NEW OPERATION IDEA
FOR
EXISTING INDUSTRIAL ESTATES

Æ IMPLEMENTATION OF ECO-INDUSTRIAL PARK CONCEPT
INTO WATER MANAGEMENT OF EXISTING INDUSTRIAL ESTATES

by

Chiu Kwan Hon

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School of Environmental Sciences
University of East Anglia
University Plain
Norwich
NR4 7TJ

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獻給我的父母, 謝謝他們對我這些年的支持
**ABSTRACT**

Sustainability requires a consideration of the environmental dimension as well as social integrity and economic efficiency. Further, ecological systems emphasize interaction and interdependence. Definitions of Eco-Industrial Parks have begun to address this by referring to them as communities of business. In order to determine the EIP implementation possibility for existing industrial estates, water management in case-study was used to examine the possibility. After analysis, potential water closed-loop cycle was determined. Checklist, checklist-dependant questionnaires and methodology in this dissertation has been developed as an analytical package for further implementation.
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## GLOSSARY

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<td>Cornell WEI</td>
<td>Cornell University Work &amp; Environment Initiative</td>
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<td>EA</td>
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<td>Eco-Industrial Park</td>
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<td>EPA</td>
<td>Environmental Protection Agency</td>
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<td>IE</td>
<td>Industrial Ecology</td>
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<td>SD</td>
<td>Sustainable Development</td>
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<td>SS</td>
<td>Strong Sustainability</td>
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<td>SSSI</td>
<td>Sites of Special Scientific Interest</td>
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<td>UK</td>
<td>United Kingdom</td>
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<td>UNEP IE</td>
<td>United Nations Environmental Programme Industry and Environment</td>
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<tr>
<td>WS</td>
<td>Weak Sustainability</td>
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<td>WCED</td>
<td>World Commission on Environment and Development</td>
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INTRODUCTION

In 1987, the concept of sustainable development (SD) was introduced. Environment, economy and society become key components of the SD triangle. To achieve sustainability, two strategies, command-and-control and market mechanism, have arisen (Miller, 1999). Relevant regulations and legislations at the national and international levels have been enacted to regulate human activities, for example, the Environmental Protection Act in the United Kingdom, and international law of natural resources protection, etc. These legislations and agreements not only protect the environment by restricting discharges and emissions, but also increase the general public’s awareness. To meet the legal requirement and increase competitiveness, different approaches have been outlined and applied to various business activities. However, most of the above classify environmental problems into separate areas (Allenby 2002). In the current situation, the environment is difficult to manage in an integrated way, although legislations and agreements can allow for clear objectives and targets for each specific component of the environment. The “Industrial Ecosystem” which mimics the interaction within natural ecosystem to industrial activities is one of the sustainable approaches (Lowe et al., 1997a). The “Eco-Industrial Park” is the application of Industrial Ecosystem methodology to modify by-product exchange within industrial parks. The aim of EIP is to achieving zero waste production through mimicking the food net within the natural ecosystem and to reduce use of resources (Lowe, et al. 1997b).

Many new EIP projects have been undertaken in Canada, the USA and the UK (Cornell WEI, 2002, Deutz, et al. 2003). Although some EIPs projects failed, several projects are still running properly or under development (Cornell WEI, 2002). However, most of the projects are focussed on designing new EIPs rather than modifying existing industrial estates to the EIP criteria (ibid). This research aims to fill the gap by investigating the application method for implementing the EIP criteria to existing industrial parks.

In this dissertation, a method of converting an existing industrial estate to an EIP by implementing EIP criteria to water management will be analysed. The overall objective is to develop a framework for applying the concept of “Eco-Industrial Park” to existing industrial parks. An existing industrial park located at Attleborough, Norfolk has been used as a case study. Several EIP-related questions will be answered by examining the case study. The questions include whether the EIP concept can be apply to an existing industrial park, what kinds of essential and add-in information are required for the baseline study and what the potential method of implementation and obstacles to it are. Checklists, questionnaires and
methodology in this dissertation will be discussed and evaluated to develop a guide package for future application through studying these questions.
RESEARCH CONTEXT ANDAIMS

The concept of sustainable development (SD) has been introduced in the Brundtland Commission’s report *Our Common Future* (WCDE, 1987). The framework for sustainable development was developed at the Earth Summit in Rio de Janeiro in 1992 (United Nations, 2003). The most common and acceptable definition is as follows:

*Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs* (WCDE, 1987).

Bruce (1992) explained this concept in more depth:

“First, development must not damage or destroy the basic life support system of our planet earth: the air, the water and the soil, and the biological systems. Second, development must be economically sustainable to provide a continuous flow of goods and services derived from the Earth’s natural resources, and thirdly it requires sustainable social systems, at international, national, local and family levels, to ensure the equitable distribution of the benefits of the goods and services produced, and of sustained life supporting systems.”

In other words, the objective of the concept is to allow an increase in people’s living standard (broadly defined) with particular emphasis on the well-being of poor people, at the same time avoiding uncompensated and significant costs on future generations (Turner, *et al.*, 1993). As the SD means different things for different people (for example: UN 1991, Goodland, Daly & El Serafy, 1991, and Falkenmark, 1988), two positions have been advocated. These are as Weak Sustainability (WS) and Strong Sustainability (SS) (Turner, *et al.*, 1993). WS requires the transfer of an aggregate capital stock to be not less than the one that exists now, i.e., people can accept serious environmental consequences while increasing economic benefits. On the other hand, SS means that any benefit in any component area may not be the cause of environmental degradation in the other two areas, except on a limited basis. Since environmental degradation can damage relevant economic development (WCDE, 1987), SS has been adopted in this dissertation for maintaining and improving the natural environment.

The primary objective of all levels of the government is maintaining and / or increasing the growth rate of the economy, one of the triple bottom lines of SD (Miller, 1997). The “Industrial Estate” emerged in industrialized countries towards the end of the nineteenth century as a means of concentrating industrial activities and boosting the economy (UNEP IE
An industrial estate, in its simplest definition, can be described as

“a large tract of land, sub-divided, and developed for the use of several firms simultaneously, distinguished by its shareable infrastructure and close proximity of firms.” (Peddle, 1993).

Since the 1970s, there has been a massive increase in the number of industrial estates worldwide (UNEP IE, 1997). According to a survey of estates of various types, carried out by the International Development Research Council (IRDC) in 1996 (Cited in UNEP IE, 1997), there were 12,600 estates in 90 countries, with around 200 in the UK. The numbers continue to rise. As industrial estates encourage a concentration of industrial activities (UNEP IE, 1996), the environmental impacts of each factor are multiplied by the presence of the others (RIET experts forum, 1998) leading to major impacts on the environment, human health, safety and finance. Therefore, the levels of resource consumption and environmental degradation involved in our current economic/industrial system is one of the major obstacles to achieving sustainability (Lowe et al., 1997).

Since 1989, a systemic concept for dealing with environmental problems caused by industry has appeared after evolving for several decades (e.g.: ECE 1978, Erkman 2003, Gussow and Meyers 1970, Hoffman 1971, and Jones et al. 1994). Because this concept mimics the best features of the biological analogy within a natural ecosystem, it has been called the “industrial ecosystem”. The underlying concept of the industrial ecosystem was introduced by Frosch and Callopooulos (1989), who stated that:

“The traditional model of industrial activity, in which industrial manufacturing processes take in raw materials and generate products to be sold plus waste to be disposed of, should be transformed into a more integrated model: an industrial ecosystem. In such a system the consumption of energy and materials is optimised and the effluents of one process, whether they are spent catalysts from petroleum refining, fly bottom ash from electric power generation or discarded plastic containers from consumer products, serve as raw materials for another process.”

Gertler (1995) gave a valuable definition for developing industrial ecosystems:

“An industrial ecosystem is a community or network of companies and other organisations in a region to chose to interact by exchanging and making use of by-products and/or energy in a way that provides one or more of the following benefits
over traditional, non-linked operations:

- Reduction in the use of virgin materials as resource inputs
- Reduction in pollution
- Increased systemic energy efficiency leading to reduced systemic energy use
- Reduction in the volume of waste products requiring disposal (with the added benefit of preventing disposal-related pollution)
- Increase in the amount and types of process outputs that have market value.”

*(Gertler, 1995 Chapter 1)*

In this concept, the system of raw materials extraction, manufacturing processes, product use and waste disposal in the community should imitate the recycling of materials in the natural ecosystem (Smolenaars, 1996).

Gradel and Allenby conceptualised the relationship between environment and industries/Industrial Ecosystem (cited in Lifset and Graedel, 2002). Typology A indicates the current industrial system, which requires unlimited resource and produces unlimited waste. Typology B and C shows ecosystems which used external energy and limited resource and generate limited waste, and resources which will be reused and recycled in the ecosystem (see figure 1).

*Figure 1: The Models of Three Typologies of Ecosystem by Gradel and Allenby (Cited in Lifset and Graedel, 2002)*
Typology A is a model shows current system, it consumes unlimited resource and generates unlimited waste. Typology B shows the ecosystem(s) consume external energy and limit resource, most of by-products are recycled and/or reused within the ecosystem(s) and only limited waste will be produced. Typology C shows a ideal ecosystem, all the by-products will be reused as raw materials. Only energy will be consumed externally.

As Industrial Ecosystem (IE) is a useful framework for helping to achieve a more sustainable industrial development, it is attractive for project designer and decision-maker (Balkau, 2002). Industrial estates have the potential to be important players in implementing the IE concept (ibid). Eco-industrial parks are based on industrial ecology concepts - they aim to improve business performance while reducing pollution and waste (Cohen-Rosenthal, 1996). A US-Environmental Protection Agency research project (cited in Lowe et al. 1997b) defined this as follows:

An eco-industrial park is a community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resource issues including energy, water and materials. By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would realise if it optimised its individual performance only.

The goal of an EIP is to improve the economic performance of the participating companies while minimising their environmental impact. Components of this approach include new or retrofitted design of park infrastructure and plants; pollution prevention; energy efficiency; and intercompany partnering. Through collaboration, this community of companies becomes an “industrial ecosystem.”

For example, the industrial symbiosis in Kalundborg, Denmark is one of the most successful Eco-Industrial Parks (Christensen 1999). In this case, all by-products, such as water, energy, sulfur in gas, and biomass have been reused by the power station, the oil refinery, the plasterboard factory, the biotechnological company, and communities. The symbiosis relationship has been shown as figure 2.
In the UK, there are well advanced plans to develop a Sustainable Growth Park in South Yorkshire (Green Futures, 2002) and a Business Council for Sustainable Development initiative for a National Industrial Symbiosis Programme with target sites in the Humber subregion, the West Midlands, Merseyside, Southampton, Grangemouth, the North East and Ireland (BCSD, 2002).

The EIP recognises the connection of materials, products and waste, and the importance of sharing infrastructure and services provided by the natural environment and local communities (Côté and Cohen-Rosenthal, 1998). Therefore, it has potential to lead beneficial impacts on industries, environment and society and achieve SS.

For the companies involved, the EIP offers an opportunity to save cost and expand revenues in existing daily operations. Increasing efficiency may enable the participators to produce more competitive products. In addition, the companies could create new markets through exchanging information and waste. Members may be able to identify new organisational, legal and economic innovations. Furthermore, training, purchasing, emerging management team, and environmental information system can help the members to achieve greater economic efficiency and sustainability.
As the EIP can encourage the efficiency of process efficiency and sharing of the infrastructure and services, both the degree of demand on natural resources and the degree of pollution production may be reduced. It can provide therefore as a real setting for the principles of sustainable development in action. Such a park is likely to attract leading-edge and green corporations and open niches for new local ventures. Both will create new career opportunities and boost the economic growth rate. Apart from these, it may help to provide a healthy, safe, and sustainable living environment to the residents and employees. The enhanced processing efficiency and reusing and recycling can maintain and even preserve local and/or regional natural environmental features.

The major components of the environment are air, water, soil, wildlife, minerals, and natural recycling systems (Miller 1997). The United Nations consider water to be the major issue for the 21st century due to its essential function for natural life and human beings as water is widely used in household, commercial, industrial and agriculture (EA, 2003). It is a limited and precious resource, due to its annual available amount depending upon rainfall (EA, 2003). Only 0.606% of total water globally is readily accessible to the world (Miller, 1997). Water usage has a direct impact and an indirect one on the natural environment (Environmental Agency, 2003).

Any chemical, biological, or physical change in water quality that has a harmful effect on living organisms or makes water unsuitable for desired uses can cause water pollution (Miller, 1997). For instance, heavy metals in effluent could be accumulated in sediment, and be trapped in the space within soil when the effluent passes through (EPA, 2003a, 2003b). Like the direct impact on water quality, pollutants such as PCBs (Polychlorinated biphenyles), may be biologically and chemically resistant.

In order to conserve water resources, different legal frameworks restrict water usage and discharge. The European Community has been developing a policy on water since the 1970s. According to Taylor (2001), there are three areas related to water, surface water, groundwater and hazardous substances. In each area, the improvement targets and timetables have been specified. For instance, all EU surface waters and groundwaters will have to be improved to ‘good quality’ by 2016. Quality will be measured with respect to meeting all chemical quality standards together with achieving good ecological standards. In addition, there will be a requirement to severely restrict and in some cases to eliminate the discharge of hazardous substances. The discharges of priority hazardous substances must be reduced to zero within 20 years of their identification. Because of requirements of the complex Water Framework Directive, significant restrictions and potential significant technical problems and costs are required. Moreover, the monitoring requirements of this Directive will require a very large
increase in activity by the UK agencies. Therefore, it is vital that industries are essential to establish some initiatives for better management and efficient use of water. Due to the complex structure of industrial estates, wastewater discharged from different types of tenant industries affects the overall quality and quantity of effluent (UNEP IE, 1997). The complex nature of discharged water will reduce the wastewater treatment efficiency and pollute the water table and soil (UNEP IE, 1997). A number of researches have been completed on managing energy exchange and efficiency, water management and waste management in general areas (e.g.: Silvo et al., 2002, Akisawa, 1999, Mohanty & Panda, 1995 and Rathi, 2003). Compared with these researches, however, there are only few studies of water management in the industrial ecosystem. Therefore, water management in an existing industrial park is chosen as a object of study to look at the issue of maximising the efficient use of water on the estate.

In this dissertation, the term “water management” includes the development of alternative water resources, water efficiency, exchange within the industrial park and the community and wastewater treatment. It will improve protection of the long-term future environment and compliance with legal requirements, thus encouraging sustainable development.
GUIDES AND BEST PRACTICE SAMPLES

During the development and implementation of the concept of the EIP, different suggestions for implementation have been published (e.g.: Côté and Cohen-Rosenthal, 1998, Grant, 1997, Lowe et al. 1997b, UNEP IE 1997).

Grant (1997) pinpointed that a commitment to applying ecosystem principles to site planning and design is at high priority. Moreover, some applications of the EIP concept, such as eco-efficiency and ecological recycling, have specific applications. Eco-efficiency requires managers to minimize waste production and discharge and the ecological recycling require industries to seek to avoid exporting by-products behind to the site surroundings the site. For conserving water, for example, on-site wastewater treatment is the core of the whole strategy. The collection and disposal of wastewater and precipitation runoff and wetlands (natural and artificial ones) within or near with the industrial estate can treat and reuse wastewater on-site.

In addition, range of solutions has been introduced to reduce or eliminate the environmental impacts and achieve sustainable development in the technical report on Environmental Management of Industrial and Environment which was released by the United Nations Environment Programme’s Industry and Environment Office (UNEP IE 1997). Waste minimisation, recycling, and environmental management systems (EMSs) are the alternative elements for environmental management (UNEP IE 1997). Apart from the guidelines, a checklist for designing new eco-industrial parks has been attached to the Appendix. Although the UNEP did not publish a guide for implementing the concept of the EIPs, it established the outlines of such system, which include End-of-pipe treatment, Dynamic Input and Output, Clean Production, and Environmental Management Systems. For example, four options for EMSs in industrial estates have been mentioned in the RIET expert form. Those options, Enterprise, Infrastructure, Comprehensive and Environmental Charter, can offer more cost-effective integrated pollution control and address cumulative impact at different levels. These approaches stress the importance of source control which could be another core component of the EIP, and represents the final integration of the economic, environmental and social dimensions of SD (UNEP IE 1996, Lowe, et al.1997).

As a core element of the EIP is by-product exchange between companies to reduce waste generation and resource consumption (Lowe, 1997c), opportunities for the related information exchange are important for EIP implementation. The Nova Scotia Materials Exchange (RRFB Nova Scotia, 2002), for instance, is a web-based database for residents and businesses to
submit and browse listings of unwanted waste materials and post notices of materials needed. The residents and firms could contact the supplier directly to establish the exchange.

In reviews of seven eco-industrial park studies (Kalunborg, Denmark; Burnside Industrial Park, Nova Scotia, Canada; Bayport Industrial Complex in Pasadena, Texas; Londonderry, New Hampshire; Yale University Reports; and Brownsvill, Texas, Matamoros, Mexico and Devens industrial ecology project in Massachusetts, USA), substantial economic and environmental gains were found with EIP development. The annual economic and environmental benefits were found in these studies (Lowe et al., 1997a, 1997b, Martin, et al. 1996, Eco-Efficiency Centre, 2003). From the review, the annual reductions of millions of pounds of materials, waste and emissions were identified. The research showed significant potential for reductions in water drawdown. The examples also illustrated the major characteristics of an eco-industrial park. They are:

1. Material, water, and energy flows;
2. Companies within close proximity;
3. Strong informal ties between plant and estate managers;
4. Minor retrofitting of existing infrastructure; and
5. One or more anchor tenants (Grant, 1997)

For instance, the Devens industrial ecology project has taken some initiatives to fit the characteristics. The project altered the existing industrial activity (Devens Industrial Ecology Project, 2003). The project identified major material flows, and tried to recruit new companies to fill the closed loop material flows. Moreover, the water cascading process improved greywater reusing and recycling. In order to improve the relationship between the companies some activities, such as semi-monthly luncheons, have been held. As a result of the gatherings, closer ties can be developed and managers could work in more collaborative environment.

Apart from the case of Devens, Burnside Industrial park is the other Best Practice Sample. Through reviewing the website of the Eco-Efficiency Centre (2003), the industrial park produces a water-related fact sheet and action suggestions for public and company managers. For instance, Côté (1999) suggested that rain barrels could be used to collect water for landscaping purposes, and toilets and shower heads could be retrofitted to conserve water. Furthermore, the fact sheet suggested the business managers installing and maintaining the
Aside from infrastructures, the Environmental Management System (EMS) will be acted as on an Opportunity for engaging China's Economic Development Zones in Dalian, Mainland China (UNEP, 2003). The use of an EMS (ISO 14001) by the Administrative Group of the ETDZ to develop a more comprehensive approach to the wide range of environmental issues that they face in running the zone. This case provides an excellent insight in evolving from the infrastructure option to the comprehensive option for an EMS at the estate or zone level. Another similar approach to implementing the EIP concept has emerged in France, DSA Environment (cited by Cohen-Rosenthal, 1998). An eco-label for industrial park, “Programme d’actions labelise pour la maitrise de l’environnement (PALME)” provides a slight different interpretation of the EIP (Box 1). Moreover, there is a range of success water-efficiency measures at company level published at the Eco-Efficiency Centre (2003). Farnell Packaging Ltd. in the Burnside Industrial Park, for instance, strides in the conservation of resources and waste reduction have been achieved, and its 128 employees have adopted a philosophy that incorporates progressive practices into their daily routine. Moreover, the company has installed a closed loop glycol-based cooling system to reduce water consumption. According to the company’s report, the annual saving is greater than $5000 and the reduction in water consumption is 85%.

These guides and best practice examples (BPEs) have identified the different strategies to

### BOX 1: Some Elements of the PALME label for industrial parks (cited by Cohen-Rosenthal, 1998)

1. Prepare a site development plan, and have available the relevant regulations and guidelines  
2. Prepare an initial baseline “State of Environment” report for the site  
3. Establish a landscaping plan and architectural requirements for buildings  
4. Ensure compliance with (environmental) regulations and by-laws, and adherence to operational guidelines  
5. Establish and implement a plan for natural flora and fauna to maintain or re-establish the ecological balance of the site  
6. Implement a public awareness and information programme concerning natural environmental and conservation  
7. Establish an advisory service for clean technologies  
8. Develop and implement a “clean construction site” programme  
9. Establish a plan for solid waste management  
10. Establish a plan for industrial wastes and effluents  
11. Establish a plan for management of rainwater and surface runoff, and construction of any necessary installations  
12. Advise enterprises on noise reduction measures and materials for buildings and machinery  
13. Monitor site air quality and noise  
14. Establish an energy management plan for the site  
15. Investigate alternative energy sources  
16. Establish a liaison mechanism with relevant local authorities  
17. Establish a monitoring and coordination unit for the above
achieving aims of EIP. Through studying them, the methodology which is undertaken in this dissertation has been established. The suggestions and strategies in the guides and BPEs will be analysed and used in this case study.
**METHODODOLOGY**

In order to develop a guide framework, a systematic methodology is a core element. The detailed steps were identified as the following by Lowe, 1997 and Ehrenfeld, 1994. The methodology has been separated into four categories. In the first section, commitments from the landlord of the industrial estate and tenants companies have been made. In the data collection section checklists and checklist-dependent questionnaires have been developed, hence information and data related to the case have been collected in different ways. During data analysis and implementation, the methods of applying the EIP concept to water management in the case-study has been identified. Since the implementation of EIP depends on the checklists, checklist-dependent questionnaires and methodology, were revaluated by studying the case. These three will be organised as a guide package for further application.

In this research, Haverscroft Industrial Estate at Attleborough, Norfolk was used as a case study. To identify the baseline environment, existing tenant industries, quality and quantity of water related to company’s activities, and wastewater treatment process were surveyed by questionnaires and field-study. In addition, the surrounding environmental features were studied through consulting with stakeholders. Information collected has been used to determine potential water-efficiency measures.
**Figure 3:** The framework of methodology to implement EIP into water management (adopted from Lowe et al. (1997) and Ehrenfeld, J.R., (1994))
1 Commitments:

Asking commitments from tenant companies’ managers and landlords are an essential and important stage in this methodology. In this dissertation, the commitments from Haverscroft Industrial Estate were gained through Eco-Tech Centre at Swaffham, Norfolk as this research is part of an EU-funded project led by the centre. Aside from this, the relationship of trust already built between the centre and the industrial estate could improve the responses from the tenants and landlord.

2 Data Collection Section:

2.1 Literature review

The relationship between SD and EIP has arisen and been discussed in the past two decades. In addition, different implementation frameworks of EIP have been developed due to theoretical and practical experience. Elements in these frameworks were reviewed and concluded to develop a checklist and questionnaires which are used in this dissertation.

2.2 Checklists and checklist-depended questionnaires design

After the previous stage, a water-specific checklist (attached in Appendix A) was developed based on the framework (e.g.: Lowe, et al. 1997b, UNEP IE, 1996). The evaluated and simplified checklist could be understood by environmental specialists and the general public. To gather information required by checklist, two sets of questionnaires, one for landlords of industrial estate and the other is for the tenant managers, have been designed.

2.3 Collect information on surrounding environmental features

In this stage, specific information related to the surrounding environmental features of the estate has been collected, shown in Table 1. It was important to collect these data because they could provide a clear picture of the characteristic surrounding environmental features.
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<tr>
<td>Conservation Areas</td>
<td>Environment Agency, English Nature</td>
<td></td>
</tr>
<tr>
<td>Historical precipitation data at</td>
<td>The Met. Office</td>
<td></td>
</tr>
<tr>
<td>Attleborough region, and England &amp; Wales</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 1: Information related to environmental features around the case-study.**

*Problems in this stage:* There is no meteorological station at Attleborough, therefore, no accurate local historical rainfall data has been collected. After contacting the officer of the National Meteorological Archive Scott Building Sterling Centre, monthly precipitation data collected by the stations located at Rockland St Peters and Morley St Botolph, which are the two nearest meteorological stations (view as figure 4), and have been used to simulate the situation at Attleborough. Apart from the location of the stations, the data set collected at each station has some problems. Some data at some months/years are missed, and the most recent is 2001. To overcome the problems of missing data, the data from these two stations were combined. In other words, the precipitation data between 1993-1995 and 1998-2001 from Morley St Botolph was joined into the data set of Rockland St Peter (the original data was shown in the Appendix F and G).
2.4 Collecting information of water inputs and outputs in the estate by sending questionnaires to tenants and landlords.

The questionnaires designed for tenant companies and estate landlords, which is attached in the Appendix, were sent to the estate by Eco-Tech Centre in May. Ideally, the results of the questionnaires can be used to analyse the related elements of water management, such as quantity, distribution in time and the quality of water input and output of each company (Lowe, et al., 1997b). In addition, other questions were sent to the Anglian Water Ltd. to ask for the information on wastewater treatment and discharge.

Problems in this stage: In this stage, uncompleted questionnaires were the major problem although the percentage return was 100%. Questions concerning water consumption, use and disposal were confidential for some tenant companies, and several tenant companies cannot provide detailed data due to lack of monitoring and recording. In addition, several questions in the two questionnaires seemed difficult for those who did not have sufficient knowledge. For instance, most of the interviewees could not understand meaning of the “relationship of trust” in questions asking about the relationship between tenants and landlords. Moreover, the answers to several questions required time-consuming and costly monitoring. For example, there are no responses for the question concerning the inventory of wastewater processes.
Moreover, the fate of wastewater, such as discharge location and treatment process, from the industrial park, cannot be identified because of the lack of response from Anglian Water Ltd.

2.5 Visiting the industrial estate and surrounding environment in order to realise and observe what the realities are

In this stage, the site-visit was important for disseminating the collected information and check for matches with existing businesses. The visiting times were shown in Table 2:

<table>
<thead>
<tr>
<th>Visit Day</th>
<th>Data collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>29th May, 2003</td>
<td>Tenant industries and surrounding areas were identified</td>
</tr>
<tr>
<td>14th June, 2003</td>
<td>The storm water holes and areas eroded by water were identified.</td>
</tr>
<tr>
<td>20th June, 2003</td>
<td>Photos were taken and the roof area was measured.</td>
</tr>
</tbody>
</table>

Table: The visiting day and data collection

During the visits, the relevant data could be collected and used to support the questionnaires and verify the answers. Photos were taken under authorization. The scale and type of industries, the current on-site existed water-relative facilities were identified.

3 Data Analysis Section

3.1 Determine water-involved processing for each tenant and estate-wide operation

The data collected from the previous stages could be used to determine the water-involved processing in the estate. The water-involved process for each tenant and whole estate has been analysed (listed in table 3). The study could determine the quality of water consumption in the process.
Table 3: Elements in data analysis section

Problem in this stage: As the answers related to water-involved process and inventory in the questionnaires are time-consuming and knowledge-specific, the information could not be identified by studying the answers. To deal with this problem, general benchmarks for industrial sectors were used in this case-study.

3.2 Analysing quality and quantity of water consumption and discharge in each tenant and whole estate.

The quality of discharged water can be identified by studying relevant discharge consents and the quantity of water discharge could be analysed by evaluating the individual water bills (listed in table 3). As the amount and distribution of flow in time are different for each tenant, the volume requirement for each element in the water flow system is unique. The amount of
consumed water and wastewater could be used to determine the capacity of water facilities.

*Problem in this stage:* Water bills were not allowed to be collected due to lack of trust with the tenants and confidential purpose. The actual water-related information, such as quality and quantity, cannot be determined, so benchmark of the relative industrial sector and gender of the employees, therefore, was used in this dissertation.

3.3 Identify the potential significant environmental receivers around the case-study.

Through studying the information related to surrounding environmental features, potential environmental receivers were identified. The criteria listed in table 4 can be used to identify significant water receivers.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of wastewater</td>
<td>Components in the wastewater and the concentration are important factor to determine the potential environmental impacts.</td>
</tr>
<tr>
<td>Quantity of wastewater</td>
<td>Amount of wastewater is other factor. Either little amount but high concentration or low concentration but huge amount can cause significant impacts.</td>
</tr>
<tr>
<td>Level of wastewater treatment</td>
<td>Different levels of water treatment strongly affect the final characteristic of discharge.</td>
</tr>
<tr>
<td>Distance between disposal location and the potential area</td>
<td>Longer distance can provide more opportunity for wastewater degradation.</td>
</tr>
<tr>
<td>Type of water receiver</td>
<td>Total amount of water in the receiver and plantation in the receiver could dilute the final discharge. In addition, it affects carrying capacity.</td>
</tr>
<tr>
<td>Whether water extract from the potential areas</td>
<td>The water extracted from the potential source affects the water supply. It can affect the carrying capacity.</td>
</tr>
<tr>
<td>Importance of the areas</td>
<td>Type of the area reflects concern levels and importance of the area.</td>
</tr>
</tbody>
</table>

*Table 4: Criteria and reasons for identifying the potential significant environmental receivers.*

3.4 *Identify potential niches of close loop cycle within the estate and with the nearby environment to utilise existing water flows*

The quality and quantity of waste water discharge for each tenants and the whole estate are different. Hence, by reference to the data collection section, potential water-exchangeable niches have been identified.

*Problem in this stage:* Since there is not detailed water-related information, the quality and
quantity of water consumption and discharge of each company is undetectable. As a result, the water-interchange loop between tenants is difficult to determine in this case. However, the overall water consumption and discharge can be calculated by summed up benchmark of each tenant. The estate-level water collection, delivery and treatment facilities could be identified.

4 Implementation Section

4.1 Determine potential niches in close-loop cycle

The concept of the EIP is to mimic the biogeochemical relationship in natural ecosystems. In order to implement the concept, an action plan should be defined (GG67, 2003). In the plan, current operational cost, target cost and potential actions should be defined. According to the result of data analysis, the potential niches, such as consumers and businesses, alternative water resource, and cost-effective water treatment facilities, have been determined. To apply the EIP concept to existing industrial estates, a suitable and cost-efficient close-loop exchange cycle could be proposed.

Problem in the Stage: success of this stage depends strongly on the previous sections. Potential customers and businesses which could reuse the by-products may be identified to fit into the close-loop cycle. In this case-study, as the water-related process of tenants and whole estate cannot be determined, the direct inter-exchange of water between tenants cannot be identified. However, the estate-level water exchange cycle could be implemented.

4.2 Evaluate the advantages and disadvantages of the cycle.

The advantages and disadvantages of the by-products exchange cycle were evaluated after implementation and operation. The efficiency of closed-loop cycle should be analysed by monitoring which is part of management system. Through the evaluation, the exchange cycle was used to illustrate a potential opportunity with wide application.
INFORMATION OF THE CASE STUDY

During the research, several limitations occurred in the case-study. Therefore, some assumptions had to be made in the later stages.

For example, accurate water-related data could not be collected. The tenants in Haverscroft Industrial Estate are all Small- /Median-Sized Enterprises, most of them do not have any EMS in operation. As a result, the essential water-related information, such as quantity and quality of wastewater, cannot be collected during the data collecting because of lack of monitoring and documentation programmes. The limited research time does not allow building the trust relationship with some tenant companies. It means that some existing water-related data cannot be collected because of commercial confidentiality. In order to overcome this problem, benchmark of industrial sector and human daily usage had to be adopted to identify the general level of water consumption and discharge.

Aside from the water consumption and discharge data of tenants, some external environmental information also could not be collected due to the lack of response from some stakeholders. As a result, the potential environmentally significant water receivers could not be identified accurately.

1 Environmental information

1.1. Local rainfall

Comparison of the historical annual precipitation of England & Wales with that of Attleborough region (Figure 5) shows that the Attleborough region (620 millimetres) has a lower average level of annual precipitation than that of England & Wales (928 millimetres) in average.
Average Rainfall (1969 - 2001) at Attleborough Region and England & Wales

Data Source: The Met. Office

UK  Attleborough Region

<table>
<thead>
<tr>
<th>Rainfall in Millimetres</th>
<th>0</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
<th>700</th>
<th>800</th>
<th>900</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>928</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>620</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5: Average rainfall at Attleborough (620 millimetres) and England & Wales (928 millimetres) from 1969 to 2001.

In addition, through studying Figure 4 which was using rainfall data from the meteorological station at Rockland St Peter (Station No.: 204710) and Morley St Botolph (Station No.: 189349), the annual precipitation at this area falls into a constant range (figure 6). According to the local precipitation data (figure 5 and 6), the rainfall level was low throughout the area and the average varies from 600 to 670 mm per year. Although the most current predictions are for annual rainfall to increase, summers will become warmer and drier, meanwhile, winters would be wetter and stormier (LEAP of Ely, 2002). Although the relative drier climate limits the water supply and stresses the emergency of water efficiency, the precipitation could be developed to re-use in some domestic and production processes which do not require pure water. After purity treatment, the precipitation could be used for washing and even drinking (Gould and Nissen-Petersen, 1999).
Figure 6: Historical annual and monthly rainfall data (1969 – 2001) at Attleborough and England & Wales. Above: Historical annual rainfall data for 32 years, the range is from 400 millimetres to 800 millimetres and the trend is constant. Below: Average monthly precipitation at Attleborough area. The range is narrower, and amount of precipitation each month is similar.

To determine the potential for using precipitation runoff, the total runoff can be analysed by using the calculation formula developed by Gould and Nissen-Petersen (1999), which is shown as follow:
\[ S = R \times A \times C_r \]

Supply \hspace{1cm} Rainfall \hspace{1cm} Area \hspace{1cm} Coefficient (Runoff)

Where: \( S \) = Mean Rainfall Supply in cubic metres (m³)

\( R \) = Mean annual rainfall in metres (m)

\( A \) = Catchment area in square metres (m²), for a roof or sloping catchment, it is the horizontal plan area which should be measured

\( C_r \) = Runoff coefficient

In this case, the value of \( A \) (total area of industrial estate) is 21,594 square metres, \( R \) (average annual precipitation) is 0.69 metres and \( R \) (average monthly precipitation) is shown in table 5. So the annual precipitation harvesting is:

\[ S = 0.69 \text{ m} \times 21594 \text{ m}^2 \times C_r \]

The monthly harvesting is:

\[ S = R \times 21594 \text{ m}^2 \times C_r \]

After calculated, the result is shown in table 5 by using different runoff-coefficient values:

<table>
<thead>
<tr>
<th>Average Precipitation</th>
<th>Potential Rainfall Harvesting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(m³) ( C_r = 0.8 )</td>
</tr>
<tr>
<td><strong>January</strong></td>
<td>54.54</td>
</tr>
<tr>
<td><strong>February</strong></td>
<td>38.55</td>
</tr>
<tr>
<td><strong>March</strong></td>
<td>47.32</td>
</tr>
<tr>
<td><strong>April</strong></td>
<td>52.39</td>
</tr>
<tr>
<td><strong>May</strong></td>
<td>44.54</td>
</tr>
<tr>
<td><strong>June</strong></td>
<td>54.28</td>
</tr>
<tr>
<td><strong>July</strong></td>
<td>49.30</td>
</tr>
<tr>
<td><strong>August</strong></td>
<td>49.68</td>
</tr>
<tr>
<td><strong>September</strong></td>
<td>50.93</td>
</tr>
<tr>
<td><strong>October</strong></td>
<td>55.59</td>
</tr>
<tr>
<td><strong>November</strong></td>
<td>65.03</td>
</tr>
<tr>
<td><strong>December</strong></td>
<td>57.55</td>
</tr>
<tr>
<td><strong>Annual</strong></td>
<td>619.72</td>
</tr>
</tbody>
</table>

Table 5: Annual and Monthly Potential Rainfall Harvesting at the estate, where runoff coefficient is different (0.8 ~ 0.9). The annual and monthly average precipitation are calculated from the historical precipitation data (1969~2001).
As shown in table 5, the potential annual harvested rainfall is 11374.81m³ where the $C_r$ is 0.85, and it is 10705.70m³ where $C_r$ is 0.8.

1.2. Sensitive environmental receivers:

After contact with English Nature, there are two important wetland SSSIs which location is shown in figure 7 in the vicinity of Attleborough:

- **Swangey Fen SSSI**: it locates at the south-west of the industrial estate. In addition to its SSSI status, in additional to its SSSI status, the site has its international importance and is a component of the Norfolk Valley Fens Special Area of Conservation (SAC).

- **Old Buckenham Fen**: it is located at the south of the industrial estate.

Moreover, several plantations and heaths areas are near with Attleborough. Hargham Heath, Brakehill plantation and Burthill plantation, for instance, locates at the south of the industrial estate, and the river Thet passes Attleborough. However, there is not any sensitive areas within a 1 kilometre of the industrial estate (Environment Agent, 2003, Personal Contact). Asides from these major receptors, there are some water pools around the industrial estate.

![Figure 7: Natural environment nearby Haverscroft Industrial Estate (OS Survey map, 2002)](image_url)

The water quality of rivers near the estate, which include Buckenham Stream, Stow Beden Stream, and Thet, are poor. The water quality of river Thet, for example, has been contaminated...
since 1985. According to the Chemical and Biological General Quality Assessment (GQA) grades of river Thet, the range of chemical GQA grades is from fair to poor, both of phosphate and Nitrated GQA are high or very high. They all indicated that the quality of surface water are lower than standard.

Aside from the surface water, the ground water was also studied. The site of industrial overlies a major aquifer with soils of intermediate leaching potential (EA, Personal contact, 2003). In other words, the potential groundwater impact may be happening as wastewater contaminates ground water through leaching into soil. However, from figure 8, there is not protected groundwater area under the site of case-study. Therefore, the significance may be reduced.

![Source Protection](image)

**Figure 8: The aquifer under the study area. (Source: Environment Agency, 2003. scale: 1:250,000)**

According to Environment Agency (2003, Personal Contact), there are four areas surrounding the industrial estate, which have consent for discharge currently, apart from the industrial estate. Three of them are sewage discharges (final/treated effluent), and one is unspecified. In addition, Anglian Water services Ltd. have also held two discharge consents which are located at Cambridge. These two consents are sewage and miscellaneous discharges. All of them may have contaminated the water bodies around the site of case-study.

Focus on detail, agriculture and resident areas are major elements of the surrounding
environment (figure 9). The pumping station in a reservoir which is suited at the east of the estate collects storm water from the industrial estate and pumps it into the reservoir. The water will be used to adjust the water level in the surrounding system. In addition, a garage is located at the north-west of the estate, and a large grassland is at the south of the estate. In the industrial estate, most of areas are buildings and transportation areas (roads and car parks). Only 2 small areas of grasslands exist in the centre of the estate. However, because of water erosion, the plantation cover at these areas is relatively poor (shown in figure 10). Limited vegetation area on the estate may decrease the biodiversity and efficiency of water retention at the site.
Figure 9: Surrounding environmental feature at Haverscroft Industrial Estate at Attelborough, Norfolk. (Source: EDINA Digimap)
Figure 10: Vegetation cover on the estate

2 Information related to the industrial estate and tenant companies

Haverscroft industrial estate locates at the south-west part of Attleborough. This private estate began operations in 1976. However, the estate organises any major infrastructure work by cooperation with Breckland County Council. In this estate, the small retail and light industries are major tenants. The estate does not have an estate-wide environmental management system and formal monitoring process in operation, but the landlord is willing to operate such system in the future. There have not been any initiates undertaken to build up a relationship of trust between tenants and operate information-exchanged opportunities although he was willing to encourage them. Therefore, the information on water-efficiency Best Practice Sample has not been disseminated between tenants. There are 27 tenant companies in the industrial estate currently (shown in figure 11). Refer to the definition of European Commission (European Commission, 1996), all of the companies can be classified into micro- / small-size private enterprises as the range of number of employee in these companies are from 2 to 35 people. In order to overcome the problem of lacking water information, benchmark has to be used.
According to the finding from data collection section, there are not any on-site water treatment facilities on the estate. Storm water grids on the estate (see in Figure 12), work with municipal sewers, manholes and sumps, collected and delivered surface wastewater into the Anglian Water sewerage system. In other words, Anglian Water Ltd. is responsible for the whole industrial wastewater treatment service. Since the quality of wastewater often fall below the minimum legal criteria, the landlord has not received any concern or complaint related to any water issues listed in the questionnaires. However, during the site-visit, evidences of water erosion (figure 10) have been identified. These evidences prove that the efficiency of water collection in the sewerage system is relatively lower. Although the returned questionnaires showed that most of tenants do not have any discharge consent, but some evidences of potential water pollution was found during site visit. Petrol leakage (figure 13) from the mower repairs, for example, may cause potential water pollution on surface water and groundwater.
While studying the relationship between tenants, almost all companies identified that they know manager(s) of other tenants in the estate. However, there is not any cooperation or environmental-friendly themes on the estate to enhance the relationship. However, one company exchanges all information with its parent company within the estate. The information-exchange way could be acted as a sample or model for future cooperation. When asking the willing to set up an waste-exchange information database, 91% of tenant will not set up/do not know how to establish the database, while only 9 per cent of companies are prepared to build
Although the actual water consumption of each company could not be determined in the study period, benchmark of industrial sector and daily domestic use (male and female) had to be used. The range of water consumption is from 165.00 to 5085.00 cubic meters annually. The total principal water consumption for the whole industrial estate is 16739.80 cubic metres. In order to identify average monthly demand of whole estate, the annual demand can be divided by 12, which is:

\[
\text{Monthly demand} = \frac{\text{Annual demand}}{12}
\]

\[
= \frac{16739.80}{12}
\]

\[
= 1394.98 \text{ (m}^3\text{)}
\]

The amount of principal annual and monthly water demand identified the potential amount of water consumption and discharge during a year. They will be compared with the potential harvested precipitation runoff on the estate to analyse the possibility of runoff reuse.
IMPLEMENT THE CONCEPT OF IE INTO THE CASE

1 BASIC DESCRIPTION OF WATER CLOSE-LOOP SYSTEM

In order to apply the concept of EIP into water management, the water use in this estate should be modified to the ecosystem typology B and C mentioned before. According to a table in GG67 (Environment Technology Best Practice Programme, 2003), the closed loop recycle with treatment can save 60~90% water per project. However, lack of information interchange between tenants at this case cannot be identified. Instead, In this case, several approaches, such as alternative water supply, on-site wastewater treatment, recycle, estate-wide Environmental Management System (EMS) and environmental-friendly schemes, all were suggested and undertaken in guides and BPEs, can be implemented to apply the EIP concept into water management. They were categorized into two sections. In the infrastructure construction section, the rainfall catchment, source control and treatment wetland have been introduced. The infrastructure aftercare management, environmental-friendly schemes and group environmental management system have been classified in the management section.

After comparison of the local rainfall and water consumption of industrial estate, precipitation can be used as an alternative water supply although East Anglia is driest region in England (National Rivers Authority of Anglia Region, 1994). The wastewater produced from the whole estate and precipitation runoff in the estate could be collected and stored in a constructed treatment wetland for treatment and future use. In addition, source control approaches could also be implemented to reduce the water consumption in the tenants and whole estate. As most of companies consume and generate relative low water annually, BPS could be acted as an archer in this estate. However, because of the soil characteristic, any wastewater treatment infrastructures have be followed precaution principal to prevent water contaminations

Sufficient management could maintain and/or enhance the efficiency of water-related facilities. Joint Environmental Management System (EMS) can be applied in this case. In order to increase environmental awareness and water efficiency, a group EMS certification programme is one of cost-effective methods. Furthermore, relative environmental education and training opportunities could be provided to employees. These opportunities will bring the concept of EIP into daily operation. Meanwhile, educating together can maintain and enhance the relationship between companies and/or employees (Detuz et al., 2003). The relationship is an essential part for future information exchange. Moreover, the infrastructure aftercare managements are also important for maintaining and enhancing the water efficiency.
2 INFRASTRUCTURE CONSTRUCTION

- **On-site Constructed Treatment Wetland**

According to Hynes (1969), effluents are an essential by-product of modern civilization. During the business activities of different industrial sectors, various types of combinations of pollutants are generated. For example, car body repair workshops generate solvent waste, and printing plants release inks and dyes (Stauffer 1998). In order to treat wastewater to cope with legal requirements, wastewater treatment plants are required. However, the off-site treatment facilities may cause other problems. Transport of wastewater, for instance, will cause other environmental problems, such as leaching and energy consumption. Therefore, the on-site wastewater treatment can provide an environmentally sound strategy. It prevents migration of potential water pollution during water transportation and can also provide a biological wastewater treatment and develop an alternative water supply source by recycling wastewater (Kadlec and Knight, 1996).

The on-site natural system can be a low-cost, low energy solution that works by recycling resources within a biological system (Stauffer 1998, Shutes, 2001). As there are not any natural wetlands near the case study, to prevent potential ground water pollution, constructed wetlands could be designed near/in the industrial estate as an alternative. The treatment wetland gives economic, environmental and social benefits at the same time. Firstly, treatment wetlands are not inexpensive to build and operate but they usually cost less than chemical and physical treatment processes (Mitch and Gosselink, 2000). The wastewater could be treated and reused as raw material. It will reduce the cost of water consumption. Apart from the economic benefit, wetlands have been described as “nature’s kidneys” in which wastewater can be treated to prevent any potential water pollution (Mitch and Gosselink, 2000). In addition, wetlands can attract different wetland-base species to form a wetland ecosystem. Therefore, it can be acted as a public recreational area for local communities and some interest parties, such as birdwatchers, and joggers (Shutes, 2001, International Water Association, 2000).

Although there are several different types of treatment wetland systems, but they all rely on three key components: microbes, plants and substrate (Stauffer, 1998). The substrate from wastewater and other water sources supports the plants, while the roots of the plant provide a home for a variety of microbes. The treatment wetlands have been proved that they can prove secondary and tertiary treatment for municipal wastewater and remove metal, adjust pH, reduce BOD and filter suspended particles in industrial wastewater (Karathanasis, et al., 2003, Schwartz & Boyd, 1995).
There exist two types of constructed wetland system: surface-flow wetlands and subsurface-flow wetlands. Just as name of surface-flow wetland implies, the water lies above the surface of the substrate. On the other hand, the wastewater flows through the substrate rather than above it at the subsurface-flow wetlands (Stauffer, 1998). The choice of wetland system mainly depends on quality of wastewater and relevant legal requirements. For example, horizontal system is efficient for reducing the levels of BOD and total suspended soil (TSS), but not for ammonia nitrification (Mantovi, et al., 2003). Since the treatment process occurs below the ground surface where condition are generally warmer during the winter, subsurface-flow constructed wetlands is more suitable than surface-flow one for this case (Stauffer, 1998, Mitch and Gosslink, 2000).

Although subsurface-flow wetlands are common in Europe, a combination of these two types of wetland system with different vegetations was chosen to improve treatment efficiency (Poach, et al., 2003, Steinmann, et al., 2003). Shutes, et al. (1996) has claimed an idealised layout of constructed wetland which was shown in figure 14. The wastewater should pass through an oil separator and direct to settlement pond to reduce the substances volume. After the pre-treatment, the treatment generally occurs if effluent passes first through a vertical flow system and then through a horizontal flow system. In this design, ammonia can be nitrified to nitrate by aerobic bacteria in a vertical flow system and the product can be denitrified to nitrites and nitrogen gas in horizontal flow system by anoxic bacteria. Other chemical pollutants, such as BOD, total suspended solids, and phosphorus can be treated at both systems. Furthermore, the biological pollutant, such as pathogen, faecal coliform, can be removed in horizontal flow system by bacteria and fungi because of longer retention time (Hill, 2003, Karathanasis, et al., 2003). The efficiency of pollutant remove varies considerable, from virtually nil to greater than 90% but generally they are acceptable (see Table 6).
<table>
<thead>
<tr>
<th>Constituent</th>
<th>In (milligrams per litre)</th>
<th>Out (milligrams per litre)</th>
<th>Removal efficiency (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>38.8</td>
<td>10.5</td>
<td>73</td>
</tr>
<tr>
<td>Suspended solid</td>
<td>49.1</td>
<td>15.3</td>
<td>69</td>
</tr>
<tr>
<td>Ammonia</td>
<td>7.5</td>
<td>4.2</td>
<td>44</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>14</td>
<td>5</td>
<td>64</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>4.2</td>
<td>1.9</td>
<td>55</td>
</tr>
</tbody>
</table>

Table 6 Performance Data for an Average Constructed Wetland (Source: Pries, 1994). This table shows the removal efficiency of different constituent in a constructed wetland. Although the efficiency varies, they can be improved by limited water loaded and better management.

However, an impermeable liner should be installed under the base soil of the treatment wetland in this case to prevent the leaching of wastewater and sludge (EA, Personal Contact, 2003). Stauffer (1998) suggested that “many poor results can be attributed to systems that are overloaded, poorly managed, poorly designed, optimized for the removal of different pollutants or not yet fully established.” From that point, the further sufficient managements are required to maintain and enhance the treatment efficiency.

- **Rainfall Catchments**

The pollution, over-exploitation of existing sources and maintenance problems increase the pressures on finite water resources. (e.g.: Postel, 1992, Falkenmark, 1989). Thus, rainwater catchment is one simple and efficient water resource. In the last 20 years, the rainwater collection has undergone a major renaissance in many countries (Boers, T.M. and Ben-Asher, J., 1982, Gould and Nissen-Petersen 1999).

The collected precipitation runoff can be used in industrial process and domestic usage. To harvest the rainfall, the rainwater catchment system consists of a number of components:

- A collection surface where the rainwater runoff if collected
- A storage reservoir where the rainwater is stored until required
- A delivery system for transporting the water from the catchment to the storage reservoirs.

(Pacey and Cullis, 1988, Gould and Nissen-Petersen 1999)

According to the Met. Office (Figure 3), the average annual precipitation (1969~2001) at Attleborough is 620 millimetres and average monthly precipitation is quite similar (about 51.64
millimetres) for each month. Comparing with the overall annual demand in the whole estate (16739.80 m³), the amount of potential harvested rainfall can supply 63.95% \((C_r = 0.85)\) or 67.95% \((C_r = 0.8)\) water consumption. Similar, average monthly demand is also higher than potential monthly harvested rainfall. Through this aspect, the harvested rainfall can supply some water consumption in the industrial estate. The runoff in the estate can be collected as one of the alternative water sources.

To collect the rainfall runoff, a catchment system has its specific catchment surface, storage reservoir and distribution system (Tian Y., Li F. and Liu P., 2003). The wide variety of catchment surface can be used to collect and concentrate the rainwater. In this case, the roof catchment and ground catchment can be used. The roof area of each unit and concrete transport infrastructures are impermeable because they are already in place and designed to shed water. Therefore, the runoff coefficient \((C_r)\) is relatively high \((0.8–0.85)\). The runoff coefficient takes into account any losses due to leakage, evaporation and overflow (Gould and Nissen-Petersen, 1999).

In order to convey rainwater runoff from the catchment surface to the storage reservoir, delivery systems is required. They can divide into different systems for different catchment system. In this case, the existing gutters and stormwater collection system on roads and parking areas can be used as delivery system. However, the gutter system requires modification because a properly fitted and maintained gutter-downpipe system is capable of diverting more than 90 per cent pf all rainwater runoff into the storage tank (Ree 1976). The size of gutters and downpipe system and rubbish removal are important issues for the delivery system. In general, the simplest and cost-efficient method for rubbish removal, such as leaves and other debris, is to place a coarse wire mesh over the top of slightly raised downpipe inlet at the end of the gutter. The disadvantage of this method, however, is that it is easily blocked and can stop the inflow completely. As a result, a guttersnipe, a self-cleaning coarse rainwater filter system, can be implemented (Finch, 1994). In addition, the size of gutters and downpipe system affects the efficiency of rainwater collection. The runoff may be lost during heavy storms if gutters are too small and overflow. According to Hasse (1989), a useful rule of thumb is to make sure that there is at least 1 cm² of gutter cross-section for every 1 m² of roof area. Apart from wider gutters and downpipe, splash guards, which were originally developed, can be installed on corrugated-iron roofs to prevent runoff overshoooting the gutter due to the gradient of the gutter (Skinner, 1990). For the ground catchment, the slope of road surface can direct rainwater to the edge. Grids at the edge can collect the runoff. However, additional underground pipelines which connect with the existing stormwater grids can be installed to transport the runoff to
storage tank.

After collecting the runoff, the collected water has to be treated and stored for future consumption. Referring to the objectives, the type of reservoir is designed and constructed carefully as this part is most expensive for the whole system. In this case, the surface of the catchment system, such as the road and parking area, may cause water contamination due to leakage of petrol and other hydrocarbons (see figure 12). Therefore, treatment of harvested rainwater runoff is necessary before future use. A constructed treatment wetland is used as a storage reservoir and treatment facility.

Since catchment area, delivery system and water storage are three basic factors that impact on the cost of rainwater harvesting, total installation cost is a function of catchment area, storage size, rainfall pattern, evaporation, land management factors, seepage rates of the catchment and the tank, and irrigation depth and area (Pandey, 1991). In this case, the existing roof area and road surface could be acted as catchment system, the treatment wetland could be used to store and treat collected runoff, and existing stormwater grids could be a part of delivery system. As a result, addition cost of the rainfall catchment is to install a collection pipe from the grids.

In addition, reused grey-water which is the used water from bathtubs, showers, sinks and laundry machines (Stauffer 1998) could be an alternative water source rather than rainwater collection. This quality of grey-water is unsuitable for drinking or other secondary use without any treatment. It, however, can be used for other purposes, such as irrigation or toilet flush. To reuse it, the grey water collection system could be installed in this estate. Similarly with the rainfall catchment, the collected grey-water can be transported to the wetland, and then treated before reuse.

**Waste Minimisation**

Apart from developing alternative water sources, reduction of water consumption is the other component for implementing the concept of the EIP. East Anglia has been indicated as the driest region in the whole United Kingdom. The pressure of water supply is stress with population increasing (National Rivers Authority, 1994). The situation increases the urgency of water efficiency. Therefore, Waste minimise is one of alternative suggestions in this case (Ilomäki, M. and Melanen, M., 2001). The opinions for the source control are low flush WC, controlled flow volume taps, water control devices and reduce water usage in manufacturing process, etc. (Environmental Technology Best Practice Programme (GG67), 2003).
The common water taps in industrial and domestic usage wastes large quantities of water during production and cleaning process. To save water at source, spray taps can be installed in the toilets and production facilities. For example, a two-stage device, which is recommended by Environment Agency, can simply inset into the outlet of most round taps. When the tap is initially turned, the water will be sprayed out. At this spray mode, the water is forced out and mixed with air. As the tap is turned on further, the two-stage device can switch to full flow. It can reduce the water usage as less than 2 litres of water per minute will be used in the spray model (Tapmagic Ltd., 2003). Apart from the taps accessories, passive infrared (PIR) sensors can be installed to detect activity in areas and thus control water supplies (GG67, 2003). The long-life batteries can ensure the PIR in operation for 3-4 years. Asides from these additional equipments, the most cost-effective alternative is to use a single valve for area isolation which is closed manually by the “last person out”. It can prevent the water leaching at the non-working time.

Using water to flush away faeces and urine is one of the biggest contributors to water pollution, even in industrial estates. It is also a tremendous waste of water. Ecological engineer Greg Allen (1993) pinpointed that “Waste doesn’t exist in nature. What is discarded by one is the food of another. What we are doing by discarding our faeces into the ocean is, in effect, mining the soils, denying them the return of that nutrient, and soiling our water in the process.” (Allen 1993). According to this viewpoint, composting toilets was the alternative to returning the nutrient into nitrogen/carbon cycles and reduce water consumption. Unlike pit privy, organic matters, faeces, urine and toilet paper in composting toilets are decomposed aerobically by bacteria and other microorganisms. The effectiveness of decomposition is relatively high, it can reduce the volume by as much as 90 per cent, and leave a humus-like residue. However, in reference with studies of Fittschen and Niemczynowicz (1997) and Stauffer (1998), good aeration, sufficient moisture and ambient temperature (at least 15 degree) must be maintained. In general, the composting toilet installed in house is smaller and inexpensive. As there are not enough organic matters to generate sufficient heat, a low-temperature heater is required. Apart from that, a fan should be installed to prevent the anaerobic condition and odour. The composted matters in this small toilet should be removed at least once a year. They could be used as soil conditioner and fertilizer for the vegetation at the estate (Vinnerås, et al., 2003).

However, as composting toilet is uncommon in a society accustomed to flushed toilets, a psychological barrier may arise. Therefore, another alternative is to use flush control. The RIP can also be used in this case. Moreover, a needle valve for cisterns and a fulfilled plastic bottle for toilets can be installed to improve water consumption (GG67, 2003). The problem for the
flush control is to ensure the cisterns and toilets must be flushed at the minimum frequency necessary to remain hygienic.

3 Management systems

Apart from infrastructure construction, the relative management systems and education schemes are also a part of strategy to implement concept of the EIP. In addition, EIP-related education schemes are important for the estate to maintain and enhance the awareness of the EIP. Such schemes can join with the training section of the estate-wide EMS to provide different level of information to employees and managers. These schemes can also provide the opportunity for tenant to build the trust relationship. Since the by-product and raw materials exchange is one of core elements for EIP, the information exchange is also important. The exchange can be undertaken during the implementing estate-wide EMS and education schemes or setting up an information-exchange database. To maintain and enhance the efficiency of related infrastructure, some after-care management schemes are required. The detailed discussion is mentioned in the following section.

- **JOINT EMS CERTIFICATION FOR SMES**

According to the EIP implementation guide of UNEP IE (1997), one of the components is Environmental Management System (EMS) (Singhai, S. and Kapur, A., 2002). The EMS, such as ISO 14001 certification can bring benefits to companies and environment (Raines, 2002). An EMS has been defined as

> ‘the part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy’ (EN ISO 14001. §3.5, p10).

The EMS can lead benefits to company and environment (e.g.: Côté, R. and Balkau, F. 1998, Ofori, G. et al., 2002, and Zutshi, A. and Sohal, A., 2002,). However, implementing EMS requires substantial resources, both financially and in terms of staff, therefore, many SMEs are hesitant of implementing EMSs (Ammenberg, et al., 1999, United Stated Commission on Sustainable Development, 1998). Hillary (1996) claimed that all of SMEs in UK found that the initial stages, such as the environmental review, register of significant environmental aspects and policy requirements, difficult. Ammenberg et al. (1999) pointed out that a cost-effective solution that facilitates the implementation and maintenance of complete EMSs in SMEs is an important issue for companies. As all of the tenants at the case-study are Micro- / Small-Size
Enterprises, it is difficult for them to implement Environmental Management System by themselves. As a result, an estate-wide EMS programme, a joint process of Acorn Method™ and Hackefors model, can help the tenants adapt the EMS and improve their environmental and commercial performance. Hackefors model is a joint EMS certification model developed by Hackefors Industrial District, and Acorn Method separates the EMS implementation process into six independent phases. Integration of these two approaches can not only simplify the implementation process, but also be more cost-efficient and flexible for SMEs.

By studying the Joint EMS certification at Hackefors Industrial District in Linkoping, Sweden (Ammenberg et al., 1999), a business association seems to be an essential part for developing group EMS certification in the Hackefors model. Environmental coordinators from each company formed an EMS Group and led by a centre coordinator. The whole model is similar with a large company, the tenant company is acted as department. All of the related decisions and commitments were made by this group led by a central environmental co-ordinator. Each company undertaken the environmental review and training programmes under supervised. However, to ensure the independence of internal audit, co-ordinator cannot audit own company, but other member’s. External auditing could be completed by auditing only one enterprise within each line of business at a time as the documentation and procedures conform for enterprises within the same line of business. Under this model, all the members can get individual EMS certification.

In addition, the Acorn Method™ from BS8555 (The Acorn Trust, 2003) separates the whole formal EMS implementation process into

![Figure 15: The Acorn Method™ Framework](Source: The Acorn Trust)
six independent phases (figure 15). At each phase, the third-party audit with certification can be subjected. The advantage of this method is the clients, tenants and/or whole estate in this case, can stop at any time after phase completed and rejoin at the later level. It removes the problem of lengthy implementation with no feedback and becomes more user-friendly approach for SMEs. According to Burr (UEA lecture note, 2003) and the Acorn Methods, several successful cases can be referred to. For instance, Prodrive, a company to design, build and test prototype vehicles for automotive sector, has achieved ISO 14001 within 9 months by using Acorn Method™.

As the result, the modified Joint EMS programme model could encourage the tenant in the case-study implementing EMS easier. To apply this model to Haverscroft Industrial Estate, the landlord, who is manager of BPS, could be the centre co-ordinator to provide the EMS implementation experience to other tenants as BPS has got ISO 14001 EMS certification. The landlord can organise a business association and EMS coordinators committee to implement a Joint EMS programme. The EMS-committee could implement the Hackefors model by following Acorn Method™ model. Since the tenants companies joined in the programme could gain the EMS certification thereafter, the EMS is not only increasing the competitiveness of each tenant and whole estate, but also reducing the resource consumption and waste production, i.e., a ‘win-win’ result for business and the environment.

- **Environmental Friendly Schemes**

Apart from the Joint EMS programme, increasing employees’ environmental awareness is another important approach for implementation EIP. The awareness can be enhanced by organising environmental-friendly schemes and action plan.

By reviews the success EIP cases, the environmental-friendly schemes can be classified into cooperation schemes, resource efficiency schemes. For example, Land Stewardship at Stonyfield Londonderry Eco-Industrial Park is a cooperation partnership scheme. Deutz et al. (2003) claimed that information-/ by product-exchange, core element of EIP concept, cannot occur if there is lack of trust between companies or individuals. Therefore, any cooperation schemes, either formal or informal, provide opportunities for companies/individuals to enhance their relationship of trust. Apart from this, resource efficiency schemes or investments such as water use survey (GG67, 2003) and energy star scheme can encourage the companies to install effective instruments or undertake relevant initiatives. For example, water, energy and/or material can be conserved through these schemes.
In addition, education and training schemes can provide essential knowledge of the EIP and environmental protection to managers and employees of each tenant. These schemes can be integrated into the training stage of EMS. Similar with a study undertaken by Myatt, et al. (2003), For example, the knowledge can be transferred by environmental coordinators system in Hackefors model. Relevant conferences or seminars held by centre environmental coordinator, government agency and/or experts can provide information and knowledge to the environmental coordinator of each company (see Deven Sample in Guides and Best Practice Samples section). The knowledge will be transferred to employees in their company through informal or formal methods, such as note boards, technical memoranda and meetings. The level of knowledge for environmental coordinators and employees could be different. The coordinators should have sufficient information of the pollution-potential processes, but, for employees, they need the knowledge related to their positions only.

- **Database**

The main component of EIP concept is by-products exchange and reuse. However, it is also a difficult part. Deutz et al. (2003) claimed that “... in the longer term ...there is considerable scope for attempting to build upon the interchange of material and energy flow...” Therefore a database for tenant companies to exchange by-product/raw materials information could be set up.

Referring to the story of Nova Scotia Material Exchange website (RRFB Nova Scotia, 2002), a waste-material information database can help the tenants exchange their unwanted materials and increase the marginal. At the website, company can provide detailed information of any available and wanted materials (raw material / by-products). The information includes the name, category, quantity, location, frequency, etc. As the information exchange is limited in an estate level, the database could be undertaken on paper, but not internet. After organising the business committee, which has been mentioned above, the member could be asked to submit a registry form for material-exchange. For example, the members could specify the quantity of wastewater production and quality of water consumption. Then, the interchange can be established between the tenants themselves.

- **Infrastructures managements**

The efficiency of water-related infrastructures cannot be maintained without sufficient management. In this case, the infrastructures suggested before require different management.
As mentioned before, the treatment efficiency of treatment wetland is varies significantly because of poor management. To overcome the problem, some regular management is suggested (Shutes et al. 1996, Stauffer, 1998). Firstly, if there is several treatment beds are being used, the effluent should be shifted periodically from bed to bed. It can ensure sufficient retention time for biodegradation and sedimentation in each bed. Furthermore, the treatment wetland may need to be flushed regularly. The substances settling out from the effluent support aquatic plant and microbes, however, of there is too much sediment in the wetland may decrease the biodegradation rate because the soil condition will become anaerobic. Although the anoxic condition is suitable for denitrification, other redox reaction rates, such as BOD degradation and nitrification, will be slower. Moreover, the vegetation requires occasional attention, which includes planting, weeding and seasonal harvesting. The planting and harvesting is important for treatment efficiency as uptake rate of vegetation is fastest when it is growing to maturity. Seasonal planting, harvesting and flooding can maintain the vegetation in the treatment wetland system in the growth phase, i.e. maintain and enhance the treatment efficiency by removing the old plants and introducing the new seeds. In addition, the quality and quantity of effluents should be monitored regularly to prevent overload. Finally, some fishes and swamps can be introduced into the wetland. The lives may bring ecological and economic benefits. Other animals, such as otters and kingfishers, may be attracted to a wetland, hence, a wetland system may be created in long term. Furthermore, an aquaculture business may be created if the treatment wetland is on a large scale (Korn, M, 1996, Lin, et al., 2003). The aquatic species can be processed and canned for pet food. That could be seen as an aquaculture farm from some aspects.

Aside from the wetland management, the rainfall catchment systems are also required some maintenance. Regular inspection, cleaning, maintenance and occasional repairs are essential for long-term success (Grould and Nissen-Petersen, 1999). The inspection and cleaning plan should be adapted since the design phase. The gutter, downpipes, catchment surface, and delivery system need to be checked frequently and cleaned out from time to time. The frequency could be decided in relation to the climate. In this case, the frequency should be increased in winter and decreased in summer.

4 Summary of Water Close-loop Cycle

To summarise, all of the management practices could be integrated and implemented at the same time or separated as different approaches and implemented at different times. In the case of integration, the management of infrastructures, environmental-friendly schemes and
database maintenance can be integrated into EMS. The responsible and monitoring programme should be defined clearly in the objectives and target phase in EMS implementation. The duration and frequency of the monitoring programme will be determined by its objectives which may include: monitoring for compliance with discharge consent or operating agreement with the Regulatory Authority; establishing a long-term management programme to ensure the continued functioning of the constructed wetland, waste minimisation practices and the rainfall catchment; or further understanding of the processes which take place within a wetland (Shutes, et al. 1996).

However, in the case of separation, an overall implementation schedule should be defined with agreement of all stakeholders, such as tenant companies’ management, landlord and interests parties. The timing periods and achieving targets should be specified in the schedule to ensure the application.
EVALUATION OF RESEARCH

1 EVALUATION OF FRAMEWORK

Referring to the objective of this research, the framework for applying the concept of “Eco-Industrial Park” to existing industrial parks can be developed by integrating the checklists, questionnaires (see in appendix) and methodology used in this research. Aim to develop the framework for wide application, part of check points, questions and methodology cannot be applied in the case-study.

The checklist for landlords and tenant managers is adapted by the implementation guideline published by UNEP IE (1997) and suggestions from Deutz et al. (2003). The original guideline was designed to collecting environmental and business information for new EIP project. To achieve the objectives of research, the guideline has been modified. Aside from the guideline, the relationship between landlord and tenants has been asked because of Deutz’s suggestions. The questionnaires are refer to the checklists and used to collect the information.

During the survey, the advantages and disadvantages of checklists and checklist-dependent questionnaires have been identified. Some points/questions in the checklists and questionnaires are more important than others. Therefore, some have been identified as major components, and others can provide additional information for further implementation.

For the checklists, the main elements include the information about surrounding environmental features, nature of the tenant industries, quality and quantity of water consumption and discharge (inventory of water-related processes), and elements under the trust relationship section. Through completing these check points, the appliers can identify the essential water-related information for implementing the EIP concept into water management in existing industrial parks. The surrounding environmental features, such as sensitive areas, surface water and groundwater, can be used to determine the potential environmental receivers, alternative water sources and alternative water treatment facilities around the existing industrial park. Information on the nature of tenant industries can provide a general picture for potential water usage and discharge. In general, a similar quality and quantity of water consumption and discharge may happen with similar business types. Moreover, the water interchange between business sectors can also be pre-determined by using this information. Therefore, the water delivery system, either consumption or discharge, could be installed between the tenants in similar sectors and potential customers. The inventory of water pollutant releases could provide more detailed information related to water quality. This information can be used to identify
whether wastewater treatment is required before reusing by other company as raw materials. Asides from the water-specific information, the trust relationship section can determine whether the target industrial park has encouraged tenant companies to build any formal and/or informal partnerships between themselves, and the attitude of the tenant to build up these partnerships. Apart from these, other check points can provide add-in value for the implementation. For example, information about undertaking EMS at company- and estate-level and water-related initiatives will identify the current situation at the industrial park. In addition, the landuse at the industrial park, historical rainfall data and current wastewater collection and treatment service provider can be acted as parameters to develop the suitable water closed-loop. To conclude this part, at the minimal level, the consultant could identify the answers of the major constituent for implementation.

The questionnaires are used to find out the answer for completing checklists. As Baumgartner and Heberlein (1984) claimed that, cover letter is important for response (cited in Bryman, 2001). The covering letter (attached in Appendix) explained the research objective in brief and assured the respondent of the confidential nature of all replies. In order to maintain the interest of the reader, the number of words in the covering letter was limited. Referring to requirement of checklists, the questionnaires have been classified into different sections. After reviewed the responses, the questionnaires could be modified a little to improve the efficiency of data collection. The question related to the business nature of tenant, for instance, can be changed to ask the SID code of the interviewee because similar industries will register under same SID Code. Therefore, it is easier for consultants to categorize the tenant companies by using SID Code rather than using general description. The other example in the questionnaires is the question asking for number of employees. In the original design, the question did not specify in number of men and women However, as amount of daily water usage are different between men and women, i.e., women consumes more water in general (Anglian Water Ltd., personal contact, 2003), the overall water consumption in domestic should be different. Moreover, the answer of some questions such as on-site water facilities could be identified by site-visiting. Furthermore, some external information source, such as local country council, Environment Agent, and English Nature, could be asked for some questions’ answer. The answers from external sources could be compared with the responses from interviewees to verify the accuracy. Apart from questionnaire design, the trust between consultants and interviewees is also important for data collection.

Due to the limitation of the case-study, part of methodology could not be applied. For example, the stage for identifying the potential industries in water closed-loop cycle could not be
undertaken. However, the stages could be undertaken with sufficient data. The suggestions for EIP implementation provide one of application directions for further development. They could be implemented at the same time or separately. Although some suggestions are water-specific, the management scheme, such as Joint EMS and environmentally friendly schemes, can be applied at any stage of development. The other suggestions could be modified or cancelled to adapt to the real situation. The natural wetland, for instance, could be used as a treatment wetland if it is nearby and suitable for wastewater treatment.

2 FURTHER APPLICATION OF THE GUIDE PACKAGE.

As mentioned in literature review section, the EIP could manage several elements, such as water, energy, material and light. Since the framework is water-specific, any further application rather than water related should be modified before implementation. For example, some parameters of core elements in the checklist should be changed a little if using it for developing material closed-loop cycle. The inventory of water-related processes should be modified to survey any production process generated material wastes. In other words, the quantity and quality of raw materials and by-products for each tenant should be identified under similar surveys in this research. Aside from the inventory, other elements, such as nature of tenant companies and environmental features, will need to modify some parameter to collect the relevant information. Similar with the main points, some add-in check points, such as historical local rainfall data, may also need to change or cancel. However, the checklists may not require modifying or cancelling every component. Checkpoint for EMS and relevant consents could be remained as the answer may still provide similar value for implementation.

3 FURTHER RESEARCHES

In this research, implementation of the EIP concept is the overall objective. However, since the water consumption and discharge is a relatively small amount for the SMEs in Haverscroft Industrial Estate, the potential for water exchange within the estate is limited. Moreover, the limited effluent may not be enough to support a treatment wetland. Apart from that, the cost of infrastructure construction may be obstacle for small sized companies. As a result, the concept of “Eco-Industrial Network” (EIN) could be adopted. The EIN is not restricted within a estate, but for all potential interchanged customers. In this case, the possibility of water exchange between Haverscroft Industrial Estate and Attleborough could be researched. The domestic and industrial wastewater from the town and the industrial estate could be collected and delivered to the larger scale treatment wetland or the customers. After sufficient treatment, the water could be transported back to the town and estate for recycle. This model can maintain the long-
term dynamic balance because of enough niches.

Aside from the EIN model, the employees and local residents’ motivation for implementing EIP and/or EIN could be studied in the future. During this research, the managers and landlords’ motivation have been asked. However, as the employees are major forces for implementation, their attitude may affect the result of EIP application. Similarly, the residents’ opinions may also affect the result of the EIN implementation. These social research topics are also important for implementation, quite apart from the technical and management researches.
CONCLUSION

To achieve sustainable development, several strategies have arisen. Industrial Ecology integrates different models, such as Pollution Prevention and the Environmental Management System, to conserve the environment and increase economic benefits by encouraging by-product exchange. Eco-Industrial Park is one of practices of Industrial Ecology.

The objective of this research is developing a framework for implementation the EIP model to water management in existing industrial estates. Haverscroft Industrial Estate was used as a case-study. A research methodology was developed by reference to the literature. Following the methodology, water-specific checklists and questionnaires were designed, and the suggestions and recommendations were all undertaken based on the collected data. Therefore, the checklists, questionnaires and methodology have been integrated as a guide package for future applications after evaluation. The suggestions for the case-study could also be an example for future references.

Because of lack of accurate water information on each tenant, potential water exchange between tenants cannot be determined although it is a core component for the EIP concept. Some infrastructures, such as the rainfall catchment system and on-site treatment wetland, have been suggested for construction. Some management practices have also been recommended to ensure on-site water efficiency and improve the employees’ environmental awareness. From result of this case-study, the EIP concept could be applied to existing industrial estates. However, as the site location, types of tenants and infrastructures are impossible to change significantly, the suggestions and recommendations should be undertaken after considering the local environment, both natural and artificial, and cost-efficiency.
REFERENCE:


Ammenberg, J., Borjesson, B., Hjelm, O., (1999), Joint EMS and Group Certification, Greener Management International: 28


Bruce, J.P., (1992), Meteorology and Hydrology for sustainable Development, World Meteorological Organisation No. 769, Secretariat of the WMO, Geneva, Switzerland

Bryman, A. (2001), Social Research Methods, Oxford University Press


Deutz, P., Gibbs D., and Proctor, A., (2003), Eco-industrial Development: its potential as a stimulator of local economic development, paper presented to the annual meeting of the Association of American Geographers, New Orleans,


Environmental Technology Best Practice Programme, (2003), Cost-effective water saving devices and practices (GG67), Environmental Technology Best Practice Programme


European Commission, (1996), Journal of the European Communities, no. 107/6, Brussels

Falkenmark, M., (1988), Sustainable Development as seen from a water perspective, IN Perspectives of Sustainable Development, Stockholm Studies in Natural Resources Management, No. 1, Stockholm, pp.71-84


Frosch, R. A. and Gallopolous, N. E., (1989), Strategies for manufacturing, Scientific American:261(3), pp. 144-52


Hasse, R., (1989), Rainwater Reservoirs abobe Ground Structures for Roof Catchment, Gate, Vieweg, Braunschweig/Wiesbaden, Germany


Hynes, H B N, (1960), the biology if polluted waters, Liverpool University Press, Liverpool.


Lin, Y., Jing, S and Lee, D., (2003), The potential use of constructed wetlands in a recirculating aquaculture system for shrimp culture, Environmental Pollution, Vol.: 123:1, pp. 107-13


Miller, G.T., JR, (1997), Environmental Science: working with the Earth 7th edition, ITP,


National Rivers Authority (Anglia Region), (1994), Water Resources in Anglia, National Rivers Authority.


nitrified liquid swine manure, Ecological Engineering, Vol.: 20:2, pp. 183-97


Rathi, A.K.A., (2003), Promotion of cleaner production for industrial pollution abatement in Gujarat (India), Journal of Cleaner Production: 11, pp.583–590


Skinner, B., (1990), Community Rainwater Catchment, Unpublished Report, Water Engineering and Development Centre, Loughborough University, UK


Waterfall, P.H., (1998), Harvesting rainwater for landscape use, Arizona Department of Water Resource


**Internet resource:**

Anglian water Co. (2000), Introduction to using water wisely, [Online], Available through http://www.anglianwater.co.uk/ [4-June, 2003]


U.S. Environmental Protection Agency, (2003°), Surface Water Contamination, in *Superfund* for students and teachers, [Online], Available from
http://www.epa.gov/oerrpage/superfund/students/wastsite/srfcspil.htm [13-April, 2003]

U.S. Environmental Protection Agency, (2003b), Groundwater Contamination, in Superfund for students and teachers. [Online], Available from
http://www.epa.gov/oerrpage/superfund/students/wastsite/grndwatr.htm [13-April, 2003]

**Personal Contact:**

Anglian Water, (2003), Enquire for the Information of Wastewater Collection, Treatment and Disposal Service

Conservation Design Forum, Inc. (USA), (2003), Enquire ofor the Information of Conservation wetland Design

Eco-Tech Centre, (2003), Enquire for the Information of Case-Study

English Nature, (2003), Enquire for the Information of Specific Areas at Attleborough

Environment Agency, (2003), Enquire for the Case Surrounding Environmental Information
APPENDIX A - CHECKLIST

Water Management in Industrial Estate
(Applying Eco-industrial concept)

Basic Information of Industrial Estate:

1. Name, address and operation time
2. Contact person for environmental affairs:
3. Ownership: (delete unsuitable ones)
4. Scale of the estate:
5. Layout and landuse of the estate: (identified from the layout of industrial park)
6. Environmental features:
7. Nature of the tenant industries in the estate:
8. Services provided by the estate to the tenant firms:
9. Nearby socio-economic feature:

Water Section for Industrial Estate:

1. Map of drainage system
2. What water facilities existed in the estate?
3. If there are on-site wastewater treatment facilities, which type of treatment is implemented?
4. Who is responsible for the industrial wastewater collection, and how to collect the water?
5. Who is responsible for the industrial wastewater treatment services, and how?
6. Who is responsible for the industrial wastewater disposal services, and how?
7. Has the estate implemented the environmental management system (EMS)?
8. Moreover, who is responsible for the elements of the EMS of the estate?
9. Does the EMS of the estate include water management?
10. Does the estate have some practices to ensure water efficiency and reduction?
11. Is the quality of wastewater generated from estate discharge concerns?
12. Does the quality of wastewater often

13. Have any concerns or complaints been expressed about the following issues related to water?

14. Which environmental parameters related to water issue are regularly monitored?

15. What environmental studies related to water have been carried out, and by whom?

**Relationship of Trust:**

1. Do(es) manager(s) of the estate know managers of all tenant companies in the estate?

1. Does the industrial estate have some information exchanged centre or similar centre?

2. Does the industrial estate provide the water-relative information exchange opportunities between tenants and estate (i.e. forum, exhibition and meeting)?

3. Does the industrial estate provide the water-relative information exchange opportunities between urban and estate (i.e. forum, exhibition and meeting)?

4. Has the estate had any activities to enhance or maintain the relationship between the tenants?

5. Does the industrial estate promote some cooperative schemes to tenant companies?

6. Does the industrial estate provide some incentive to encourage tenant companies shift to environmental-friendly?

7. Does the industrial estate maintain a database about each tenant companies’ raw material requirement and quality and quantity of waste they generated?

**Basic Information of Tenant Company:**

1. Name, address and operation time

2. Contact person for environmental affairs:

3. Ownership: (delete unsuitable ones)

4. Scale and nature of the plant:

5. Figure of Production Process

**Water Section for Tenant Company:**
1. the drainage map if applicable

2. What water facilities existed in the company?

3. If there are on-site wastewater treatment facilities, which type of treatment is implemented?

4. Who is responsible for the industrial wastewater collection, and how?

5. Who is responsible for the industrial wastewater treatment services, and how?

6. Who is responsible for the industrial wastewater disposal services, and how?

7. Has the estate implemented the environmental management system?

8. Moreover, who is responsible for the elements of the EMS?

9. Does the EMS include water management?

10. Does the company have any practices to ensure water efficiency and reduction?

11. Is the quality of wastewater generated from plant discharge concerns?

12. Does the quality of wastewater often

13. Have any concerns or complaints been expressed about the following issues related to water?

14. Which environmental parameters related to water issue are regularly monitored?

15. What environmental studies related to water have been carried out, and by whom?

16. Inventory of water pollutant releases

**Trust Relationship Building in the tenant companies:**

1. Do(es) manager(s) of the company know managers of other tenant companies in the estate?

2. Does the company exchange water-relative information with other tenant Companies?

3. Does the company take some activities to build the trust relationship with other tenant companies?

4. Has the estate had any activities to enhance or maintain the relationship between the tenants?

5. Has the company joined any activities held by estate? How often?
6. Is the company willing to provide information of raw material(s) and waste to the industrial estate manager to maintain the database

Relevant Factors:

1. The local long-term runoff data (present at different year):

2. Water sources (groundwater and surface water)(study from map):

3. Sensitive Areas
Dear Sir/Madam,

**Request for Information about water management**

I am a postgraduate studying Environmental Science at the University of East Anglia. Currently, I am undertaking a dissertation concerning the application of the concept of “Eco-industrial Park” in water management, which is a part of a project led by Ms. Nina Cunningham at Eco-Tech Centre.

I would very much appreciate it, if you could help me by filling in the attached questionnaire regarding your industrial park. This should only take about 5-10 minutes, and all the information given would of course be treated in the strictest confidence. It would be most helpful if you could possibly send it back to me by email at c.hon@uea.ac.uk by the 30th June, or post to me. My postal address is:

CK Hon  
School of Environmental Science  
University of East Anglia  
Norwich  
NR4 7TJ

I would be more than happy to send you a short summary of my dissertation, (which will be completed during August), on request.

Thank you in anticipation for your help with this.

Yours faithfully,

CK Hon
**APPENDIX C - QUESTIONNAIRE FOR ESTATE MANAGER**

Please give your answer (e.g. a, b, c) in the bracket / spaces provided:

Name of Industrial Estate: ____________________________
Address: __________________________________________
Year Operation Started: ____________________________

Contact person for environmental affairs:
Name: ____________________________
Position: ____________________________
Fax: ____________________________
Telephone: ____________________________
E-mail: ____________________________

1. Could you please to specify the ownership of your estate:
   (a) Private    (b) Public    (c) Public / Private partnership
   *Your answer: (              )*

2. Who is responsible for organising major infrastructure works in your estate?
   (e.g.: landlord / tenant association)
   ____________________________

3. Who assumes the cost of major infrastructure works? (e.g.: landlord / tenants)
   ____________________________

4. What types of land-use occurs on your estate:
   (a) Export processing zone    (b) General industrial zone    (c) Residential zone
   (d) Commercial zone    (e) Natural area    (f) Undeveloped area
   (g) Infrastructure (transport and park area, etc.)  
      (h) Others
   *Your answer: (              )*
5. What are the major industries in your estate:

(a) Petrochemical processing
(b) Heavy industrial processing
(c) Light industrial processing
(d) Biotech / Chemical manufacturing
(e) Energy generation
(f) Construction industry
(g) Information technology
(h) Food processing
(i) Drinks manufacture
(j) Textile manufacturing
(k) Others (please specify: )

Your answer: ( )

6. Please describe how units on the estate are organised (e.g.: unit labelling system in operation, 1A, 1B, 2A, etc.)

Your answer: ( )

Please enclose a map of the estate if available

7. How concerned are you about water use / resource?

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not concerned</td>
<td>Neutral</td>
<td>Very concerned</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Your answer: ( )

8. How concerned are you about water discharge / pollution?

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not concerned</td>
<td>Neutral</td>
<td>Very concerned</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Your answer: ( )

9. Who is currently responsible for the industrial wastewater collection, treatment and disposal services in the estate?

10. Which water facilities currently exist on your estate?

(a) None (direct discharge to land)  (b) Cooling towers  (c) Sumps
(d) Foul drainage  (e) Septic tanks  (f) Storm water drains
(h) Water wells on site / on adjacent properties  (i) others:
11. Are there any on-site water collection and/or treatment facilities? (e.g.; rainfall catchment, physical treatment plant, etc.)
(a) Yes  (b) No
Your answer: (___________)

If YES, please provide detailed information:

If NO, have you considered of using such on-site facilities?
(a) Yes  (b) No
Your answer: (___________)

12. Does your estate have an estate wide Environmental Management System in operation?
(a) Yes  (b) No
Your answer: (___________)

Please enclose the environmental policy of your estate if answer is YES

If yes, which standard (ISO 14001 and/or EMAS) and who is responsible for the system?

And, does the system include water management?
(a) Yes  (b) No
Your answer: (___________)

If NO, would you consider implementing an estate-wide EMS in the future?
(a) Yes  (b) No
Your answer: (___________)

13. Has your estate made any commitments to improving water efficiency
and / or wastewater reduction on an estate level (e.g. in an environmental policy)?
(a) Yes (b) No
Your answer: (____________________)
Please enclose the detailed information if your answer is YES

14. Does your estate undertake any initiatives to ensure water efficiency and / or wastewater reduction on an estate level?
(a) Yes (b) No
Your answer: (____________________)
Please enclose the detailed information if your answer is YES

15. Do any of the services you provided generate wastewater?
(a) Yes (b) No (please skip question 16)
Your answer: (____________________)
If yes, do you have any discharge consents?
(a) Yes (b) No (please skip question 16)
Your answer: (____________________)
Please provide detailed information of the discharge consents if your answer is YES

16. Does the quality of wastewater which is covered under discharge consent often
(a) Meet the maximum criteria (b) Fall below the maximum criteria
(c) Exceed the maximum criteria
Your answer: (____________________)

17. Does your estate undertake any monitoring process for wastewater?
(a) Yes (b) No ((please skip question 18)
Your answer: (____________________)
If No, would you be prepared to introduce such a process?
(a) Yes (b) No
Your answer: (____________________)
18. Which parameters related to water use and/or wastewater discharge are regularly monitored and by whom?

<table>
<thead>
<tr>
<th>Parameter (e.g.: water bill / BOD)</th>
<th>Monitored by…</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

19. Have you received any concerns or complaints about the following issues related to water?

<table>
<thead>
<tr>
<th>Issues</th>
<th>Never</th>
<th>Sometimes</th>
<th>Often</th>
<th>Source of complaint</th>
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</thead>
<tbody>
<tr>
<td>Water supply</td>
<td></td>
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<tr>
<td>Wastewater collection</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Wastewater storage</td>
<td></td>
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<tr>
<td>Wastewater treatment</td>
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<tr>
<td>Wastewater transportation</td>
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<td></td>
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<tr>
<td>Treated water disposal</td>
<td></td>
<td></td>
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<tr>
<td>Specific odour</td>
<td></td>
<td></td>
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<tr>
<td>Aesthetic/visual impact</td>
<td></td>
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<tr>
<td>Disease vectors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contaminations</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Please enclose the information of the complaint(s)

20. Have any studies related to water use in your estate have been carried out, and by whom?

<table>
<thead>
<tr>
<th>Studies</th>
<th>Researchers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

21. Does your estate encourage any information exchanged activities
<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has your estate undertaken any activities to enhance or maintain the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>relationship between the tenants? (e.g.: informal communication)</td>
<td></td>
<td></td>
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<tr>
<td>Your answer:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If YES, please specify the activities and when:</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Does your estate promote any cooperative schemes to tenant companies?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Your answer:</td>
<td></td>
<td></td>
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<tr>
<td>If YES, please specify the scheme:</td>
<td></td>
<td></td>
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<tr>
<td>Does your estate provide incentives to encourage tenant companies</td>
<td></td>
<td></td>
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<tr>
<td>to shift to environmental-friendly operations? (e.g.: Energy Star scheme)</td>
<td></td>
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<tr>
<td>Your answer:</td>
<td></td>
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<tr>
<td>If YES, please specify the incentive:</td>
<td></td>
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<tr>
<td>Does your estate maintain and enhance a database about raw materials and</td>
<td></td>
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<tr>
<td>wastes of each tenant company?</td>
<td></td>
<td></td>
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<tr>
<td>Your answer:</td>
<td></td>
<td></td>
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<tr>
<td>If No, would you prepared to set up such a database in the future?</td>
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<tr>
<td>Your answer:</td>
<td></td>
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</tbody>
</table>
26. Do you receive any water-related information from government and/or other sources (e.g. Anglia Water, Environwise, Environmental Agency)?
   (a) Yes   (b) No

   Your answer: (____________________)

   Please specify the source and information:
   
   If yes, is the information disseminated to tenants?
   (a) Yes   (b) No

   Your answer: (____________________)

May I phone or email you in case I have questions to your answers and/or ask further questions?
   (a) Yes   (b) No

   Your answer: (____________________)

I would be most grateful if you would enclose a copy of any detailed information related to the above questions

My Postal Address:

        CK Hon

        Room 1B, Orwell Close,
        University of East Anglia,
        Norwich
        NR4 7TJ

Thank you for completing the questionnaire 😊
**APPENDIX D - QUESTIONNAIRE FOR MANAGER OF TENANT COMPANIES IN THE ESTATE**

### General Information:

<table>
<thead>
<tr>
<th>Name of company</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td></td>
</tr>
<tr>
<td>Year Operation Started</td>
<td></td>
</tr>
</tbody>
</table>

### Contact person for environmental affairs:

<table>
<thead>
<tr>
<th>Name:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Position:</td>
<td></td>
</tr>
<tr>
<td>Fax:</td>
<td></td>
</tr>
<tr>
<td>Telephone:</td>
<td></td>
</tr>
<tr>
<td>E-mail:</td>
<td></td>
</tr>
</tbody>
</table>

### Ownership:

- □ Private
- □ Public
- □ Public / Private partnership

1. **Scale and nature of the plant:**
   - Total surface area (m²)
   - Total number of tenant employees F: _______ M: _______.
   - Major business type
   - Products

2. **Does your company have car park?**
   - □ Yes
   - □ No

### Figure of Production Process

<table>
<thead>
<tr>
<th>Water-Related Production Process</th>
<th>Quantity of Water in Waste Water</th>
<th>Quantity of Waste Water</th>
<th>Quality of Waste Water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>
4. Inventory of water pollutant releases

<table>
<thead>
<tr>
<th>Release location</th>
<th>Process</th>
<th>Pollutant</th>
<th>Concentration at release point</th>
<th>Annual release</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

5. Is the quality of wastewater generated from your company discharge consents?
   □ Yes   □ No

   If NO, does the quality of wastewater be monitored by your company?
   □ Yes   □ No (please skip question 6 and 7)

   If YES, Please enclose the historical monitoring data of the wastewater

6. Which environmental parameters related to water issue are regularly monitored and who responses to?

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Monitored by…</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

7. Does the quality of wastewater often
   □ meet the maximum criteria   □ below the maximum criteria

8. Have any concerns or complaints been expressed about the following issues related to water? (√ if appreciate)

<table>
<thead>
<tr>
<th>Issues</th>
<th>Seldom</th>
<th>Often</th>
<th>Source of Stakeholder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water supply</td>
<td></td>
<td></td>
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<tr>
<td>Wastewater collection</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Wastewater storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wastewater treatment</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Wastewater transportation</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Treated water disposal</td>
<td></td>
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<tr>
<td>Specific odour</td>
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<tr>
<td>Aesthetic/visual impact</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Disease vectors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contaminations</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. Any water facilities existed in your company?
   □ None (direct discharge)   □ Cooling towers
   □ Municipal sewers   □ Septic tanks/fields   □ Storm water drains
10. Is there any on-site wastewater treatment facility?
   □ Yes  □ No
   If YES, which type of treatment is implemented?
   □ Physical □ Chemical □ Biological
   If NO, are you willing to implement an on-site treatment?
   □ Yes  □ No

11. Who is responsible for the industrial wastewater collection, treatment and disposal services?

12. Does your company having an Environmental Management System (EMS) in operation?
   □ Yes  □ No (Please skip question 13)
   If Yes, which standard (ISO 14001 and/or EMAS) and who is responsible for the EMS?
   If NO, will your company be prepare to implement EMS in the future?
   □ Yes  □ No

13. Does the EMS include water management?
   □ Yes  □ No

14. Would your company be interested in an estate wide EMS covering every company in the estate, monitored and maintained by estate landlords?
   □ Yes  □ No

15. Does your company have any initiatives to ensure water efficiency and reduction in production process?
   □ Yes  □ No
   Please enclose the detailed information (e.g. water bill, practice process, etc)

16. Does your company have any initiatives to ensure water efficiency and reduction in the domestic use?
   □ Yes  □ No
   Please enclose the detailed information
   If No, do your company receive any water-related information from government and/or other sources (e.g. Anglian Water, Environwise, Environmental Agency)?
   □ Yes  □ No
   Please Specify: Enclose the information of the complaints
17. What environmental studies related to water have been carried out, and by whom?

<table>
<thead>
<tr>
<th>Study</th>
<th>Researchers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

18. Does your company exchange waste/raw material information with other tenant companies?

☐ Yes  ☐ No

If YES, please specify how and when:

____________________________________________________________________

19. Does your company undertake any activities to build the waste/raw material exchange relationship with other tenant companies?

☐ Yes  ☐ No

If YES, please specify how and when:

____________________________________________________________________

20. Has the landlord had any activities to enhance or maintain the relationship between the tenants?

☐ Yes  ☐ No

If YES, please specify how:

____________________________________________________________________

21. Has your company joined any activities led by estate? How often?

☐ Yes  ☐ No

If YES, please specify how:

____________________________________________________________________

22. In the future, will your company be prepare to provide water-related to the industrial estate manager to maintain a database for waste exchanging

☐ Yes  ☐ No

23. Could you please to attach the drainage map if applicable

May I phone or email you in case I have questions to your answers and / or ask further questions?

☐ Yes  ☐ No
APPENDIX E - LOCATION OF HAVERSCROFT INDUSTRIAL ESTATE

Location of Haverscroft Industrial Estate at Attleborough, Norfolk
Surrounding environment of Haverscroft Industrial Estate at Attleborough, Norfolk
**APPENDIX F - HISTORICAL PRECIPITATION DATA OF ATTLEBOROUGH (1969-2001)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual Data (mm)</th>
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<td>63.2</td>
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<td>42.8</td>
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**N.B.**: This table integrated the data from two metrological stations near Attleborough, which are Rockland St Peter and Morley St Botolph because of data incompletion. Number in black is data from Morley St Botolph, and Number in red is data collected from Rockland St Peter.
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Average Annual Precipitation (mm) **927.8**
## APPENDIX H – RESULT OF QUESTIONNAIRES

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