to sustainably manage groundwater quality in order to protect all resources and users.
Guidelines for the Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste	Department of Water Affairs and Forestry	These guidelines prescribe the procedures for landfill site permits and monitors waste disposal procedures to ensure environmental compliance.
National Nuclear Regulator of 1999	Department of Minerals and Energy	Regulates nuclear activities to provide for the protection of the people, the environment and property against nuclear damage.
Occupational Health and Safety Act No. 85 of 1993 and relevant Regulations	Department of Manpower	This Act "*provides for the health and safety of persons at work and for the health and safety of persons in connection with use of plant and machinery; the protection of persons other than persons at work against hazards to health and safety arising out of or in connection with the activities of persons at work and to provide for matters connected herewith"* (Department of Environmental Affairs and Tourism, 2006a: 4-11).

Appendix 10a: Minimum emission standards for combustion installations (South Africa, 2010)

Description	**Liquid fuel combustion installations used for steam or electricity generation**		
Application	**Capacity equal or greater than 50MW heat input per unit**		
Substance	**Chemical symbol**	**Plant status**	**mg/Nm³ under normal conditions of 3% Oxygen and at 273 Kelvin and 101.3kPa**
Particulate Matter	None	New Existing	50 75
Sulphur dioxide	SO_2	New Existing	500 3500
Oxides of Nitrogen	NO_x expressed as NO_2	New Existing	250 1100
Description	**Gas combustion installations used for steam or electricity generation**		
Application	**Capacity equal or greater than 50MW heat input per unit**		
Substance	**Chemical Symbol**	**Plant Status**	**mg/Nm³ under normal conditions of 3% Oxygen and at 273 Kelvin and 101.3kPa**
Particulate Matter	None	New Existing	10 10
Sulphur dioxide	SO_2	New Existing	400 500
Oxides of Nitrogen	NO_x expressed as NO_2	New Existing	50 300

Appendix 10b: Minimum emission standards of organic chemicals manufactured by the organic chemical industry (South Africa, 2010)

Description	***"The use and manufacture of hydrocarbons including acetylene, acetic, maleic or phthalic anhydride or their acids, carbon disulphide pyridine, formaldehyde, acetaldehyde, acrolein and its derivatives, acrylonitrile, amines and synthetic rubber. The manufacture of organometallic compounds, organic dyes and pigments, surface active agents, the polymerization or co-polymerization of any unsaturated hydrocarbons, substituted hydrocarbon (including vinyl chloride), the manufacture, recovery or purification of acrylic acid or any ester of acrylic acid, the use of toluene di-isocyanate or other di-isocyanate of comparable volatility, or recovery of pyridine."***		
Application	**All sites with a production capacity of more than 100 tons per year, and storage tanks of greater than 500 cubic meters capacity.**		
Substance	**Chemical symbol**	**Plant status**	**mg/Nm³ under normal conditions of 3% Oxygen and at 273 Kelvin and 101.3kPa**
Total volatile organic compounds (Thermal)	None	New Existing	150 150
Total volatile organic compounds (Non-Thermal)	None	New Existing	40 40
Sulphur trioxide	SO_3	New Existing	30 100
Acrylonitrile	CH_2CHCN	New Existing	5 5
Methylamines	CH_5N	New Existing	10 10

Appendix 11: Environmental impact assessment of the participating organizations of the Durban Chemicals Cluster (Pages 234 – 243)

Aspect	Impact assessment	Impact	Spatial scale	Temporal scale/duration	Significance/ severity	Possibility of occurrence
Air quality	Air pollution can occur due to the following activities: • Emissions from combustion of methane gas and fuel oils via boiler stacks; • Emissions from burn out furnace and distillate vapours; • Emissions generated by the operation of the plant processes and extraction systems; • Exhaust emissions from diesel and petrol vehicles and forklifts; • Release of vapours from tank vents during offloading and storage of chemicals and fuels; • Fugitive emissions from tank vents and chemical reactions; • Spillages during drumming out of product or tanker loading of product, resulting in release of fugitive emissions; • Emissions as a result of the operational and maintenance failure or inefficiencies of the waste gas scrubber systems; • Welding fumes as a result of maintenance activities; • Release of refrigerant gases to atmosphere; • Spillages of chemicals and fuels during offloading of raw material road tankers into storage tanks; • Incorrect raw material charged into reaction vessels;	• Impact on ozone depletion, global warming and climate change. • Health hazard to employees and surrounding communities. • Reduction in natural fossil fuel resources. • Poor company image.	Global to regional	Medium to long term	High	High

Aspect	Impact assessment	Impact	Spatial scale	Temporal scale/duration	Significance/ severity	Possibility of occurrence
	• Release of distillate vapours to atmosphere if the scrubber water becomes saturated; • Critical instrumentation failure resulting in overfilling of vessels, pressure increase in vessels or spillages; • Incorrect plant operation during emergency situations; • Open packaging; • Forklift damage to raw material and product packaging; • Leaking raw material and product containers and tanks; • Overloading of tankers delivering products to customers resulting in vapour release; • Overloading of incoming raw material tankers emitting vapours to the atmosphere; • Pilot plant trials; • Laboratory gas line leaks; • Laboratory extraction system emissions; • Generation and handling of asbestos waste and asbestos powder; • Vapour release during sampling of vessels.					
Air quality	Air pollution due to hazardous dust creation as well as non-hazardous dust creation and dispersion of fine solids during the following activities: • Offloading of chemicals and bag pigment powders; • Raw material bag breakage; • Sampling;	• Dust inhalation. • Damage of the eyes. • Damage of the central nervous system. • Health hazard to employees. • Risk of explosion.	Site specific	Short to medium	Medium	High

Aspect	Impact assessment	Impact	Spatial scale	Temporal scale/duration	Significance/ severity	Possibility of occurrence
	• Packaging contaminated with raw materials; • Packaging contaminated with product; • Dryer operational processes; • Catalyst and additives preparation; • Solid state polymerization operation; • Dust release during weighing of raw materials; • Dust creation during charging of reactors or vessels.					
Air quality	Air pollution due to a fire or explosion as a result of: • Offloading and storage of flammable raw materials; • Storage of flammable products; • Plant operations; • Storage and decanting of diesel and paraffin.	• Loss of human lives. • Loss of revenue. • Loss of employment. • Loss of equipment. • Impact on climate change. • Property damage. • Fines and prosecution. • Poor company image.	Regional	Long	High	Medium
Air quality	Release of large volumes of nitrogen during unloading, storage or usage.	• Suffocation of persons in the immediate vicinity of the release.	Site specific	Short	High	Low
Air quality	Air pollution due to breakage of fluorescent tubes.	• Health hazard to employees.	Site specific	Short	Medium	Low
Air quality	Air pollution as a result of the handling of asbestos waste.	• Health hazard to employees.	Site specific	Short	Medium	Low
Water quality	Generation of effluent (non-hazardous liquid waste).	• Degradation of potable water resources, rivers, streams and water ecosystems.	Regional	Medium	Medium	Medium

Aspect	Impact assessment	Impact	Spatial scale	Temporal scale/duration	Significance/ severity	Possibility of occurrence
Water quality	Contamination of water systems due to a fire or explosion as a result of: • Incorrect plant operation and control; • Runaway exothermic reactions; • Incorrect charging of raw materials (too little or too much) and incorrect ratio of reactants; • Omissions of raw materials; • Charging of a different raw material than specified resulting in runaway reactions; • Incorrect order of raw material addition resulting in over pressurization in the reactor; • Energy source failure resulting in runaway reactions; • Agitator operation failure resulting in runaway reactions; • Critical instrumentation failure, such as temperature and pressure transmitters, load cells or flowmeters and actuators; resulting in runaway reactions; • Contamination of reactors with cleaning detergents or previous products or intermediate products; • Spillages from poorly packaged laboratory samples.	• Loss of human lives. • Loss of revenue. • Loss of employment. • Contaminated water and soil systems due to contaminated fire water.	Regional	Long	High	Low
Water quality	Ground water pollution due to: • Offloading and storage of chemicals and kerosene; • Spillages of chemicals, additives and distillate; • Spillages from underground raw material chemical storage tanks into ground water; • Fork truck and vehicle oil leaks; • Storage of raw materials in an open air store.	• Degradation of potable water resources, rivers, streams and water ecosystems.	Regional	Medium to long term	Medium	Medium

Aspect	Impact assessment	Impact	Spatial scale	Temporal scale/duration	Significance/ severity	Possibility of occurrence
Water quality	Effluent water pollution due to: • Offloading and storage of chemicals and kerosene; • Spillages of chemicals, additives and products; • Spillages of hazardous waste material at production site; • Spillages of hazardous waste water treatment chemicals such as caustic soda, biocides; • Incorrect disposal of water used to wash drums containing residual hazardous chemical waste, for recycling purposes by contractor; • Compound mixing process; • Pilot plant trials.	• Contamination of effluent water. • Contamination of potable water resources, rivers, streams and water ecosystems.	Site specific	Short to medium term	Medium	Medium
Water quality	Waste water generation due to: • Process plant operation; • Floor washing.	• Presence of organic and inorganic compounds in waste water reaching water ecosystems.	Regional	Medium term	Medium	Medium
Water quality	Storm water contamination due to: • Chemical contaminants entering the storm water system; • Abnormal plant operations; • High pressure reactor explosions; • Overflows, spillages and leakages from the effluent system; • Spillages during offloading and loading of trucks; • Spillage due to incorrect stacking of raw materials and products in warehouses; • Leaks or spillage during transfer of effluent to the neighbouring organization or municipality waste water treatment plant;	• Presence of organic and inorganic compounds in waste water reaching water ecosystems.	Regional	Medium	Medium	Medium

Aspect	Impact assessment	Impact	Spatial scale	Temporal scale/duration	Significance/ severity	Possibility of occurrence
	• Spillages or leakages in the ablution facility; • Spillages from the storage and decanting of diesel, paraffin and other fuels; • Storage of raw materials in an open air store.					
Soil quality	Soil contamination as a result of semi-solid and solid waste generation: • Hazardous and non-hazardous solid waste generation due to plant operation; • Incorrect disposal of waste at the hazardous landfill site; • Generation of paper waste.	• Loading of landfill sites. • Biodiversity degradation at landfill sites. • Soil acidification. • Surface and sub-soil leachate contamination at landfill sites.	Regional	Long	High	Medium to high
Soil quality	Soil pollution due to spillages of : • Raw materials; • Products; • Fuel; • Distillate; • Water treatment chemicals; • Oils and lubricants; • Paints and thinners; • Ablution facilities; • Spillages during charging of reactors and vessels; • Spillages during sampling of vessels; • Spillages during drumming off; • Spillage from hazardous waste skips; • Spillages during desludging and disposal of sludge into effluent pits; • Leakages of effluent into the soil; • Storage of empty open top containers with residual chemicals on grass fields; • Storage of hazardous waste skips on grass fields;	• Biodiversity degradation. • Soil degradation. • Fire. • Groundwater contamination. • Human exposure resulting in illness.	Regional	Long	Low	Medium to high

Aspect	Impact assessment	Impact	Spatial scale	Temporal scale/duration	Significance/ severity	Possibility of occurrence
	• Spillages or leakages from underground raw material chemical storage tanks into soil; • Forklift driving into raw materials and product containers; • Spillages from open packaging; • Spillages as a result of accidents from overloaded incoming raw material tankers.					
Water quality/soil quality	Incompetence of personnel and/or equipment and instrumentation failure resulting in: • Spillages as a result of overfilling of vessels; • Spillages during effluent sampling; • Spillages during decanting of sludge; • Spillages during effluent transfer; • Incorrect waste disposal; • Incorrect handling of contaminated drums.	• Groundwater pollution. • Storm water contamination. • Degradation of potable water resources, rivers, streams and water ecosystems. • Soil contamination.	Regional	Medium	Medium	Medium
Water quality/soil quality	Heavy rainfall resulting in: • Loss of containment in bunded areas containing chemical residues; • Overflowing of open effluent tanks or pits; • Washout of chemical residues into storm water systems.	• Groundwater pollution. • Storm water contamination. • Degradation of potable water resources, rivers, streams and water ecosystems. • Soil contamination.	Regional	Medium	Medium	Medium
Natural resources	• Consumption of potable water. • Consumption of non-renewable energy sources such as fossil fuels. • The operation of air compressors results in high consumption of energy.	• Depletion of natural resources. • Air pollution. • Emissions of carbon dioxide and other related emissions that contribute to global warming.	Regional to global	Long	High	High

Aspect	Impact assessment	Impact	Spatial scale	Temporal scale/duration	Significance/ severity	Possibility of occurrence
Natural resources	Recycling of plant waste such as: • Drums and containers; • Paper and plastic; • Scrap metal.	Recycling of waste conserves raw materials and energy and reduces landfill usage.	Regional	Long	High	High
Natural resources	Waste generation due to : • Generation of paper waste or non-hazardous solid waste; • Generation of hazardous sludge from production processes; • Incorrect separation of waste; • Generation of laboratory hazardous wastes; • Cross contamination during raw material storage; • Raw material losses during weighing of raw materials; • Waste from sample drainages.	• Loading of landfill site. • Use of land for landfill site. • Soil and environmental contamination. • Legal compliance. • Waste generation.	Regional	Medium	Medium	High
Noise	High noise levels as a result of: • Sound from air compressors; • Release of condensate and steam; • Venting of oil haze from equipment powered by compressed air; • Noise from emissions; • Noise from eductors; • Noise from process operations.	• Noise pollution. • Health hazard (hearing loss). • Air pollution. • High energy consumption resulting in depletion of natural resources.	Site specific	Short to medium term	Medium	Medium
Health hazard	Mercury pollution as a result of incorrect disposal of fluorescent lighting tubes.	• Health hazard. • Soil contamination. • Water contamination.	Site specific	Long	High	Low
Health hazard	Manual loading of raw materials contained in bags, buckets and drums.	Health hazard.	Site specific	Medium	Medium	High

Aspect	Impact assessment	Impact	Spatial scale	Temporal scale/duration	Significance/ severity	Possibility of occurrence

Production quality	Poor production quality as a result of:
	• Manufacture of out of specification product;
	• Delivery of poor quality or out of specification product to the customer;
	• Leak on vessel energy transfer jacket resulting in contamination/polymerization/gelation/ runaway reaction;
	• Contamination of finished product as a result of being pumped into the wrong storage tank;
	• Contamination of finished product during transportation to customer as a result of unclean tankers or associated transfer lines and pumps; as well as unclean containers or drums;
	• Poor quality of labels and incorrect labelling.
		• Product that has to be reworked or disposed of resulting in:
		  • Increased usage of natural resources;
		  • Increased air emissions;
		  • Increased solid hazardous waste and increased landfill usage;
		  • Increased waste water production;
		  • Double handling resulting in poor productivity.
		  • Poor company image.
			Site specific	Medium	Medium	High

Company image	• Ineffective preservation of products resulting in:
	  • Returned products;
	  • Rework;
	  • Additional costs.
	• Poor housekeeping.
	• Poor site maintenance.
	• Un-calibrated equipment resulting in:
	  • Incorrect formulation;
	  • Poor product quality.
	• Mislabelled or expired products.
	• Non-declaration of listed substances.
		• Poor company image.
		• Production loss and wastages.
		• Profit loss.
		• Customer claims.
		• Accidents.
			Site specific	Medium to long term	High	High

Aspect	Impact assessment	Impact	Spatial scale	Temporal scale/duration	Significance/ severity	Possibility of occurrence
Research and development	The lack of pilot plants or laboratory scale-up batches resulting in: • Missed opportunities; • Lack of flexibility; • Difficulty in optimizing existing processes; • Unstable finished products; • Inadequate experimental design.	• Poor profit optimization. • Poor production optimization. • Loss of existing and potential customers. • Product discontinuation. • Incorrect trial results.	Site specific	Long	High	High

Appendices 12 -15: Companies A, B, C and D's environmental related costs and revenues (These are available to view on the attached disc on the back cover of the thesis)

Appendix 16: Analysis of variance (ANOVA) of the cost categories, total environmental cost and environmental revenue for the four participating organizations (Pages 245 – 250)

Anova: Single Factor

2012 Waste and emission treatment costs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Company A	12	1783146	148595.5	626802892.3
Company B	12	7814750.23	651229.1858	77881001163
Company C	12	783466	65288.83333	57359460.52
Company D	12	5464347.04	455362.2533	2525867316

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.6626E+12	3	8.87534E+11	43.77962296	2.89724E-13	2.816465817
Within Groups	8.92001E+11	44	20272757708			
Total	3.5546E+12	47				

Anova: Single Factor

2013 Waste and emission treatment costs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Company A	12	1666555	138879.5833	650695180.8
Company B	12	4999433.03	416619.4192	9537416315
Company C	12	890856	74238	24872995.45
Company D	12	5343183.83	445265.3192	2686301255

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.29269E+12	3	4.30897E+11	133.6188914	4.02247E-22	2.816465817
Within Groups	1.41892E+11	44	3224821437			
Total	1.43458E+12	47				

Anova: Single Factor

2012 Prevention and environmental management costs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Company A	12	1311063	109255.25	1452590746
Company B	12	9821722.21	818476.8508	2.72959E+12
Company C	12	1269333	105777.75	22265033709
Company D	12	30883724	2573643.667	4.67181E+11

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.87654E+13	3	1.62551E+13	20.18961789	2.22944E-08	2.816465817
Within Groups	3.54254E+13	44	8.05123E+11			
Total	8.41908E+13	47				

Anova: Single Factor

2013 Prevention and environmental management costs

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Company A	12	1521077	126756.4167	7306128591
Company B	12	4055173.08	337931.09	202683403.3
Company C	12	172182	14348.5	141452936.6
Company D	12	32641619	2720134.917	1.04301E+11

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.96512E+13	3	1.98837E+13	710.440683	2.86521E-37	2.816465817
Within Groups	1.23147E+12	44	27987872457			
Total	6.08826E+13	47				

Anova: Single Factor
2012 Material purchase value of nonproduct output
SUMMARY

Groups	Count	Sum	Average	Variance
Company A	12	968923.8677	80743.65564	14921186988
Company B	12	572093.8202	47674.48501	5629166860
Company C	12	3965.421527	330.4517939	1310380.657
Company D	12	0	0	0

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	55781443582	3	18593814527	3.618940894	0.020244464	2.816465817
Within Groups	2.26068E+11	44	5137916057			
Total	2.8185E+11	47				

Anova: Single Factor
2013 Material purchase value of nonproduct output
SUMMARY

Groups	Count	Sum	Average	Variance
Company A	12	588956.0913	49079.67427	16313402317
Company B	12	0	0	0
Company C	12	0	0	0
Company D	12	0	0	0

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	21679329840	3	7226443280	1.771903405	0.166437707	2.816465817
Within Groups	1.79447E+11	44	4078350579			
Total	2.01127E+11	47				

Anova: Single Factor
2012 Processing costs of nonproduct output
SUMMARY

Groups	Count	Sum	Average	Variance
Company A	12	166511.1481	13875.92901	58443093.68
Company B	12	55217.11686	4601.426405	54429850.23
Company C	12	31807.35644	2650.613036	4675991.574
Company D	12	387321.8974	32276.82478	1172704864

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6594188559	3	2198062853	6.814358086	0.000715826	2.816465817
Within Groups	14192791796	44	322563449.9			
Total	20786980355	47				

Anova: Single Factor
2013 Processing costs of nonproduct output
SUMMARY

Groups	Count	Sum	Average	Variance
Company A	12	180360.9666	15030.08055	143875334.6
Company B	12	32367.22778	2697.268982	72895523.61
Company C	12	17104.49561	1425.374634	13612489.79
Company D	12	686726.4574	57227.20478	3389444461

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	24620278258	3	8206759419	9.068673817	8.65318E-05	2.816465817
Within Groups	39818105902	44	904956952.3			
Total	64438384161	47				

Anova: Single Factor

2012 Total environmental expenditure

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Company A	12	4229644.016	352470.3347	24536775410
Company B	12	18263783.38	1521981.948	3.21933E+12
Company C	12	2088571.778	174047.6482	22417091160
Company D	12	36735392.94	3061282.745	4.87912E+11

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.37793E+13	3	2.12598E+13	22.65175109	5.07599E-09	2.816465817
Within Groups	4.12961E+13	44	9.38548E+11			
Total	1.05075E+14	47				

Anova: Single Factor

2013 Total environmental expenditure

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Company A	12	3956949.058	329745.7548	23981967002
Company B	12	9086973.338	757247.7781	10023165294
Company C	12	1080142.496	90011.87463	138513356
Company D	12	38671529.29	3222627.441	1.05898E+11

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7.48367E+13	3	2.49456E+13	712.5182363	2.6905E-37	2.816465817
Within Groups	1.54046E+12	44	35010438200			
Total	7.63772E+13	47				

Anova: Single Factor

2012 Environmental revenue

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Company A	12	400911	33409.25	428515268.4
Company B	12	114214	9517.833333	66276083.06
Company C	12	28960	2413.333333	11396088.24
Company D	12	351666	29305.5	27826418.45

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8140805114	3	2713601705	20.32607704	2.04849E-08	2.816465817
Within Groups	5874152440	44	133503464.5			
Total	14014957554	47				

Anova: Single Factor

2013 Environmental revenue

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Company A	12	401174	33431.16667	225093798.3
Company B	12	250470	20872.5	79729088.64
Company C	12	10022	835.1666667	2379331.97
Company D	12	746700	62225	1848349867

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	23788619348	3	7929539783	14.71463359	8.94656E-07	2.816465817
Within Groups	23711072948	44	538888021.6			
Total	47499692296	47				

Appendix 17: Calculation of waste water taxes

Company	Sampling year	Chemical oxygen demand (COD) mg/l	Waste water discharge per annum, kl	COD per annum, kg	Annual equivalent German waste water tax, Rands
A	2012	15 773	2 175	34 306	343 063
A	2013(COD values assumed to be the same as 2012 as no analysis was performed in 2013)	15 773	1 885	29 732	386 517
C	2012	6 745	13 427	90 565	905 651
C	2013	4 509	11 188	50 447	655 807
D	2012	7 560	64 311	486 191	4 861 912
D	2013	3 790	45 714	173 256	2 252 329

Calculation of waste water tax amount:

Description	Cost
German waste water tax as at 1998	36 Euros/50 kg COD
German waste water tax adjusted for CPI, 2012 (Refer to note 4 below)	48 Euros/50 kg COD
German waste water tax 2012 in Rands (at R10.53/Euro)	R505/50 kg COD
German waste water tax 2012 in Rands per kg	R10/kg COD
German waste water tax adjusted for CPI, 2013	49 Euros/50 kg COD
German waste water tax 2012 in Rands (at R12.83/Euro)	R629/50 kg COD
German waste water tax 2013 in Rands per kg	R13/kg COD

4. Inflation rate = (CPI 2012 - CPI 1998/CPI1998)x100

Description	Value
CPI 2012	115.65
CPI 1998	86.87
Inflation Rate	33.13
German waste water tax adjusted for CPI, 2012	48
CPI 2013	117.21
CPI 1998	86.87
Inflation Rate	34.93
German waste water tax adjusted for CPI, 2013	49