OPPORTUNITIES FOR THE USE OF INDUSTRIAL ECOLOGY PRINCIPLES FOR ENVIRONMENTAL MANAGEMENT IN DEVELOPING COUNTRIES

A Case Study of Matsapha Industrial Estate in Swaziland

A research report submitted in the Faculty of Engineering and the Built Environment, in partial fulfillment of the requirements for the degree of Master of Science in Engineering

By

Mboni Z. Dlamini

University of the Witwatersrand,
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DECLARATION

I declare that this research report is my own unaided work. It has never been submitted for any degree or examination in any University or carried out by any institution before.

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Mboni Z. Dlamini

Date: _____

DEDICATION

To my wife PATRICIA and my late mother VIOLET

To all those who have a quest for knowledge and are inspired by positive aspects of life. To all those who appreciate the role of environmental engineers in sustainable development and the improvement of the quality of life.

ACKNOWLEDGEMENTS

My sincere gratitude goes to all the people who have supported me during the research work. It is not possible to mention all the people to whom I am indebted for the success in completing this research.

First I would like to thank my supervisor Professor Prvoslav Marjanovic for his guidance and inspiration during my research. He has given me a new way of looking at environmental problems which has made this research work a real challenge. There were times when I was looking for a prescription for my research. Professor Marjanovic never gave me one instead he gave me a foundation on which to base my approach. I thank him for that.

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ABBRIVIATIONS

BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DFE	Design For Environment
EIP	Eco-industrial Park
IE	Industrial Ecology
Kg	Kilogran
KWH	Kilowatt-hour
LCA	Life Cycle Assessment
m^3	Cubic Metre
MEE	Ministry of Enterprise and Employment
MEPD	Ministry of Economic Planning and Employment
mg/l	Milligrams per litre
MHUD	Ministry of Housing and Urban Development
MNRE	Ministry of Natural Resources and Energy
NGOs	Non Governmental Organisations
NOx	Nitrogen Oxides
R	Rands – Currency of the Republic of South Africa
SEA	Swaziland Environment Authority
SEB	Swaziland Electricity Board
SOx	Sulphur Oxides
SWSC	Swaziland Water Services Corporation
t	Tones
TSS	Total Suspended Solids
UNEP IE	United Nations Environment Programme – Industry and Environment
VOCs	Volatile Organic Compounds
Yr	Year

ABSTRACT

Human activity is characterised by the use of energy and materials to produce goods and services with wastes as by products. Population growth and development has increased the requirement of materials and energy which means more wastes. Industrial development has lead to a faster conversion of material and energy which means even more wastes. This has caused significant negative environmental impacts that are threatening natural resources and ecological balance from which the required materials are obtained. Developing countries are faced with the difficulty of balancing economic development and environmental protection. A development programme that is based on prioritising economic development at the expense of the environment is not sustainable.

The main objective of this research is to investigate the potential of using industrial ecology principles to address the environmental problems of developing countries. This is done by using a case study of Matsapha Industrial Estate in Swaziland. The term *industrial ecology* is derived from an analogy to biological ecosystems, in which waste from one organism is food to another making the system sustainable because of the closed waste loop. Braden Allenby (1992) defines industrial ecology as: "Industrial Ecology may be defines as the means by which a state of sustainable development is approached and maintained. It consists of a systems view of human economic activity and its interrelationship with fundamental biological, chemical and physical systems with the goal of establishing and maintaining the human species at levels that can be sustained indefinitely, given continued economic, cultural and technological evolution".

Using a cross sectional data set, appropriate environmental performance indicators of the case study area were determined. Three broad categories of environmental performance indicators are used. These are:

- Resource Use
- Emissions
- Management of Community Interactions

The investigation of the opportunities of using industrial ecology principles in the case study area is done by setting up scenarios where the principles are applied. The results are then compared with established environmental performance indicators. The industrial ecology principles considered are:

- Systems Approach
- Industrial Symbiosis
- Industrial metabolism
- Integrated Approach
- Diversity or Flexibility
- Shared resources

Of the six, five were applied. Industrial metabolism was not applied because of the scope of the research.

The research indicates that the use industrial ecology principles do improve the environmental performance of the case study with some economic benefits.
The research also revealed that industrial ecology improves the interaction between the three components of industrial ecosystems i.e. the industrial activity, the social and the ecological or environmental component thus establishing the foundation for sustainable development. It is also revealed that industrial ecology provides the means of moving towards closing the waste loop in a way that recognises the importance of balancing the economic objectives of industrial activities and the environmental objectives of the public sector as well as the social responsibility of both the industrial and public sector.

The research recommends that industrial ecology principles be used to address the environmental problems of the case study area because of the many benefits that would be realised particularly the achievement of both economic and environmental objectives.

The main recommendations of the research for the case study area are:

- Identification of the I**ndustrial Estate Manager**. The recommended industrial estate manager in the case study area is the existing Matsapha Town Board. It is therefore not an individual but an institution. This institution would be the organising force that will facilitate and coordinate the interaction between the three components of the eco-industrial system.

- **Resource Recovery** in the form of recycling be the eco-industrial theme because of the absence of an anchor industry.

- Further research focused on industrial metabolism and use of various wastes as inputs for other industries

1 INTRODUCTION

1.1 General Introduction

This research has been inspired by the continuous pollution problems and the lack of success of waste management and pollution control efforts by the public sector and some industries in Matsapha Industrial Estate Located in Swaziland. This estate is used as a case study area. Pollution control efforts in the case study area have been a result of public outcry particularly those who are in the downstream and down wind of the case study area. It is clear that the industries have different objectives from those of the government. Economic benefits appear to be the primary objective for industry while economic development is in the forefront of government's priorities. The Ministry of Enterprise and Employment (MEE) focuses on industrial development. Economic development takes priority in the Ministry of Economic Planning and Development (MEPD). The environment and human health is then caught in the middle. Environmental quality is a concern to the Swaziland Environment Authority (SEA) a small but essential government arm that has the task of balancing environmental protection and economic development.

This research therefore explores whether industrial ecology principles can be used to find the common ground where both environmental and economic objectives are considered simultaneously. If these two objectives can be met, the pollution problem of the case study area can be addressed and a foundation for sustainable development would have been established.

1.2 The Research Strategy

1.2.1 Back ground

The purpose of the research is to determine whether Industrial Ecology principles can be used to address the environmental problems of industrial estates in a developing country. A case study was used. The case study area is an industrial estate in Swaziland located in Matsapha. Five research questions were used to guide the research. The research focused on the waste component of the environmental

problems of the case study area. This is because pollution is the main environmental issue. The research steps are summarised in figure 1.1

1.2.2 Research Strategy

The research approach is divided into three major steps that are linked starting from the establishment of the baseline where the corner stones of the research are established leading to conclusions where the answers to the research questions and recommendations are presented.

1.2.2.1 Establishment of the base line

Step 1 establishes the baseline where the research questions are presented and the reference points in the form of environmental performance indicators are established. Step 1 begins with **data collection**. Because of lack of time series data on wastes and environmental management, it was necessary to collect a cross sectional data set. Data collection involved interviews and available documents. The main source of the data was from interviews. Initially questionnaires were sent to the industries in the case study area. The response was very slow and those who responded gave very general information which could not be useful for the research. It was discovered later that the main reason was that data on wastes and other environmental issues was not kept. It was then necessary to change the strategy. Direct visits to the industries were made where specific personnel were instructed by the company's authorities to attend to the data collector. Because of lack of documented data, additional information that was used to estimate the quantities of wastes was sought from the industry personnel. The additional information included number of truckloads, one ton van, tractor trailer, skips, bins etc. of waste transported to the landfill per day, week or month. Some sections of the questionnaires could not be filled for some industries because they did not have the specific data. Due to this the questionnaire format was not strictly followed. The personnel interviewed consisted of production managers, section managers, business owners, personnel managers and officers responsible for environmental issues.

The data was collected from Fifty five companies in the case study area. All big companies were visited and as many as possible of the smaller ones. This was to ensure that the data collected is representative of the area.

To get the exact number of industries in the case study area was difficult because there is no industrial estate manager and the information kept in central government offices is for the entire country and is not up to date. The Matsapha Town Board has information on the number of plots and their owners for purposes of property tax collection. Some of the plots are not developed, some of the developed plots are not occupied, some of the occupied plots are actually rented from the owners and some of the plots are rented to different industry firms.

Data collection was followed by **data analysis.** Data analysis consisted mainly of waste characterisation. From the data collected, the wastes were characterised in order to establish their quantities, types as well as other relevant information such as the quality of the wastewater and waste management practices in the case study area.

From the data and other information, the waste related **environmental performance** was analysed. First the waste related environmental issues of the case study area were identified then these were used to develop the environmental performance indicators. The information from the waste characterisation was used to establish the waste related environmental performance indexes. The indexes could not be benchmarked because of lack of time series data. They are used as reference points against which the effects of industrial ecology principles are measured. To determine the effects of industrial ecology principles, environmental performance objectives were stated.

Step 2 consists of the investigation of the effects of applying industrial ecology principles in the case study area. This is done by assuming specific applicable scenarios in the case study area. The results from these scenarios are then reflected against the base line and reference points established in step 1 in order to interpret the results. Six industrial ecology principles were considered. The principles were first screened. The screening of the principles was to determine whether they are within the scope of the research and their applicability in the case study area. After the screening, five were eventually applied.

The results of the application of the industrial ecology principles were then analysed and compared to the reference environmental performance indexes and performance objectives

In step 3 conclusions and recommendation are made based on the previous steps. The information from the analysis of the results as well as lessons learned from the research was used to draw conclusions on whether the research questions were answered and other relevant information. Based on the conclusions and the analysis of the result of applying the Industrial ecology principles, recommendations for the case study area are made.

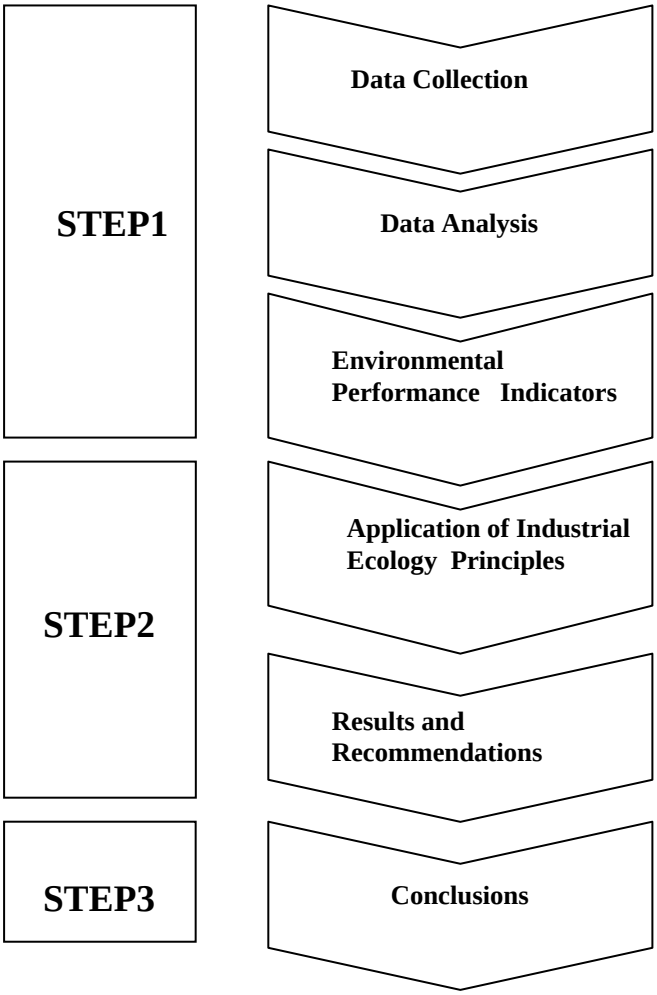

Figure 1.1 Research Steps

1.3 Layout of the Thesis

The layout of the thesis is described with reference to the above steps (Fig 1.1) and specific chapters falling into these steps.

1.3.1 Step 1 Establishment of the Base Line

Step 1consists of the first five chapters. In **chapter 1** the background of the case study area is presented as well as the key stakeholders that have a role to play in the waste related environmental performance of the case study area. Chapter 1 establishes the fundamental concepts of industrial ecology and some aspects of it. The potential of industrial ecology as a solution to the waste related environmental problems of the case study area is discussed in section 1.8. The research problem and research questions are stated in sections 1.6 and 1.10. The scope and limitations of the research is stated in section 1.12. The general scope of the research is set at the eco-industrial systems level focusing on the waste related aspects of the environmental performance. Lack of time series data has been a major limitation of the research.

The research strategy and the methodology followed are described in 1.2. The strategy being divided into 4 steps with step one establishing the baseline, step two investigating the industrial ecology principles, stage 3 analysis of the results form the application of the industrial ecology principles and then stage 4 being the recommendations and conclusions.

Chapter 2 is the literate review where the current knowledge base on the subject of industrial ecology is discussed through available literature and publications. The major fact that has been established here is that the recognition of industrial ecology as a field is very new and therefore the related literature is not yet well structured. The other aspect that is revealed by this chapter is that industrial ecology has been in practice for many years without realising it as a field.

Chapter 3 is the waste from the industrial estate is characterised and where possible quantified. The waste is divided into three main categories i.e. solid waste, industrial waste water and emissions to air. The cost of waste management in the case study

area is discussed as well as waste management practices in the industrial estate and other information on resource and energy use.

In **chapter 4** the environmental performance indicators are developed. These are used to determine the influence of industrial ecology principles in the case study area. In order to facilitate this, environmental performance indexes are determined from the waste characterisation information in chapter 3. With the lack of time series data, the indexes are used as the baseline against which the influence of industrial ecology in the case study area is compared.

1.3.2 Step 2 Investigating the Application of Industrial Ecology Principles

Step 2 consists of chapters 5, 6 and 7. This stage involves the investigation of the application of industrial ecology principles as well as the analysis of the results.

Six scenarios were investigated in **chapter 5** where six industrial ecology principles are applied and investigated in order to establish their effect on the environmental performance.

In **chapter 6** the results of the application of the principles are analysed and discussed. The analysis is based on the comparison of the environmental performance after the implementation of industrial ecology principles with the baseline environmental performance indexes. Other aspects of the waste related environmental performance are also analysed.

Chapter 7 describes how the research questions are addressed by the research.

1.3.4 Step 3 Conclusions and Recommendations

Step 3 involves the conclusions and recommendations. This is contained in chapter 8.

In **chapter 8** the information established throughout the research is used to draw conclusions and recommendations.

1.4 Industries and Industrial Estates

Of all the human activities that are imposing a heavy burden on the environment, industrial activities are in the foreground (Berkhout and others. 2001). Industrial activities are all about the utilisation of resources and energy to produce goods and services. Inevitably during the process, wastes are generated. The wastes have a profound impact on such resources as water, air, land, biodiversity etc.

An industrial estate can be described as a large piece of land subdivided and developed for the use of several industries simultaneously (Peddle, 1993). In an industrial estate there are many shareable services and infrastructure due to the close proximity of the industries.

While the environmental impacts of industrial estates are due to a wide variety of factors such as the occupation of a large area, the generation of wastes and their release to air water and land, is the major environmental problem. Industrial estates provide an opportunity to manage the environmental issues of industries and industrial estates collectively.

1.5 Current Approaches to Pollution Problems

Environmental pollution and its control has for some time been a major environmental concern for policy makers. In addressing the wastes and pollution problem, governments in many developing countries have adopted several strategies with different degrees of success. The “command and control” approach, which is characterised by legislation, regulation and litigation, is the most commonly used approach to which industries have responded by focussing on end-of-pipe treatment striving to comply guided by pollution standards for effluents and air releases. These standards are set by government. This has prompted the proliferation of waste treatment technologies for industry to buy.

The cost of end of pipe approach has been considered high by some industries. To this managers have had to carefully consider the benefit-cost of end of pipe waste treatment. Basically this entails the decision of whether to pollute and pay or meet the

pollution standards set by government and avoid penalties. The implementation of waste treatment plants by industries in developing countries is not driven by the desire to improve their environmental performance but to comply with government regulations and always the environment looses out. Lack of data in developing countries makes the comparison of the fines and the environmental damage of pollution difficult.

Pollution control is seen by managers in industry as distinct from the production process and therefore is seen as additional costs. Even though in-plant pollution control has now been accepted as essential for waste minimisation, managers still lump together the expenditure of in-plant and end of pipe pollution control. The result is that pollution control is made to appear as expensive additional expenditure that does not translate to profit by contributing to production. Some managers to justify their pollution often use this view.

Many countries in the developing world have realised that the benefits of pollution control outweighs the costs. This realisation has prompted many countries to adopt innovative strategies that involve communities, consumers, investors and policy makers in fighting pollution. In addition to establishing and enforcing standards or charges, regulators achieve more positive results in controlling pollution through programmes designed to provide correct information to communities and markets on environmental performance of industries. This has prompted industries to be more proactive in reducing pollution rather than being forced to do so by regulators. The regulatory triangle (see Figure 1.2) has been recognised to be effective and put to practice by many developing countries.

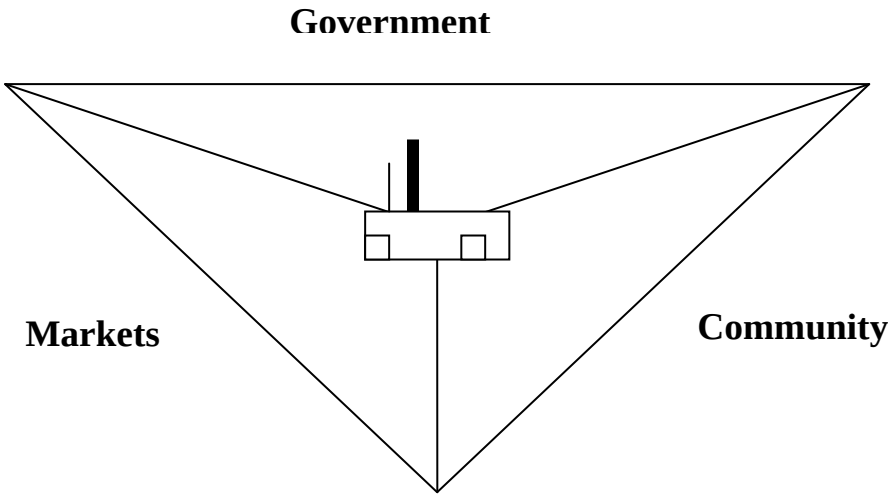

Figure 1.2 Regulatory Triangle
Adapted from Greening Industry – World Bank Policy Research Report (2000)

Indonesia has successfully implemented a programme called "PROPER" which stands for Programme for Pollution control, Evaluation and Rating (Greening Industry – World Bank Policy Research Report, 2000). This programme involves the rating and publicly disclosing factories' environmental performance and compliance with regulations **(see Table 1.1).** The response to this has been a voluntary reduction of pollution. This approach has been adopted by other countries because of its success.

The Philippines has used environmental user fees where industries are charged for pollution based on how much the pollution is above the set standards (Greening Industry – World Bank Policy Research Report, 2000).

When industries are operating in compliance mode, their efforts are limited to avoiding fines and legal actions taken against them. This is not sustainable and there are many environmental surprises that remain hidden. Shifting from compliance mode is best effected economic incentives are used by bankers and creditors are worried by liabilities and reduced sales to customers who are environmentally conscious

Table 1.1 Indonesia's Rating System

Source: (Greening Industry – World Bank Policy Research Report, 2000).

PERFORMANCE LEVELS	PROPER RATINGS
Gold	Clean technology, waste minimisation, pollution prevention
Green	Above standards and good maintenance, house keeping
Blue	Efforts meet minimum standards
Red	Efforts do not meet standards
Black	No pollution control efforts Serious environmental damage

Other approaches such as pollution modelling, life cycle assessment, pollution prevention, design for environment etc. are being used by industry and regulatory bodies but still come short of eliminating the pollution problem because of various factors including the cost implications. In developing countries some of these technologies can only be afforded by a relatively few big multinational companies whose primary aim is largely to elevate their public image.

There has been a lot of talking about recycling in developing countries but its implementation is not yet fully developed. Within an industry, the benefits of recycling are either not fully understood or generally managers are reluctant to change what has been accepted as the way of doing things. Outside the industries the incentives for recycling as well as the infrastructure from the waste generators through the recyclers to the markets for the recycled materials is not well developed.

Because of the command and control approach in developing countries, end of pipe treatment approach by industry will continue to be the main response to their environmental issues. This means that industries will continue to operate in compliance mode an approach that is far from sustainable development.

Despite the existence of the above approaches and the extensive development of waste treatment technologies, the problem of pollution still persists in developing countries. A different approach that may have to recognise the above approaches is therefore necessary.

1.6 The Problem

Industrial estates tend to concentrate the environmental problems of the individual companies within a specific relatively small area. In addition to environmental problems that are directly caused by the individual companies, there are additional environmental impacts from infrastructure, transport services, housing and other services. These impacts though not directly caused by the individual companies, are a direct result of the companies being in the industrial estate. The improvement of the environmental performance of an industrial estate therefore cannot be achieved by only focusing on the individual companies in isolation. Some environmental problems have to be addressed collectively for environmental improvement to be realised.

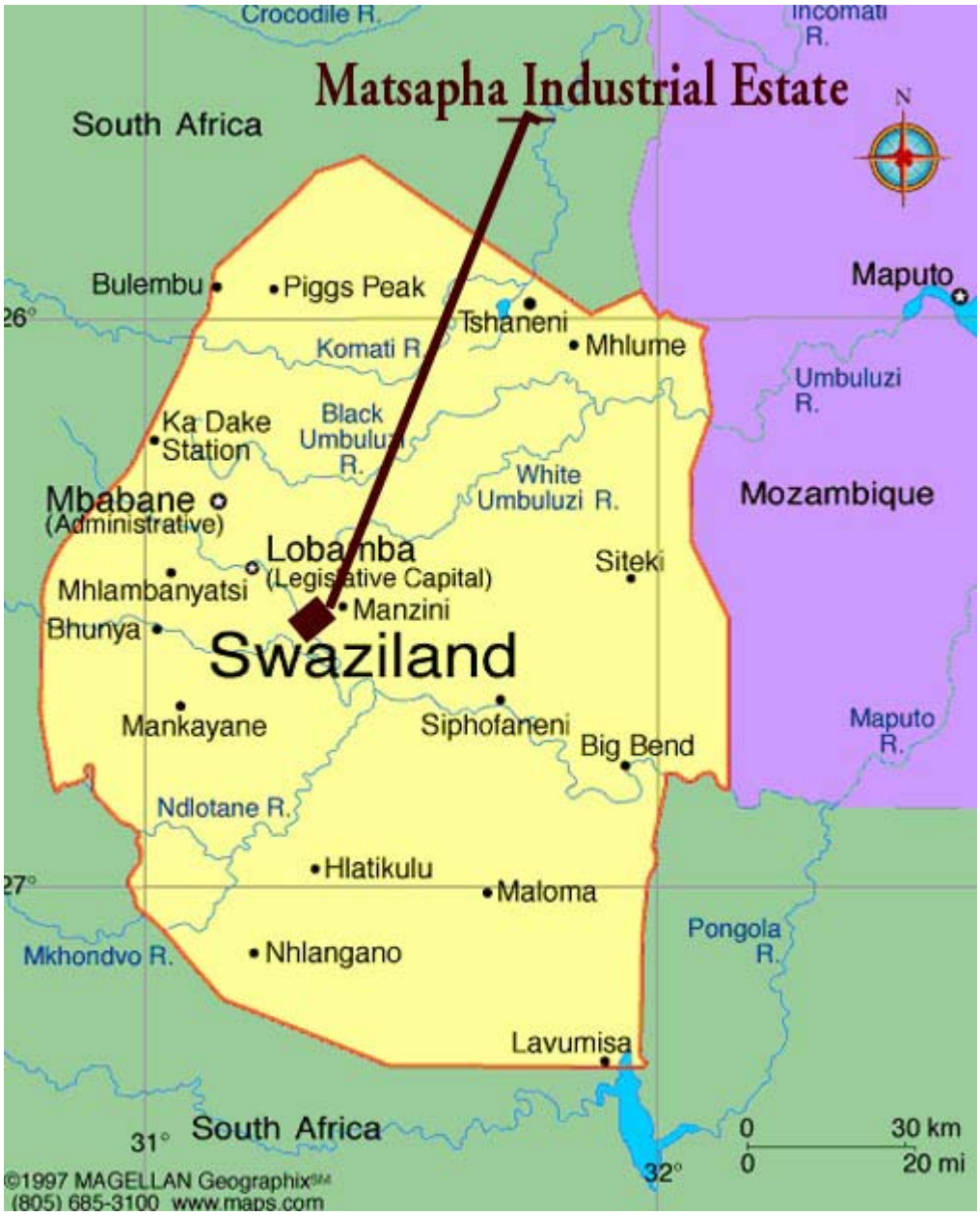

Figure 1.3: Location of Matsapha industrial Estate in Swaziland

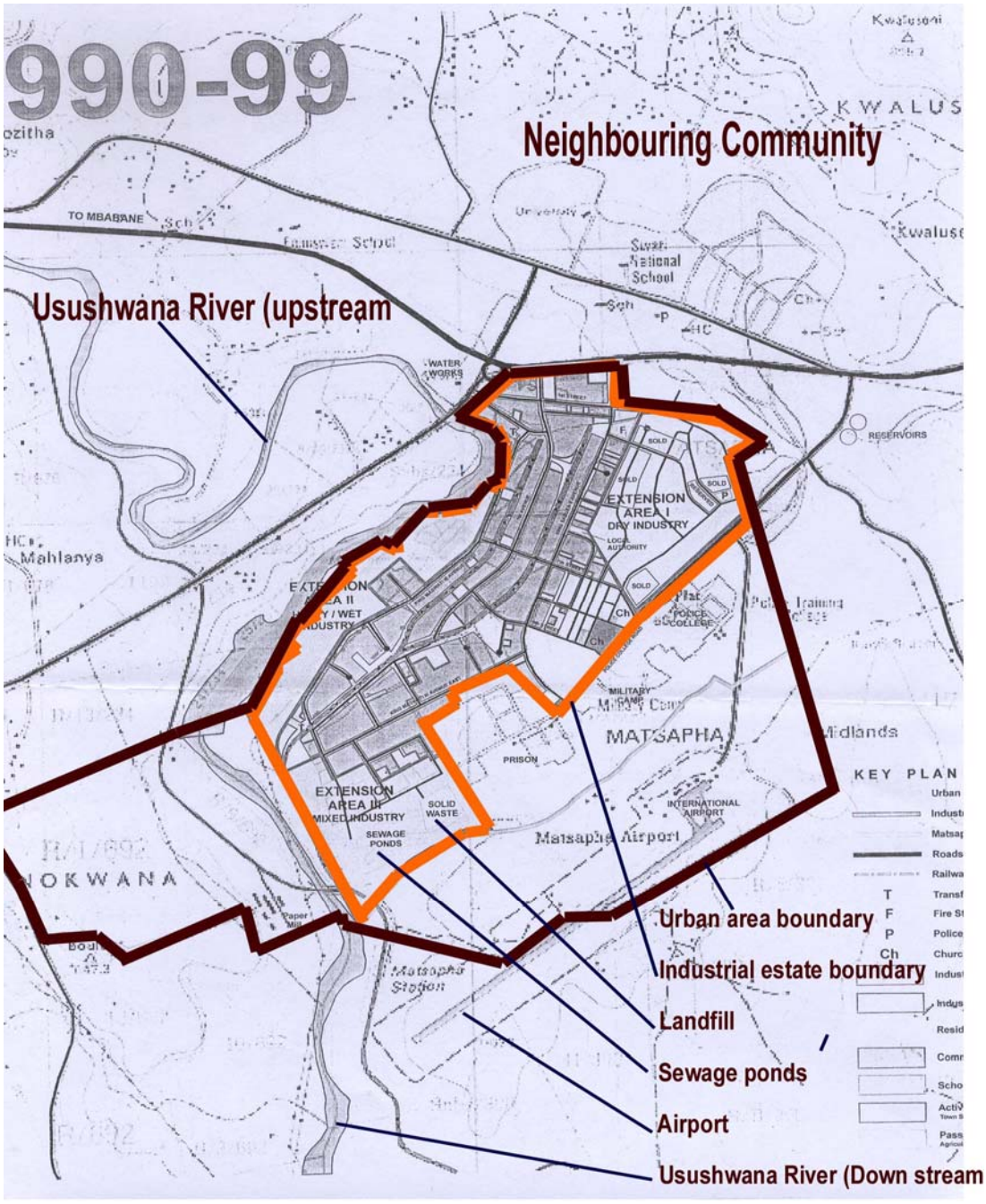

Figure 1.4: Map of the case study area

Source: Matsapha Town Board

In the study area Matsapha Industrial Estate, the industries are operating independent of each other and the uncoordinated environmental issues of estate has added to the deterioration of its environmental performance and continues to decline. As a result the Swaziland Environment Authority (SEA) addresses pollution problems on a company-by-company basis with a command and control approach. This has proved to be very inefficient because of insufficient resources both human and financial to monitor all the industries in the industrial estate as well as the rest of the country. For these reasons enforcement of environmental legislation does not achieve the intended results and the environment continue to deteriorate.

1.6.1 Key Environmental Problems of Matsapha Industrial Estate

The key environmental problems of Matsapha Industrial Estate in order of priority are:

- The river downstream of the industrial estate being heavily polluted.
- Chronic shock loads of wastes into the sewer system killing the microbial functioning of the sewer treatment plant.
- Unaccountable hazardous wastes.
- Poor solid waste management system.
- Chronic fish kills in the adjacent river as a result of pollution incidences usually unaccounted for.
- Lack of cooperation between the industries and uncomplimentary industrial activities resulting in wastage of energy and resources.
- Unaccountable air emissions.
- Lack of clear environmental responsibilities among the regulatory bodies

In general the situation in the Matsapha Industrial Estate is characterised by the attitude of “Extract as much profit as possible” without due consideration of the cost of environmental services rendered to the industries and the estate as a whole.

This clearly demonstrates that there is no clear environmental agenda for the Matsapha industrial area. This is true in many industrial estates in developing countries. This research therefore seeks to find an appropriate and effective environmental agenda for the industrial estate in order to improve its environmental performance and set the stage for sustainable development

1.7 Stakeholders

In Matsapha Industrial Estate, there are no clear-cut responsibilities for environmental issues among all the bodies that are involved in the running of the estate. The Town Board that is running the industrial estate does not consider pollution issues as its responsibility and is not involved in the pollution incidences caused by the tenant industries or resulting from the estate in general. The town board provides infrastructure development, collects property rates and provide very superficial solid waste collection system.

The environmental issues of the Matsapha industrial estate involves many stakeholders who needs to play their roles in the management of the environmental issues. Table 1 below gives the key stakeholders and their importance in the case study area.

Table 1.2: Stakeholders of Matsapha industrial estate

STAKE HOLDER	ROLE IN THE CASE STUDY AREA
The Swaziland Environment Authority	Enforcement of the Environmental Management Act and its regulations
The Industries	Responsible for the actual industrial activity
Ministry of Enterprise and Employment	Responsible for industrial development under which the industrial estate falls
Ministry of Housing and Urban Development	Responsible for urban areas of which Matsapha industrial estate is
Swaziland Water Services Corporation	Provides portable water and runs the sewer system in Matsapha industrial estate
Ministry of Natural Resources and Energy	Responsible for the regulation of energy issues
The Neighbouring Communities	They are on the receiving end of pollution impacts and are a source of labour

1.7.1 Ministry Of Enterprise and Employment

The Ministry of Enterprise and Employment (MEE) under which the industrial estate falls, has no clear responsibility on the estate's environmental performance its focus is promoting investment and the growth of the industrial estate.

1.7.2 Ministry of Housing and Urban Development

Matsapha is regarded as an urban area under the Urban Development Act This act is under the custody of the Ministry of Housing and Urban Development (MHUD). This ministry therefore has a stake in the estate and is actually represented in the town board. As an urban area, the management of Matsapha industrial estate is the responsibility of MHUD. This responsibility has been delegated to MEE because of the fact that it is an industrial estate. MHUD approves the appointment of town board members. However the ministry is not involved in the residential aspect of the labour force of the industrial estate.

1.7.3 Swaziland Water Services Corporation

The Swaziland Water Service Corporation (SWSC) provides portable water to the estate and runs the sewer system. The sewage treatment facility consists of oxidation ponds. Some industries have entered into some agreement with SWSC to discharge their effluent into the sewer system with charges. The charges are based on the concentrations discharged. SWSC therefore has its own monitoring system for the industries that are discharging into their sewer system. It is not clear whether The SWSC is concerned with the water consumption of the industrial estate or not. To them more consumption means more business.

1.7.4 Ministry of Natural Resources and Energy

The Ministry of Natural Resources and Energy (MNRE), is responsible for the energy aspect and water apportionment as well as the quality of both surface and ground water resources. On the quantity aspect of the water, the ministry monitor the river flows and the number of water boreholes. Currently there are no water conservation programmes initiated by the ministry in Matsapha Industrial estate. The Water Bill that is currently being debated seems to address many important issues including a price tag on the abstraction of water from public water bodies. This Bill will be

replacing the Water Act of 1967. The ministry has been involved in the promotion of energy efficiency initiatives in the industrial estate.

1.7.5 The Swaziland Environment Authority

Everybody is expecting the Swaziland Environment Authority to respond and take actions for every environmental issue and incident in the estate. The most significant environmental issue in the industrial estate is pollution and solid waste management. Under these circumstances the SEA can only use the command and control approach taking pollution issues on an industry-by-industry basis. With this approach there is no improvement of the environmental performance of the industrial estate as a whole. The SEA expects the Town Board to play a major role on the environmental performance of the industrial estate but seemingly the Town Board has no legal obligation for environmental issues of the estate. The SEA therefore is expected by everybody to solve the environmental problems of the industrial estate.

1.7.6 The Industries

The industries themselves fall into a wide spectrum of characters. There are those who have no time for environmental issues. They are only interested in the economic aspect of their business. There are those who only talk in support of environmental protection but have no practical evidence. Others have environmental management system certification or are in the process of implementing environmental management systems. Others even have wastewater treatment plants either for pre-treatment in order to reduce costs for discharging into the sewer system or it is a requirement from the parent company abroad as a result of export market requirements or company image.

1.7.7 The Communities

There is another group of stakeholders that is often overlooked or its role not understood. This is the public or the communities around and within the industrial estate that are impacted by the environmental issues or contribute to the impacts some times even benefiting from the industrial estate. In the case of Matsapha Industrial Estate all the above categories of the communities do exist. The role of the communities or the public in the improvement of the environmental performance of the industrial estate cannot be overlooked.

1.8 The Potential of Industrial Ecology as a Solution

Because of the complex nature of the environmental issues of the Matsapha industrial estate, the problems cannot be dealt with in a conventional way using legislation and the command and control approach. An approach that will address the environmental problems in a manner that will recognise the complex role of all the stakeholders and their relationship is what is needed. Of prime importance is the relationship between the stakeholders themselves, the stakeholders and the industries, the industries between themselves, as well as the industrial estate and the environment.

The interest here is the net impact of the relationship web on the environment as a result of the use and transformation of energy and materials into goods and services as well as the role played by the various stakeholders. The situation resembles the relationship in a natural ecological system. Industrial ecology therefore has the potential to provide the answer to this problem. The research topic **Opportunities for the Use of Industrial Ecology Principles for Addressing Environmental Problems of Industrial Estates in Developing Countries** using the case study of Matsapha Industrial Estate in Swaziland is therefore appropriate. This can thereafter be used as a framework for industrial estates in developing countries. The practice of industrial ecology represents an environmentally acceptable, sustainable means of providing goods and services (Manahan, 2000)

1.9 Overview of Industrial Ecology

1.9.1 Definition of Industrial Ecology

There is no single definition of industrial ecology that is generally accepted. Most definitions comprise of similar attributes with different emphasis. (Garner and Keoleian, 1995). These attributes includes the following:

- A systems view of the interaction between industrial and ecological systems
- The study of material and energy flows and their transformation
- A multidisciplinary approach
- An orientation towards the future
- A change from linear (open) system to cyclical (closed) system so tat waste from one industry is used as a an input for another

- An effort to reduce the Industrial system's environmental impacts on ecological systems
- An emphasis on harmoniously integrating industrial activity into ecological systems.
- The idea of making industrial systems emulate more efficient and sustainable natural systems
- The identification and comparison of industrial and natural systems hierarchies

All these attributes are relevant to the problem of the Matsapha Industrial Estate.
The adopted working definitions of industrial ecology for the specific problem of Matsapha industrial site are those given by Braden Allenby and Ernest Lowe.

- "Industrial Ecology may be defines as the means by which a state of sustainable development is approached and maintained. It consists of a systems view of human economic activity and its interrelationship with fundamental biological, chemical and physical systems with the goal of establishing and maintaining the human species at levels that can be sustained indefinitely, given continued economic, cultural and technological evolution". (Allenby, 1992)

- "The heart of Industrial Ecology is a simple recognition that manufacturing and service systems are in fact natural systems, intimately connected to their local and regional ecosystem and global biosphere. The ultimate goal is bringing the industrial systems as close as possible to being a closed loop system with near complete recycling of all materials." (Lowe, 1993).

These define industrial ecology with emphasis relevant to the Problem of Matsapha Industrial estate. They emphasise the management of industrial activity on a sustainable basis by seeking the essential integration of industrial activity into ecological systems without jeopardising the economic value of the industrial system. The objective here is to minimise the environmental impact of industrial estates to ensure the ecological viability of natural systems and the protection of human health from industrial pollution.

1.9.2 Key Aspects of Industrial Ecology

Some key elements of Industrial Ecology relevant to the research that are worth mentioning are:

1.9.2.1 Systems Approach

Because of the complex nature of industrial systems, and the multidisciplinary nature of industrial ecology, a systems approach is necessary. The system boundary depends on the scope of the research work.

The research is about the environmental impacts caused by the transformation of materials and energy into goods and services by industrial activities. It is therefore logical that ecosystems is categorised according to the material and energy flows associated with them. There are three basic types of ecosystems (see fig 2.).

A type I system is depicted as a linear process in which materials and energy enter one part of the system and then leave the system either as products or by-products/wastes (Garner and Keoleian, 1995). In this system wastes and by-products are not recycled and therefore rely on a constant supply of materials and energy as well as a limitless waste sink. This system is not sustainable because some resources that are a source of the materials that the system depends on are finite. In addition to that, the natural ecosystems have a finite assimilative capacity for wastes. This system is referred to as an open system

In a Type II system some wastes are recycled or reused within the system while others still leave the system. An interaction webs exists in this system where by-products or wastes are used as inputs by other components of the system. This is much characterised by present-day industrial systems. In Matsapha the level of interaction and recycling is very small. This industrial estate is leaning more towards a type I system and is currently not sustainable. The intervention of industrial ecology will shift it towards a Type III system.

A Type III system is one where “The boundary between resources and wastes does not exist, since output from one organism is an input for another” (Bailey, 1997). Energy and wastes are constantly recycled and reused by other organisms and

processes within the system. Type III system represents natural ecosystems, which are highly integrated, closed systems. This system is sustainable and is the basic goal of industrial ecology, which is closing the waste loop.

In industrial systems, in addition to establishing the category or type of system, it is also important to decide on the level of the industrial system to be considered. The systems level perspective (See Figure 3) establishes the system boundary as well as the vantage point, from which the industrial system is considered, analysed or studied. An industrial system can be viewed from many different vantage points. This could be the entire system as a whole, at company level, at product level, a particular material flow or a particular process within a company. The choice of a vantage point depends on the objectives and the scope of the exercise. In this thesis, the entire industrial ecosystem of the Matsapha industrial is considered because the environmental performance of the industrial site as a whole is of interest.

1.9.2.2 Industrial Symbiosis

This is a very important aspect of industrial ecology because it is one of the cornerstones of closing the loop. In natural systems there are numerous symbiotic relationships. Such relationships usually occur between two non-related organisms that live together in a mutually beneficial arrangement. In an industrial ecosystem, industrial symbiosis would be characterised by an arrangement where companies utilise each other's by-products and or wastes (Stanley, 1999). To achieve this there is need to create synergies among the industries. In this research this element would be investigated.

1.9.2.3 Industrial Metabolism

Industrial metabolism focuses on the efficiency of the flow of energy and materials within an industrial ecosystem. This could be looked at from different levels varying from the entire industry to the individual processes and materials. Improving the metabolic pathways of industries leads to the reduction of material and energy loses (Stanley, 1999). This also contributes to the minimisation of waste generation and like industrial symbiosis, it also leads to the closing of the loop.

1.9.2.4 Integrated Approach

The integrated approach of industrial ecology stems from the recognition that environmental issues of industries are not limited to pollution and the involvement of the implicated industries. It includes other stakeholders such as government, the host communities, the consumers etc. There is need therefore for input from many disciplines such as law, economics, business administration, natural resources engineering, ecology etc. the research will consider all the relevant disciplines to the extent that they are directly related to the waste aspect of industrial activity.

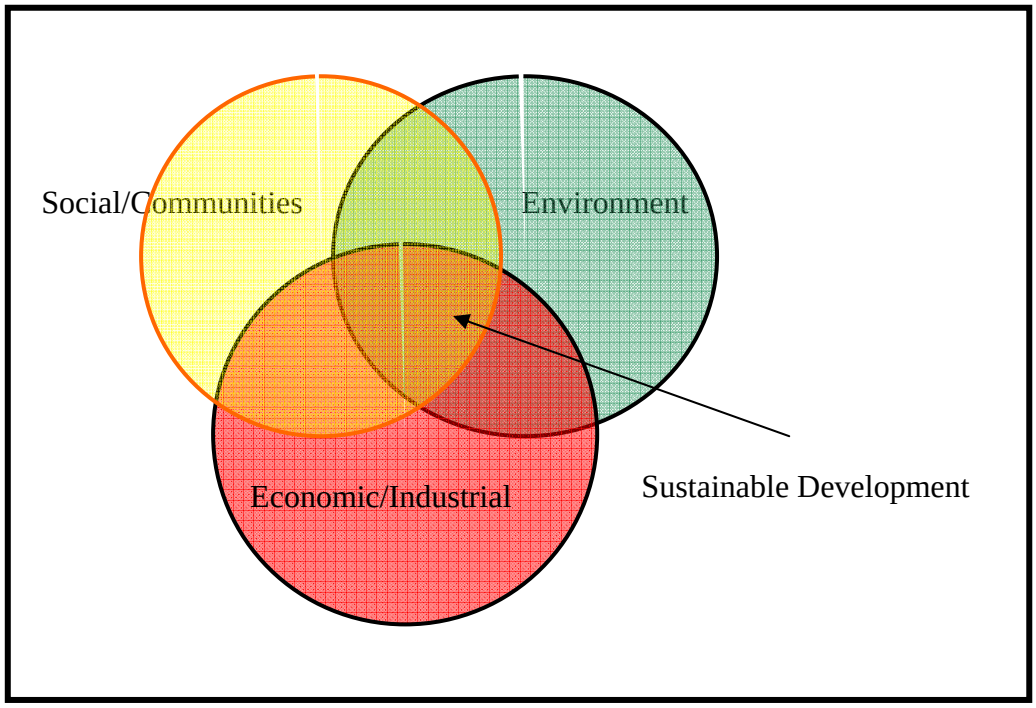

Figure 1. 5 Components of an Industrial System
Source: (Marjanovic, 2003)

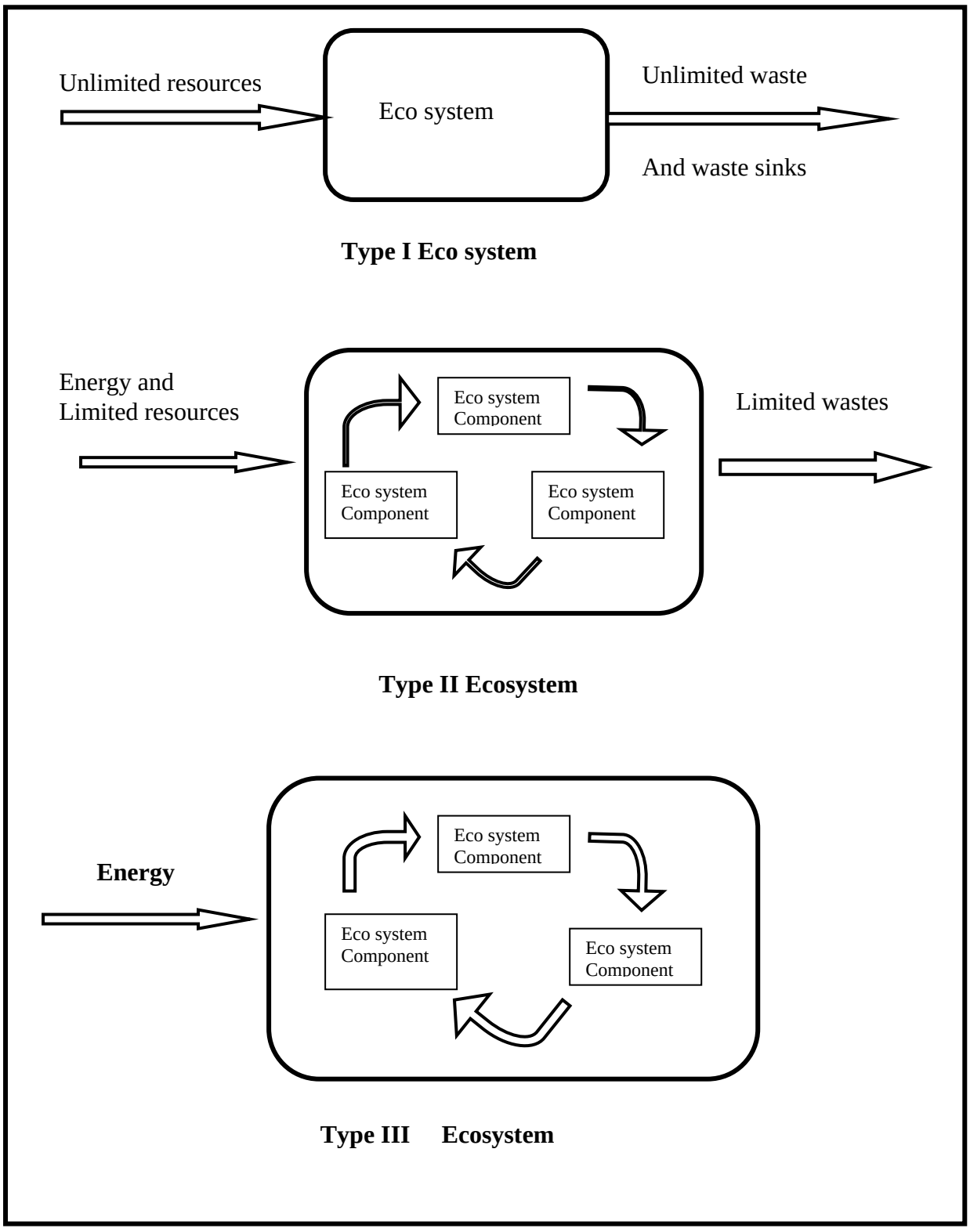

Figure 1.6 Types of Ecosystems
Source : Adapted from Braden Allenby

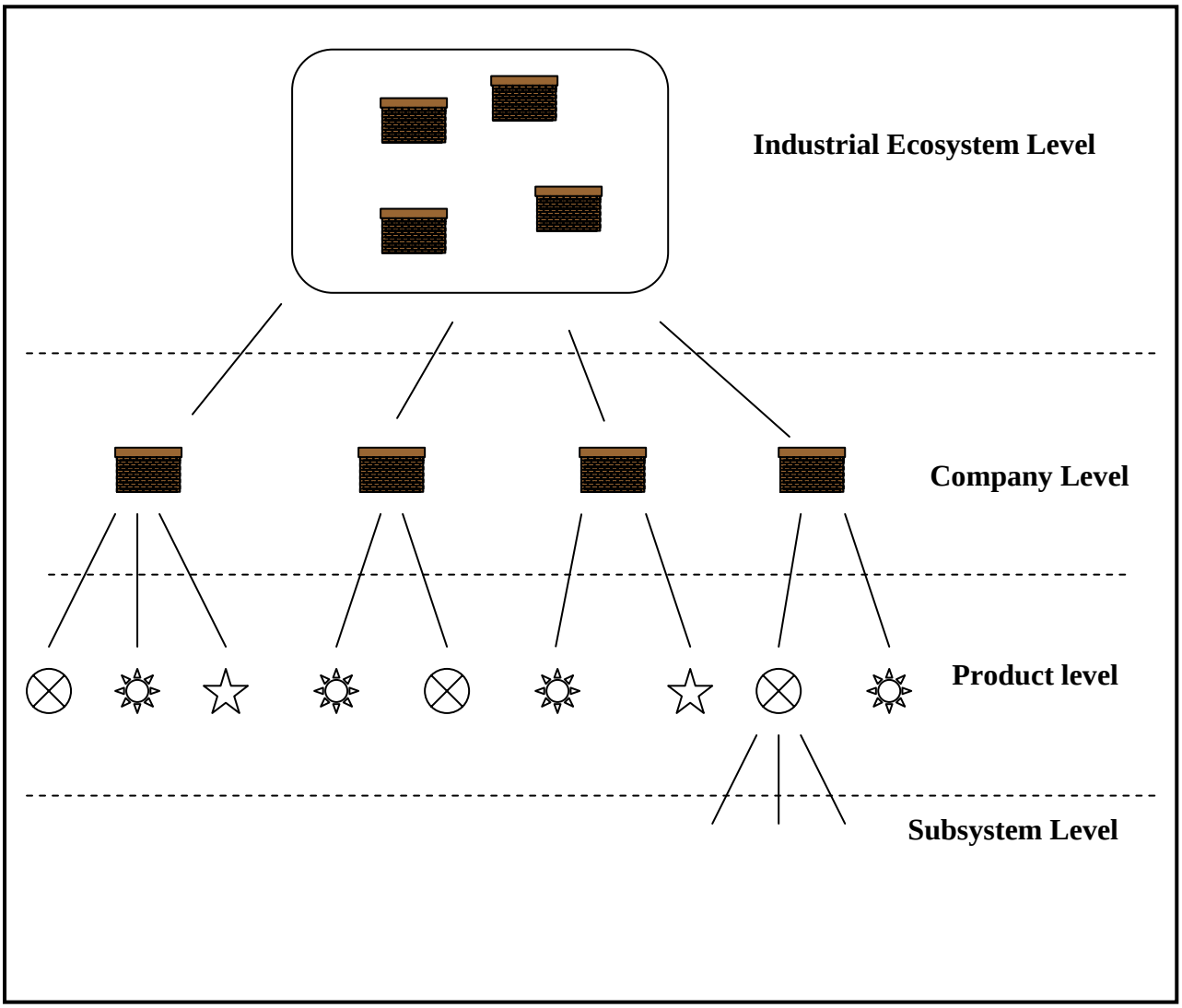

Figure 1. 7 Industrial Ecosystems Levels

Source: Robert Reid Bailey (1997) MSc. Thesis- Designing Robust Industrial Ecosystems

1.9.2.5 Diversity and Flexibility

Diversity is very important in an industrial ecosystem so that as the systems dynamics changes, the ecosystem maintains stability and continues to operate as a closed system. It is therefore necessary to have a wide variety of industries so that if one experiences economic problems or other problems that may necessitate it to wind up business, the system does not collapse. The system also has to be flexible by being able to accommodate new industries. These two aspects are important for the stability of the system (Lowe, 2001).

1.10 The Key Research Questions

The research seeks to find effective means of addressing the environmental problems of industrial estates in developing counties, particularly those caused by the generation of wastes. The lack of success of traditional methods of addressing pollution problems in the study area has lead to the belief that industrial ecology has a great potential for addressing the problems. The research work is guided by the following research questions:

1. **Can the use of industrial ecology principles provide the answers to the environmental problems of industrial estates in developing countries?** With continued pollution problems despite the existence of environmental legislation and various pollution abatement technologies, it is evident that there are fundamental issues that the current approach is failing to overcome. Learning from nature where there is no external force or interference except solar energy, seems to be the way to go. Over the years natural systems have managed to function properly by self regulating, managing the transformation of energy and materials as well as what might be regarded as waste from an external view without collapsing. This research question therefore investigates the potential of industrial ecology.

2. **Can focussing on the environmental component of a system ensure sustainable development in the context of industrial activities?** Industrial activity is all about providing goods and services through the transformation of materials and energy. For industrial activity to continue to provide the goods and services there must be a healthy reliable supply of materials and

energy. Currently the wastes produced are affecting the very resources essential for the industrial activity by pollution, the amounts of waste produced and energy consumed does not seem to ensure the sustainability of the industrial estate.

3. **What are the key elements of sustainable development in the context of industrial activities?** The concept of sustainable development has different meanings to different people depending on their background and what is viewed as the most important issue in development. Sustainable development is therefore viewed from different angles. This research is looking at the concept of sustainable development from the point of view of maintaining or improving economic performance of industry without reducing the capacity of the environment to sustain the demands placed on it by the industrial activities.

4. **How can industrial estates in developing countries be transformed into eco industrial parks?** Currently Matsapha Industrial Estate is nothing more that a collection of firms that are operating independent of each other. In this situation, environmental issues are being addressed on an industry-by-industry basis. This is demanding on both human and financial resources. Some environmental impacts that cannot be attributed to individual industries are not easily addressed. This is the cause of the continued decline of the environmental performance of the industrial estate. There is need for cooperation and complementarities among the individual industries in order to facilitate the concepts of industrial symbiosis, industrial metabolism, shared services etc. that are in the heart of Eco Industrial Parks (EIP).

5. **What are the short-term measures that are necessary to contain the environmental problem of the case study area?** With the assumption that the transformation of the study area into an eco industrial park cannot be achieved overnight, there is need to identify short term measures that will contain the current environmental problems and setting the stage for transformation.

1.11 Assumptions

To answer these research questions, the following assumptions are used as a point of departure

1. A systems approach will offer an appropriate vantage point for understanding the environmental problems of industrial estates in developing countries.

2. By managing the environmental component of an industrial system in a comprehensive manner, the deviation from the equilibrium of inputs and outputs of the industrial or economic component of the system will be substantially reduced thus ensuring the performance of the system in a sustainable manner.

3. The sustainability of a system cannot be achieved overnight with a prescription (Big Bang conversion). It will take a gradual transformation by providing the foundation and setting the stage for a gradual progressive change evolving towards a desired goal.

4. In order to effectively address the sustainability of an industrial estate, the whole system has to be considered. Approaching the environmental issue by focussing on compliance only is not sustainable.

1.12 Scope and Limitations

Industrial ecology being a multidisciplinary approach and hence its integrated nature, involve and draws from principles of a wide range of disciplines such as economics, sustainable development, engineering, ecology, environmental management, law etc. The scope of this research determines the level and detail to which these principles are used. This research is focussed on the environmental component of the industrial system. The in-depth evaluation of the other related disciplines is beyond the scope of this research thus the research is limited to their direct implication to environmental management particularly issues of wastes and pollution.

Lack of time series environmental data in developing countries is a limitation to this research. A cross sectional data is therefore used. This is a reality that has to be lived with in environmental issues of developing countries.

The work presented in this thesis is on the environmental aspect of the industrial estate. The environment is also diverse it is therefore important to narrow down to the specific environmental component that is most problematic in the area in order to be focused. The scope of this research is limited to those aspects that are relevant to pollution and waste management at planning level. This is because pollution is the main troublesome environmental problem of the case study area and indeed in many industrial estates in developing countries. This problem is not viewed in isolation from the community and the economic aspects, which are the other components of the industrial ecosystem. (See figure 1.2).

From the systems perspective the problem will be investigated at the industrial ecosystem level (see figure 1.4). This level is in line with the purpose of the research that of finding answers to the research questions that establishes the basis for developing strategic framework for environmental management options for industrial estates in developing countries.

This therefore establishes the system boundary and vantage point from which to approach the research work.

1.13 Purpose of the Research

The research seeks to determine how the concept of industrial ecology can be put into practice to solve an existing problem. Basically the research work adds to the information base of industrial ecology. The vantage point chosen implies that at the practical level, the research results are primarily useful to environmental planners and government agencies.

2. LITERATURE EVIEW

2.1 Industrial Ecology as an Agenda for Industry

The purpose of this literature review is to identify what has been previously done on the subject of industrial ecology and to what extent the research questions of this research work have been addressed.

Industrial ecology is an emerging field and thus there is still much discussion and debate over its definition and other aspects relate to its applicability (Garner and Keoleian, 1995). It is only recently that industrial ecology is being viewed as a new framework for organising industrial activity for sustainable development. Publications on the subject of industrial ecology are very recent.

The more the subject is discussed, the more it appears to be complicated because it draws from a variety of established disciplines such as law, sociology, economics, engineering, ecology and environmental management. For this reason industrial ecology is an integrated approach. The literature consulted either discuss industrial ecology as a subject or its application in the form of designing and implementing eco-industrial parks. The Eco Industrial Parks Hand Book for Asian Countries (Lowe, 2001) describes the elements of designing and operating an eco industrial park (EIP) and outlines how the related disciplines are integrated at the planning stage. The whole spectrum such as the technology needed for the functioning of an EIP, recruitment of tenant industries, financing EIP, by-product exchange etc. is outlined. Important to note is that the discussion in this handbook is about well planned EIPs. In this document, the importance of setting measurable environmental, social and economic goals is stressed. This is in line with the integrated approach of industrial ecology. Fritz Balkau in his presentation entitled “Managing Environmental Issues in Industrial estates (An Application of Industrial Ecology, 1997)” recognises the fact that industrial estates needs a special approach in the form of industrial ecology in order to be able to effectively deal with environmental issues unique to industrial estates. He states that “The number and close proximity of so many potential polluters, require a more closely adapted approach” More so because some of the environmental impacts

associated with industrial estates are not directly caused by the individual industries but are related to services, infrastructure and many other human activities that have nothing to do with the direct operations of the individual industries. He points out that industrial ecology principles can be used to develop a framework that brings together the main elements of a practical environmental management plan. However he does not explain how these principles can be used particularly in developing countries. This aspect is the core of this research work.

Garner and Keoleian (1995) discuss the role of industrial ecology as a strategy for environmental impact reduction for industry. They discuss the elements of industrial ecology as well as the system tools to support industrial ecology such as Life Cycle Assessment (LCA), Design for Environment (DFE) etc. They state that industrial ecology seeks to transform industrial activities into a more closed system. What is not coming out clearly is how can this be practically implemented. They state that there is need for further developing industrial ecology. This includes a clearer definition of industrial ecology, a clearer definition of sustainable development in the context of industrial ecology as well as more participation from a cross section of the other related fields.

The potential of industrial ecology in addressing the environmental burden of industrial estates has been recognised and accepted by many people (Tibbs, 1992). Tibbs states that industrial ecology is an environmental agenda for industry. He notes that the environmental agenda of companies today is frequently driven by a list of individual issues such as promoting recycling, minimising the production of hazardous wastes etc. While these lists can to a certain extent address localised pollution problems at company level, there remains the possibility of environmental surprises that may have impacts beyond the company premises. That is why industrial ecology is seen as the appropriate environmental agenda because of its holistic approach that goes beyond the company level.

This is because there is no overall accepted frame work to shape comprehensive environmental programmes of industrial estates. The United Nations

Environment Programme - Industry and Environment (UNEP IE) has published a document on The Environmental Management of Industrial Estates, (1997). This document recognises that industrial estates have to be considered as a system when dealing with their environmental issues. The recommendation is that in developing environmental guidelines for existing industrial estates, the first thing is assessing the existing environmental conditions and issues then determine the priorities for action for the estate. The priority for Matsapha industrial estate is pollution abatement. The role of industrial ecology on the environmental management of industrial estates is also recognised. Benefits of by-product exchange that have been realised by Kalundborg for example are living examples of the effectiveness of industrial ecology. These benefits include reduced air, water, and land pollution and reduced levels of resource consumption. These have a direct economic benefit to the participating companies as well as ensuring compliance with regulations.

Industrial ecology is a paradigm shift from conquering nature to cooperating with it (Tibbs, 1992). This orientation is ideal for the desired goal of achieving improved environmental performance without jeopardising the economic aspect of industrial activity. Some managers feel that there is enough regulation from government and argue that any extra governmental action towards industry in the form of added regulatory burden run the risk of weakening the long term health of the economy and will detract more from future wealth and quality of life than would the postulated environmental deterioration. This may well be efforts by some managers to win the hearts of politicians whose understanding of development seem to be inclined more to economic development as defined by economists. In reality however the implication of the true cost of environmental degradation in the market place is important (Tibbs, 1992). Tibbs's paper states that industrial ecology requires applying a variety of disciplines such as ecology, engineering, economics and public policy. Industrial ecology integrates the environmental issues to economic activities and provides for the shift from viewing environmental issues as overheads by focusing on compliance to taking them as strategic and integral to economic activity (Allenby, 1999). An effective environmental agenda will be one that

industry will align with easily (Tibbs, 1992) and that is one that will not jeopardise economic development.

"As industrial ecology frames a new paradigm for structural balance and environmental optimisation in the industrial system, the inevitable policy dimension of such a broad goal cannot be avoided" (Allenby, 1999). Allenby discusses the policy aspects of industrial ecology. This establishes the fact that an appropriate policy framework is necessary to support industrial ecology.
An important aspect that is recognised by Tibbs is the fact that the results of an industrial ecology approach will be a gradual overall transition over time taking several decades.

2.2 Industrial Ecology in Practice

Aspects of industrial ecology have been practiced for many years simply because it was and still is logical for instance to use maize stover as animal feed and the animal manure to fertilise the maize fields. The most cited example of industrial ecology in practice is that of Kalundborg in Denmark. The industrial activity in Kalundborg demonstrates a well-developed industrial symbiosis in practice. Industrial symbiosis alone achieves a significant portion of the goals of industrial ecology that of balancing the economic and environmental goals. In Kalundborg this industrial symbiosis has generated millions in revenue from by-product exchanges and additional cost savings from business efficiency improvements. The symbiosis in Kalundborg is however not the result of a careful environmental planning process. It has been the result of a gradual development of cooperation between the individual industries and the Kalundborg municipality. None of these co-operations were specifically required by law or regulation. Each By-Product Exchange (BPX) or trade has been independently negotiated. This research will determine whether this is possible in the study area. The earliest deals in Kalundborg were purely economic. But recently initiatives have been made largely for environmental reasons (Balkau, 1997). From a stage where the cooperation happened by chance, this has developed into a high level of environmental consciousness where the participants are constantly exploring new avenues of environmental

cooperation. Kalundborg is therefore a practical example of the application of sustainable development marked by a high level of closing the waste loop.

The PALME model in France has made a major move towards organising the stakeholders to view the industrial estate as a system. Here the various social and industrial partners, through consultations and negotiations developed and signed a common charter for the estate which lists the actions required of each organisation (Balkau, 1997).

2.2.1 Locations of some eco-industrial estates

Table 2.1 Locations of some eco-industrial estates

Source: UNEP IE report number 39 The Environmental Management of Industrial Estates, 1997

COUNTRY	ECO-INDUSTRIAL ESTATE
Canada	Burnside Industrial Park, Nova Scotia
	Bruce Energy Centre, Ontario
	Port Industrial District, Ontario
United States	Brownsville, Texas
	Cape Charles, Virginia
	Baltimore, Maryland
	Chattanooga, Tennessee
	Plattsburgh, New York
	Burlington, Vermont
Denmark	Kalundborg
Sweden	Linkoping
France	Sophie Esterel
	Charlon-sur-Saone

2.3 Published papers

There are may published journals focusing in industrial ecology and related fields.

J. Korhonen, in his paper entitled: Industrial Ecology in the Sustainable Development Model, emphasised the importance of industrial ecology principles as a strategy for sustainable development. He states that the attraction in the concept of industrial ecology lies in its application of the natural ecosystem metaphor to industrial ecosystems. Industrial symbiosis is singled out as the most commonly used natural ecosystem metaphor (Korhonen, 2004) .

A question is sometimes asked whether industrial ecology is a field or only a metaphor. This question is illustrated by the paper published by John Ehrenfeld [6] he states that predominant work within industrial ecology to date has been based on the flow aspect of the ecological metaphor while less has been done to explicate is structural or systems aspects.

Tracy E. Casavant and Raymond p. Cote (Journal of Cleaner Production, 2004) in their paper they emphasise the systems approach. They state that environmental problems are not linear therefore optimising individual processes may not necessarily lead to lower environmental impacts. They argue that higher efficiencies and lower environmental impacts are more effectively achieved by optimising a system of processes. “Optimising for one type of pollution is likely to result in the generation of higher values of another type, for example minimising air pollution may increase water pollution” This means that it is important to consider the entire system and design the interface between the industrial system and the environment. They also discuss possibilities to apply chemical process simulation in the design and planning of industrial ecosystems.

The article by Jouni Korhonen, Donald Huisingh and Anthony S.F. Chiu (Journal of Cleaner production, 2004) provide an overview of the applications of industrial ecology. The authors base their article on the papers published by others on the subject. They look into the theory and concepts, tools, instruments

and metrics, cases and applications and conclude by a section on the critique and call for future work in industrial ecology. The paper states that “Despite the fact that all successful documented cases of industrial symbiosis to this day have been self-organising. It goes on to state that some authors and development officials have suggested that increased planning might deliver better results than spontaneously evolved market coordination” The paper suggest that comprehensive planning is unlikely to live up to the expectations of the planners. This overview “illustrate that industrial ecology is a provocative and attractive concept”.

The most relevant research to this research work is that of Brownsville in Texas and Matamoros in Mexico, which was done by a multidisciplinary team, Sheila A. Martin and others in 1996. This research investigates the economic, environmental, technical and regulatory issues of these industrial estates. The purpose of the project was

- To demonstrate the potentials economic and environmental benefits of an EIP
- To articulate a process for a successful EIP development
- Examine the regulatory issues surrounding successful EIPs
- Identify technologies that are important to the success of the EIP concept

The Brownsville/Matamoros case study is viewing the industrial set-up from the perspective of an EIP.

Robert Reid Bailey studied the design of robust industrial ecosystems in his MSc. Thesis. He focused on the design aspect for eco industrial parks.
Georgios Ioannis in his research thesis entitled: Reorganisation and Inter-Firm Networking, 2003: In search of Environmental Co-location Economies, explores the benefits of co-location. He concludes that co-location may enhance collective capabilities and allow both firma and the public sector to realise environmental savings in the form of less expensive provision of environmental management infrastructure and services. He states that the extent of these savings depends on a number of factors such as labour force and management

characteristics, the type and strength of inter-firm networks as well as existing environmental and industrial policies.

Other related researches focus on the tools and technologies that can be used in industrial ecology such as Design for Environment and Life Cycle Assessment. W. Dewulf in his research thesis entitled: A Proactive Approach to Eco-design, 2003, suggests a proactive approach through integration of eco design in the early stages of a design process. Tracy Dowie focused on the physical disassembly to address the problem of wastes arising from a variety of products in her research entitled: A Disassembly Planning and Optimisation Methodology for Design. In his research thesis entitled Product oriented Environmental management, 2001, Frank de Bakker concludes that the improvement of environmental performance of products over their life cycle is influenced by a variety of stakeholders such as customers, suppliers, government and the public. He states that this stimulates a firm's desire to acquire competitiveness and advantage.

2.4 Technologies for Industrial ecology

A number of case studies describe the economic and environmental benefits that result from pollution prevention activities. Pollution prevention however is focusing on individual companies. It is the combination of several technologies that is important for the applicability of various aspects of industrial ecology in an industrial estate and their collective results will determine the level of success. The Brownsville/Matamoros case study (Martin and others, 1996) describes the importance of technologies in an EIP. Of importance are technologies that take advantage of economic efficiency and provide environmental benefits to the industrial estate. Any technology that reduces the cost of air pollution abatement, water discharges, hazardous wastes, and solid waste will reduce the cost of complying with the associated regulations. The report divides the technologies important for EIPs into the following six categories:

- Transportation technologies
- Recovery, recycling, reuse and substitution technologies
- Environmental monitoring technologies

- Information technologies
- Energy and energy-efficient technologies
- Water treatment and cascading technologies

Several books that deal with specific aspects of the technology categories were read in order to capture the elements that would be applicable in a developing country situation. These elements are those that will be compatible with existing production systems, the skills of the existing workforce and managers as well as the cultural and chosen environmental criteria. Richard Bahu and others (1997) refers to this as the selection of the best practicable environmental option (BPEO).

2.5 Areas of Divergence in Industrial Ecology

Even though there is a general agreement on the elements of industrial ecology and its natural systems metaphor, there are areas of industrial ecology where opinions differ. An Indigo Development publication (Lowe, 1997) outlines areas where there are differences of opinions in industrial ecology with respect to scope and emphasis. “The following differences often go to the heart of how different researchers define industrial ecology.

- Timescale: Some industrial ecologists emphasize incremental change in existing systems. Others speak of far reaching transformation of industry and society.
- The ecosystem model: With some, a very popular theme is modeling industrial systems upon the principles and dynamics of ecosystems. However, some ecologists and many engineers question the usefulness of this approach.
- Materials flows: Some industrial ecologists focus on the task of increasing the efficiency and reducing the impacts of materials flows in industry and society. In some articles the whole field appears to be little more than this.
- Scope of application: Much discussion focuses on change in manufacturing industries, while other practitioners emphasize that IE is relevant to agricultural, service and financial industries, as well as the

design and management of public policy, infrastructure, and facility operations. A few extend IE's domain to the realm of consumer behavior.

- Key ecological concerns such as biodiversity, carrying capacity, and restoration are emphasized in the work of university researchers but are seldom mentioned by more technically oriented industrial ecologists. (Allenby & Graedel's definition does emphasize carrying capacity. 1995)
- Some see institutional change as a fundamental component of IE. Others discount this, emphasizing the centrality of technical innovation to IE.
- Materials choices: The shift from non-renewable, synthetic materials to renewable bio-materials is a central concern for some industrial ecologists. Others focus on improving the environmental performance of petroleum based and other synthetic materials.

Industrial ecology is both a field of scientific research and a framework for design and decision making in public and private sectors. These two aspects should be seen as complementary rather that divergent…" (Lowe, 1997)

2.6 Conclusion

Case studies that are documented are explaining how activities of existing industrial estates or large corporations such as Indigo, relates to EIPs or industrial ecology. Because of the multidisciplinary nature of industrial ecology, these case studies try to consider all the components of an industrial system. They consider the case studies from the perspective of an ideal EIP. The thrust of this research however is to determine how the principles of industrial ecology can be applied to existing industrial estates in a developing country in order to pave the way to sustainable development. The literature review has shown that industrial ecology is a provocative and attractive concept and that there are some differences of opinions in some aspects of industrial ecology. This research has been inspired by the continuous pollution problems in the case study area therefore it is only those aspects of industrial ecology that are relevant to problems of pollution that are going to be investigated in this research. The focus is on the environmental component of the industrial system particularly the waste aspect. The depth to which the other components (the social and the economic) are investigated is limited to their direct relevance to the waste

aspect. Most of the existing literature is about the designing and implementation of EIPs. The wok of Robert R. Bailey (1997) in his Master of Science thesis looks into the designing of a robust industrial ecosystem.

The Brownsville/Matamoros case study by Sheila A. Martin and others is close to the work of this thesis. The relevant aspect of this particular case study is the fact that it looks into an existing industrial set-up but focuses on the elements of a process for successful EIP development using an existing situation. The main problem of the Matsapha industrial estate and indeed many industrial estates in developing countries is that of pollution. The Brownsville/Matamoros case study does not directly address the fundamental purpose of this research, that of determining how the principles of industrial ecology can be converted into concrete action in industrial estates of developing countries in order to close the waste loop and therefore addressing the persistent environmental problems. There are many other aspects that makes the Brownsville/Matamoros case study not directly relevant to developing countries particularly countries in southern Africa. These include the availability of time series data, corporate behaviour, cultural practices, available technology, economic status of the USA, financing institutions, investor confidence etc.

Industrial ecology being a new field, the relevant literature is not well developed and structured. The most available literature is published papers.

Based on the literature review it s concluded that none of the research questions are adequately addressed by previous work. The tools used by previous work as well as the information and knowledge developed are certainly useful to this research work. More information and knowledge base will be added by this research work.

3 DATA ANALYSIS

3.1 Waste Characterisation

The purpose of the data analysis is to establish the profile of the wastes and other waste related issues of the industrial activities of the case study area. This information is used for the determination of the environmental performance of the case study area.

There is no agreed international standard for waste stream analysis or waste characterisation (Anonymous, Ireland EPA Publication, 1996). Waste characterisation tends to be based on the objectives or purpose for which the exercise is done. Many countries have national procedures designed to meet specific objectives. Waste characterisation can be based on a number of objectives such as:

- Disposal based
- Treatment based
- Recycling
- Determination of environmental burden
- Public awareness
- Determination of environmental performance indices
- Litigation/legal implications

The information generated is therefore dependent on the objectives. There are two main objectives of the waste stream characterisation in this research. The first objective is to establish the waste-related environmental performance of the case study area. The second is to identify opportunities of using industrial ecology principles for reducing the environmental burden of the industrial estate thus improving its environmental performance. This implies that a combination of all the above listed waste characterisation objectives is considered in this research to the extent applicable at the eco-industrial system level. The information generated from the waste characterisation provides waste types, composition and quantities of solid waste and effluents as well as waste oil derived from the collected data and other valuable information.

Most of the industries in the case study area do not keep data on wastes. The types of wastes generated were established visually as well as by interviews with specific personnel. For most of the industries visited it has been possible to estimate quantities based on such available information as number of loads taken to the disposal site.

All the industries that discharge into storm water drains do not have quantitative effluent data. Where information for quantitative estimations is not available, qualitative description of the wastes is provided. For air emissions there is virtually no quantitative data in the case study area. The information on air emissions is therefore qualitative. It has been necessary to qualitatively describe some of the wastes arising from unplanned creation and emissions of wastes. These include fugitive emissions, leaks, spills and general lack of containment.

The waste related environmental performance of the industrial estate is not only a function of the wastes generated by the industries some sources of wastes are not attributable to any particular industry. These include the informal sector, the general public, vehicles emissions and indiscriminate disposal anywhere. There is no quantitative wastes data from these sources and also there is no information that can be used to estimate the quantities. The wastes from these sources are only described qualitatively.

The waste streams are divided into three main categories. These are:

1. Solid waste and other wastes disposed of on land
2. Industrial wastewater
3. Air emissions

3.2 Solid Waste

It has been possible to estimate quantities of solid waste for most planned sources. The information given during data collection was the number of loads taken to the landfill. The loads are described as number of dustbins, number of 1 tone van, tractor-trailer, and number of skips. These were per given period. The average weight of wastes from these was obtained from the Mbabane landfill where a weighbridge is used.

The sources of solid wastes are from industrial activities, commercial establishments, the informal sector and other human activities not directly linked to industrial activity. There is a wide spectrum of types of solid wastes generated in the case study area. The broad waste types found in the case study area are paper, plastic, scrap metal, scrap tyres, glass, wood, waste oil, garden waste, construction waste, textile cuttings, coal ash, other organic wastes. Waste oil is included in the solid waste category in accordance with the Waste Regulations of 2000. This is because waste oil is disposed of on land. A mixture of any of the above solid wastes is commonly found. Table 4.1 below gives the quantities of the different solid waste types generated in the study area.

Table 3.1 Solid waste types generated in Matsapha Industrial Estate

WASTE TYPE	**QUANTITY (TONES/YEAR)**	**WEIGHT %**
Scrap metal	470.6	2.0
Paper	1646.0	6.9
Plastic	641.1	2.7
Textile cuttings	672.0	2.8
Organic	9839.0	41.5
Scrap tyres	205.4	0.9
Special	22.6	0.1
Coal ash	2943.0	12.4
Oil	36.3	0.2
Glass	552.2	2.3
Wood	65.0	0.3
Mixed	6591.5	27.8
TOTAL	**23684.7**	**100**

Recycling of scrap metal is very active in the case study area so much so that all the metal waste in the industrial estate is sold to the scrap metal merchants. Of the 9839 tones of organic waste generated, 5940 tones from the maize mill and 2200 tones

from the breweries are sold to animal feed manufactures. This leaves 1699 tones of organic waste disposed in the landfill.

Table 4.2 gives solid waste resulting directly from the industrial activity that is disposed

Table 3.2 Solid waste disposed

WASTE TYPE	QUANTITY (TONES/YEAR)	WEIGHT %
Paper	1646.0	10.9
Plastic	641.1	4.3
Textile cuttings	672.0	4.5
Organic	1699.0	11.3
Scrap tyres	205.4	1.4
Special	22.6	0.1
Coal ash	2943.0	19.5
Oil	36.3	0.2
Glass	552.2	3.7
Wood	65.0	0.4
Mixed	6591.5	43.7
Total	**15074.1**	**100**

The quantitative information presented above represents waste directly related to industrial activity. There are other sources of solid waste in the case study area that are not directly linked to the activities of the industries. These are the informal sector, general public and indiscriminate dumping by some businesses not serviced by the town board as well as some irresponsible waste service providers.

The informal sector comprises backyard servicing of motor vehicles, street vending of food and other related products as well as vending of non-food items. The wastes generated from these sources include paper plastics, wood, engine oil, food, tin cans, and bottles. The town board does not take responsibility of these wastes and therefore they are discarded anywhere sometimes burnt onsite. This is a major cause of the littering that is evident in the industrial estate. Waste oil is disposed on site causing

land contamination and pollution of both surface and ground water. Waste tyres can be found anywhere sometimes burnt to recover metal for recycling.

The general public generates the same wastes types as the informal sector with the exception of waste oil. These wastes are also discarded anywhere because there is no organised waste bins in the industrial estate.

3.2.1 Scrap Metal

Scrap metal consists of a variety of metal types both ferrous and non-ferrous. The metal wastes come in all sorts of sizes and forms. There are three scrap metal collectors in the case study area. The scrap metal is then transported to South Africa for recycling. The public is very active in the scrap metal collection that they sell to the scrap metal merchants. Most of the industries that generate scrap metals sell it to the scrap metal merchants. The industrial estate is not littered with scrap metals. The scrap metal collection is well established and as a result no scrap metal is disposed in the landfill.

3.2.2 Paper

Waste paper includes cardboard. This is generated by almost all the industries in the form of office waste, packaging and waste paper from printers and cardboard manufacturing. There is a tissue paper manufacturing company in the case study area that uses waste paper but there is no organised waste paper collection in the case study area. The tissue paper manufacturer imports its waste paper from South Africa. Very small quantities of waste paper is sourced from within the country and this is from anywhere in the country. The waste service providers in the industrial estate do collect waste paper but for some reasons they are not guaranteed a market by the tissue paper manufacturer. As a result most of the waste paper ends up in the landfill.

3.2.3 Plastic

Waste plastic is also from almost all the industries. This comes in the form of plastic sheets, plastic bags, juice containers and other products made of plastic material. There is one company that grinds and palletises waste plastics and four manufactures of plastic products in the case study area ranging from plastic tubes to plastic bags and domestic containers. The recycling of plastics is also not well organised.

3.2.4 Scrap tyres

Scrap tyres are from retailers of new tyres who also fit tyres to vehicles. There is one retreading company from which rubber dust is generated. Most waste tyres end up in the landfill where waste salvagers burn the tyres to recover metal. The public takes a few of the tyres for various purposes.

3.2.5 Coal ash

Coal ash is from companies that use coal in boilers to generate steam. The ash is taken to the landfill or disposed elsewhere.

3.2.6 Textile cuttings

Textiles cuttings are from the numerous Chinese garment-manufacturing companies most of which are fairly new. These companies either use a waste service provider or take their waste to the landfill themselves. The textile waste can be found anywhere in the industrial estate though the landfill is within the premises of the industrial estate. The plastic palletising company has indicated an interest in the waste textile cuttings for which a market in South Africa has been identified.

3.2.7 Wood

Waste wood is not common in the case study area because there are no big timber related industries. Only two very small furniture manufactures were found in the case study area one run by three people and the other with eight employees. The rest of the wood waste is from various uses such as renovations packaging etc. Only two industries have quantitative data on waste wood.

3.2.8 Glass

Waste glass consists largely of bottles for various beverages and plate glass. There are two companies that have quantitative data on waste glass. Waste glass is found everywhere in the case study area. These are from liquor outlets and the general public. All the industries have some form of waste glass in their wastes. There is no waste glass collection in the case study area. A manufacture of glass ornaments is located about 40 kilometres from the case study area and only takes clear glass from anywhere in the country.

3.2.9 Organic waste

Organic waste consists of spent grain, spoilt food products, garden waste and wastes from abattoirs. Most of the organic waste comes from the breweries, abattoirs, bakery and milling companies. The other sources are restaurants, garden maintenance and canteens. Some of the wastes are taken by manufactures of livestock feed or collected directly from the restaurants by pig and chicken farmers. Quantitative data is from the big companies.

3.2.10 Waste oil

There is more waste oil in the case study area than is reflected in the data. This is because many of the waste oil generators are in the informal sector. The quantitative data is from the few who store the waste oil in containers. The recycling of waste oil is not organised. Occasionally companies from South Africa come to collect waste oil for recycling. The rest of the waste oil is disposed either on site or in storm drains.

3.2.11 Special waste

Special waste is the term used in the Waste Regulations of 200 for hazardous waste. Waste oil is listed as special waste in the Waste Regulations but is deliberately discussed separately because it can be easily addressed separately. The rest of the special wastes are from laboratories, clinics, pharmacies and production processes. These consist of many different chemical compositions in small quantities. Because of

lack of data most of the special waste from the industries is included in the mixed wastes.

3.2.12 Mixed

Mixed waste consists of all the spectrum of wastes found in the industrial estate. Most of the companies presented the data in the form of mixed waste because there is no waste stream separation in the case study area. Only three companies have some form of waste separation. These are multinational companies who are either in the implementation of some environmental management system or it is a general requirement from the parent industry.

Solid waste management in the case study area is not systematic. The town board only collects general waste through a contractor. Transportation of the industrial waste to the landfill is the responsibility of the individual industries. Some businesses are either not serviced by the town board or the service is unreliable that these businesses have to take care of both their general and industrial waste. The industries either transport the waste themselves or engage a contractor. These wastes are not always taken to the landfill, they are sometimes dumped indiscriminately anywhere. There are many evidences of such dumping through out the industrial estate. There are therefore two groups of solid waste transporters in the case study area, contractors or the industries themselves

3.3 Industrial Wastewater

3.3.1 Discharges

Reliable quantities of effluent are from the companies that discharge directly into the sewer system. This is because these companies are paying for discharging into the sewer system to the Swaziland Water Services Corporation. For this reason both the industries and the Swaziland Water Services Corporation find it necessary to monitor the quantities and the quality of the discharges. Important to note here is the fact that the monitoring is not driven by environmental concerns but by financial implications.

Discharges to storm water drains by some industries are not continuous. All the industries that discharge into storm water drains do not have quantitative data.

Table 3.3 Effluent Discharges into the Sewer System

EFFLUENT SOURCE	EFFLUENT m^3/yr	AVERAGE COD (mg/l)	POLLUTION LOAD (Kg/Yr)
Cadbury	44400	8929	396.4
M&F Plastics	No data	No data	
Nampak	No data	No data	
Parmalat	6000	2864	17.2
Swazi Poultry	31500	No data	
Swaziland Beverages	19100	2452	468.3
Swaziland Meat Industries	93000	330	30.7
YKK	61169	559	341.9
TOTAL			**1254.5**

3.3.1.1 Discharges to the River

There are two industries discharging directly into the river. Two underground storm drains were also identified.

Table 3.4 Discharges Directly to the River

Discharge Source	Total Annual Volume (M^3)	Cod (Mg/L)	Annual COD Load (Tones)
Drain A	31,536	1,000	31.5
Drain B	63,072	800	50.5
Conco	37,045	100	3.7
Swazi Paper Mill	750,000	10,000	7,500
Sewerage Treatment Plant	346,896	500	173.4
TOTAL			**7,759.1**

Total pollution load to water from the case study area is **7 759.1 tones/yr**

The discharges from drains A and B contain a variety of pollutants including toxic substances. Toxic substances in the case study area include solvents, paints, break fluid, heavy metals, ink, dry cleaning chemicals, dyes, oil and many other unidentified chemicals. The laboratory analysis was for COD Zink Lead Mercury and Chromium. The heavy metal analysis was done to give an indication of heavy metals in the case study area.

3.3.1.2 Effluent Categories

The effluent can be divided into two broad categories for purposes of industrial wastewater treatment. These are:

- Organic effluents. These are effluents that can be classified as non-toxic. They contain mainly organic substances that can be treated by using microbial action.
- Non-organic effluents. These can be classified as toxic. They contain mainly inorganic and other toxic substances.

3.4 Emissions to Air

None of the companies in the case study area have quantitative data on air emissions. Air pollution in the industrial estate is evidenced by industrial odours, poor vision as a result of photochemical smog and smoke. Industrial odours and other nuisances are linked to localised air pollution sources.

Table 3.5 Sources of Air Pollution

Pollutant		Source
Smoke	❑	**Coal fired boilers**
	❑	**Landfill**
	❑	**Residential houses**
	❑	**Informal sector**
VOCs	❑	**Solvents**
	❑	**Spray painting**
	❑	**Other chemicals**
Smell	❑	**Abattoirs**
	❑	**Landfill**
	❑	**Sewerage treatment plant**
	❑	**Some industries**
	❑	**Brewery**
Dust	❑	**Landfill**
	❑	**Dirt roads**
	❑	**Construction**

In addition to the sources from the industrial estate, smoke and photochemical smog is coming from domestic fuel burning, bush fires, vehicles, petrol and diesel distribution points from the nearby city of Manzini and the neighbouring communities. Even though there are no quantities for air pollutants, there are many sources of air pollution directly from the industrial estate. These are

3.5 Cost of Waste Management

The cost of waste management is that of effluent charges and solid waste transportation.

For effluent only those that discharge into the sewer system are charged by the Swaziland Water Services Corporation (SWSC). The charges are based on the effluent quality and quantity. The total cost of effluent is **R 2,508,000.00** and this is for **1,019,407.5 m^3 per year**

For solid waste the cost is only for waste transportation. The waste transportation is either done by the industries themselves or the industries contract out the waste transportation. The Matsapha Town Board collects office waste and other general wastes and includes the charges in the property tax. The total cost for solid waste transportation per year is **R 2,090,620.00** and this is for **16,612.8 tones per year.**

4. THE ENVIRONMENTAL PERFORMANCE OF THE CASE STUDY AREA

4.1 Environmental Impacts

In the context of the scope of this research, the environmental performance of the case study area is a function of the environmental impacts and the environmental stressors. The environmental stressors are defined as the raw material and energy requirements as well as the emissions to air, water and soil. The environmental impacts are defined as the changes in the quality and quantity of natural resources and the quality of the environment resulting from the stressors. (Miettinen and Hamalainen, 1998).

The environmental impacts of the case study area can be divided into four broad categories and these are:

- Resource depletion

  Resource depletion is important for the industries, the communities and government authorities that have to ensure sustainable industrial development as well as equity sharing of the resources between industry and the communities.

- Human health impacts

  Human health is important for the communities who are directly affected buy pollution as well as government authorities that have to protect the communities from pollution impacts as well as shouldering the burden on the health care system.

- Ecological impacts

  Ecological are important to the communities who depend on the productivity of the ecosystems for their livelihood as well as government authorities that have the mandate to protect the environment.

- Nuisance

  Nuisance is important for the communities as it affect them emotionally and their comfort.

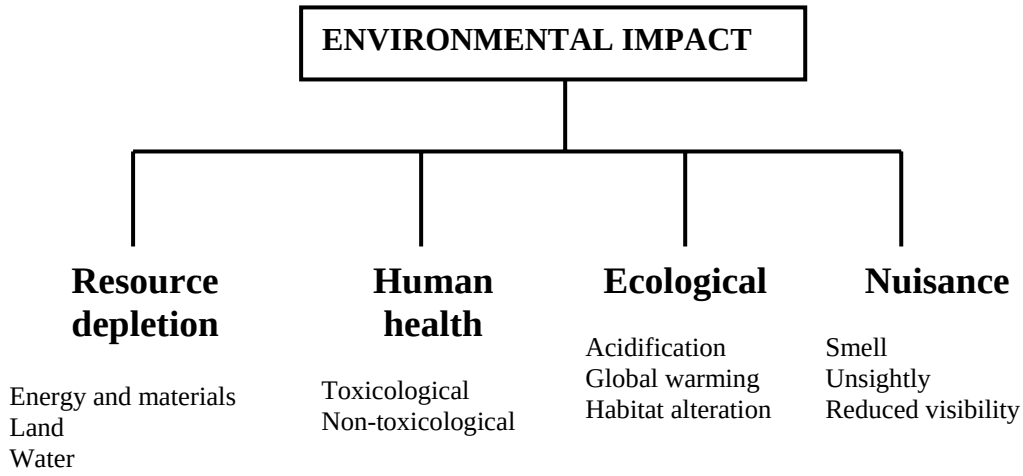

Figure 4.1 Environmental impacts categories and their examples (Adapted from P. Miettinen and R. P. Hamalainen, 1998)

4.1.1 Environmental Stressors and their Impacts

Two main environmental stressors relevant to the research are considered. These are:

- Resource and energy requirement
- Emissions

4.1.1.1 Resource and Energy Requirements

4.1.1.1.1 Material Requirement

In the case study area the industrial activity is based on secondary material. The only primary material that is used extensively in the case study area is water. Coal is used by a few industries that have coal-fired boilers.

4.1.1.1.2 Water Requirement

Water requirement is an important stressor even though some companies do not use water as part of their production or primary activity. The mere existence of a company means there is need for water for basic personal hygiene. The severity of the impact of water requirement is determined by the efficiency of water use and the use of brown water where necessary and possible. The environmental impacts of water requirement of the industrial estate are:

- Resource depletion. This result in reduced water availability for down stream users.
- Ecological impact Because of the reduced flows of the river down stream of the industrial estate, the aquatic ecosystem is affected in two ways. First the riparian vegetation has changed. There are now a lot of invasive weeds that seem to tolerate the changed flow regime and the water characteristics of the adjacent river. Secondly the assimilative capacity and self-purification of the river is significantly reduced. This is evidenced by the constant complaints by communities and other users of the water downstream.

Water recycling is not practiced in the case study area. There appears to be no concern on how much the companies pay for water. The interviews during data collection indicate that the companies seem to be content with the water bills sent to them by SWSC. No water conservation initiatives or track records on the water use were indicated. Some dry industries when asked about the seemingly high water bill for the staff complement, simple stated that may be there is a fault in the meter.

4.1.1.1.3 Energy Requirement

Even though the impacts of the generation of electricity are external to the system boundary considered in this research, the use of electricity as an environmental stressor has implications on the quantity of electricity in the national grid. Reduced electricity consumption per unit product, means improved production efficiency therefore reduction in emissions.

Use of coal means continued depletion of the non-renewable resource, air pollution and generation of coal ash as waste. The environmental impacts of coal mining are beyond the system boundary of this research.

4.1.1.2 Emissions

4.1.1.2.1 Solid Waste.

Solid waste has direct environmental impacts in all the four categories i.e. resource depletion, human health, ecological and nuisance. Important aspects of solid waste as an environmental stressor are quantity and types of solid waste. The environmental impacts of solid waste in the case study area are:

- Ground and surface water pollution by leachate.
- Air pollution by smell.
- Land requirement for waste disposal.

Salvagers in the landfill burn things for warming themselves as well as recovering some substances such as metals from scrap tyres and other items. This contributes to air emissions.

The industrial waste disposed in the landfill contains various toxic substances that makes the leachate toxic.

4.1.1.2.2 Emissions to Water.

The important environmental stressors to water bodies in the case study area are COD, BOD, TSS and toxicity. These are constantly being released into the adjacent river. Chronic shock loads of these stressors result in fish kills and the collapse of the sewerage treatment plant causing unpleasant smell and raised BOD and COD. The environmental impacts of these stressors are:

- Reducing the quality of water in the adjacent river.
- The depletion of dissolved oxygen.
- Chronic decimation of aquatic life including the active microbes in the sewer treatment plant.
- Human health impacts of users of the river downstream.

The decline in water quality has implications on resource depletion in that communities downstream at times cannot use the water from the river, Human health for downstream users, ecological impacts and nuisance in the form of smell and murky water body.

The chronic failure of the sewerage treatment plant suggests that there is a strong possibility that some companies do discharge toxic substances into the sewer system secretly either through illegal connections or emptying contents of liquid waste down toilets. It is also possible that some companies release large amounts of concentrated effluent into the sewer system at periods where the SWSC would not be able to take samples in order to minimise costs. While there is no conclusive evidence for obvious reasons, the chronic failure of the treatment plant can be explained by releases of shock loads that kill the microbes in the ponds.

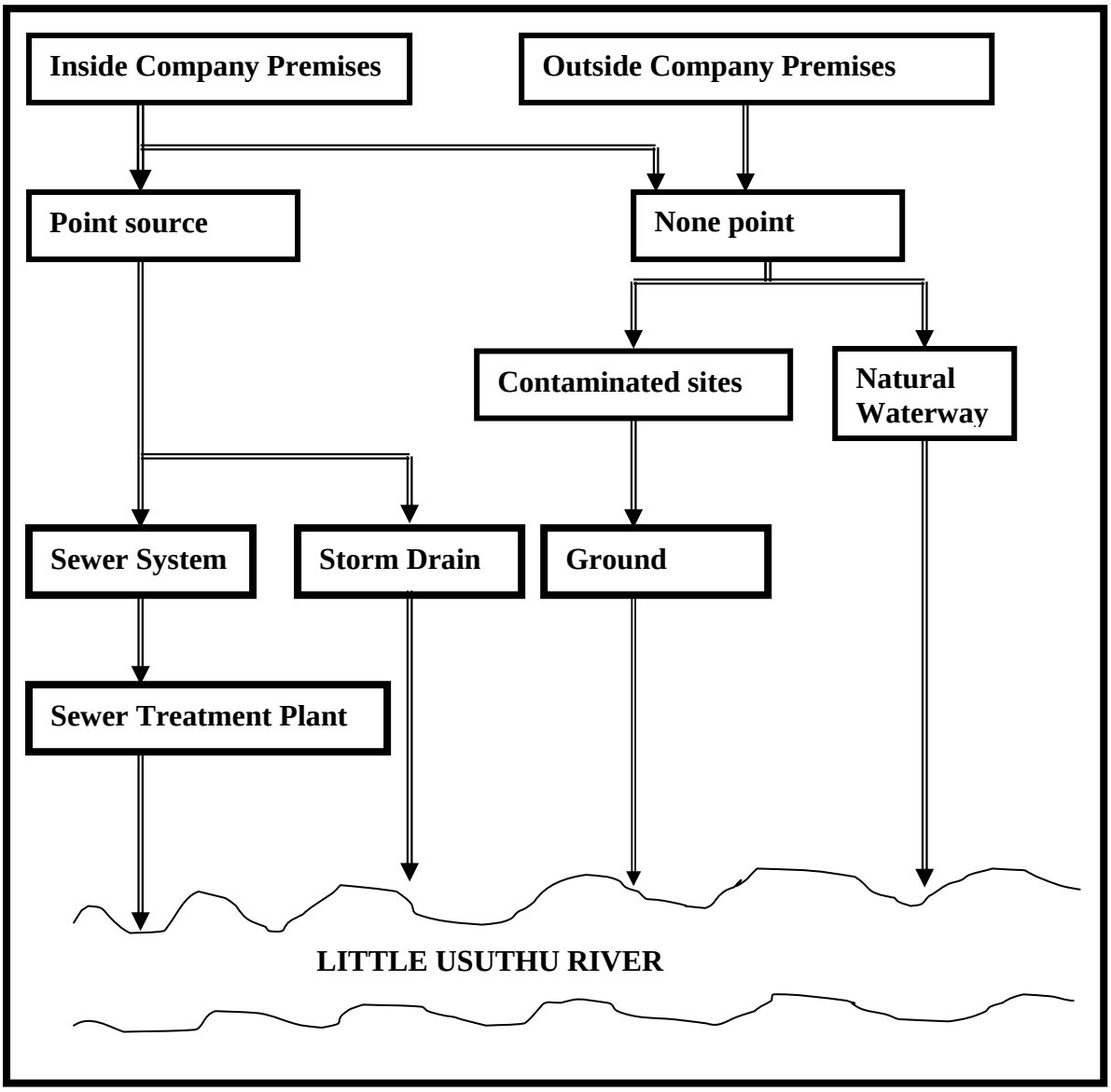

Figure 4.2 Pathways for Pollutants to the River

4.1.1.2.3 Emissions to Air.

Environmental stressors on air are CO_2, NOx, SOx Particulates and VOCs. Though these stressors cannot be pinned solely to the industrial estate, the estate has its fair contribution to these stressors and therefore contributes to the environmental performance status of the estate. The environmental impacts of these stressors are:

- Reduced quality of the air
- Reduced visibility.
- Global warming.
- Acid rain.

These have implications on human health, ecological and nuisance.

Wastes and pollution issues are addressed on ad hog basis by different parties for different reasons usually not for environmental reasons. Only one industry has a functional wastewater treatment plant as a requirement of its international parent industry.

Because of lack of data some of these impact can only be described qualitatively

4.2 Development of Environmental Performance Indicators

4.2.1 Environmental Issues of the Case Study Area

The purpose of this section is first to discuss the environmental issues of the case study area as a foundation for establishing the environmental performance indicators. Then develop the environmental performance indicators against which the potential for Industrial Ecology as a solution for addressing the environmental problems of the industrial estate will be determined.

In order to develop appropriate environmental indicators for the case study area it is important to discuss the main environmental issues of the case study are. The environmental indicators have to relate to the environmental issues. Matsapha Industrial estate is characterised by many environmental issues. Some of the issues are primarily issues of other sectors, which have environmental implications. Because of the scope of the research and data limitations, only those issues that have a direct link on the environmental performance of the case study are considered. The issues are lumped into a few key issues that can be viewed from the industrial system level

while recognising the company level as the primary source of the issues. This is in line with the eco industrial system level at which this research is approaching the case study area.

The major environmental issues of the case study area are predominantly related to environmental emissions. The neighbouring communities, NGOs, Government agencies, communities down stream of the industrial estate have been concerned with the environmental impacts of the industrial estate. All categories of environmental emissions (emissions to water, air and land) are a serious environmental concern. That is why the focus of the research is on the wastes aspect of the environmental component of the eco industrial system.

4.2.1.1 Emissions to Water

Water pollution is a concern for a wide range of users as well as the institutions that have been entrusted with the management and monitoring the quantity and quality of the water resources. Down stream of the industrial estate water is a scarce resource therefore communities rely on the river that passes next to the industrial estate for both domestic water and agricultural which includes livestock. These are rural communities and therefore there is no formal water supply system. This means that communities draw their water directly from the river. Needless to say this is a serious health issue. The communities have been complaining to all forums available. There have been complaints from commercial farmers downstream. The problem of chronic fish kills is not easy to tackle because the source of toxic effluent released through storm drains cannot be predicted or located. Industrial effluent containing inorganic compounds and other hazardous wastes cannot be deal with by the oxidation ponds. The sewage treatment pant is therefore a victim of shock loads of industrial effluent that affects the microbial action of the oxidation ponds and results in untreated sewage water being released into the river. Leachate from the solid waste disposal site is a constant source of pollution to the river.

4.2.1.2 Emissions to Air

Other companies tend to burn their solid waste within their premises regardless of the type of waste. This poses a serious health issue for anyone exposed to such emissions. The solid waste disposal site, which is within the industrial estate, is constantly

burning, and salvagers (scavengers) burn waste tyres to recover metal. There are a lot of small garages that paint cars. Solvents and other VOCs from industrial activities are not accounted for. Smoke from coal fired boilers though a problem only during start up, they add to the cumulative effect from all the other sources of air emissions. There have been some reported complaints of smoke from residents.

4.2.1.3 Land Contamination

There are many contaminated site in the industrial estate resulting from many small garages, indiscriminate disposal of hazardous wastes, as well as formal French drains utilised by some companies. Though the impact of land contamination is not yet evident, it is a problem that cannot not be ignored.

4.2.1.4 Resource Use

Issues related to resource use are those of water and energy consumption. Though water availability for the industrial estate is not a problem, the use of water is directly related to the effluent problem and also the fact that downstream of the industrial site is a water scarce area. The environmental impact of raw materials in the case study area is related to the wastes generated. The main issue with materials and energy the case study area is efficient use.

4.2.1.5 Urban Quality Environment

Urban environment quality issue is related to lack of green belts, lack of storm water control, management of informal businesses, smell and general aesthetics of the estate.

4.2.1.6 Biodiversity

Issues of biodiversity are limited to the impact of aquatic life from pollution and lack of green belts that could provide habitat to a number of species. There are no environmentally sensitive areas (as defined in the Environmental Management Act) around the industrial estate. There is no area that is a habitat to special species of fauna or flora. The industrial estate is surrounded by commercial agriculture, densely populated residential areas and the airport.

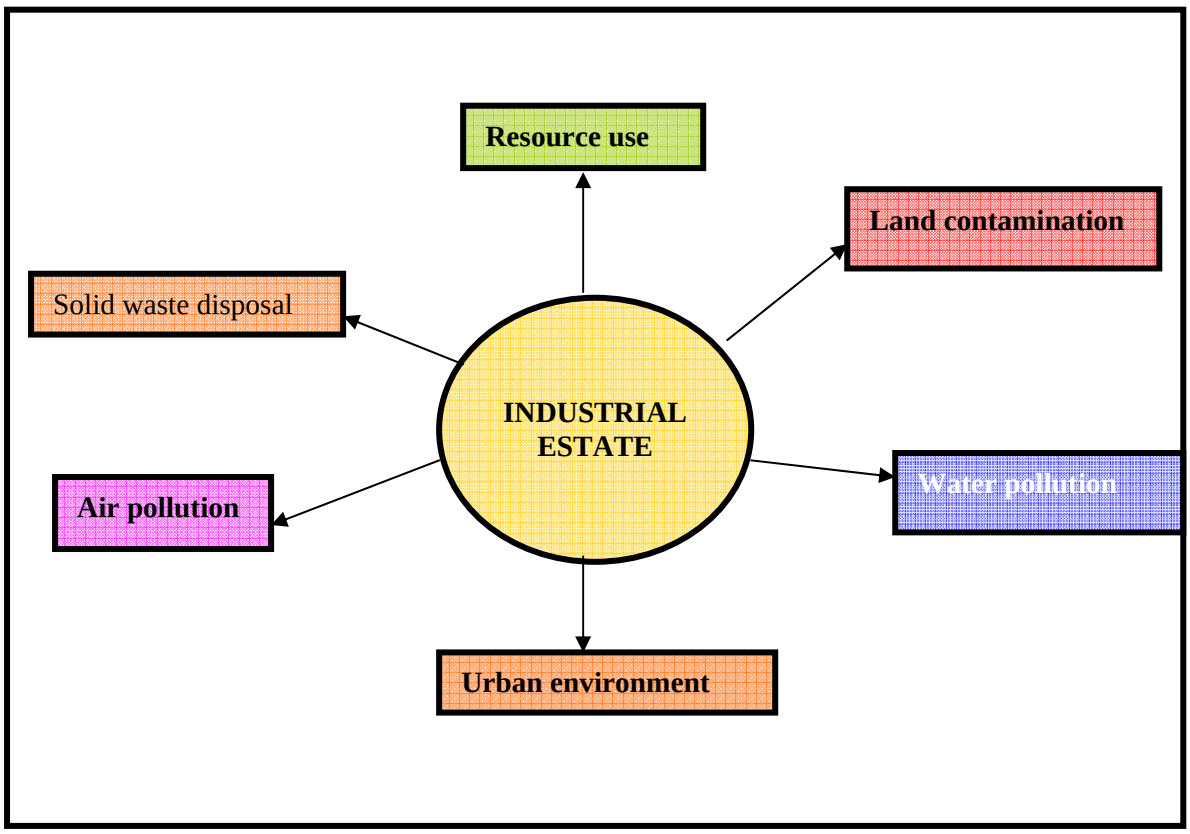

Figure 4.3 Environmental Issues of the Case Study Area

4.2.2 Environmental Performance Indicators

4.2.2.1 Uses of Environmental Indicators

Environmental performance indicators are used by various groups of people, individuals and organisation for different purposes. Table 4.1 below summarises the different uses of environmental performance indicators by different organisations.

The use of environmental indicators in this research goes beyond the analysis of trends and patterns. They are mainly used to determine how they respond to the application of industrial ecology principles.

Table 4.1 Users of Environmental Performance Indicators
Source: Adapted from F. Berkhout et al, 2001

USER	PURPOSE
Business managers	Business management and external communication
Banks and Insurers	Assessment of long term economic risks
Fund managers	Response to the demand for environmental and ethical concerns to be considered in investment decisions
Environmental groups	Exertion of political pressure
Policy makers	Evaluation of effectiveness of different policy instruments
Neighbouring communities and the Public	Determination of environmental impacts
Researchers	Analysis of patterns and trends

4.2.2.2 Criteria Used for the Case Study Area

As this research is focusing on the environmental component of the eco industrial system, environmental performance is the main criteria used in determining whether Industrial Ecology is useful for addressing the environmental problems of the case study area. Environmental performance indicators offers more direct test of the applicability of Industrial Ecology principles.

Environmental indicators are not designed to provide the full picture of the environmental issues but rather help to reveal trends (ananimous, OECD Reference Paper, 2003). The interpretation of environmental indicators may be facilitated either by quantitative or qualitative information or both. This is because some issues do not lend themselves to evaluation by quantitative measures either because of lack of quantitative data, as is usually the case in developing countries or because of their very nature.

In order to measure or determine the impact or influence of industrial ecology on the environmental performance of the industrial estate, it is essential to establish

appropriate environmental indicators. The environmental indicators that are chosen for the case study area are based on the identified major environmental issues and data availability.

Because different people use environmental performance indicators for different purposes, it is important to base the selected indicators on a specific set of criteria in order for these indicators to serve the purpose for which they have been chosen. Listed below are the criteria to be met by the environmental performance indicators in the case study area. The indicators should:

- Provide a representative picture of the case study area
- Be simple and easy to interpret
- Be able to show trends
- Be responsive to changes in related human and industrial activities
- Be relevant to the environmental issues of the case study area
- Be well founded in technical and scientific terms
- Should relate to issues at the industrial eco system level

The selection of the number of indicators is a balance between doing justice to complexity on one hand and pragmatism about data availability, quality and purpose on the other hand. A large number of indicators will tend to clutter the overview it is intended to provide. A reasonably small number of indicators that also adequately meet the set criteria are expected to give a reasonably good representation of the overall environmental performance.

4.2.2.3. Indicator Framework

One of the key elements of industrial ecology is closing the waste loop. The quantity and characteristics of the wastes is a function of the materials and energy inputs as well as the production technologies and environmental practices. The production technology aspect is not considered in the selection of environmental indicators because they go deep into the company and product level while the focus of this research is at the industrial ecosystem level. The selection of the indicators is therefore based on the inputs and outputs in the form of wastes resources and energy. Another appropriate indicator for which data was availed is the cost of waste management. This includes wastewater treatment and solid waste disposal. The cost of waste disposal gives only one aspect of the costs associated with wastes in a quantitative form but is significant enough to shed light on the economic implications

of wastes. The indicators described above are quantitative indicators. The performance is thus given as an index of two elements.

Qualitative indicators are also used either to express indications of some aspects of environmental performance for which quantitative data is not available or can only be expressed in a descriptive way. These include:

- Improvement of the aesthetics of the industrial estate
- Community support
- The use of energy efficient design and operating procedures

Three broad categories of environmental indicators are identified. These are:

- Performance indicators linked to quantitative objectives
- Performance indicators linked to qualitative objectives
- Descriptive indicators. These generally describe major conditions

The environmental indicators of the case study area are summarised in figure 4.4 below.

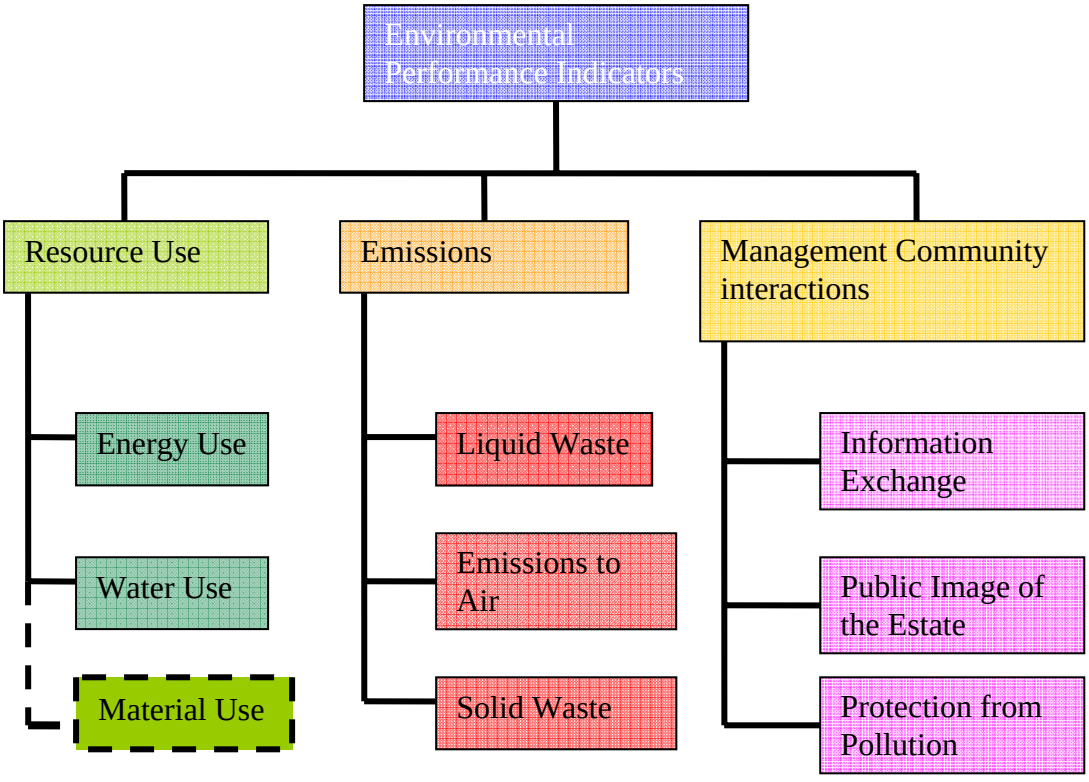

Figure 4.4: Environmental Indicators of the Case Study Area Adapted from UNEP IE Technical report No. 39
(*The indicator in broken lines was not used in the case study)*

Table 4.2 below gives a summary of the quantitative environmental indicators of the case study area

Table 4.2 Quantitative Indicators

INDICATOR	FUNCTIONAL UNIT	PERFOMANCE INDEX
Energy use	Electricity purchased (KWh/year)	Quantity of Electricity (KWh/year Quantity of product (tones/year)
Water use	M^3/year	Quantity of water use M^3/year Quantity of product (tones/tear)
Material use	Tonnes/year	**Q**uantity of material used tones/year Quantity of product tones/year
Emissions to water	COD (Kg/year)	Total COD Quantity of product tones/year
	M^3/year	Total volume of effluent Total volume of water used m^3/year
Solid waste	Tones/year	Quantity of Solid waste (tones/year) Quantity of product (tones/year
Cost of waste management	Rands	Cost of waste management (E/year) Quantity of product (tones/year)

4.2.2.3.1 Resource Use

4.2.2.3.1.1 Energy Use

There are two main sources of energy in the study area. These are electricity and coal. Heavy oil is not used in the study area. Petrol and diesel are used for transportation and since they are not directly used in the production process they are not considered.

Electricity is expressed as total KWH purchased per annum. Coal is expressed in tonnes per annum. The performance index is:

$$\frac{\text{Electricity purchased (KWh/year)}}{\text{Quantity of product (tones/year)}}$$

And

$$\frac{\text{Quantity of coal (tones/year)}}{\text{Quantity of product (tones/tear)}}$$

A low value means efficient energy use and therefore better environmental performance

4.2.2.3.1.2 Water Use

Water availability is not an issue in the case study area however its consumption is directly related to effluent and other discharges. There are also environmental issues related to the purification of the water. Water is expressed in cubic metres per annum. The performance index is:

$$\frac{\text{Total quantity of water used } m^3\text{/year}}{\text{Total quantity of product tones/year}}$$

A low value means efficient water use and therefore a better environmental performance

4.2.2.3.1.3 Material Use

Material use is expressed in tones per annum. The performance index is:

$$\frac{\text{Quantity of material used tones/year}}{\text{Quantity of product tones/year}}$$

A low value means efficient material use and therefore a better environmental performance

4.2.2.3.2 Emissions

4.2.2.3.2.1 Emissions to Water

Both quality and quantity is of importance. The quality is expressed in total COD per annum and quantity in cubic metres per annum. The performance indices are:

$$\frac{\text{Total COD}}{\text{Quantity of product tones/year}}$$

And

$$\frac{\text{Total volume of effluent } m^3/\text{year}}{\text{Total volume of water used } m^3/\text{year}}$$

A low value means cleaner production and therefore a better environmental performance

These indexes are determined only for those industries that have the data.

4.2.2.3.2.2 Solid Waste

Solid waste is expressed in tones per annum. The performance index is:

$$\frac{\text{Quantity of solid waste tones/year}}{\text{Quantity of product tones/year}}$$

A low value means cleaner production and therefore a better environmental performance.

4.2.2.3.2.3 Emissions to Air

Air pollution in the case study area is difficult to deal with because of lack of data. It is an important issue because of the airport that is within two kilometres of the industrial estate as well as the densely populated neighbouring communities. Air emissions are not accounted for in the industrial estate. And there are a lot of fugitive and diffused air emissions. The environmental indicator for air emission is therefore qualitative based on the assumption that the presence of Air pollution abatement technologies as well as accounting for the emissions, will result in reduced air pollution and an improved environmental quality.

4.2.2.3. 3 Socio-Economic

Socio-economic indicators are not directly attributable to specific environmental issues. However an improved socio-economic status of the neighbouring communities may be linked to environmental improvements or the other way round. The establishment of small enterprises engaged in recycling and waste management in the industrial estate, will improve the economic status of the communities as well as improving the environmental performance of the industrial estate. Official development assistance of environmental projects by government and the industries to the communities is another indicator. If the industrial estate does not contribute to the economic development of the communities and continue to pollute the resources on which the communities depend there would be no community acceptance. Improved public image and relationship of the industrial estate and the neighbouring communities is an indirect indicator of the environmental improvement. Socio-economic indicators of the case study area are therefore qualitative.

4.2.2.3.4 Cost of Waste Management.

The cost of waste management includes cost of wastewater treatment, solid waste disposal. There has not been any environmental penalty or pollution incident compensation imposed on the industrial estate or the tenant companies. With the new Environmental Management Act coming into force, these charges are going to be effected. The performance index for cost of waste management is:

$$\frac{\text{Annual cost of waste management (R)}}{\text{Quantity of product (tones/year)}}$$

A low value means reduced waste quantity or toxicity and therefore better environmental performance.

This index includes the management cost of both solid waste and effluent.

4.2.2.4 Environmental Performance Objectives

The environmental performance objectives of the case study area are divided into four categories listed below:

- Efficient use of resource
- Reduction of environmental emissions
- Cost effective and cost recovery of waste management
- Management of environmental and community interactions

4.3 Environmental Performance of the Case study Area

4.3.1 Environmental Performance Challenges in the Case Study Area

The environmental performance of an Industrial estate is a function of the industrial activities including other activities not directly related to production or services and environmental management practices within the industrial state.

Measuring or describing the environmental performance of an industrial estate presents many challenges. Some of the challenges that are faced in the case study area are:

- Combining the environmental impacts of industries from different sectors and different economic activities into impacts at the eco industrial level.
- Limited or lack of data for some wastes and their aspects made it difficult to quantify some impacts and hence the environmental performance has to be supplemented with qualitative description.
- There is no reference point against which the environmental performance can be measured.
- Lack of time series data necessitated use of cross sectional data.

Faced with these challenges the environmental performance indicators had to be lumped into simple ratios or indices. The current environmental performance determined on the basis of the available data is taken as the reference point against which the impact of implementing industrial ecology principles is compared. This reference point is assumed to be unacceptable based on the description of the environmental impacts, the environmental problems currently experienced as well as the lack of effective and measurable environmental management practices in the industrial estate. The environmental performance therefore is geared for continuous improvement from the established reference point.

The determination of the environmental performance of the cases study area is based on the wastes generated and their associated impacts, resource requirement as well as the environmental management activities and their effectiveness.

4.3.2 Environmental Performance Related to Solid Waste

Only solid waste disposed is considered

The performance index is:

$$\frac{\text{Quantity of solid waste tones/year}}{\text{Quantity of product tones/year}} = \frac{\mathbf{15074.1}}{\mathbf{1178335}} = \mathbf{0.012}$$

This is taken as the reference point. Therefore in order to improve the environmental performance, the waste generated per product has to be less than the index.

4.3.2.1 Solid Waste Management Practices in the Industrial Estate.

Recycling of some solid wastes does take place within the industrial estate. This involves collection of specific waste types by individuals to recyclers. There are three solid waste types that are recycled in the industrial estate. These are paper scrap mental and plastics. Sometimes the companies sell the wastes to the recyclers. Waste segregation is not practiced in the case study area only two companies were found to have some sort of waste segregation to a limited extent. There is one by-product exchange in the case study area. This is between the brewery and an animal feed producer. A summary of Solid waste management practices in the case study area is:

- There is recycling of some solid waste types in the industrial estate.
- There is superficial waste collection system
- There is one by-product exchange
- There is limited waste segregation practiced by two industries

4.3.2.2 Shortfalls:

- No solid waste treatment in the industrial estate
- No systematic waste collection system in the industrial estate
- No data is kept on sold waste
- The cost of waste disposal is very variable from industry to industry which means that it is not the true cost
- The town Board does not take responsibility for littering.
- Recycling not organised
- The performance of the landfill is poor. There is no containment in the landfill and also leachate is released. There is no control of waste salvagers.

All the identified shortfalls have negative impacts on the solid waste related environmental performance of the industrial estate. The waste management activities though they have positive impacts, they are not efficiently implemented. The waste collection by the Town Board is superficial and recycling is not organised. Only two industries in the case study area have some sort of waste segregation.

From the above facts it can be concluded that the solid waste related environmental performance index of **0.012** represents a poor environmental performance.

Table 4.3 Effects of Current Solid Waste Management Practices on the Environmental Performance

CURRENT SITUATION	IMPLICATIONS	DIRECT IMPACT ON THE ENVIRONMENTAL PERFORMANCE
Recycling	Waste reduction	Positive
Waste collection	Waste containment	Positive
By-product exchange	Waste reduction	Positive
	Economic benefit	Positive
Lack of waste treatment	This has implications on the leachate	Negative
	The volume of the waste is not reduced and therefore takes up more airspace in the landfill	None
Lack of systematic waste collection	Indiscriminate disposal	Negative
	Littering	Negative
Lack of data	Waste management planning difficult	Negative
	Measuring environmental performance difficult	Negative
Erratic waste management cost	No proper budget for waste management	Negative
	Current waste management cost not a true reflection	Negative
Littering not accounted for	No public waste receptacles	Negative
	Indiscriminate disposal	Negative
Recycling not organised	Recycling not effective	Negative
	Job opportunities missed	Negative
Limited waste segregation	Facilitates recycling	Positive
Landfill not properly run	Leachate seeping through	Negative
	No containment	Negative

4.3.3 Environmental Performance Related to Emissions to water

The performance index is

$$\frac{\text{Total COD load (tones)}}{\text{Quantity of product tones/year}} = \frac{7759.1}{1178335} = \mathbf{0.007}$$

$$\frac{\text{Total Discharge into the environment } m^3/\text{year}}{\text{Total volume of water used } m^3/\text{year}} = \frac{1201432}{1184586} = \mathbf{0.91}$$

These indexes are taken as reference points.

The above Environmental performance indexes for emissions to water are determined from those industries that have the necessary data. The total water pollution load from the case study area could not be normalised because the discharges are from the entire industrial estate not only from the visited industries therefore total volume of water used and quantity of products is not applicable.

4.3.3.1 Wastewater Management Practices

The only waste water treatment plant that caters for the entire industrial site is the sewer treatment plant run by SWSC. Only seven industries are known to be discharging their effluent into the sewer system. One of them seems not to be known by SWSC. The other five discharge at a fee. There is one effluent treatment plant using activated sludge in the industrial estate. This belongs to a company that is manufacturing soft drink concentrate. This is a requirement from the overseas parent company.

There are three approaches that can be taken in order to improve the effluent related environmental performance:

- Reduce the volume of the wastewater if the concentration remains the same. This requires efficient use of water.
- Reduce the concentration if the volume remains the same. This requires an effluent treatment plant.
- An ideal situation is when both the volume and the concentration are reduced.

An important point to note is that all the above options do not prevent emissions to the environment. They only prevent or reduce emissions to the river. The resultant sludge from a wastewater treatment plant would have to be disposed.

4.3.3.2 Shortfalls

- Majority of industries are discharging into storm water drains
- The charges by SWSC have no incentive for waste minimisation
- No provision for industrial wastewater collection in the estate
- No data on quantities and quality for industrial wastewater
- None of the industries have containment structures
- No water conservation initiatives

Table 4.4 Implications of the Current Situation on the Environmental Performance with Respect to Emissions to water

Current situation	Implication	Impact on the performance
Use of sewer treatment plant	Microbes in the ponds are killed	Negative
Activated sludge effluent treatment plant	Prevent pollution of the river Generates sludge	Positive Negative
Use of storm water drains	River pollution	Negative
SWSC charges	Conflict of interest because More pollution means more revenue	Negative
Lack of industrial wastewater reticulation	No containment of industrial wastewater	Negative
Lack of data	Industrial wastewater planning difficult	Negative
Lack of containment	Land contamination Pollution of the river	Negative Negative
Lack of water conservation initiatives	No minimisation of industrial wastewater quantities	Negative

The chronic failure of the sewerage treatment plant suggests that there is a strong possibility that some companies do discharge into the sewer system secretly either through illegal connections or emptying contents of liquid waste down toilets. It is also possible that some companies release large amounts of concentrated effluent into the sewer system at periods where the SWSC would not be able to take samples in

order to minimise costs. While there is no conclusive evidence for obvious reasons, the chronic failure of the treatment plant can be explained by releases of shock loads into the sewer system that kill the microbes in the sewer treatment plant.

The present situation and wastewater management activities all have negative impacts on the effluent related environmental performance. The activated sludge industrial wastewater treatment plant of the soft drink manufacture does not contribute to the improvement of the environmental performance of the industrial estate. The sewer treatment plant also does not contribute to the improvement of the environmental performance as its own performance is affected by the industrial wastewater. This means that the environmental performance related to emissions to water index of **0.007** for COD and **0.91** for total effluent, represents poor performance. This index is taken as a reference point.

4.3.4 Environmental Performance Related to Air Emissions

Environmental performance related to air emissions can be only described qualitatively because there is no data on air pollution. There have been complaints from neighbouring communities as well as some tenant industries. The main problem is that the air pollutants cannot be solely pinned on the industrial estate. The present situation however does indicate that there are a lot of air pollution sources in the industrial estate. These releases wide range of pollutants including CO_2, SOx, NOx, VOCs, Smoke, Dioxins and Furans from the constantly burning landfill.

4.3.4.1 Short Falls

- No monitoring of ambient air quality
- No industry monitors releases to air.
- No industry has air pollution abatement plants.

Table 4.5 Implications of the Current Situation on the Environmental Performance

CURRENT SITUATION	IMPLICATIONS	IMPACT ON ENVIRONMENTAL PERFORMANCE
No monitoring of ambient air quality	No data on ambient air quality	Negative
No industry monitors releases to air	No data on emission releases from the industries	Negative
No industry has installed air abatement equipment	Point source air pollution	Negative
Existence of coal fired boilers	Point source air pollution	Negative
Land fill constantly burning	Air pollution including dioxins and furans	Negative
Presence of open air spray painting and Use of solvents	Diffused air pollution	Negative

The air pollution related environmental performance is poor. There is no positive aspect in the current situation with respect to emissions to air. No data on air emission releases from the industries.

4.3.5 Environmental Performance Related to Energy Use

The environmental performance indexes for energy use are for those industries that have the relevant data.

$$\frac{\text{Quantity of electricity (KWh/year)}}{\text{Quantity of product (tones/year)}} = \frac{35{,}710{,}200}{1174305} = \textbf{30.41 Kwh/tone}$$

Electricity is the major source of energy in the industrial estate. The environmental impacts of electricity generation are at the power station situated far away from the case study area. The amount of electricity consumption per product is an indication of the efficiency of the production system of that plant. Electricity use therefore has an indirect impact on the environmental performance.

The use of coal in the industrial estate is not substantial. Coal is used for boilers. The impacts of air emissions due to coal combustion in the case study area are difficult to establish without data on ambient air quality in the case study area.

It is not possible to say whether the environmental performance related to electricity use is good or poor because there is no information on energy efficient initiatives in the industrial estate. Therefore the index value of **30.41** only gives a reference point, which will be useful for future research work.

4.3.5.1 Management Practices

There are some energy saving initiatives lead by the Ministry of Natural Resources and Energy. At present these activities are at discussions stage with no projects on the ground. Swaziland Electricity Board (SEB), a power distribution body has no energy saving programmes. To SEB more consumption means more revenue.
The performance indexes of coal and energy only gives the reference point

4.3.6 Environmental Performance Related to Material Use

4.3.6.1 Environmental Performance Related to Water Use.

The environmental performance is:

$$\frac{\text{Quantity of water used } m^3/\text{year}}{\text{Total quantity of product tones/year}} = \frac{1{,}174{,}965}{1{,}174{,}305} = \mathbf{1.0}$$

The environmental impacts of water use are a result of the efficiency with which water is used. Firstly more water used means a large effluent volume. Secondly the minimum flow necessary to sustain the ecological viability of the river downstream of the industrial estate is not currently met and lastly water availability downstream of the case study area is a big issue. The canal to the hydropower station contributes to the low flow rate of the river downstream. Efficient use of water by the industries would therefore add to the flow rate of the river and improve its ecological viability.

With the exception of water, the industries in the industrial estate do not use Natural resources as inputs to their production processes. Coal is used as a source of energy

and will be covered under energy. This means that the environmental impacts of the other inputs con only be determined using Life Cycle Analysis. This is beyond the scope on this research. The impacts of material use in the case study area come in the form of the wastes they produce and this is covered under emissions. Efficient use of material will contribute to the improvement of the environmental performance because the waste per product would be less. The environmental performance is not only dependent on the efficient use of material but also the type of material used has a direct impact in terms of the hazardousness or toxicity of the waste generated. For this reason it is not meaningful to determine the environmental performance related to material use for industries that are not in the same industrial sector such as the case in the case study area. The performance index of **1.0** therefore only gives an idea of the environmental performance and serves as a reference point for future detailed research work on material metabolism.

4.3.6.1.1 Water Management Practices.

Currently there are no water conservation initiatives in the case study area. The industries themselves seem to accept the water bills without question. This was established during the data collection where the managers had no idea of how much they pay per unit volume of water. SWSC has no plans for establishing programmes of efficient use of water. This is expected because to SWSC, more water consumed means more revenue. There is no one that seems to have an interest on efficient use of water except the SEA

The water use related environmental performance index of **1.0** represents a poor environmental performance based on the above facts on the lack of management of water use. This index is used as a reference point.

4.3.7 Environmental Performance Related to the Cost of Waste Management

The environmental performance is:

$$\frac{\text{Cost of waste management (R/year)}}{\text{Quantity of product (tones/year)}} = \frac{4{,}598{,}620}{1{,}160{,}335} = \mathbf{3.96}$$

The issue with the cost of waste management is whether what is paid is a true cost or not. If it is not a true cost it means that the waste management is not effective whether

the cost is too high or too low. What it means is that who ever pays is not concerned about the effectiveness of the waste management. The erratic costs obtained during data collection suggest that the waste management costs incurred in the industrial estate is not related to the amount of wastes managed. This can either be low or high. The index of **3.96 R/tone** of product, for cost of waste management therefore gives a reference point, which can be evaluated with more data after a comprehensive waste management system, is implemented.

4.3.8 Environmental Performance Related to Other Issues

There are other issues that are indirect indicators of the environmental performance of the industrial estate. These are:

- Management of the relationship between the industrial estate and the neighbouring communities
- Existence of dedicated environmental officers in the industries
- Free environmental services
- Existence of a clear champion for the estate
- Clear roles and responsibilities of all the stakeholders
- Environmental accountability

4.3.8.1 Management of the Relationship between the Industrial Estate and the Neighbouring Communities

The public image of the industrial estate is very important. If the industrial estate is to have successful environmental management programmes, the participation of the communities is crucial. If the industrial estate does not contribute to the economic development of the communities but continue to pollute the resources on which the communities depend the relationship between the communities and the industrial estate would be poor. Presently the relationship is very poor. This is indicated by numerous complaints by the communities about pollution of the environment. The public would view any initiative by the industry with suspicion. As a result members of the communities do not practice environmentally friendly habits. The industrial estate is full of litter.

4.3.8.2 Existence of Dedicated Environmental Officers in the Industries

Only three industries have been found with designated environmental officers. In the rest of the industries the production manager, the sales person, the general manager or the accounts officer filled the questionnaire. In most cases a combination of these were involved. Environmental matters therefore are not a priority.

4.3.8.3 Free Environmental Services

The use of the environment as a sink is taken as free services hence the current environmental problem of the industrial estate. This is a recipe for poor environmental performance, which is the case.

4.3.8.4 Lack of Clear Roles and Responsibilities for all the Stakeholders

Presently none of the stakeholders seem willing to take the responsibility for the environmental performance of the case study area hence the poor performance.

4.3.8.5 No Clear Champion for the Industrial Estate

There is no one to lead any environmental programmes a well as to monitor and coordinate the interactions between the industries. The industries are operating independent of each other. Opportunities for economics of scale in environmental management are missed. This has lead to poor environmental performance.

The above issues are a clear indication that the environmental performance of the case study area is very poor.

5. APPLICATION OF INDUSTRIAL ECOLOGY PRINCIPLES TO THE CASE STUDY AREA

5.1 Screening of the Principles

In this chapter the principles of industrial ecology are applied and the effects they have as well as the changes they bring to the case study area are described.

The principles were introduced in chapter one where their definition and significance in industrial ecology were discussed. The six principles that are considered are:

- Systems Approach
- Industrial Symbiosis
- Industrial metabolism
- Integrated Approach
- Diversity or Flexibility
- Shared resources

Each principle is first screened in order to determine whether the principle is within the scope of the research and whether the conditions on which the implementation of the principle depends can be met with reasonable administrative changes and additional financial input. This is very important because if the conditions cannot be met then there is no opportunity for that principle in the case study area.

If the principle is not within the scope of the research but directly related to wastes, the principle is not applied but the components that are directly related to wastes are included in the discussion. If the conditions cannot be easily met, the question is asked whether the application of the principle is critical or not. If it is critical then it is applied with the understanding that government or other relevant organisations would have to bridge the gap. If it is not critical then it is not applied. The steps taken in the application of the principle are summarised in figure 5.1

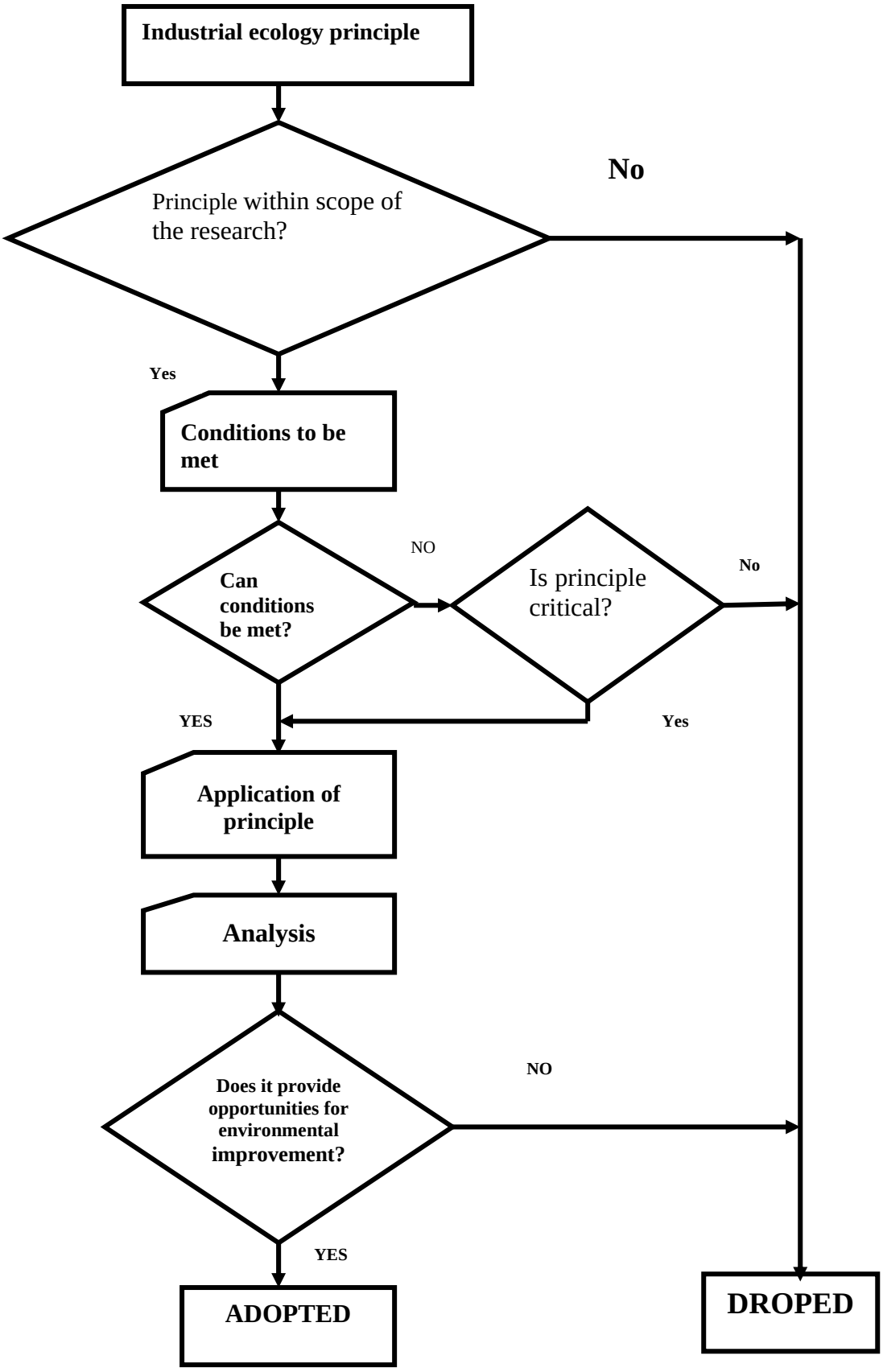

Figure 5.1 Application of the principles

5.2 Application of the Principles

5.2.1 Systems Approach

5.2.1.1 Conditions to be met

This principle establishes the system boundary from which the waste issues are viewed. Therefore the Systems Approach principle is within the scope of the research. Even though this principle does not directly affect the flows of wastes, it does influence how the wastes are managed and therefore directly affects the environmental performance of the system.

There are two important conditions that need to be met for a systems approach. These are:

- The existence of an industrial estate manager. This will be the focal point of the eco-industrial system.
- Appropriate supporting legislation. This will legitimatise the industrial estate manager's position with respect to the eco-industrial system.

The Matsapha Town Board is the logical body to take the position of industrial estate manager. The Town Board falls under the Ministry of Housing and Urban Development (MHUD) governed by the Urban Government Act of 1969. The industrial estate however is under the Ministry of Enterprise and Employment (MEE), which is the ministry responsible for industrial development. This may seem confusing and perhaps a hurdle for the management of the case study area. This situation presents two important opportunities. First the presence of the Town Board brings forward a possible and appropriate candidate for the industrial estate manager in the context of industrial ecology. The Urban Government Act and the Environmental Management Act provides the foundation for the legal basis and what needs to be done is streamlining and harmonisation of these and other relevant legislations. Secondly the involvement of two ministries in the case study

area means there is already cooperation between these ministries. This cooperation only needs to be developed in the context of the systems approach.

The conditions on which the systems approach depends can therefore be met in the case study area.

5.2.1.2 Situation before Systems Approach

- There is no industrial estate manager in the context of industrial ecology. Though there is a Town Board, its interaction with the industries is on individual basis and is mainly related to the collection of property rates where the company owns the property otherwise the Town Board interacts with the property owner.
- The industrial estate is viewed as a collection of firms acting independently not as a system.
- There is no structured relationship between the industrial estate and the neighbouring communities. The communities view the industrial estate as a polluter of their natural resources.
- The Town Board is running the case study area as a town not an industrial estate.
- The industries in the case study area are practically not accountable to the Town Board for their environmental impacts.
- Efforts on environmental management, by some of the industries and government agencies do not succeed in improving the environmental performance of the industrial estate because they are addressed as individual isolated cases without considering the bigger picture and the cumulative effect from all the industries.

5.2.1.3 Introducing a Systems Approach to the Case Study Area

The introduction of a systems approach, bring several fundamental features into the case study area.

- Industrial estate manager
- Environmental issues viewed from the industrial estate perspective
- The industrial estate-ecological interface can be clearly defined
- The relationship between the individual industries and the industrial estate as a whole with respect to the industrial estate-ecological interface becomes recognised.
-

The presence of the industrial estate manager provides a focal point for planning and implementation of applicable industrial ecology principles in the case study area.

In the systems approach only inputs entering the system (energy and materials) and outputs leaving the system (wastes and products) are considered in the environmental performance of the case study area. This makes it easy to determine and measure the environmental performance of the case study area. In this approach the management of wastes become flexible thus making it easy to improve the waste related environmental performance.

5.2.2 Industrial Symbiosis

5.2.2.1 Conditions to be met

Symbiosis is fundamental to the functioning of natural systems. It is therefore the easiest principle to understand when connected to industrial activities. This principle is therefore within the scope of the research. Like natural systems, there are conditions that have to be met for the principle can be implemented in the industrial system.

Conditions for industrial symbiosis (by-product exchange) are:

- Economic incentives
- Collocation
- Organising force
- Supportive legislation
- Diversity

Economic incentive is very essential for industrial symbiosis. Many examples of industrial symbiosis started bilaterally because they made economic sense. If it makes economic sense it does not external forces to make it happen. The existence of the by-product exchange between the breweries and the animal feed manufacturing company indicates the presence of economic benefits. The various recycling activities in the case study area indicate the presence of economic benefits for recycling.

Collocation is important for the cost effectiveness of industrial symbiosis. Transportation costs are reduced if the participating industries are located close to one another. The industries in the case study area are less than three kilometres from each other. Promoting by-product exchange between industries within the industrial estate makes collocation a condition that can be met. There is need to bring those companies that receives by-products from the case study area to be located within the industrial estate. This is more challenging.

An organising force that will manage and or coordinate the interaction between the industries is essential for industrial symbiosis. The industrial estate manager is the appropriate body that can serve this purpose. The industrial estate manager does not get involved in the economic aspect of the by-product exchange but ensures that the by-product exchange activity does not result in negative environmental impacts and is run in accordance with applicable legislations. This condition depends on the existence of the industrial estate manager a condition that is also essential for a systems approach a fundamental principle of industrial ecology. Assuming that the systems approach is in place, this condition is therefore met.

Supporting legislation is important in industrial symbiosis particularly when it comes to the definition of waste and controlled wastes. The importance of defining waste in the context of industrial ecology cannot be overemphasised. The Waste Regulations 2000 does define waste but may need to be clarified or aligned to issues of industrial symbiosis. With the presence of the Environmental Management Act and the Waste Regulations 2000, this condition can be met.

Diversity is crucial for industrial symbiosis to be sustained. Because of the eco-industrial systems level at which the case study area is viewed, the sustainability of industrial symbiosis is considered from the overall symbiosis activity in the case study area not individual cases of symbiotic activities. The diversity condition is difficult to meet because the establishment of the relevant industries in the case study area is not under the control of anyone. Lack of an anchor industry also does not make the diversity issue any better. How ever, diversity can be realised with the participation and cooperation of both the industries and the government. The government and the industries can facilitate the establishment of small-scale companies or even informal sector activities that are based on the by- products of the case study area and therefore will have a significant contribution to the improvement of the environmental performance of the case study area.

5.2.2.2 Situation before Industrial Symbiosis

There is only one true by-product exchange in the case study area. This exists between the brewery (by-product source) and an animal feed company (input). The other by-product exchange activities are between the companies in the industrial estate (milling and abattoirs) as sources and companies or other users outside the case study area as recipients of the by-products. The rest of the activities are in the form of recycling of some solid wastes. These include:

- Scrap metal collection
- Waste paper recycling
- Plastic recycling
- Salvaging of reusable substances

Recycling in the case study area is not organised and therefore it is not as effective as it can be hence the current environmental performance. The plastic pellet manufacturer has an established market with the plastic products manufacturer probably because the pellet manufacture used to work for the same company. Scrap metal collection is very active in the industrial estate. There are two well established and one coming up scrap metal collectors in the case study area. There are also salvagers usually called scavengers who salvage various usable items including food items.

Recycling of wastewater is not practiced in the case study area.

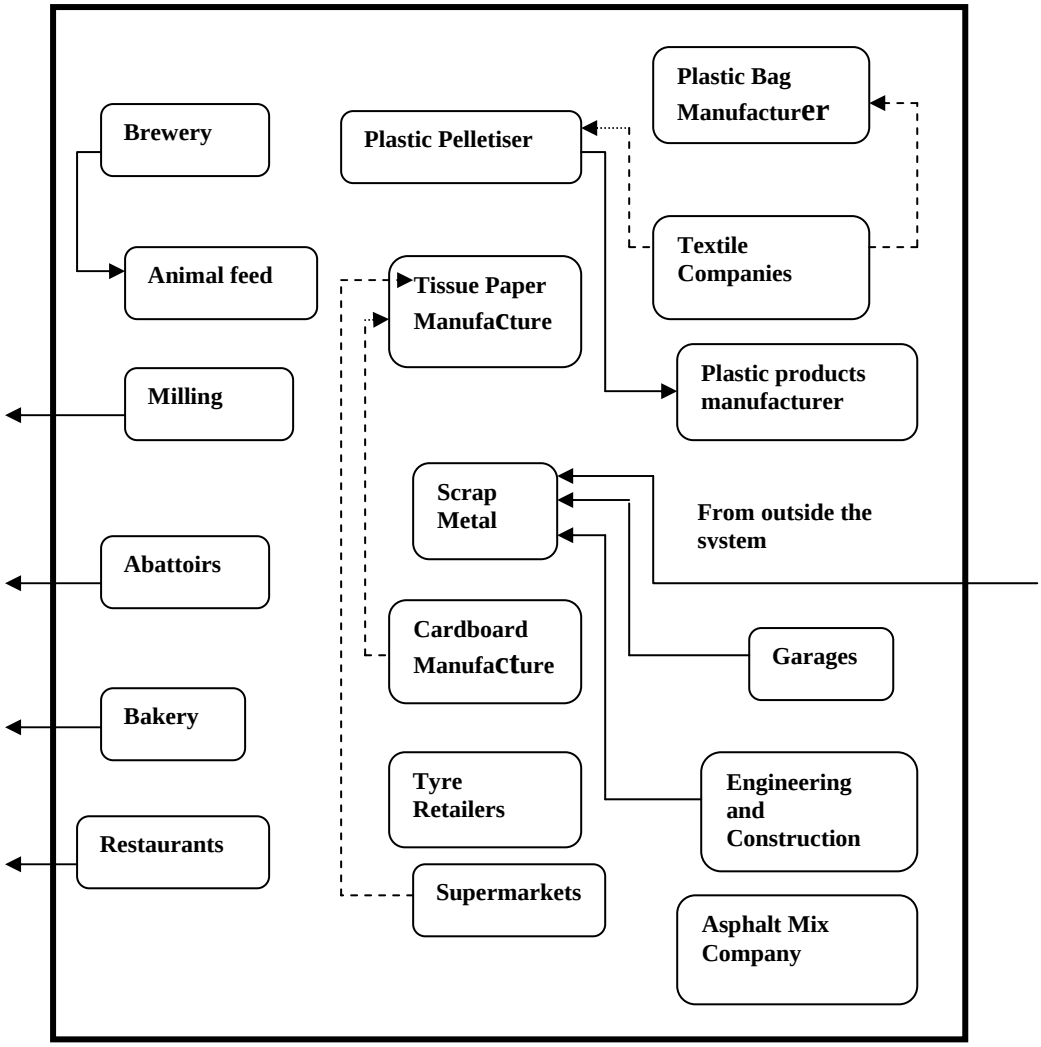

Figure 5.2: By-product exchange and recycling in the case study area before implementing Industrial Symbiosis.

Source: Adapted from S. A. Martin, 1996

Broken lines indicate unorganised recycling and by-product exchange.

Sources of scrap metal come from both within and outside the case study area. Some companies supply their by products to recipients outside the case study area.

5.2.2.3 Implementing Industrial Symbiosis

5.2.2.3.1 Introducing Networks that Need Little or no Additional Investment

- All waste plastic bought by the plastic recyclers
- All waste paper bought by the tissue paper manufacturer
- The asphalt mix company gets waste oil from vehicle servicing companies.

This is can be easily implemented because both the sources and the markets for the wastes are available within the industrial estate.

In order to facilitate this recycling based by-product exchange, there is need to introduce a link between the waste producers and the recyclers. The necessity of the link is brought about by the fact that recycling of these products in the case study area is not as effective as it can be yet the economic incentive is there. A possible explanation is that the collection of these wastes is not cost effective because of the individual quantities from the different companies. The link will address this issue. The link must have nothing to do with the industry operations. This is an opportunity to involve the communities because the cost effective dimensions for the communities is much smaller.

In order to put this concept into operation the industrial estate manager put in place an organised collection system where interested members of the communities would collect the recyclables and sell to the recyclers. This is a job opportunity for the communities. This requires the cooperation of the companies and it should not be a problem because it is to the benefit of he companies themselves.

5.2.2.3.2 Introducing Additional Networks that May Need Some Investments.

- Introduction of new animal feed companies that will buy appropriate wastes from the abattoirs and milling companies
- Introduction and promotion of entrepreneurs that will make secondary products from tyres such as mats, shoe soles, sandals etc.
- The industrial estate manager put in place a waste oil collection and storage system in order to have viable quantities for waste oil users such as the asphalt mix company and oil recyclers from the Republic of South Africa. This can easily get support from the petroleum industry.

- A market for textile cuttings is identified. There are already indications that there is a market in the Republic of South Africa.
- Introduce compost making. This is another opportunity for involving the neighbouring communities. This will use the ruminant contents from the abattoirs, garden and other organic waste from the estate, spent grain from the brewery and other sources of organic waste. Other wastes such as food waste, textile cuttings, paper not suitable for recycling etc can be composted as a waste treatment option that can reduce the quantities of the wastes that are land filled as well as reduce leachate problems. This can be located at the landfill.
- Introduction of an integrated farming system near or within the industrial estate as a project for the neighbouring communities to utilise the following wastes:
    1. Spent grains from the brewery, milling companies and food waste from restaurants used to feed pigs
    2. Fishponds to use waste from the pigs.
    3. Spent grains can also be used as a substrate to grow mushrooms.
    4. Compost from the landfill can be used for organic farming to grow cash crops.
- Water cascading. The brewing process-water or wash water from the abattoirs is used in the integrated farming system to wash the pigsties with the slurry taken to fishponds. The water can also be used for irrigation in the integrated farming system.
- All of the textile industries are constructed with iron sheet and steel frames. Appropriate brown water therefore can be used for cooling during summer by rooftop sprinkling.

These opportunities for industrial symbiosis can be realised with the participation and support of both the industries and the government. It is after all to the benefit of both parties if the environmental performance of the industrial estate is taken as an important issue.

There are many other possible positive developments that can arise as a result of the industrial symbiosis.

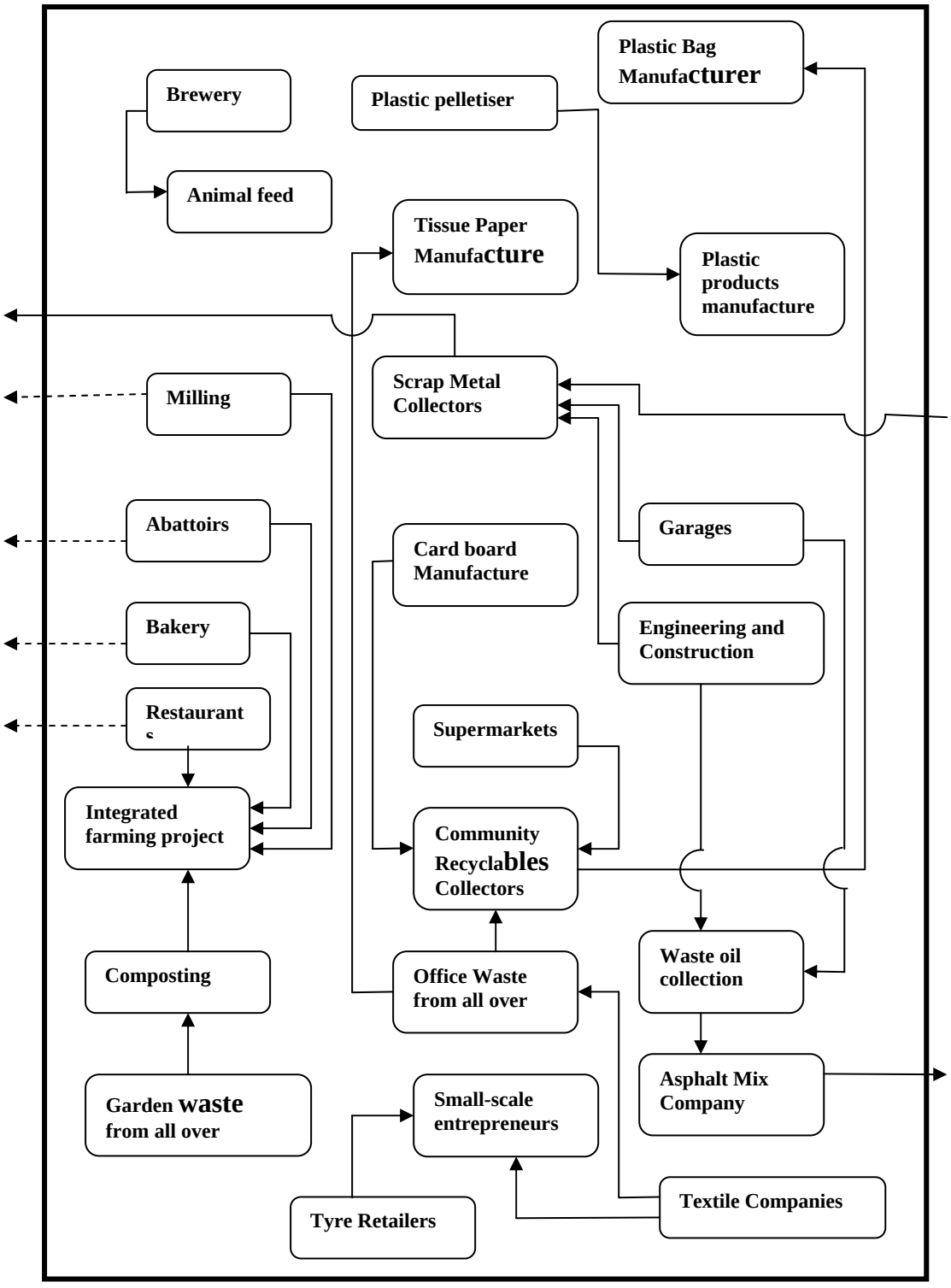

Figure 5.3 By-product exchanges and recycling in the case study area after implementing Industrial Symbiosis.

Source: Adapted from S. A. Martin, 1996

Broken lines indicate reduced flows.

Flow lines coming from outside the system boundary indicate recyclables coming from outside the case study area and those going out of the system boundary mean waste recipients outside the case study area.

5.2.3 Integrated Approach

5.2.3.1 Conditions to be met

Issues of industrial activities involve a wide range of disciplines such as economics, sociology, legal, science and technology. Therefore the environmental aspect of industrial activity needs inputs from these disciplines. This means the Integrated Approach principle is within the scope of this research.

For Integrated Approach to be successful, the conditions to be met are:

- Cooperation between the different stakeholders
- Existence of a lead agency that will coordinate the interaction between the stakeholders
- Commitment of the stakeholders.

The cooperation that exists between MEE and MHUD is a starting point. The Town board with the status of the industrial estate manager is the appropriate coordinator of the integrated approach to the environmental issues of the case study area. The environmental impacts of pollution from the case study area and its associated long-term financial and social implications, is enough to ensure commitment from the stakeholders. Assuming that the Town Board takes the status of industrial estate manager and that the objective of government is to ensure sustainable industrial development, the above conditions can be met.

5.2.3.2 Present situation in the industrial estate is characterised by:

- Lack of cooperation between the industries, Government and the communities concerning the environmental impacts of the industrial estate.
- No clear roles and responsibilities between the Government, industry and the communities with respect to the environmental performance of the industrial estate.
- Efforts on environmental management, by some of the industries and government agencies do not succeed in improving the environmental performance of the industrial estate because they are addressed as individual isolated cases without considering the bigger picture and the stakeholders involved.
- The communities view the industrial estate as the cause of destruction of their livelihood, decline in their health status and pollution of the natural resources on which they depend.
- There is no common link between the industrial estate, the government and the communities.

5.2.3.3 Implementing Integrated Approach

Taking an integrated approach produces the following results:

- The common link between the industrial estate, the communities and the government become established in the form of the industrial estate manager.
- All aspects related to wastes and pollution issues are considered in the environmental management of the case study area
- All stakeholders are involved in the environmental issues of the case study area.

5.2.4 Shared Resources

5.2.4.1 Conditions to be met

The principle of Shared Resources is one of the benefits that industries in an eco-industrial system can get. The shared resources that are of interest in this research are those that are related to waste issues such as common waste treatment plant, information centre for cleaner production, waste minimisation and environmental technologies. This principle is therefore within the scope of this research.

For shared resources to be in place there are conditions that have to be met. These are:

- Capital investment for infrastructure development
- Reliable source of revenue for recurrent costs
- Binding agreement for all participating industries.
- Appropriate legislations that will apply to the shared resources such as pollution standards, Legislation governing non profit making entities etc.

Currently there is no budget for capital investment from anywhere. This is because the environmental issues of the industrial estate seem to have no home. Logically the responsible ministry is MEE. The condition of capital investment cannot be met in the short term. With adequate justification that embraces government policy on sustainable development, budget for capital investment can be put on the agenda.

The source of recurrent costs falls squarely on the sources of the wastes. There is enough documentation on the long tern benefit to industry for environmental protection. With the infrastructure in place, industry only need to be held accountable for their environmental impacts while at the same time being given appropriate options that will minimise the short term economic impacts of pollution prevention. This is also a long-term effort.

The industrial estate manager can coordinate preparation of legal agreements pertaining to resources that are shared.

Appropriate legislation exists only needs to be streamlined to address environmental issues of industries in the context of industrial ecology. This again can take a long time particularly where amendments may be necessary.

5.2.4.2 Present situation

- Currently management of wastes in the industrial estate is very ad hoc
- SWSC accept industrial wastewater into the sewer system. This makes the sewer treatment plant inefficient with chronic failures.
- Solid waste collection by the Town Board from the individual companies is very superficial.
- Some contracted waste service providers by some of the companies as well as some companies themselves dispose of the waste indiscriminately.
- The landfill is poorly managed with constant burning and generating leachate that constantly pollute the river.
- Wastes from the informal sector and the public are not collected.
- Storm water drains are used as effluent discharge points by some industries causing chronic fish kills.

Considering the fact that the pollution problems of the case study area are caused by lack of accountability of the industries for their environmental impacts, lack of responsibility by the industries and the Town Board as well as lack of containment of emissions to air, water and land, Shared resources has a potential of addressing these problems. Therefore even if the conditions for shared resources are difficult to meet, this principle is critical to the environmental problems of the case study area. Its implementation is therefore tested.

5.2.4.3 Introduction of Shared Resources

There are many types of shared resources only those that are directly related to waste issues are going to be considered. Shared resources that can be introduced in the case study area are:

- Shared industrial wastewater management
- Shared solid waste management
- Information centre for new régulations, environnemental technologies etc.
- Site-wide umbrella permitting
- Shared emergency management

Shared solid waste and wastewater management have two aspects the ownership and technical aspects. The ownership aspect of the management can either be contracted out to a competent service provider or owned by the industries through an appropriate structured entity such as a board of directors consisting of a number of elected representatives from the industries. On the technical aspect, wastewater management can either be divided into organic and inorganic industrial wastewater or mixed industrial wastewater. The appropriate options depend on a number of points and the aim is to maximise benefits and minimise costs.

For ownership the choice depends on:

- The relative costs
- Whether the companies have control on the efficiency of the waste management
- Whether the efficiency depend on the ownership
- Whether the industries are involved in the waste management or they pay and forget

For industrial wastewater management, the choice depends on:

- The relative costs
- Whether the option has an opportunity for reuse of wastewater

- Which option is more efficient
- Whether the option reduces the quantity of the wastewater to be treated

Table 5.1 and 5.2 shows how the different options relate to the above points. A + signs represents a favourable situation and a - sing represent an unfavourable situation. A + and – signs means it can either be favourable or unfavourable depending on the prevailing circumstances.

Table 5.1: Ownership of shared resources

Issues / Option	Efficiency control	Relative cost	Direct involvement	Efficiency
Contracted out	-	-	-	+ -
Owned by the industries	+	+	+	+ -

Table 5.2: Industrial Waste Water

Issues / Option	Opportunity for wastewater reuse	Efficiency	Quantity reduction	Relative capital cost	Relative running cost
Mixed industrial wastewater	-	-	-	+	-
Separation of industrial wastewater	+	+	+	-	+

These are subjective qualitative judgements used for deciding which combination of waste management option will be tested in the case study area. From the above tables the combination of waste management option is one that is owned by the industries with the industrial wastewater treatment based on the separation of

organic and inorganic industrial wastewater. The industries will not be bothered by the day-to-day and technical details of the industrial waste management. This will be left to the entity. Because the industries own the entity, they will have control of the efficiency of the entity. The money they pay will only be for waste management not for profit making therefore will reflect the true cost of the industrial waste management. With this involvement the business owners would have a reason to engage in cleaner production and waste minimisation.

The information centre is very essential and can develop into a cleaner production centre with time.

Site-wide umbrella permitting when referred to pollution is advantageous because it allows for flexible industrial waste management within the eco- industrial system because only wastes leaving the eco-industrial system are subject for permitting not wastes from the individual industries. This makes it easy for the SEA to monitor the environmental performance of the industrial estate.

Shared emergency management help to prevent accidental spillages and contain spillages that may occur as well as facilitate timely warning of all that are likely to be affected including the neighbouring communities and relevant government agencies.

The success and benefits of the above shared resources can lead to more shared resources being entered into such as bulk purchase of some inputs, business incubators etc.

5.2.5 Industrial Metabolism

5.2.5.1 Conditions to be met

The flow of materials and energy within a production system goes down to company level. Industrial metabolism directly relates to waste issue. Improving the metabolic pathways of energy and materials reduces wastes and energy losses while increasing production per unit material. Because industrial metabolism is at company level, it is outside the scope of this research and therefore this principle is not applied.

5.2.6 Diversity

5.2.6.1 Conditions to be met

Diversity is a key element of an eco-industrial system because it buffers changes. Diversity refers to the eco-industrial system level and therefore it is within the scope of the research.

Diversity for the case study area depends on:

- Whether there are incentives for new industries to invest in the eco-industrial system.
- Whether there is an anchor industry that offers opportunities for the utilisation of wastes and by-products.
- Whether appropriate industries can be established in that case study area.
- The eco-industrial theme of the case study area.

The decision to invest in a given location depends on the investor neither government nor the industrial estate manager has control on the decision of the investor. However if there are incentives then the chances are increased. The Government is building factory shells in the case study area so that investors only have to bring their equipment and do minor construction work. The wide spectrum

of industries in the case study area though small, the situation is ideal for small waste salvagers that can supply bigger recyclers with inputs. This condition can therefore be reasonably met with some effort

There is no anchor industry in the case study area therefore the different industries in the case study area are not linked to any industry. This condition cannot be met.

The presence of recycling activities in the case study area suggests that this could be the eco-industrial theme for the case study area. In this case diversity is possible.

These conditions do not depend on each other therefore diversity is possible in the case study area.

5.2.6.2 Diversity in the Case Study Area

Because of the lack of an anchor industry in the case study area, recycling is the only activity that can be supported on a sustainable basis by the kind of diversity that exists in the case study area. The coming and going of industries into and from the case study area will not upset the recycling that is established by the introduction of industrial symbiosis in section 5.2.2. This confirms that the eco-industrial theme for the case study area is resource recovery based on recycling.

6. RESULTS AND DISCUSSIONS

6.1 Effects of Industrial Ecology Principles on the Case Study Area

In this chapter the results of the application of the industrial ecology principles are analysed and their effect on the waste related environmental performance of the case study area discussed.

6.1.1 Systems Approach

This principle establishes the system boundary and the industrial estate manager. The industrial estate manager is not an individual but an institution which is the Matsapha Town Board.

The system boundary enables the waste issues and the environmental performance to be viewed from the industrial estate perspective. The interface between the industrial estate and the environment is therefore recognised allowing for the design of the ecological-industrial estate interface for addressing the pollution issues. The industrial estate manager represents the organising focal point for environmental issues in the industrial estate. The changes that occur as a result of the application of the industrial ecology principle are:

- A body to which the industries are accountable for their environmental impacts is established as the industrial estate manager.
- Environmental issues are considered from the eco-industrial system level allowing for flexible management of wastes within the system.
- A body that have the duty to coordinate the communication between the industrial estate and the neighbouring communities is established as the industrial estate manager.
- The institution that is responsible for the environmental performance of the industrial estates becomes clear.
- The environmental impacts of the industries or the industrial estate as a whole then features in the activities of the Town Board that has now assumed the status of the industrial estate manager.
- The industrial estate is now viewed as a system instead of a collection of firms.

The results of implementing the Systems Approach principle does not directly affect the flow of materials and wastes however this principle provides for a systematic management of the industries with respect to environmental issues. With the industrial estate manager in place and the system boundary defined. The focal point for interaction between the neighbouring communities and the case study area become established. A key aspect of this principle is that the industrial estate is viewed as an eco-industrial system instead of a collection of individual firms. This is an important feature for an organised management of the environmental issues of the case study area.

6.1.2 Industrial Symbiosis

Industrial symbiosis directly affects the flow of materials and wastes. The important aspect of this principle is the increased utilisation of wastes within the system by taking them as inputs for other industrial activities. This reduces the wastes that would otherwise be emitted to the environment. The introduction of industrial symbiosis in the case study area as shown in figure 5.3, leads to the following:

- All waste paper collected and bought by the tissue paper company. = 1646 tones.
- All plastic waste collected and bought the plastic pellet maker and the plastic bag manufacturer. = 641.1 tones
- All organic solid waste from food processors are sold to animal feed manufactures and sent to the integrated farming project or composted. = 1699 tones
- All waste oil collected for recycling. = 36.3 tones
- All textile cuttings collected and sold for reuse = 672 tones
- Some waste tyres utilised by the small entrepreneurs
- Mixed waste reduced because of improved waste separation at source as a result of the system put in place by the industrial estate manager.

Total solid waste that is diverted from the landfill as a result of industrial symbiosis is equal to **4,694.4 tones.** The waste to be disposed then becomes:

15,074.1 – 4,694 = **10,379.3 tones**. This is 69% solid waste reduction.

The average transportation cost for this amount of solid waste is:

10,379.3 tones x 126 .00 Rands per tone = **R 1,307,791.80**. The cost saving is therefore:

R 2,090,620.00 - R 1,307,791.80 = **R 782,828.20**

This is a **37%** transportation cost reduction from R 2,090,620.00.

The environmental performance index related to solid waste then becomes

10379.3 /1178335 = **0.009** solid waste per unit product.

Scrap metals are not considered because they are adequately collected for recycling. Only wastes that are disposed to the environment are considered in the waste related environmental performance.

Scrap tyres and the reduction of the mixed waste are not included in the calculation of the new environmental performance because the quantity that can be utilised by the small entrepreneurs cannot be reasonably estimated and also the composition of recyclables in the mixed waste cannot be reasonably estimated. The impacts of these two components are described qualitatively as improving the waste related environmental performance. The actual environmental performance index related to solid waste is therefore better than the **0.009**

It can be noted that recycling forms a major component of the industrial symbiosis in the case study area. This indicates that in the absence of an anchor industry, the eco-industrial theme for the case study area is likely to be **Resource Recovery** in the form of recycling.

Recycling takes the role of a waste treatment plant therefore it is important that all the functional components of a waste treatment plant are in good operating form. In this case the sources and the markets for the recyclables have to exist simultaneously. The waste collectors and salvagers introduced in the case study area are like micro organisms cleaning up in a natural system.

Recycling can be easily implemented because both the sources and the markets for the wastes are available within the case study area. The big question is why this is not currently taking place at a scale that would effectively minimise these wastes going to the landfill in an organised manner since the economic benefit is there? Possible reasons are:

- Managers in the industrial estate are only concerned about production, which is their main priority. Anything else including the environment comes second.
- Taking the waste to the recyclers or the recyclers collecting the wastes from the individual companies is not cost effective because of the quantities from the individual companies.
- There are no charges for the use of the landfill.

The introduction of the waste collectors and the salvagers provides a link between the waste producers and the recycles. This only address the above points partially particularly the issue of cost effectiveness. The other points may be addressed by the introduction of the other principles.

The link must have nothing to do with the industry operations. This is an opportunity to involve the communities. The industrial estate manager put in place an organised collection system where interested members of the community would collect the recyclables and sell to the recyclers. This is a job opportunity for the communities. For industrial symbiosis to be sustained, cooperation and participation of all involved parties is necessary. It is the duty of the industrial estate manager to coordinate this cooperation.

6.1.3 Diversity

The implementation of this principle is beyond the control of anyone. Not even the industrial estate manager can control it. Government policy and other interventions such as incentives can influence the coming of new industries, as is presently the case with the textile industries.

The existence of different types of industries in the case study area is ideal for a recycling based eco-industrial theme.

Resource Recovery (recycling) being the theme for the eco-industrial system in the case study area, the wide spectrum of industrial activities with different economic activities provides the diversity necessary for recycling. This is because of the wide spectrum of industries in the case study area. If one or several industries move out of the eco industrial system, the total recycling activity would not be affected.

6.1.4 Shared Resources

Shared resources that are of interest in this research are those that relate to wastes. Shared resources that are entered into in the case study area by the industries affect the flow of materials and wastes both directly and indirectly.

The pollution problems of the case study area are caused by lack of accountability of the industries for their environmental impacts, lack of responsibility by the industries and the Town Board, free environmental service as well as lack of containment of emissions to air, water and land. The industrial ecology principle of Shared Resources has a potential for addressing these problems.

Most of the new textile companies have benefited from the factory shells constructed by government as an incentive for new investors. The factory shells however do not have wastewater treatment plants constructed hence a common industrial wastewater treatment plant is ideal.

With the current pollution problems in the case study area, the principle of shared resources has a potential for addressing these problems effectively and reliably.

Wastes being managed by using shared resources that are owned by the industries themselves and wastewater being divided into organic wastewater and inorganic wastewater, results in the following achievements:

Waste management become systematic with adequate collection of solid waste and treatment of industrial wastewater.

- Wastewater from storm drains and other discharge points is reticulated to a common wastewater treatment plant.
- No industrial wastewater is discharged into the sewer system.
- There is an opportunity for wastewater cascading. Brown water from the treated organic wastewater is then reused for lawn irrigation, rooftop cooling, use in the integrated farming etc.
- SWSC focuses on the management of sewerage only. The sewer system is freed from industrial wastewater shock loads and therefore becomes efficient reducing the current average COD load (see table 6.1).
- The collection of industrial wastewater from storm water drains eliminates the problem of chronic fish kills in the adjacent river.

Wastewater treatment does not eliminate the wastes but converts them from one form to another. The net environmental performance for industrial wastewater remains the same. However this allows for the design of the interface between the environment and the eco-industrial system. The result is the protection of the adjacent river from pollution.

The design of the interface between the eco-industrial system and the river is based on the pollution standards. For COD the pollution Standard is 75 mlg/l. The COD load removed is based on the discharges that are directly to the river. The assumption made is that the 75mg/l is achieved with the new industrial wastewater management base on shared resources.

(Average COD – 75) X Annual discharge.

Table 6.1 gives the COD load prevented from polluting the river.

Total COD load before implementing the industrial ecology principle of Shared Resources = **7759.1**

COD removed after implementing the industrial ecology principle of Shared Resources = **7667 tones**. This is a **98%** removal

Table 6.1 COD load removed after implementing Shared Resources

Pollution Source	**Volume m^3/ yr**	**COD**	**COD (mg/l) (Actual COD-75)**	**COD Removed (Tones)**
Drain A	19100	1000	925	29.2
Drain B	31500	800	725	45.7
Conco	37045	100	25	0.9
Swazi Paper Mills	750000	10000	9925	7443.8
Sewer treatment plant outflow	346896	500	425	147.4
TOTAL				**7667**

It must be noted that the specific COD from the individual companies is not important for the pollution index at the eco-industrial system level. This is the flexibility of wastewater management within the eco-industrial system resulting from the Systems Approach.

The calculated value of COD removed only gives an indication of the water quality improvement not the total quality of the effluent because the removal of other toxins and heavy metals may be more difficult. The efficiency of inorganic wastewater treatment plant cannot be reasonably estimated while that of the

organic wastewater treatment plant can be assumed to meet the pollution standard of 75mg/l.

The industries do not have to be bothered by the technical details and the day-to-day running of the industrial waste management. They are involved in decision making during board meetings. The day-t-day running of waste management is left to the entity formed. The entity would be run professionally and technically sound. Because the industries own the entity, they will have control of the efficiency of the entity and thus ensure minimum environmental impacts. The money they pay will only be for all aspects of the industrial waste management not for profit making therefore will reflect the true cost of the industrial waste management unlike the present situation. With the industrial wastes managed at cost recovery, the business owners now have a reason to engage in cleaner production and waste minimisation thus reducing the cost of the industrial waste management. This also adds to the much-needed data from the individual industries for planning at the eco-industrial system level.

Site wide permitting allows for a flexible waste management system because it is only the wastes that leave the eco-industrial system that are considered in the environmental performance. This permitting includes waste management licensing as required by the Waste Regulations 2000. This is licensed to the waste management entity leaving the individual industries to concentrate their efforts to the economic aspect of their activity, as is the case now but with reduced negative environmental impacts.

Accidental spillages would be prevented and when they occur, timely containment and warning of all that are likely to be exposed including the neighbouring communities and relevant government agencies is activated. This is possible with the existence of shared emergency management services.

The information centre is very important in the eco-industrial system for the dissemination of information on regulations and environmental technologies. With time the information centre can develop into a cleaner production centre where information on industrial metabolism can be found by industries ready to advance to the next level from end of pipe treatment to pollution prevention.

The success and benefits of the above shared resources can lead to more shared resources being entered into such as bulk purchase of some inputs, business incubators etc.

6.1.5 Integrated Approach

The implementation of the industrial ecology principle of Integrated Approach has resulted in the consideration of all the components of the eco-industrial system in addressing the waste related environmental issues of the case study area. These are: The industry representing the economic aspect, the communities representing the social aspect and the environment or ecological aspect. With these components considered all the stakeholders are then involved in the management of the environmental performance of the case study area. The consideration of these components is a basis for sustainable development. The key benefits from this are:

- Opportunity for balancing the economic development and environmental protection of the case study area.
- Opportunity for revealing the true cost of the environmental burden of the industrial estate and the long term benefits of environmental protection.
- Opportunity to involve the communities thus incorporating the social aspect of industrial activities.

The integrated approach therefore ensures that all the stakeholders and their associated disciplines are involved in the environmental issues of the case study area. This is a recipe for sustainable development. The case study area is therefore shifting from the compliance mode to risk management and on its way to sustainable development.

6.2 Summary of the Results

6.2.1 Effects of the Industrial Ecology Principles on the Environmental Performance

The effect of the industrial ecology principles on the environmental performance related to resource use could not be quantitatively determined because these could be best dealt with using industrial metabolism and this involves activities at the company level. Environmental performance related to emissions to water is expressed descriptively because wastewater treatment does not make the waste disappear but changes it from one form to another. Even though opportunities for reusing the waste sludge somewhere else may arise, this would need further research because of possible heavy metal contaminations and other toxins.

6.2.1.1 Quantitative results

The environmental performance related to solid waste improved from 0.012 tones of waste per tone of product to 0.009.

The cost of solid waste transportation has improved by 37% from R 2090620.00 to. R1307792.00. This is a cost saving of **R 782,828.00 per year**

6.2.1.2 Qualitative Results

6.2.1.2.1 Planning and organisation

The planning and organisation of the management of waste related environmental performance has improved because of the following:

- Existence of the industrial estate manager
- Systems approach
- Integrated approach
- Jointly owned waste management system

6.2.2 Effects of the Principles on the environmental performance objectives

The impact of the industrial ecology principles on the environmental performance objectives set in section 5.2.2.5 are summarised in table 7.2

With the exception of Diversity, the table indicates that all the principles address at least two of the four performance objectives directly. Diversity does not directly address any of the performance objectives but directly support industrial symbiosis support.

Table 6. 2 Effects of the principles on the performance objectives

= Objective addressed **= Objective not addressed**

Effect / Cause	Efficient use of resources	Reduction of emissions	Community interactions	Cost effective waste management
Systems Approach	○	✚	✚	○
Industrial Symbiosis	✚	✚	○	○
Integrated Approach	○	✚	✚	○
Diversity	○	○	○	○
Shared Resources	✚	✚	○	✚

Table 6.3 Effects of the Principles on the Environmental Issues

ISSUE	BEFORE	AFTER	REMARKS
Land contamination	Poor	Better	Waste oil collected and no storm water drain disposal industrial
Urban quality	Poor	Better	Improved solid waste collection
Biodiversity	Poor	Much improved	No fish kills
Community integration	Poor	Much improved	Job opportunities and improved communication
Environmental services	Free	Free	Not directly addressed by the principles
Environmental accountability	Poor	Much improved	Industrial estate manager in charge
Waste management cost	Erratic	True cost	Existence of shared resources

6.3 Discussion

The implementation of the industrial ecology principles is largely dependent on the existence of the industrial estate manager as a focal point and organising body. The improvement of the environmental performance of the case study area is best addressed by the systems approach. In the system approach it is not the environmental performance of the individual industries that are considered in the environmental performance of the industrial estate but the cumulative performance resulting from the interaction and relationship of the industries. The water emission related environmental performance of the coca cola industry in the case study area can be described as good because of its effective wastewater treatment plant but that has no effect on the environmental performance of the case study area that remains poor. This demonstrates the importance of systems approach in the case study area.

Three of the implemented principles will not function in the case study area without the industrial estate manager. These are Systems approach, integrated approach and shared resources. These are the principles that facilitate the planning and organisational aspect of the management of the environmental performance of the case study area. The importance of planning and organisation is not in waste related environmental performance only but all aspects of environmental management. Industrial symbiosis and diversity are not necessarily dependent on the industrial estate manager. However the presence of the industrial estate manager makes their implementation more organised.

The industrial ecology principle of Shared Resources has addressed three of the environmental performance objectives. This reinforces the importance of the Systems Approach. Shared Resources requires the participants to interact and work as a system. At least two of the performance objectives are addressed by the industrial ecology principles with the exception of the Diversity Principle.

The impacts of the industrial ecology principles on some of indicators such as resource use could not be determined because of lack of data and the scope of the research. This requires Industrial Metabolism to be in place at company level and the information from that can then be used at the eco-industrial system level. This means that for quality data at the systems level it is essential that quality information is available at company level. This remains a challenge in the case study area.

With the systems approach and integrated approach, the opportunity of community involvement is availed. This is very important for the public image of the industrial estate, community acceptance and better understanding of the environmental problems experienced by the communities as a result of the industrial estate.

7 RESPONSES TO RESEARCH QUESTIONS

7.1 Research question 1. Can the use of industrial ecology principles provide the answers to the environmental problems of industrial estates in developing countries?

Chapter 5 addresses this question and the results in chapter 6 confirm that industrial ecology principles hold the answers but things cannot happen on their own. All the stakeholders have to play their respective roles. The right incentives have to be provided; the obstacles have to be removes. The objectives of the industries, the public sector and the communities have to be considered with their relative importance

7.2 Research question 2. Can focusing on the environmental component of an industrial system ensure sustainable development in the context of industrial activities?

The Implementation of Integrated Approach ensured the participation of all stakeholders. This provides the ground for bringing all aspects related to the environmental problems of the case study area. In this approach all the components of the eco-industrial system are considered and the area of intersection between all three components represents sustainable development (see figure 1.4). Profit making and remaining in business being the primary objective of the industries, only the economic component featured prominently in the industrial activities of the case study area before industrial ecology. This resulted in the pollution of the environment and human health impacts. Focusing on the environmental component helped in forging the links with the other two components because the environment is impacted by the industry and the communities also suffers from the pollution. The industry and the communities depend on the viability of the environment.

7.3 Research question 3. What are the key elements of sustainable development in the context of industrial activity?

Through the industrial ecology principle of Integrated Approach the communities, Environment and industry were confirmed to be the three components of sustainable development.

7.4 Research Question 4. How can Industrial estates in countries be transformed into Eco Industrial Parks?

Chapter 5 identified the need for an industrial estate manager. Industrial Symbiosis identified Resource Recovery in the form of recycling as the eco-industrial theme. The establishment of shares resources ensure the design of the interface between the industrial system and the water body. Industrial symbiosis facilitated the closing of the loop. It is therefore important to identify the theme of the eco industrial system. The theme should be based on industrial ecology principles that can be readily implemented and thereafter allow gradual development of other activities such as business incubators and perhaps an anchor industry. Like in nature as mimicked by industrial ecology, time and patience are the key determinants. The only active intervention should be removal of obstacles, provision of incentives and appropriate policies and regulations that are in line with industrial ecology such as the definition of waste.

7.5 Research question 5. What are the short term measures that are necessary to contain the environmental problem of the case study area?

- Emissions to water would be adequately addressed by shared resources but this is a long tern activity. Therefore enforcement of pollution standards is the short term measure.
- Public awareness and dialog between the stakeholders for the introduction of industrial ecology as the agenda for the industrial estate.
- Promotion and organisation of the existing recycling activities. Chapter 6 identifies how this can be achieved.
- Initiation of the interaction among all the stakeholders.
- Development of a structured accountability programme of the industries for their environmental impacts to the industrial estate manager.
- Establishment of an environmental data base for continuous monitoring of the environmental performance of the case study area.

All these need the establishment of the industrial estate manager who will coordinate these activities and to whom the industries are accountable for their environmental impacts. This can be achieved with immediate effect because already the Town Board exists.

Table 7.1 summarises the time frames for activities.

Table 7.1: Activities for the implementation of industrial ecology principles in the case study area

ACTIVITY	**RESPONSIBLE INSTITUTION**	**TIME FRAME**
Identify Industrial Estate Manager (IEM)	SEA MEE MHUD	Short term
Consultations	IEM	Short tem
Roles and responsibilities	IEM SEA MEE MHUD	Short term
Data Collection	IEM SEA	Short term
Systems approach	IEM SEA	Medium term
Environmental performance indicators and objectives	SEA	Medium term
Implementation of Industrial Ecology principles	SEA IEM	Medium term
Monitoring	IEM SEA	Continuous
Environmental legislation reforms	SEA MEE MHUD IEM	Long term

The above activities are a basis for an Environmental Management Framework of the Case study area.

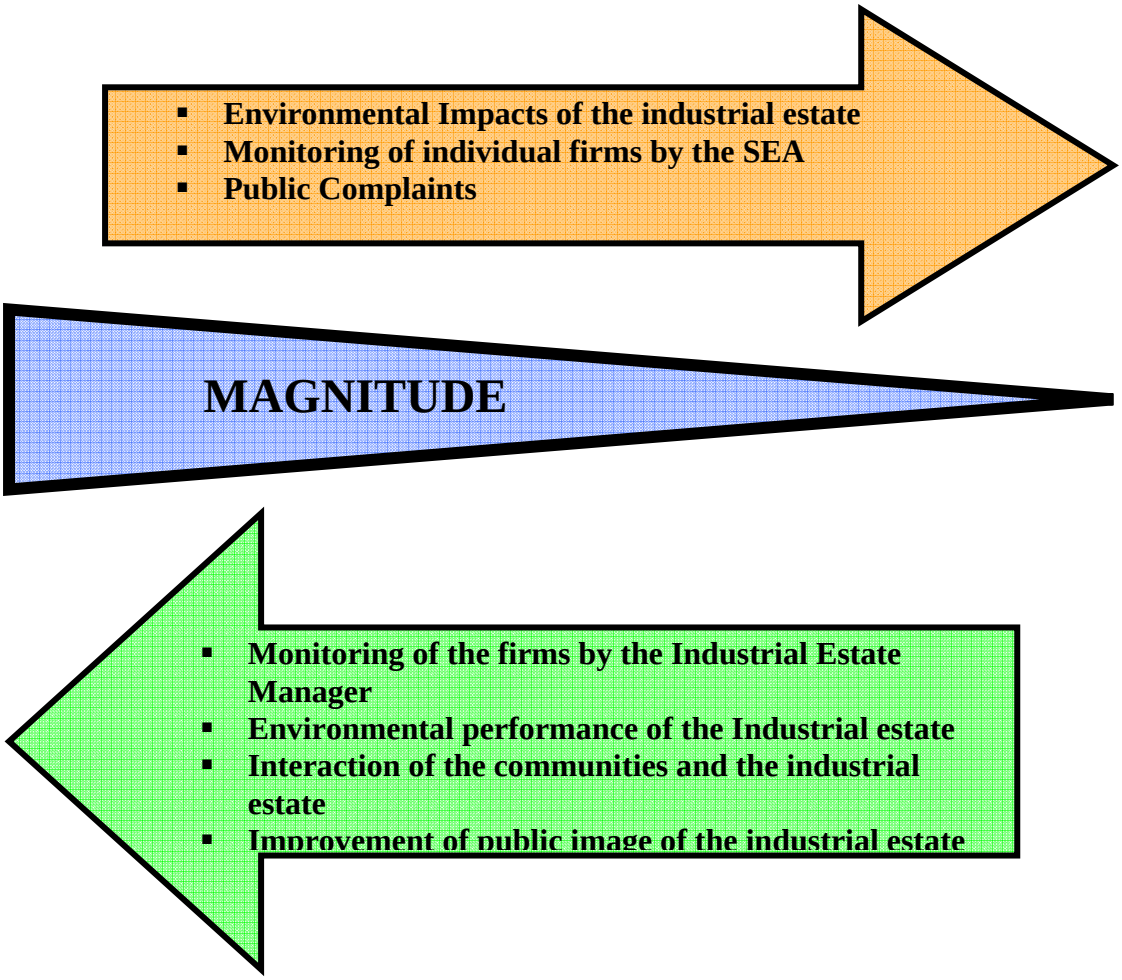

Figure 7.1: Effects of industrial ecology principles on the case study area

8 CONCLUSIONS

8.1 Response to the set Environmental Performance Objectives

The environmental performance objectives that were set for the case study area are:

- Efficient use of resource
- Reduction of environmental emissions
- Cost effective and cost recovery of waste management
- Management of environmental and community interactions

Efficient use of resources could not be investigated because of the scope of the research and lack of appropriate data. With all the other environmental performance objectives, the results of the implementation of the principles indicate that there are opportunities for the use of industrial ecology principles.

8.2 Reflecting on the fundamental causes of the environmental problems of the case study area

This research has been inspired by the continuous pollution problems and the lack of success of waste management and pollution control efforts by the public sector and some industries in the case study area. The efforts have been a result of public outcry particularly those who are in the downstream and down wind of the case study area. It became clear that government agencies have different objectives from those of the industries. Economic benefit is the primary objective for industry while environmental quality is a concern to the SEA. MEE focuses on industrial development. The Town Board focuses more on property tax collection. The environment and human health is then caught in the middle. This research therefore explores whether industrial ecology principles can be used to find the common ground where economic and environmental objectives are pursued simultaneously in addressing the pollution problem of the case study area. Following bellow are the conclusions of the research.

8.3 Environmental performance

The waste related environmental indicators in the case study area are product based. That is the quantity of the waste stream per unit product.

With the available data the current environmental performance of the case study area was established. Without benchmarks, the environmental performance was taken to be poor based on the current environmental issues. The environmental performance established from the data and other information was taken as a reference point.

8.4 Application of Industrial Ecology Principles

For waste related environmental performance, application of the principles resulted in reduced wastes. This is largely attributed to Industrial Symbiosis. Converting wastes to inputs reduces the environmental impacts. In an activated sludge wastewater treatment plant, the waste is an input to the micro organisms. It is therefore important to introduce “micro organisms” in an eco-industrial system to close the loop. The introduction of collectors of recyclables and the waste salvagers takes the form of micro organisms in nature. For the implementation of industrial symbiosis and for it to function well, there are organisational requirements that have to be met. These requirements are met with the implementation of other principles particularly Systems Approach.

Because Industrial Metabolism is beyond the scope of this research, the effect of this principles on the environmental performance related to resource use could not be investigated.

The results also show that the implementation of the principles in the case study area is dependent on the Systems Approach. The application of industrial symbiosis in the case study area suggests that the eco-industrial theme for the case study area be resource recovery in the form of recycling. Industrial Symbiosis under normal circumstances would take off naturally if economic incentives are there. The question is why this is not happening in the case study area? The reason can be found from the words of E. Cohen –Rosenthal in his publication: A Walk on the Human Side of

Industrial Ecology; “Knowledge of kinds of waste streams can provide a means to determine potential linkages. But this does not link them people do”.

Integrated Approach revealed the importance of the participation of all stakeholders including the surrounding communities Industrial Symbiosis not only presented a potential for waste reduction but also the potential benefits to the surrounding communities. These benefits directly addresses among others, poverty issues and problems of unemployment. These are national priority areas in Swaziland and many other countries in the developing world.

The pivot for the opportunities of using industrial ecology principles in the case study area has come out to be the existence of the industrial estate manager. This confirms the importance of the systems approach.

Industrial ecology principles have demonstrated that innovative environmental management practices combined with appropriate initiatives not only improves the environmental performance but also result in actual money savings. Cost savings such as the cost of wastewater treatment, landfill charges, resource materials savings etc. could be established with more data. These savings can pay for various environmental management costs. The **R 782,828.20** that was saved from the transportation cost of solid waste management alone can go along way in supporting the Town Board which is the Industrial Estate Manager.

8.5 Summary

The research does address the research questions. It can be concluded therefore that there are opportunities for the use of industrial ecology principles for addressing environmental problems of industrial estates in developing countries. However there is no one formula as indicated by the theme of the eco-industrial system of the case study area which is resource recovery in the form of recycling. Different areas will have different themes depending on the economic activity of the area and whether there is an anchor industry or not.

There is need for an environmental information system where waste and other environmental data can be collected and processed for planning and monitoring of the environmental performance of the case study area.

The conversion of the Matsapha Industrial Estate and many other industrial estates in developing counties from a collection of industries operating individually to an eco-industrial system, requires the establishment or identifying the industrial estate manager, legal reforms, investment in infrastructure, establishment of shared resources such as common waste water treatment plant etc. This requires time and careful planning through a consultative process where all the stake holders would be consulted and their respective roles be clearly defined.

8.6 Recommendations

It is recommended that the initiative to implement the industrial ecology principles in the case study area is initiated immediately. On top of the priority is the identification of the industrial estate manager and the consultations with all the stake holders. The industrial estate manager in this case is not an individual but an institution represented by the Matsapha Town Board. Table 7.1 summarises the recommended activities towards the implementations of the principles.

It is also recommended that further research be done on the use of waste as inputs to other industries and also on industrial metabolism because that is where individual companies can realise economic benefits from savings on inputs and recovery of beneficial by products.

Resource recovery in the form of recycling is recommended as the eco-industrial theme for the case study area because there is no anchor industry in Matsapha industrial estate.

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ANNEX 1 List of industries and the colleted data

TYPES OF SOLID WASTE INCLUDING WASTE ENGINE OIL

	COMPANY	Metal	Paper	Plastic	Textile cuttings	Organic	Tyre/rubber	Special	Coal ash	Oil	Mixed	Total	Total - Metal
1	AG Thomas	20						3		4	1	28	8
2	Arrow Feeds								30		1	31	31
3	Barlows Equioment	0								1	1	2	2
4	Builders Discount										2	2	2
5	Cadbury Swaziland								66		2	68	68
6	Central Medical Stores							1				1	1
7	CG. Trading		2	0.1							1	3.1	3.1
8	Conco	10.6	4	16				1			28	59.6	49
9	Construction Associates	7								10		17	10
10	Dulux										1	1	1
11	EIS Marketing										1	1	1
12	Emalangei foods		15	15							12	42	42
13	Fletcher Electrical	13								0.5	1	14.5	1.5
14	Flexi Clinic							0.6			0.5	1.1	1.1
15	Fyfe's Autoclinic									5	1	6	6
16	Golden tree										1	1	1
17	Grobac										12	12	12
18	High Tech Printing										1	1	1
19	Hong ye		45	45	180						1	271	271
20	Jubilee Printing		5								1	6	6
21	M&F Plastic		5	1							2	8	8

TYPES OF SOLID WASTE INCLUDING WASTE ENGINE OIL

	COMPANY	Metal	Paper	Plastic	Textile cuttings	Organic	Tyre/rubber	Special	Coal ash	Oil	Mixed	Total	Total - Metal
22	Master Gartmets		4	4	132						1	141	141
23	Maxiprest tyres						56.4				1	57.4	57.4
24	Mc Millen		29	1							1	31	31
25	Mchepa Chemicals							0			29	29	29
26	Medquip							0.005			1	1.005	1.005
27	Mzala's Carriers						20			6	5	31	31
28	Nampak		900					5	24		1	930	930
29	Ngwane Maize mill		29			6088				0.2	1	6118.2	6118.2
30	Ngwane Mills										365	365	365
31	Online Tyres						86				1	87	87
32	Palfridge	110	11	2							5	128	18
33	Parmalat					6					14	20	20
34	Pearl Laundry								27		1	28	28
35	Shun Manufacturing				57						9	66	66
36	Spintex		90			48					1	139	139
37	Steel & wire	288									1	289	1
38	Sun Tax				58						58	116	116
39	Sunshine Sugar										86	86	86
40	Swazi Candles		4								1	5	5
41	Swazi Paper Mills								2700		4800	7500	7500
42	Swazi Plastic							10			1	11	11
43	Swazi Poulty		100	100		363					151	714	714
44	Swaziland Beverages	22	11	77		2200		2	22	1.8	30	2365.8	2343.8
45	Swaziland Meat Industries		150	150		900		0	74		402	1676	1676
46	Swaziland Milling		48	48		1					2.5	99.5	99.5
47	Swaziland United Bakeries					8				6	187	201	201

TYPES OF SOLID WASTE INCLUDING WASTE ENGINE OIL

	COMPANY	Metal	Paper	Plastic	Textile cuttings	Organic	Tyre/rubber	Special	Coal ash	Oil	Mixed	Total	Total - Metal
48	Taitex				5						2	7	7
49	Tex Ray Swaziland		14	2		225					1.5	242.5	242.5
50	The Reclamation Group										2	2	2
51	Trentyre Swaziland						43				1	44	44
52	Tuntex		180	180	240						1	601	601
53	Turbo Diesel									1.8	2	3.8	3.8
54	Welcome Textiles										301	301	301
55	YKK										55	55	55
	TOTAL	**470.6**	**1646**	**641.1**	**672**	**9839**	**205.4**	**22.605**	**2943**	**36.3**	**6591.5**	**23067.505**	**22596.905**

Organic waste consists of spent grain, spoilt food products, waste from abbatoirs (Blood,intestines,meat pieces etc.)
Glass: Only Swaziland Beverages and Conco had quantitative data =539 + 13.2 = 552.2 tones per year
Wood: Only Construction Associates and Conco had quantitative data = 48 +17 = 65 tones per year

RESOURCE USE AND PRODUCT OUTPUT

	COMPANY	Category	Water Use (M^3/yr)	No. of Employees	Electricity Use (Kwh/yr)	Material Use (tones/yr)	Product (tones/yr)
1	AG Thomas	B/M	2063	25	80000	6500	6500
2	Arrow Feeds	B/M	1100	20	532000	12000	12000
3	Barlows Equioment	S	2062	18	62000	0	0
4	:ount	T	1478	30			
5	Cadbury Swaziland	B/M	46080	100	3784000	14362	14400
6	Central Medical Stores	D	0	28	0	0	0
7	CG. Trading	T	220	15	7000	0	0
8	Conco	B/M	42000	150	4296000	42000	11665
9	Construction Associates	S	206	23	16000	0	0
10	Dulux	B/M	5500	24	124000	66116	795600
11	EIS Marketing	T	0	35	0	0	0
12	Emalangei foods	B/M	1375	39	266000	3131	3120
13	Fletcher Electrical	S	1375	42	497000	14	30
14	Flexi Clinic	S	0	4	0	0	0
15	Fyfe's Autoclinic	S	0	15	0	0	0
16	Golden tree	B/M	688	40	35000	51	45
17	Grobac	B/M	600	28	124000	1440	2805
18	High Tech Printing	B/M	756	26	53000	266	225
19	Hong ye	B/M	413	584	639000	510	167
20	Jubilee Printing	B/M	688	24	71000	77.4	72
21	M&F Plastic	B/M	2750	50	390000	717	600
22	Master Gartmets	B/M	13750	700	337000	529	39
23	Maxiprest tyres	B/M	4125	95	160000	2160	792
24	Mc Millen	B/M	1100	35	3000	1920	1920

RESOURCE USE AND PRODUCT OUTPUT

	COMPANY	Category	Water Use (M^3/yr)	No. of Employees	Electricity Use (Kwh/yr)	Material Use (tones/yr)	Product (tones/yr)
25	Mchepa Chemicals	B/M	1031	15	18000	1044	1560
26	Medquip	D	275	8	3000	0	0
27	Mzala's Carriers	S	688	100	89000	0	0
28	Nampak	B/M	9625	85	709000	9030	6000
29	Ngwane Maize mill	B/M	0	26	0	45540	39600
30	Ngwane Mills	B/M	0	88	300000	114000	36000
31	Online Tyres	T	275	15	10600	0	0
32	Palfridge	B/M	2063	280	1065000	0	9000
33	Parmalat	B/M	18000	12	660000	13800	4800
34	Pearl Laundry	S	17	30	238000	0	0
35	Shun Manufacturing	B/M	138	400	124000	462	238
36	Spintex	B/M	2750	78	629000	2688	2400
37	Steel & wire	T	0	120	212000	0	0
38	Sun Tax	B/M	0	1600	1241000	900	550
39	Sunshine Sugar	D	0	200	1241	4052	4000
40	Swazi Candles	B/M	4125	70	177000	191	190
41	Swazi Paper Mills	B/M	750000	307	11308000	80000	42000
42	Swazi Plastic	B/M	2063	50	710000	1320	1320
43	Swazi Poulty	B/M	36000	180	1242000	6513	6000
44	Swaziland Beverages	B/M	55682	200	818000	57882	36518
45	Swaziland Meat industries	B/M	93500	120	1668000	16300	15000
46	Swaziland Milling	B/M	275	20	3200	2160	3600
47	Swaziland United Bakeries	B/M	4125	200	798000	9910	6900
48	Taitex	B/M	29	300	532000	2742	2400
49	Tex Ray Swaziland	B/M	0	1800	1153000	15000	1125
50	The reclation Group	R	0	60	1153	0	0

RESOURCE USE AND PRODUCT OUTPUT

	COMPANY	Category	Water Use (M^3/yr)	No. of Employees	Electricity Use (Kwh/yr)	Material Use (tones/yr)	Product (tones/yr)
51	Trentyre Swaziland	T	2750	15	124000	0	0
52	Tuntex	B/M	12375	1900	1029000	4160	900
53	Turbo Diesel	S	275	13	53000	0	0
54	Welcome Textiles	B/M	4125	850	532000	1440	270
55	YKK	B/M	56071	45	100000	90000	89984
	TOTAL		**1184586**	**11337**	**37024194**	**630927.4**	**1160335**

B/M = Blending or Manufacturing	**37 COMPANIES**	**S = Service**	**8 Companies**
D = Distribution or storage	**3 Companies**	**R = Recycling**	**3 Companies**
T = Trading or retailing	**6 Companies**		

COST OF WASTE MANAGEMENT

COMPANY	Category	Effluent	Cost of Effluent	Solid Waste (SW)	Costed Solid Waste	Cost of Solid Waste
AG Thomas	B/M			8		
Arrow Feeds	B/M			31		
Barlows Equioment	S			2	2	16000
Builders Discount	T			2	2	2400
Cadbury Swaziland	B/M	44400	165000	68	68	55000
Central Medical Stores	D			1	1	2000
CG. Trading	T			3.1	3.1	1800
Conco	B/M	37045	1000000	79.2	79.2	108000
Construction Associates	S			58	58	11000
Dulux	B/M			1	1	11000
EIS Marketing	T			1	1	2400
Emalangei foods	B/M			42	42	2000
Fletcher Electrical	S			1.5	1.5	1000
Flexi Clinic	S			1.1		
Fyfe's Autoclinic	S			6	6	2200
Golden tree	B/M			1		
Grobac	B/M			12	12	5500
High Tech Printing	B/M			1		
Hong ye	B/M			271	271	45000
Jubilee Printing	B/M			6	6	2200
M&F Plastic	B/M			8		
Master Gartmets	B/M			141	141	12000
Maxiprest tyres	B/M			57.4	57.4	7200

COST OF WASTE MANAGEMENT						
COMPANY	Category	Effluent	Cost of Effluent	Solid Waste (SW)	Costed Solid Waste	Cost of Solid Waste
Mc Millen	B/M			31		
Mchepa Chemicals	B/M			29	29	5000
Medquip	D			1.005		
Mzala's Carriers	S			31	31	1400
Nampak	B/M	6737.5	220000	930	930	16500
Ngwane Maize mill	B/M			11829.2		
Ngwane Mills	B/M			360		
Online Tyres	T			87	87	2000
Palfridge	B/M			18	18	33000
Parmalat	B/M	6000	143000	20	20	30000
Pearl Laundry	S			28		
Shun Manufacturing	B/M			66	66	9000
Spintex	B/M			139	139	8400
Steel & wire	T			1		
Sun Tax	B/M			116	116	9600
Sunshine Sugar	D			86	86	15000
Swazi Candles	B/M			5		
Swazi Paper Mills	B/M	750000	550000	7500	7500	1430000
Swazi Plastic	B/M			11	11	2400
Swazi Poulty	B/M	31500	24000	714	714	10000
Swaziland Beverages	B/M	19100	200000	2882.8	2882.8	66000
Swaziland Meat industries	B/M	93000	158000	1676	1676	18000
Swaziland Milling	B/M			99.5	99.5	11000
Swaziland United Bakeries	B/M			201	201	30000
Taitex	B/M			7	7	7200

COST OF WASTE MANAGEMENT						
COMPANY	**Category**	**Effluent**	**Cost of Effluent**	**Solid Waste (SW)**	**Costed Solid Waste**	**Cost of Solid Waste**
Tex Ray Swaziland	B/M			242.5	242.5	22000
The reclation Group	R			2		
Trentyre Swaziland	T			44	44	1000
Tuntex	B/M			601	601	8400
Turbo Diesel	S			3.8	3.8	1320
Welcome Textiles	B/M			301	301	18700
YKK	B/M	31625	48000	55	55	48000
TOTAL		**1019407.5**	**2508000**	**28920.105**	**16612.8**	**2090620**