THE UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING

INDUSTRIAL WASTEWATER MANAGEMENT IN ZAMBIA: CASE STUDY OF A LUSAKA SLAUGHTERHOUSE

By

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A dissertation submitted to the University of Zambia in partial fulfilment of the requirements of the degree of Master of Engineering in Environmental Engineering.

THE UNIVERSITY OF ZAMBIA

LUSAKA

1998

DECLARATION

I, Mambwe Ronald Mangule, do solemnly declare that this dissertation represents my own work and has not previously been submitted for a degree at The University of Zambia or another university.

Signature: ………………………………..

Date: 22/06/98

APPROVAL PAGE

This dissertation of Mambwe Ronald Mangule is approved as partial fulfilment of the requirements for the award of the Master of Engineering in Environmental Engineering by the University of Zambia.

EXAMINERS' SIGNATURES	DATE
....	12/8/98
....	17/12/98
....	17/12/98
....	17/12/98

ABSTRACT

In Zambia, like in many other countries, industrialisation has brought with it the problem of environmental pollution associated with industrial wastewaters. The discharge of industrial wastewater into public sewers may deteriorate sewer structures, increase maintenance costs, add problems in sewage treatment and contribute to stream pollution. Direct discharge into streams may harm aquatic life and deem the water unfit for its intended use. It is therefore necessary to reduce the volumes and strengths of wastes by a combination of measures. Realising that some work has already been done with regard to the legal, policy and administrative frameworks, this study sought to clarify the situation with regard to industrial wastewater management. The study covered three main areas, each of which had its own objectives. These were:

a) Industrial wastewater management in Zambia

- To analyse the effectiveness, relevance and currency of the relevant legal, policy and administrative frameworks with regard to industrial wastewater management in Zambia
- To assess the perspectives and awareness of local industry regarding the relevant legislative and other frameworks and the resulting responses

b) Case study of a Lusaka slaughterhouse

- To evaluate the installed industrial technology
- To establish water use patterns and conservation measures
- To assess awareness of effluent regulations and compliance requirements
- To evaluate the status of pretreatment technology
- To establish the availability of analytical facilities for water quality testing

c) Pilot plant investigations on treatability of slaughterhouse wastewater by trickling filtration

- To assess treatability of slaughterhouse wastewater by trickling filters
- To assess the potential for reducing pollution loads so as to meet discharge standards
- To provide a basis for the design of a full scale trickling filter treatment plant

Assessment of industrial wastewater management was carried out by way of an extensive literature review of the relevant legislation and local publications. This was backed by interviews and discussions with personnel from industry, relevant government departments and local authorities. The awareness and perspectives of local industries to environmental

legislation and related issues was further ascertained by conducting industrial site surveys coupled with questionnaires. The situation was further clarified by a case study of a slaughterhouse in Lusaka involving water and wastewater management. The industrial technology, water supply and consumption situation, wastewater production and treatment and attitude towards environmental protection were established by working in close co-operation with personnel in various sections of the plant. Pilot plant investigations were carried out on a rock media fixed distributor trickling filter on the treatability of slaughterhouse wastewater. Treatability studies were based on COD removal efficiency of composite samples.

It has been found that there are a lot of duplications and overlaps in responsibilities among various government departments characterised by lack of implementation and enforcement. Of all the relevant Acts, only the Environmental Protection and Pollution Control Act was being implemented though with some drawbacks. Dissemination of the necessary information to the target group had not been effective which prompted industries to advocate for regular seminars and workshops on the relevant legislation and aspects of pollution control. The case study further revealed the non-enforcement of regulations and lack of environmental awareness from industry. Pilot plant treatability studies gave results that showed average COD removal efficiencies of 37.8 and 23.9 percent at hydraulic loading rates of 0.34 m^3/m^2h and 0.49 m^3/m^2h, respectively.

Generally, the legal and institutional frameworks need to be reformulated to eliminate duplications and overlaps of authority. It is important that only one body is charged with the responsibility of pollution prevention and control. There is also need to strengthen the enforcement procedures and to launch an awareness drive to enlighten industries and local authorities on the relevant legislation and aspects of pollution control. It has been recommended that emphasis should shift from an approach based on discharge licences and permits to one which promotes a preventive approach. The case study established the need to address the aspect of enforcement and environmental awareness. For the pilot plant investigation, the effluent COD values were mostly higher than the stipulated value (1800 mg/l) for discharge into public sewers. This has been attributed to high fluctuations in influent COD that gave rise to inconsistent treatment performance. It has been recommended that the research be continued incorporating proper primary treatment (screening, equalization and settling) and an effective final clarification step.

PREFACE

This study evolved from the collaborative partnership between the Department of Civil Engineering at the University of Zambia and the Delft University of Technology of the Netherlands, through the Joint Finance Programme in Higher Education (MHO). The programme of study comprised two parts. The first part was course work undertaken at The Institute for Infrastructure, Hydraulics and Environmental Engineering (IHE) in Delft, The Netherlands. This research constituted the second and final part.

The emphasis of the MHO project, and this programme in particular, was practical research to help contribute towards establishing the Civil Engineering Department as a centre of reference for environmental and water-related issues in the country. It was with this in mind that research work was undertaken in the realm of industrial wastewater management. It is hoped that this will foster long-lasting co-operation ties with local industry. The Kembe Cold Storage Corporation, a meat packing plant, was the first industry that showed interest in this area and was selected as a case study.

ACKNOWLEDGEMENTS

I am greatly indebted to my supervisors Dr Z. Phiri and Dr J. de Koning, and my tutor Mr P. J. Duindam. Their expert advice, suggestions and criticisms propelled me forward. The laboratory technicians, Ronald Mwango and Fred Chimpukutu, deserve a part on the back for assisting me carry out the analyses. Special thanks go to Bram Van Beek from Wageningen Agricultural University, The Netherlands, for being such a skilled builder: I don't know how long the construction work would have taken without his input. I also convey my profound thanks to Kembe Cold Storage Corporation management for being actively involved by providing the labour force and according us unconditional access to their premises during the construction work and throughout the research period. I am grateful to Mr Collins Mambwe for performing an excellent welding job and Derrick Muwowo for monitoring the pilot plant.

My profuse thanks go to my wife, Thumelo, for urging me on and never complaining about the repulsive smell I always carried home with me after an outing at the slaughterhouse! You are great.

I would be failing in my duties if I did not express my gratitude to those who made everything possible by providing the necessary finances - the Dutch Government through the MHO project. Rest assured that your efforts will not come to naught. *Dank u wel!*

Lastly, but definitely not the least, I thank all the people who helped me in one way or another during my period of study. May the Almighty God bless you all.

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LIST OF ABBREVIATIONS

BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
DAF	Dissolved-air flotation
ECZ	Environmental Council of Zambia
EPPCA	Environmental Protection and Pollution Control Act
ESP	Environmental Support Programme
FOG	Fats, oil and grease
GRZ	The Government of the Republic of Zambia
K	Zambian kwacha
KCSC	Kembe Cold Storage Company
LWSC	Lusaka Water and Sewerage Company
MENR	Ministry of Environment and Natural Resources
mg/l	milligrams per litre
MHO	Joint Financing Programme for Higher Education
NCS	National Conservation Strategy (for Zambia)
NEAP	National Environmental Action Plan
NRC	National Research Council
PFAP	Provincial Forestry Action Plan
POTW	Publicly owned treatment works
ppm	parts per million
TSS	Total suspended solids
US$	United States Dollar
ZFAP	Zambia Forestry Action Plan
ZPA	Zambia Privatisation Agency

1. Introduction

1.1 Background

The worldwide concern on protection of our environment is increasingly gaining ground. Pollution of the environment through the release of waste substances has been one of the major concerns. In this regard, one of the main thrusts has been the protection of water resources from different types of pollution because, as it is said, water is life. Prevent contamination of water, and you contribute towards protecting and prolonging life.

In Zambia, as in many developing countries, industrialisation has brought with it the problem of environmental pollution associated with industrial wastewaters. For Zambia, the nature and quantities of these wastewaters have now reached a stage where they have to be monitored and controlled. The Environmental Protection and Pollution Control Act of 1990 was enacted against this background (The government of the Republic of Zambia, GRZ, 1990). The major problem has always revolved around how to address industrial wastewater pollution in a situation characterised by an alarming paucity of both information and data. Realising that some work has been done in presenting an overview of the sector with regard to the legal and administrative frameworks and other broad issues, this study sought to clarify the situation with regard to the prevailing scenario in Zambian industries.

1.2 Industrial Wastewater and the Environment

Within the general context of environmental management, the issue of industrial wastewater is becoming increasingly topical, not only in developed countries, but in developing countries as well, in many of which industrial development is hampered by lack of suitable sources of water. Conflicts among agricultural, industrial, energy and public sector water use have arisen. The discharge of industrial wastewater into public sewers may deteriorate sewer structures, increase maintenance costs, add problems in sewage treatment and may increase stream pollution. There may also be problems with the disposal of sewage sludge contaminated with metals. It is therefore often necessary to reduce the volumes and strengths of wastes by way of a combination of measures. It is against this background that the treatment of wastewater presents itself as a formidable challenge to the industrialist, the public and the state.

In order to control water pollution from industrial effluents, there is need for comprehensive legislative, institutional and administrative frameworks. In formulating the above, it is imperative that the target group be involved and well informed about the developments from the onset. This prepares industry to make decisions on the course of action to take in order to manage their waste and control pollution.

Andreadakis (1997) mentions three main control options for managing industrial liquid wastes:

- on-site treatment (involving recovery and reuse of valuable materials including water), followed by direct discharge to the aquatic environment;
- off-site treatment, in combination with other industrial effluents at a central facility and direct discharge onto surface water; and
- discharge to the public sewerage system of the untreated or pre-treated waste.

In Zambia, it is common to find direct discharge of untreated or pre-treated effluent from industries into the public sewers and even to the aquatic environment. There has not been a case where industries joined forces to have an off-site treatment in combination with other industrial effluents at a central facility.

Various regulatory agencies agree on the general approach to prevent and control pollution from industry. This is explained in the following section. Whichever way one looks at it, industries are increasingly facing a plethora of tightening restrictions on both the content and volume of their effluent. It is from this standpoint that the following general approach is the preferred way of handling waste.

1.3 Pollution Prevention and Control Philosophies

Until the late 1960s, restrictions on the discharge of wastes were not particularly stringent and, with the availability of cheap energy and raw materials, industry had little incentive to conserve their use or control the generation of wastes and their subsequent discharge into the environment (UNEP-IE, 1986). Since the UN conference on the Human Environment held in Stockholm in 1972, many countries accelerated their environmental concerns and adopted legislation to control their environment.

Most environmental protection efforts have traditionally been directed towards control of pollution from waste substances after it has been generated, the so-called end-of-pipe treatment (Lindsey *et al.*, 1996; Tipping and Brooking, 1995). Although it may sometimes be effective in protecting the environment, this method of waste management does not usually solve the pollution problem; rather, it alters the problem often by transferring pollution from one medium to another. Therefore, this has little environmental benefit. It is increasingly being realised that both industry and the environment can gain from introduction of pollution prevention strategies (Lindsey *et al.*, 1996). It is in this context that emphasis has shifted away from how to deal with the amount of wastes produced toward efforts concentrated on reducing the amounts of wastes produced. Pollution should be prevented or reduced at the source whenever feasible, while pollution that cannot be prevented should be recycled in an environmentally safe manner. In the absence of feasible prevention and recycling opportunities, pollution should be treated. Ultimate disposal into the environment should be the last resort (Theodore and McGuinn, 1992).

Figure 1.3.1 shows the hierarchy for dealing with waste. Source reduction covers any practices that reduce or eliminate the creation of pollutants and includes: equipment or technology modifications, process or procedure modifications, substitution of raw materials; and improvements in housekeeping, maintenance, training or inventory control (Lindsey *et al.*, 1996).

Recycling attempts to recover a usable material from a waste stream. A material is recycled if it is used, reused or reclaimed. Recycling through use and/or reuse involves returning waste material either to the original process as a substitute for an input material, or to another process as an input material. Recycling through reclamation is the processing of a waste for recovery of a valuable material or for regeneration. Reuse involves finding a beneficial purpose for a recovered waste in a different process.

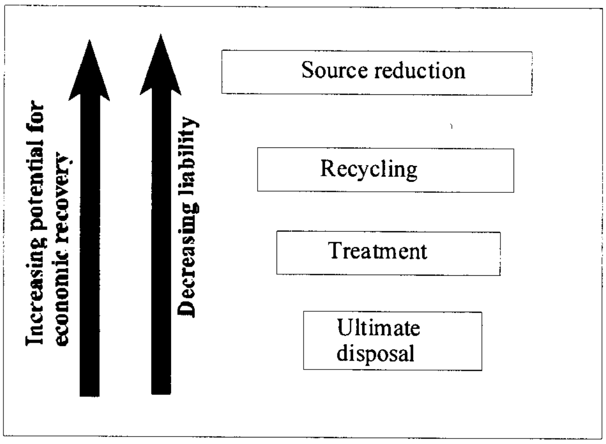

Figure 1.3.1: Hierarchy of waste management options
(After Lindsey *et al.*, 1996 and Theodore and McGuinn, 1992)

Three factors to consider when determining the potential for reuse are (Theodore and McGuinn, 1992):

1. the chemical composition of the waste and its effect on the reuse process
2. whether the economic value of the reused waste justifies modifying a process in order to accommodate it
3. the extent of availability and consistency of the waste to be reused

After source reduction and recycling, the next step is treatment by physical, biological and/or chemical treatment methods to reduce toxicity and volume of waste requiring ultimate disposal. The final effluent is discharged into water bodies or used for restricted irrigation. Sludge is disposed of by landfilling, land-farming, deep-well injection or ocean dumping.

Reducing the amount of pollutant or waste produced initially will result in a reduction of the costs associated with handling of that waste (Theodore and McGuinn, 1992). Therefore, the costs resulting from the transportation, disposal, and treatment of wastes will be lowered. In addition, income can be derived through the sale, reuse, or recycling of certain wastes. However, an economic analysis has to be carried out to determine the viability of the measures and to establish whether the investment costs can be recouped and how long that would take.

Liabilities can be short-term or long-term. Short-term liabilities are associated with releases to the environment resulting in non-compliance with permits, personnel exposure and workplace safety. Long-term liabilities result from on-site or off-site disposal if it is established that the waste is releasing contaminants into the environment and the generator is compelled to undertake remedial action (Theodore and McGuinn, 1992).

Lindsey *et al.* (1996) state that pollution prevention can be the least expensive means of reducing industrial discharges, and list some benefits to industry of properly selected and deployed pollution prevention technologies as:

- reduction of waste monitoring, treatment and disposal
- improved worker safety due to less exposure to hazardous material
- reduction of raw material usage and manufacturing cost
- regulatory compliance expense reductions
- improvements in public image and employee morale through reduced hazardous chemical emissions using safe chemical substitutes and process alternatives
- productivity gains associated with more efficient processes.

In spite of the benefits listed above, a number of industries have not instituted waste prevention measures. Some obstacles preventing investors from using environmentally sound technologies are (Lindsey *et al.*, 1996):

- insufficient awareness of the environmental effects of production processes
- lack of understanding of the true costs of waste management
- no access to technical advice
- insufficient knowledge to implement new technologies
- lack of financial resources, or
- management inertia and resistance to change

The hierarchy of waste management explained earlier falls under the concept of "clean technologies" which covers three distinct but complementary purposes (Matilla, 1989):

- Less pollution discharged into the natural environment (air, water and earth)
- Less waste; this is why reference is often made to low-waste or non-waste technologies
- Less demand on natural resources (water, energy and raw materials)

Waste minimisation does not deal with the implementation of low or non-waste technologies solely at the production stage. It is important to minimise waste at all stages of a product's life: raw material extraction, production, use and disposal after use. Conventional controls only deal with the problem of first-generation pollution, which is created in the manufacturing process and regulated by legislation, while ignoring the problem of second-generation pollution related to product use. Thus if a pollutant is created during consumption of the product, the problem is at the user's end and cannot be solved by conventional controls applied to the manufacturing process. The overall 'environmental content' of a product should be optimised (UNEP-IE, 1989). This falls under an environmental management tool known as product life-cycle assessment. It is an objective process to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and materials used and wastes released to the environment, to assess the impact of those energy and materials used and releases on the environment, and to evaluate and implement opportunities to effect environmental improvements. The assessment includes the entire life-cycle of the product, process or activity, encompassing extraction and processing of raw materials, manufacturing, transportation and distribution, use/re-use/maintenance, recycling and final disposal (UNEP–IE, 1995)

New environmental concepts, policies and management systems are being developed in order to improve industrial environmental management (UNEP–IE, 1995). In 1991, the International Organisation for Standardisation (ISO) established a Strategic Advisory Group on the Environment (SAGE) to explore environmental standardisation as a vehicle to implementing concepts of sustainable development. SAGE working groups were organised and met to develop standards frameworks in the following areas:

- Environmental management systems
- Environmental performance evaluation
- Life-cycle assessments
- Environmental labelling
- Environmental auditing
- Environmental aspects of products standards

These environmental management standards fall under the ISO 14000 series, which are developed by the ISO Technical Committee TC 207 established in 1993. Earlier work in this area in the ISO through the SAGE had either been completed or was continued by the TC.

Waste management is not only a matter of technology: it involves planning and organisation, common sense, an innovative attitude, good housekeeping - in other words, sound management practices. A successful pollution prevention programme can be achieved by properly educating all employees, customers and suppliers on the advantages of a pollution prevention programme and by including these individuals in the development and implementation procedures.

Industries in Zambia generally discharge their wastewater into sewers leading to publicly owned treatment works (POTWs) operated by local authorities. POTWs should naturally have a very close relationship with industrial plants whose wastewater they receive. Operators of POTWs need to be aware of how they will be affected and can benefit from the anticipated increase in the use of pollution prevention measures by industry. For new industries that require the services of POTWs, an agreement has to be reached for the mutual benefit of both parties.

In Zambia, although POTWs were given authority to restrict wastewater pollutants from industrial sources by the Local Administration (Trade Effluent) Regulations statutory instrument No. 161 of 1985, they accept discharges that exceed the stipulated standards. This causes great strains on treatment processes and results in poor treatment performance and often allows wastewater to pass untreated through the treatment facilities. These wastewater treatment facilities have to meet environmental standards imposed by the Environmental Council of Zambia (ECZ). ECZ focusses on POTWs and not on the number of industries serviced. In this regard, POTWs are forced into a front line enforcement role for the industries discharging into their sewers. Failure to regulate industrial effluent means a plethora of treatment plant problems and eventual inability to meet standards for discharge into water bodies. However, it still remains to be seen what ECZ can do to POTWs, which are the main culprits in contravening effluent regulations.

It is the task of the Zambian government to set a comprehensive multi-media regulatory framework which will lead to the use of low and non-waste technologies (cleaner technologies). Programmes on cleaner technologies are underway through ECZ and the Zambia Chamber of Commerce and Industry (ZACCI), as explained in section 3.5.2. Stricter environmental regulations on emissions and disposal, and tight enforcement procedures are necessary. But these must be combined with an incentive scheme: research and development, training activities and education programmes, collection and transfer of information.

Policy options for waste minimisation include creation of an information base and taxation of wastes. Among waste taxes, the concept that has found widest applications is that of effluent charges. This approach is successful provided there is sufficient competition in the market to prevent the charge being passed on to the consumer, and provided the charge is equivalent to the level of damage or at least the cost of treatment. In implementing these charges it is necessary to ensure that they are not merely taken as the licence to pollute, because rich industries would easily pay the required fees and continue polluting. Making the charges high enough to discourage such discharges would promote self-regulation and contribute towards environmental protection.

A change is likely to take place in the mentality of the producer when he understands that waste reuse is a source of valuable products and more profits. He gives it closer attention than when he sees it as an aspect of production to which priority is to be given solely on account of inspectors or social pressure.

1.4 Objectives of the Study

The major objective of the study was to give an insight into the management of industrial wastewater in the Zambia. This is dealt with under three distinct but interrelated subjects. These are (a) review of relevant legislation pertaining to industrial wastewater and other related issues; (b) case study of a slaughterhouse with regard to water and wastewater management and; (c) pilot plant investigations on the treatability of slaughterhouse effluent by trickling filtration. Each of these had its sub-objectives as listed in the following sections.

1.4.1 Industrial Wastewater Management in Zambia

- To analyse the effectiveness, relevance and currency of the relevant legal, policy and administrative frameworks with regard to industrial wastewater management in Zambia
- To assess the perspectives and awareness of local industries regarding the relevant legislative and other frameworks and the resulting responses.

1.4.2 Case Study of a Lusaka Slaughterhouse

- To analyse installed industrial technology
- To evaluate the status of pretreatment facilities
- To assess industrial water use
- To explore the potential of in-house methods to reduce water consumption and pollution
- To investigate the availability of water and wastewater analytical facilities
- To propose viable waste treatment techniques

1.4.3 Pilot Plant Investigations: Treatability of Slaughterhouse Effluent by Trickling Filtration

- To assess treatability of slaughterhouse wastewater by trickling filters
- To assess the potential for reducing pollution loads so as to meet discharge standards
- To provide a basis for the design of a full scale trickling filter treatment plant.

2. Methodology

2.1 General

This chapter presents the methodology adopted for each of the three areas covered in the study. Firstly, it delves into the aspects considered in assessing the situation regarding industrial wastewater management in Zambia. Secondly, the selection and approach of the case study are explained. Thirdly, it gives an overview of the selection, design, construction and operation of the pilot plant.

2.2 Industrial Wastewater Management

The assessment of industrial wastewater management in Zambia was carried out by an extensive consultation of the relevant legislation and local publications. Interviews and discussions were conducted with industries and the relevant authorities in environmental and water sectors.

The relevant authorities and organisations covered were:

- Ministry of Environment and Natural Resources
- Environmental Council of Zambia
- Ministry of Energy and Water Development – Department of Water Affairs
- The Water Sector Development Group
- Lusaka Water and Sewerage Company
- Local authorities in Lusaka, Kabwe, Ndola, Kitwe and Chingola

The pertinent questions raised were the role of these organisations in pollution prevention and control, their relevant legal backing, basis of pollution fees if any, penalties for contravening the relevant legislation and specific cases as examples, and relationship with other environmental authorities.

For the industries, the assessment dwelt on wastewater management, awareness and perspectives of environmental legislation and other related aspects. Questionnaires were prepared and distributed to selected industries. Distribution of questionnaires was coupled with industrial site visits to survey and assess the status of wastewater pretreatment or treatment facilities. The questions set were meant to capture finer pieces of information relating to the existence of pretreatment or treatment facilities, knowledge of wastewater characteristics and how acquainted industries were with the relevant legislation pertaining to industrial wastewater. A sample questionnaire is given in Appendix A.

The industries targeted were those in food processing or related category. The selection of industries was based on two criteria: those that mainly produce organic wastewater; and those that are more or less widely distributed in the country. These were breweries, slaughterhouses, milk-based industries, canning industries, soft drink plants and edible oil industries.

Selection of the towns was confined to the major towns where industrial activity is concentrated in Zambia. A total of seventeen industries were selected from Lusaka in Lusaka Province and Ndola, Kitwe and Chingola in the Copperbelt Province. Figure 2.2.1 is a map of Zambia showing some of the towns covered in the study. The categories of the industries visited in these towns are given in Table 2.2.1.

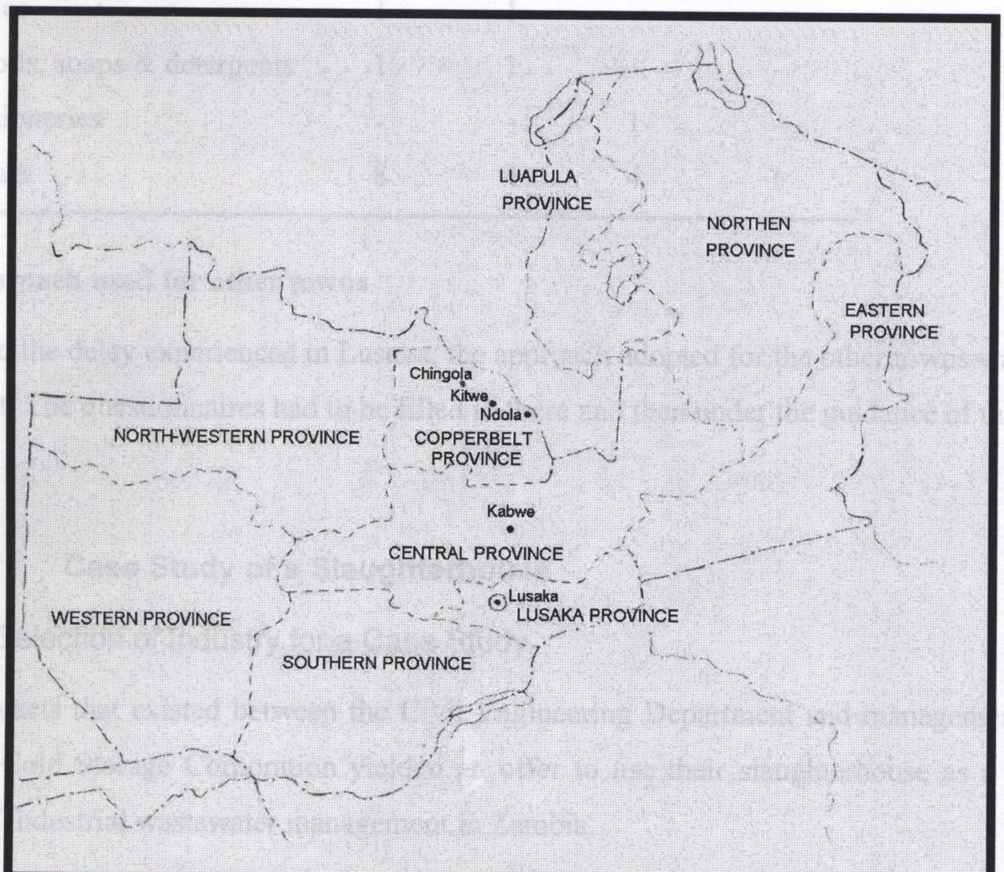

Figure 2.2.1: Map of Zambia showing places covered

a) Approach used in Lusaka and response

A period of one week was given to the selected industries to answer the questions. When distributing the questionnaires, time was allocated for short industrial surveys to establish whether or not wastewater treatment facilities were available and the status they were in. After one week, the author went around collecting back the questionnaires. In most cases, the questionnaires were not ready at the time of collection and more time had to be given. This exercise took about three months.

Table 2.2.1: Industries visited in each town

	Lusaka	Ndola	Kitwe	Chingola
Breweries	2	1	1	-
Soft drink plants	1	-	1	-
Slaughterhouses	2	1	1	1
Milk-based industries	1	-	-	-
Canneries	1	1	-	-
Edible oils, soaps & detergents	1	1	-	-
Confectioneries	-	-	1	-
Sub-totals	8	4	4	1

b) Approach used for other towns

To avoid the delay experienced in Lusaka, the approach adopted for the other towns was different. The questionnaires had to be filled in there and then under the guidance of the author.

2.3 Case Study of a Slaughterhouse

2.3.1 Selection of Industry for a Case Study

The contacts that existed between the Civil Engineering Department and management of Kembe Cold Storage Corporation yielded an offer to use their slaughterhouse as a case study of industrial wastewater management in Zambia.

The industry satisfied the following criteria as well:

- Locality- the industry was located within the city of Lusaka

- The pretreatment facility was rundown (the need for an alternative was obvious)
- The wastewater was organic to allow for biological treatment

The slaughterhouse is located in the heavy industrial area west of Lusaka along Mumbwa Road - the road to Zambia's Western Province. Figure 2.3.1 shows the location of the slaughterhouse in Lusaka.

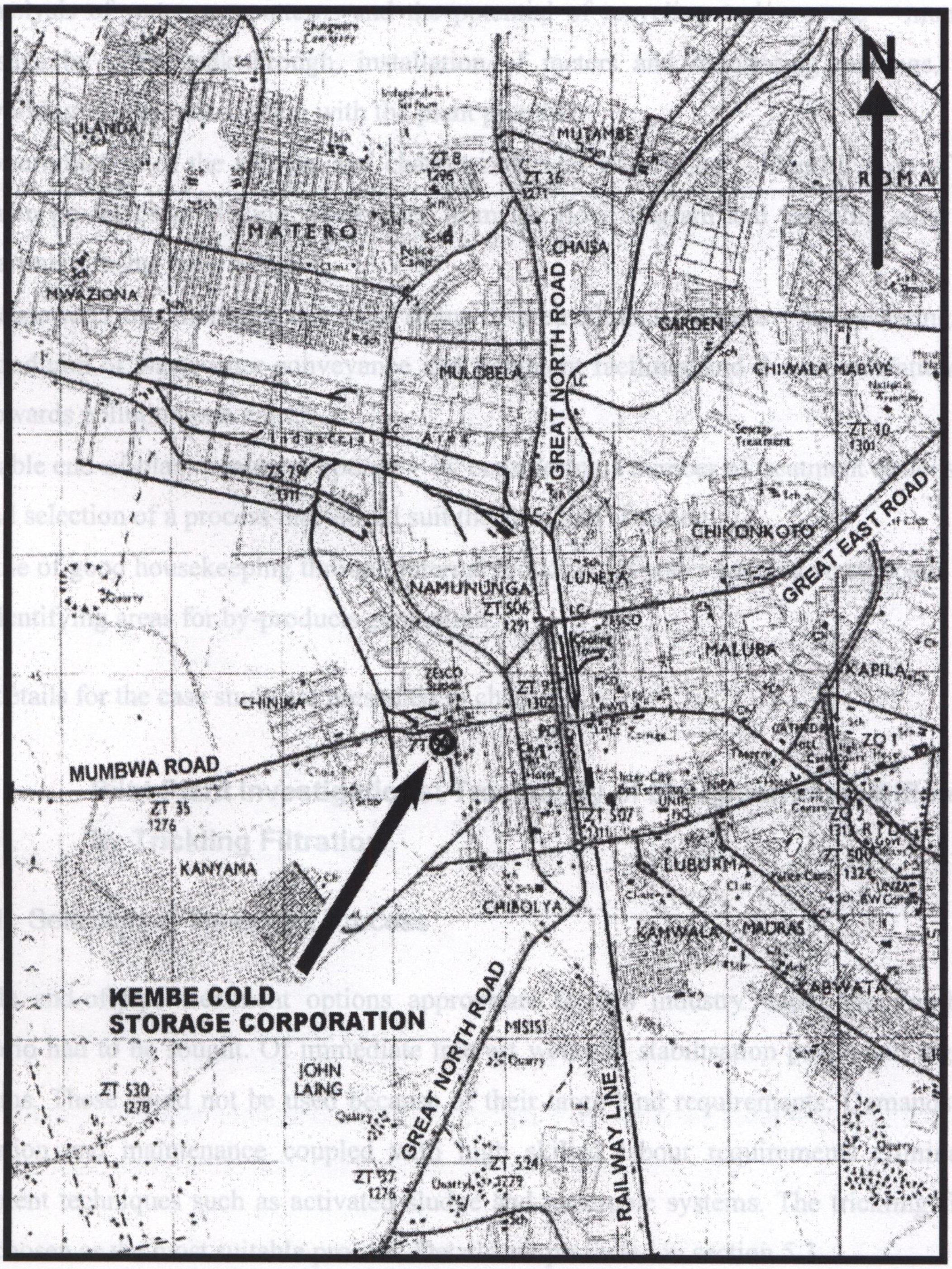

Figure 2.3.1 Location of the slaughterhouse in Lusaka

2.3.2 Approach and Areas Covered

The aspects considered and how they were implemented are given below:

- review of industrial technology – plant survey and asking technical personnel on machinery and processes. Two weeks was spent studying the slaughtering processes to produce a process flow diagram.
- analysis of water use patterns and the potential of recycling and/or reuse – monitor usage by plant walk-through, installation of meters and monitoring readings, and working in close association with the plant plumber.
- determination of the sources and characteristics of wastewater – identification of the main processes producing wastewater from the flow diagram and sampling after the various streams have merged.
- wastewater treatment practices and status of pretreatment facilities – by assessing the condition of wastewater conveyance and treatment facilities and the attitude/attention towards pollution prevention
- viable end-of-plant treatment options – by considering a number of treatment options and selection of a process that would suit the Zambian situation.
- role of good housekeeping through internal reduction of water use and waste loads and identifying areas for by-products generation.

The details for the case study are presented in chapter 4.

2.4 Pilot Plant Investigations: Treatability of Slaughterhouse Effluent by Trickling Filtration

2.4.1 Selection of Treatment Process

Viable end-of-pipe treatment options appropriate to this industry under the Zambian scenario had to be sought. Of immediate interest were the stabilisation ponds and lagoon systems. These could not be used because of their large land requirements. Demands for operation and maintenance coupled with high skilled labour requirements eliminated treatment techniques such as activated sludge and anaerobic systems. The trickling filter was chosen as the most suitable process. Details are presented in section 5.3.

2.4.2 Description of the Pilot Plant: Design and Construction

The main units of the pilot plant were a wastewater reservoir (already existing), abstraction pump, flow control tank, stilling tank, mixing tank, trickling filter, humus tank (final clarifier) and recirculation pump. All the treatment units were made from steel except for the flow control and flotation tanks and the recirculation sump, which were ready-made 210 litre plastic containers. The pipe network for distribution was of rubber hose. The steel units were given two protective coats of red oxide.

Design considerations were concentrated on the trickling filter unit. The hydraulic and organic loading rates were the points that determined the design. Detailed design considerations and construction features of the pilot plant are given in section 5.10.

A biochemical oxygen demand (BOD) value of 800 mg/l was selected. This was based on an assumed influent concentration of 1500 mg/l diluted by at least 100 percent recirculation of highly treated final effluent. By varying the flow rate, the volume and area of the filter was computed using the following relationships (Veenstra and van Duijl, 1995):

$$L_v = \frac{load(kgBOD/d)}{Volume_{filter}(m^3)}(kgBOD/m^3 filter/d) \qquad (2.1)$$

and

$$HSLR = \frac{flowrate}{Area_{filter}} = \frac{Q(m^3/h)}{A_f(m^2)}(m/h) \qquad (2.2)$$

where

Lv = volumetric organic loading rate,

HSLR = hydraulic surface loading rate, m/h

The trickling filter had a media.depth of 1.8 m and a square cross section area of 3.24 m^2 Construction details of the trickling filter are provided in section 5.10.

A fixed flow distributing system was adopted over a rotary distributor because it was easier to operate. Due to anticipated clogging problems, open distribution channels were selected to facilitate cleaning. A square cross section for the filter was selected because it was simpler to fabricate than a circular section. Steel was chosen considering the ease with which fabrication works could be carried out. Rusting was minimised by painting the surfaces with two protective layers of red oxide.

The final clarifier design was based on surface loading rate and retention time. Previously, it was felt that the clarifier be made in such a way as to be adjusted according to the flow rate. This was not done because of anticipated construction complications. The fabricated clarifier was trapezoidal in shape with a volume of about 0.8 m^3, water depth 0.75 m and liquid surface area 1.65 m^2. It had a provision for sludge removal by way of a gate valve at the bottom. Scum was skimmed from the surface manually.

Construction of the pilot plant (all the units except for the clarifier) was carried out in a period of two months - from the beginning of May to the beginning of July.

2.4.3 Operation and Experimental Programme

The plant start-up was on 10th July 1997. Five days after start-up, seed sludge was introduced from a humus tank (final clarifier) at Chunga Sewage Treatment Plant in Lusaka.

It was observed at start-up that the minimum hydraulic loading required for good wastewater distribution over the filter and to ensure that the whole area was wet was about 1.1 m^3/h. Flow distribution was very poor at lower flow rates. This also meant that the operation and classification of the filter had to be determined by the hydraulic loading rate.

On completion of the clarifier, the pilot plant was operated at fixed influent and recirculation flow rates. The total flow to the filter remained at 1.1 m^3/h. The main purpose of recirculation was to dilute the influent. The hydraulic operation regime was in the intermediate range until October 15 when, due to a high proliferation of filter fly larvae on the media, the flow rate was increased to the high-rate range[1]. Influent flow was determined by a stopwatch and graduated container while the recirculation flow was measured by a flow meter. From time to time, the flow meter reading was counterchecked by the stopwatch and graduated container.

[1] The hydraulic loading regimes for intermediate and high-rate filters are 3.7-9.4 and 9.4-37 m^3/m^2.day, respectively.

All the analyses were performed according to " Standard Methods" (APHA, AWWA, WEF, 1995). The treatment performance was based on BOD removal efficiencies because the pilot plant was constructed mainly to reduce biodegradable organic matter. Because of the time required to have results for the BOD tests, it was found necessary to analyse samples for chemical oxygen demand (COD). Periodically, the BOD was analysed in order to establish the correlation with COD. For the determination of the COD, the closed reflux titrimetric method in standard 10-ml ampules was employed. Total suspended solids (TSS) were also determined though on a much lower scale.

Sampling and analysis began towards the end of September, about ten weeks after start-up, and went on up to 31st December. Due to high variations in COD concentration between the hourly samples composite samples were found to be more appropriate.

Initially equal volumes of grab samples were collected hourly for twelve hours from 07:00 hours to 18:00 hours. For COD determination each sample was preserved with 2ml concentrated sulphuric acid for every litre of sample and stored in a fridge at about 4 °C. Before analysis, samples for each day were mixed to form one composite sample. A peristaltic pump was afterwards installed to facilitate simultaneous sampling of influent and effluent to obtain 24-hour composites. No preservation was done during the 24-hour sampling period. Samples were taken every day except for the weekends and public holidays.

2.4.4 Manning of the Pilot Plant

An operator was employed full time to oversee the pilot plant. His main responsibilities were;

- to ensure uninterrupted operation of all units of the pilot plant
- to unclog the trickling filter distribution system
- to monitor flow rate
- to collect and preserve samples
- to removal sludge and scum from the final clarifier
- to ensure that siphon worked well and supplied wastewater continuously to the abstraction sump
- to keep the area around the pilot plant clean

3. Industrial Wastewater management in Zambia

3.1 Background

The issue of the environment is becoming increasingly topical in Zambia, especially after the enactment of the Environmental Protection and Pollution Control Act (EPPCA) of 1990. This Act provided for the establishment of the Environmental Council of Zambia (ECZ) as a monitoring, co-ordinating and regulating body for all environment-related activities in the country so as to protect the environment and control pollution in particular.

One of the major thrusts of the Act is the prevention and control of water pollution. This is reflected in the follow up to the Act, the Water Pollution Control (Effluent and Wastewater) Regulations (GRZ, 1993). Industrial wastewater may be a major contributor to water pollution. It is in this regard that requirements for industrial wastewater discharge to the aquatic environment have been specifically addressed.

In order to offset the negative impacts of uncontrolled effluent discharge, a comprehensive industrial wastewater management system through formulation of appropriate legal, administrative and institutional frameworks is a necessity. Against this background, the relevant legislation and related issues in Zambia are analysed to determine how the sector is being run considering enforcement, compliance and awareness from industrial effluent dischargers. This was carried out by interviews of key personnel in selected industries and officers in the government agencies charged with the responsibility of preventing and controlling water pollution. Questionnaires were prepared and short industrial surveys undertaken to the selected industries to gather more data about their awareness and perspectives of industrial wastewater management. The following sections give details on the foregoing.

3.2 Legal and Administrative Framework

There are about twenty-eight pieces of legislation which have or could have a bearing on environmental protection and pollution control in the country (Chipungu and Kunda, 1994). The major relevant Acts dealing with industrial wastewater are:

a) The Local Government Act
b) The Natural Resources Conservation Act
c) The Public Health Act
d) The Water Act, and
e) The Environmental Protection and Pollution Control Act

3.2.1 Local Government Act

The Local Government Act was last amended in September 1991 and provides for the establishing of councils in districts, the functions of the local authorities and the local government administration system. The functions of the local authorities include the establishment and maintenance of sanitary services for the removal and destruction of all kinds of refuse and effluent and to compel the use of such services. They are also charged with the responsibility to take measures for the conservation and prevention of pollution to water supplies.

A more elaborate statement of the powers of local authorities concerning trade effluent is found in the Local Administration (Trade Effluent) Regulations, Statutory Instrument No. 161 of 1985 (GRZ, 1985). The regulations were made under section sixty-four of the Local Administration Act, 1980 and are still valid under the 1991 Act. These regulations empower the local authorities to give consents for the discharge of trade effluents in any watercourse or on any land in the area of the local authority.

The local authority also has powers to determine the conditions and standards for trade effluent to be discharged into the public sewer and into a public watercourse or on any land in the area. Appendix B gives extracts of the effluent standards as stipulated in the Local Administration (Trade Effluent) Regulations, Statutory Instrument No. 161 of 1985.

It was clear from interviews that the Local Administration (Trade Effluent) Regulations are not enforced. The local authorities responsible for implementation and enforcement seemed ignorant of the contents of these regulations. They do not have the necessary manpower and facilities to monitor effluent quality.

3.2.2 The Natural Resources Conservation Act

This Act was enacted in 1970 and its main objective is conservation of natural resources. Under the Act, the minister in the Ministry of Environment and Natural Resources is empowered to make orders for the conservation of natural resources to occupiers of land requiring them to undertake or adopt necessary measures in accordance with the appropriate conservation plan. The conservation plans provide for, *inter alia*, measures and works to prevent the pollution of public water. Environmental quality control is facilitated by the Environmental Council of Zambia and natural resource conservation falls under the Departments of Natural Resources and Forestry.

The penalties for offences under the Act are generally very low; a fine not exceeding K200 (US$0.2) and imprisonment not exceeding six months.

3.2.3 The Public Health Act

The objectives of the Act are, among other things, to provide for the prevention and suppression of diseases, and generally to regulate all matters connected to public health in Zambia. The Act therefore provides for environmental sustenance from a public health perspective.

Under the Act, it is the duty of the local authorities to take all necessary measures " for preventing any pollution dangerous to health of any supply of water which the public within its district has a right to use and does use for drinking or domestic purposes".

The aspect dealing with the prevention of water pollution has not been enforced because local authorities do not have the necessary manpower and facilities to carry out the task.

3.2.4 The Water Act

" An Act to consolidate and amend the law in respect of ownership, control and use of water; and to provide for matters incidental thereto or connected therewith".

The Act establishes the Water Board and also regulates the use of public water other than for domestic use through permits. Further, the Act provides for the offence of polluting public water so as to render it harmful to man, beast, fish or vegetation. Under the Act, any person responsible for fouling or polluting water may be directed to take adequate measures to prevent the fouling or pollution, failure to do so is punishable by a fine of two hundred Kwacha per day until the matter is rectified.

The Water Development Board administers this law and makes regulations under the Act to provide for registration, application and prescription of fees. The Department of Water Affairs (DWA) is responsible for the general administration and management of the country's water resources with respect to ownership, control and use of water.

There are no standards for water quality and that makes it difficult to determine whether the water has been polluted or not. It was also established that the DWA did not control water pollution in any way because it felt that the task was the responsibility of the Environmental Council.

3.2.5 The Environmental Protection and Pollution Control Act

The preamble to this Act reads, " An Act to provide for the protection of the environment and the control of pollution; to establish the Environmental Council and to prescribe functions and powers of the Council; and to provide for matters connected with or incidental to the foregoing".

The Environmental Protection and Pollution Control Act (EPPCA) was enacted in 1990 as a consequence of the adoption of the National Conservation Strategy (NCS) for Zambia. The NCS recognised that the powers and enforcement in the existing legislation were weak and that there was inadequate provisions relating to the power to make regulations for the control and monitoring of pollution in the environment.

The Environmental Council (ECZ) is a statutory body whose functions are to do such things as are necessary to protect the environment and control pollution to provide for the health and welfare of persons, animals, plants and the environment in general.

There are separate parts in the Act dealing with different areas of the environment and pollution control. Provisions in these areas empower the Environmental Inspectorate Division, which consists of the Pollution Control and Natural Resources Inspectorates, to make specific regulations pertaining thereto. It is against this background that the Water Pollution Control Unit under the Pollution Control Inspectorate formulated the Water Pollution Control (Effluent and Wastewater) Regulations of 1993. Among the things found in the regulations are the standards for the discharge of effluent into the aquatic environment, as well as licensing and permit requirements for the same. The Water Pollution Control Unit is also charged with the responsibility of enforcing and monitoring compliance. For polluting the environment, the polluter is made to pay through application of the "Polluter Pays Principle". One example where the principle was applied was at Indeni Oil Refinery in Ndola, the second largest city in the country. In 1994, oil was discharged from this industry into a nearby stream resulting in fish kills and an outbreak of a skin disease at a school that used the water. The company had to drill boreholes to provide an alternative source of water for the school as well as cleaning up the stream and compensating the affected farmers.

The regulations clearly spell out the offences, enforcement procedure and penalties for contravening the provisions of these regulations. Appendix C gives extracts of the effluent standards and an enforcement notice form issued to industries for contravening these regulations.

Dischargers of effluent to the aquatic environment pay for discharge by way of permits and licences as long as they are within the stipulated effluent standards. However, if pollution levels go beyond the levels for which the licence was given, ECZ may revoke the licence and impose a fine if they are convinced that the applied for licence conditions are contravened and that the effluent would endanger public health and the environment. Depending on the extent of the damage to the environment, corrective measures have to be carried out by the polluter at his expense - thus applying the polluter pays principle.

Other functions of the Environmental Council include environment education, information, research and carrying out or evaluating environmental impact assessments.

3.3 Current Government Policy

The most important document on this subject is the National Environment Action Plan (NEAP) [GRZ, 1994]. This came into being when in 1992, the government made a decision to update the 1985 National Conservation Strategy, the main policy document that led to the establishment of environmental legislation and institutions.

The NEAP was founded on three fundamental principles:

a) the right of citizens to a clean Environment
b) local community and private sector participation in natural resource management
c) obligatory Environmental Impact Assessments (EIA) of major development projects in all sectors

The overall objective of the NEAP is to integrate environmental concerns into the social and economic development of the country. As the main thrust, the NEAP identifies environmental problems and issues, analyses their causes and recommends activities required to resolve those issues. These proposals formed the basis for a detailed action plan to support the implementation of the NEAP through the Environmental Support Programme (ESP) [GRZ, 1997a]

The NEAP has five priority action areas with the greatest social cost to Zambia, namely:

1. water pollution and inadequate sanitation
2. soil degradation
3. air pollution in the Copperbelt towns
4. wildlife depletion (fish and game) and
5. deforestation

The foregoing clearly indicates that the government is truly committed to addressing environmental issues. Whether this would be backed by the appropriate measures remains to be seen.

3.4 Programmes and Projects

Programmes and projects on the environment may be divided into two categories; policy level programmes undertaken by the Ministry of Environment and Natural Resources (MENR), and policy implementation, enforcement and research carried out by ECZ.

3.4.1 Programmes and Projects by MENR

There are four main programmes being implemented, or soon to be implemented: NEAP and the related ESP, and the Zambia Forestry Action Programme (ZFAP) together with the Provincial Forestry Action Programme (PFAP). Of particular importance to this study are the NEAP and ESP.

The NEAP was briefly explained in section 3.3 above. A mechanism to implement the NEAP came into being by way of the ESP. Five major issues have been identified in the ESP, namely; water pollution and inadequate sanitation, air pollution, forestry and wildlife. ESP is an on-going programme with a number of stages. The first stage (1997 -2001) has four major components:

- institutional strengthening and legal framework
- environmental education and public awareness
- environmental information network and monitoring system
- establishment of a pilot environmental fund to promote community based environmental projects

This is being done with the support of the World Bank and the key donors being Norway and Canada.

3.4.2 Programmes and Projects by ECZ

The most important programme dealing with industrial waste is the Industrial Pollution Prevention Programme (IPPP) to be funded by Norway. This is intended to strengthen ECZ's capacity to regulate industrial pollution and waste in order to achieve acceptable environmental standards to prevent damage to persons and the ecosystem.

There are two main orientations to the programme: cleaner technology and institutional strengthening. Cleaner technology aims to introduce Zambian industries to techniques and equipment which would result in adoption of cleaner production systems. The long term goal is to introduce cleaner technology in industries facing environmental problems. Institutional strengthening would involve cooperation between the Norwegian Pollution Control Authority (SFT) and ECZ to address air pollution regulations, hazardous waste regulations, water quality guidelines and regulations, and environmental information systems. The development of water quality guidelines aims to establish whether the presence or introduction of any materials into a water resource would interfere with the intended use. This would lead to water quality information systems and development of the Kafue river basin in resource inventory, monitoring systems for water quality and industrial discharge affecting the basin.

3.5 Awareness and Perspectives of Local Industry: Questionnaire and Interview Findings

As explained section 2.2, questionnaires were prepared and distributed to seventeen selected industries in Lusaka Province (Lusaka) and Copperbelt Province (Ndola, Kitwe and Chingola). A sample questionnaire is given in Appendix A. The purpose of this exercise was to get an insight into how much industries understood the relevant legislation on the environment and how they dealt with industrial wastewater in order to prevent or control pollution. To gather more data, brief industrial surveys and interviews of personnel in charge of industrial processes were undertaken when distributing the questionnaires. The findings of this exercise are briefly explained below.

a) Legislation

On the implications of the relevant Acts as they relate to industrial effluent discharge, all the industries strongly felt that little has been done to enlighten them. In this respect, they advocated for seminars or workshops on environmental legislation and what it entails. Eleven Industries had some knowledge about the Pollution Control (Effluent and Wastewater) regulations of 1993 for discharge into the environment. None knew about the Local Administration (Trade Effluent) regulations, statutory instrument No 161 of 1985. Six industries did not seem to know anything about the regulations. The local authorities were also ignorant of the regulations they should enforce.

b) Water consumption and wastewater production

The amount of water used in the industrial processes did not seem to be of great concern. Only seven industries monitored their consumption levels and had an estimate of the amount of wastewater produced. Monitoring water usage seemed to be a neglected area most probably because they considered water a cheap resource. This is more so considering that a number of industries have boreholes to supplement water supplies from local authorities.

c) Wastewater treatment facilities

The survey revealed that wastewater treatment plants are not common in Zambian industries. Six industries had wastewater treatment facilities and all these employed physical treatment processes, mainly screening and sedimentation. However, it was observed that none had knowledge of the operation parameters (loading rates and plant capacities) of these facilities. Of the industries without treatment facilities, five felt that there seemed to be no need for treatment at the time the industries were setup because the relevant legislation was not in force then. Only one industry cited financial constraints for the inability to install wastewater treatment facilities. Three were of the view that the quality of their wastewater was good enough to be discharged without any treatment. All industries seemed willing to meet the stipulated effluent standards if well informed about their compliance requirements. As the situation stood, they were content with paying the fees for licences and permits because they were not high enough to warrant construction of wastewater treatment facilities.

d) Wastewater quality monitoring

Monitoring wastewater characteristics seemed to be a neglected area. Of all the industries visited, only six monitored the wastewater quality and knew the characteristics of their wastewater. The main parameters monitored were pH, temperature, colour, total suspended solids, conductivity and biochemical oxygen demand. The other industries appeared not to see the justification for spending money on monitoring wastewater characteristics especially with the lack of enforcement of the appropriate legislation.

e) By-products processing

Thirteen industries had some of their wastes sold or even given away as useful materials in order to reduce the amount of waste to dispose of. Most of these by-products were mainly used as animal feeds. It was observed that no industry had installed special equipment to process waste into useful by-products. All the by-products were obtained directly from the main industrial processes and either sold or given away in that state. The foregoing is a clear testimony that industries have not realised the potential of broadening their profit base by converting waste into useful and marketable by-products.

f) Discharge points and permits

It strongly came out that most industries take advantage of the public sewers for discharging their wastewater. This is mostly because these industries are situated in the designated industrial sites provided with adequate sewer connections to the public sewers. Fourteen industries discharged into the public sewers, two discharged into storm drains and one directly to a watercourse. Of the two industries that discharged into storm drains, one (Premium Oil Industries) was served with an enforcement notice from ECZ due to the unsightly conditions created by their wastewater. Effluent discharge permits and licences are given to industries by ECZ for discharge into watercourses. Local authorities do not issue permits for discharge into sewers, let alone monitor the quality of effluent they receive. In most cases, industries pay fixed charges regardless of wastewater quantities and characteristics. One surprising observation was that some industries that discharge their effluent into public sewers got permits from ECZ. This is most likely because of the inactivity of local authorities and ignorance from concerned industries.

Table 3.5.1 gives the industries visited highlighting the main aspects of water and wastewater management.

Table 3.5.1: Industries visited and some of the information gathered

City/ Town	Name of Industry	Category	Water monitoring	Wastewater monitoring	Wastewater treatment	Effluent disposal
Lusaka	Zambian Breweries Plc	Brewery	x	x	none	PS
	National breweries	Brewery	x	√	screening	PS
	Zambia Bottlers Limited	Soft drinks	√	x	none	PS
	Bonnita Zambia Limited	Dairy	√	x	None	PS
	Zambia Horticultural Products Limited	Fruit proc., soft drinks & meat proc.	√	x	none	PS
	Kembe Cold Storage Corporation	slaughterhouse	x	x	None (rundown)	PS
	Zambia Pork Products	slaughterhouse	x	x	sedimentation	PS
	Premium Oil Industries	Edible oils, soaps & detergents	x	√	sedimentation	Storm drains
Ndola	Lever Brothers (Z) Limited	Edible oils, soaps & detergents	x	√	Fat trap	PS
	Northern Breweries (1995) PLC	Brewery	√	√	None	PS
	Lyons Zambia Limited	Cannery, soft drinks & meat processing	√	√	Screening, sedimentation	PS
	Ndola Abattoir	slaughterhouse	x	x	None	stream
Kitwe	Copperbelt Bottling Company Limited	Soft drinks	√	x	None	PS
	Kitwe Abattoir	slaughterhouse	x	x	none	PS
	National Breweries PLC	Brewery	x	√	screening	PS
	Specialty Foods Company Limited	Confectionery	√	x	none	Storm drains
Chingola	Chingola abattoir	slaughterhouse	x	x	none	PS

NOTE:

1. All the local authorities in these towns/cities including Kabwe were visited.
2. All the industries are located in designated industrial sites
3. √: monitoring carried out, x: monitoring not done
4. PS: public sewers

3.6 Discussion

The stance taken by government shows the strong resolve and determination with which it wants to protect the environment - at least on paper. This trend became more pronounced after the emergence of the Environmental Protection and Pollution Control Act.

All the necessary legal and administrative frameworks have seemingly been put in place though they need to be revisited. The State of the Environment report (Chipungu & Kunda, 1994) identifies conflicts and areas of duplication as well as determining the weaknesses in relation to enforcement of the various Acts.

It is saddening, however, to note that the necessary scientific and technical know-how and awareness on the part of industry and the general public needed to translate this determination into tangible results are lamentably lacking (Phiri, 1990). The situation is exacerbated by inadequate financial resources allocated to such a demanding undertaking. As a result, the much needed audience with their target groups could not be held. (GRZ, 1997a).

Given the present state of affairs, the mammoth task of protecting and controlling pollution of the environment will be a far cry. Examples abound. The inability of Local authorities to monitor, control and enforce the Local Administration (Trade Effluent) Regulations of 1985 for discharge into their sewers coupled with the non-existent communication link with industry has contributed immensely to the poor state of sewage works they operate. This has inevitably led to the discharge of almost untreated sewage into the aquatic environment resulting in heavily eutrophicated watercourses. Worse still, industry views the provision of sewerage by local authorities almost as a free service and are content to pay the minimal fees required of them, which fees are too low to sustain operations of sewage works. Determining economic rates for sewerage would help the operation of local authorities' sewage works become self-sustaining and thus improve on their effluent discharge.

It is imperative to state here that industries discharging effluent into sewers should be answerable to local authorities and not to ECZ. Those that discharge to the environment should be the ones to comply with ECZ regulations. Local authorities are responsible for the public sewers and should therefore be the ones to issue permits for effluent into their sewers while ECZ should only give permits for effluent to watercourses. This calls for very close cooperation between ECZ and the local authorities.

It was clear that of all the relevant Acts, only the Environmental Protection and Pollution Control Act had gained ground with some enforcement of the Pollution Control (Effluent and Wastewater) Regulations. The major weakness of these regulations is the emphasis on discharge permits and licences.

These licences and permits may be viewed as the right to pollute by industrialists. As long as an industry obtains a permit, compliance requirements cease to take centre stage. This is more so because the Act seems to concentrate on the system of licences, permits and fines. The fees for the licences do not even reflect the pollution load of the discharged effluent – they are fixed for all discharges. This does not compel industries to treat wastewater in order to lower concentrations before discharge. There should be a deliberate policy to promote prevention and control of pollution from the source. There are indications that this may be the adopted approach through the Industrial Pollution Prevention Programme (section 3.4.2); which can be aptly described as a step in the right direction. Given the prevailing circumstances, only industries with the environment at heart can go into such an undertaking

The task of monitoring wastewater characteristics should be the responsibility of industries. It is imperative that a policy be put in place to promulgate self-monitoring by industries. In this approach, the responsibility of ECZ or the local authority would be to ensure that industries complied with their monitoring requirements; that is to "monitor the monitoring".

A noteworthy point is that the Local Administration (Trade Effluent) Regulations of 1985 as they relate to effluent into a watercourse are duplicated in the Water Pollution Control (Effluent and Wastewater) Regulations of 1993 under the Environmental Protection and Pollution Control Act. This duplication should be removed to provide local authorities with powers relating to effluent into their sewers so that effluent into public water courses would then be the responsibility of the Environmental Council of Zambia only. The Local authority should cease to have a dual role of enforcement agency and discharger. The extracts of the standards given in appendices B and C give evidence of the duplication of responsibility in the control of trade effluent.

The control of pollution by the DWA as stipulated in the Water Act has never been done. Chipungu and Kunda (1994) recommend that in order to streamline the provisions of the Act, there is need to revise penalties upwards because the fees are too low. This author has a different view, however, and recommends that the section dealing with water pollution in the Water Act should be repealed so that the DWA does not have anything to do with " the offence of polluting public water" . That should be the responsibility of ECZ.

The management of the Water sector is characterised by an overlap of responsibilities as shown in the matrix of Table 3.6.1. The legal framework should be reviewed to harmonise the existing statutes to eliminate duplication, conflicts and inconsistencies (Chipungu and Kunda, 1994)

Table 3.6.1 Relations Between Statutes (Adopted from ESP [GRZ, 1997a])

Statute/Authority	Protection of Environment	Control of Pollution	Regulation of water use	Conservation of Water
Water Act		*	*	*
Natural Resources Conservation Act	*	*	*	*
Environmental Protection Pollution Control Act	*	*		*
Local Government Act	*	*		*
Public Health Act	*	*		

3.7 Recommendations

The following are some of the pertinent issues to be addressed in Zambia in order to contribute towards effective environmental pollution prevention and control from industries.

a) The legal framework should be reviewed to harmonise the existing statutes to eliminate duplication, conflicts and inconsistencies. The responsibility of preventing and controlling pollution to the environment should solely rest on the Environmental Council of Zambia. Other government departments should only assist. The Ministry of Local Government, through local authorities, should only control discharges into public sewers.

b) Government should institute a policy to encourage industries establish Environmental Departments or sections and promote environmental planning and management in industry. This should be reinforced by provision of training schemes in environmental management and pollution control by way of short courses and in-house training arrangements.

c) Government should formulate a tax and incentive policy for the import of machines, materials and equipment which save energy, reduce pollution in the production process or in recycling, those used for air and wastewater treatment, as well as for research and measurement regarding environmental protection.

d) Government should encourage pollution prevention activities by provision of a legislative and regulatory climate that promotes pollution prevention. This may include removing restrictions that discourage pollution prevention activities by establishing quantitative discharge limits rather than concentration limits, except in the case of toxic chemicals.

e) There is need to promote research and development (R & D) efforts to discourage the importation of technology. This may reflect the real technological capacity of the country. Setting up of a Board to promote direct research by industry under soft loans is one way of achieving this.

f) The relationship between environmental authorities and industry should be one of mutual support and partnership. It has to be realised that the confrontational approach does not usually yield the desired results in terms of industrial pollution reduction. One way of achieving this is by making industry be aware of the existing regulatory requirements by the distribution of such information through a cooperative arrangement between the environmental authorities and industry associations.

4. Water and Wastewater Management at Kembe Cold Storage Corporation

4.1 Background of the Company

The company was founded in the 1950s as a private enterprise. After Zambia attained independence in 1964, the government embarked on a nationalisation drive that saw this company become a state enterprise under Cold Storage Board of Zambia with several branches throughout the country. The government invested a lot of money in expanding and modernising the Lusaka branch complex and commissioned it in 1976. In 1984, Cold Storage Board of Zambia changed its name to Zambia Cold Storage Corporation. Unfortunately, the corporation had a lot of problems, which resulted in operations grounding to a halt in the early 1990s. A public tender of the Lusaka branch was floated by the Zambia Privatisation Agency (ZPA) in 1995. The Kembe Group of Companies had a successful bid and signed a sales agreement to resume operations of the Lusaka branch. Due to litigation, the sale was only executed in January 1997 and the name changed to Kembe Cold Storage Corporation. From November 1995 until the execution of the sale the Lusaka branch was run under a management agreement. The new management embarked on a rehabilitation programme to restore the industrial plant to its previous state. A brief description of the plant is given hereunder.

4.2 The Plant

The industrial complex covers an area of about 6.4 hectares. The company employs 140 workers at the plant with an additional 23 stationed at their market outlets within Lusaka. The Umbrella Company is Kembe Group of Companies with subsidiaries in tanning, meatpacking and farming.

The plant mainly deals in cattle slaughters and processing. It has an installed daily capacity of 300 head. When Kembe just took over the running of the slaughterhouse, the average number of animals slaughtered per day was 25. This picked up to an average of 86 animals per day from April 1996 to June 1997. The maximum slaughter was 194 per day for the same period. There are usually no slaughters during weekends and public holidays. Sheep are also slaughtered but on a much smaller scale. There is a meat processing section that is involved in making sausages and polonies, meat smoking and pre-packing. The plant has a non-operational by-products section where condemned carcasses, offals, bones and other solid wastes were rendered into animal feeds using steam from a coal-fired boiler.

In the rehabilitation drive, the areas targeted were equipment and machinery, refrigeration and the by-products section. Though not considered as priority aspects, water and wastewater management were also looked into.

This study covered the installed industrial technology, analysis of water use patterns and establishing potentials for recycling or reuse. The other aspects of the study included determining the sources and characteristics the wastewater and its environmental impacts, treatment practices, state of installed pre-treatment facilities and the potentials for waste reduction.

4.3 Selection of Industry for a Case Study

The contacts that existed between the Civil Engineering Department and management of Kembe Cold Storage Corporation yielded an offer to use their slaughterhouse as a case study of industrial wastewater management in Zambia. Management also pointed out that it was in their interest to ensure that the company complied with all relevant environmental regulations. Furthermore, they stressed the need to look into the status of the water supply and distribution network. The first aspect considered was the industrial technology and the processes at the slaughterhouse as detailed in the next section.

4.4 Industrial Technology

Plants in the red meat industry are broken down into three major categories (McVaugh, 1979):

- slaughter houses, which kill and eviscerate the animals and transport whole or primal cuts
- processing plants which do not slaughter, but process meats for consumers
- packing plants which slaughter and process a portion or all of the animal carcasses killed at the plant.

Based on this classification, Kembe Cold Storage Corporation is a meat packing plant[1].

The slaughtering process may be considered as a series of unit operations (Steffen *et al.*, 1990). This process is shown in Figure 4.4.1, with particular reference to water use, effluent and by-products generation. The figure illustrates the sequence of slaughtering operations in block diagram form and indicates where water use, effluent generation and solid waste occur.

The lairage is the holding area where the animals are kept for one day except for the weekend when they are kept longer because there is no slaughtering. They must be slaughtered within 48 hours as stipulated in the Public Health Act. The lairage structure consists of a concrete floor with falls to floor drains. As there is no roof over this structure, storm water enters the drains during the rainy season. Drinking water troughs are supplied for the animals while in the lairage. Cleaning the area of solid waste is carried out once a day. All the effluent from the drains leads to a sump and then to the pre-treatment plant.

Stunning is carried out by means of a captive bolt pistol. The animals are tilted out on the killing floor where they are shackled and hoisted by an electric hoist. Sticking consists of severing large blood vessels by a knife over bleeding troughs. Cold wash-down water is used periodically during slaughtering periods, and hot water is supplied for sterilising of slaughter equipment.

Hooves and horns are removed by a pneumatic cutter while the animal is on the conveyor. The head is cut off manually and hung on the plucks line (conveyor). The tongue is separated from the head and conveyed by chutes to prepare them for selling. Hide removal takes place in such a way that a chain is fastened to the corners of the hide, which is in turn connected to the dehiding machine. While the chain pulls the hide, two workers standing on each side of the dehiding machine disengage the hide from the carcass by a knife. When the hide has been pulled totally free, it is automatically dropped into a chute connected to the hide room where fleshing and trimming occurs. It is then washed and transported to a tannery.

[1] In spite of this classification, slaughterhouse is used throughout this report

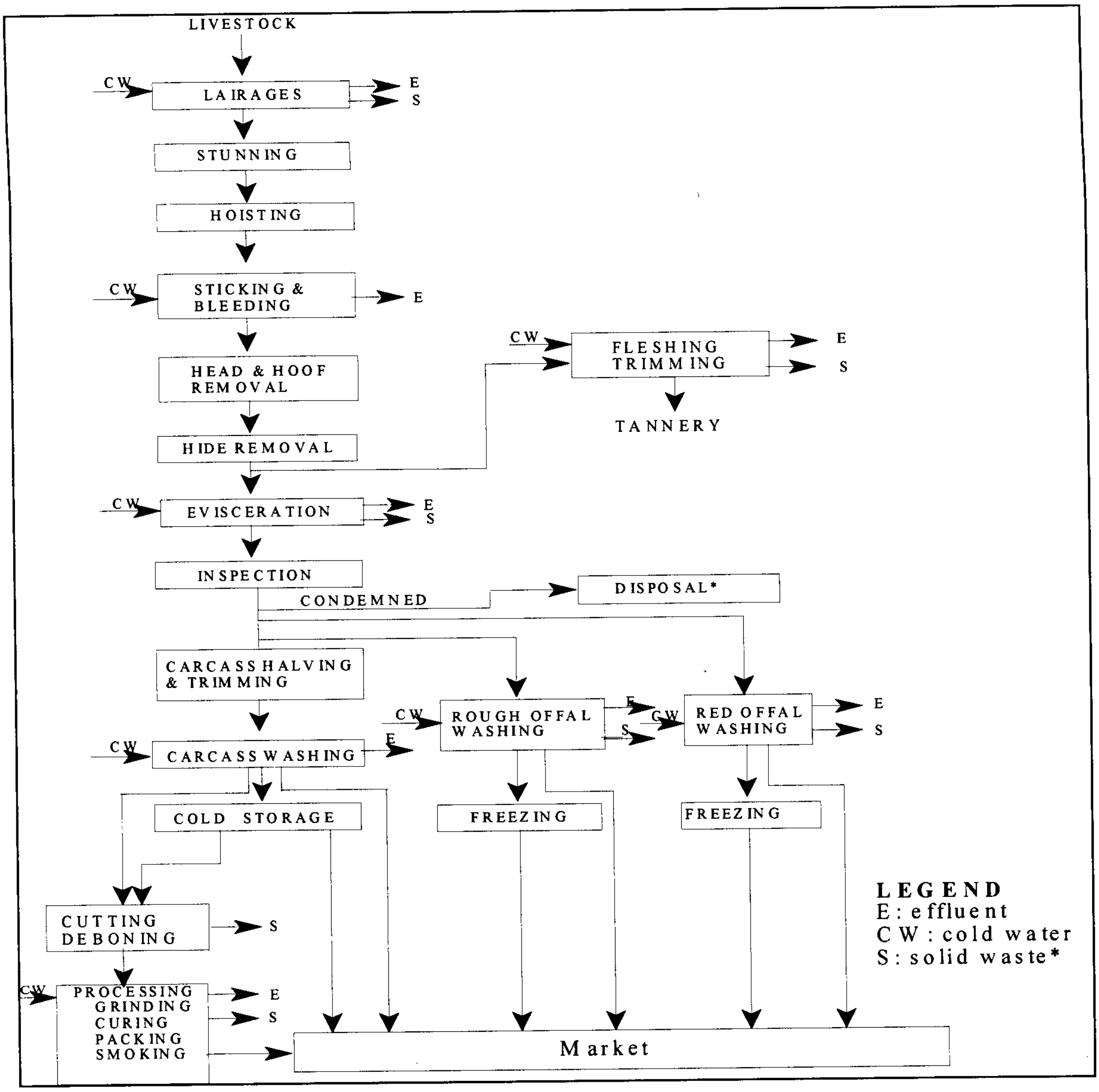

Figure 4.4.1 Block diagram of Processes at Kembe Cold Storage Corporation

(* Condemned carcasses and offals and most of the solid waste would be processed into animal feed if the rendering plant were functional)

Evisceration[2] is carried out by an electric saw after mechanically cleaving the carcass and allowing the stomach, intestines and internal organs to fall onto the moving top of an inspection table, whereafter the red offal is hung on the plucks line. The plucks line, the dressing line and the viscera conveyor are synchronised to pass an inspection point where all component parts of a single animal are inspected simultaneously to determine the suitability for human consumption.

[2] Evisceration is the opening up of the abdomen in order release the internal organs

In case these are condemned, they are chuted to the condemned area for collection and disposal. If the by-products plant were operational, these would be taken for dry rendering into animal feed. If approved, the carcass is halved by means of an electric saw and then washed manually by a high pressure-washing unit. The viscera are sorted out and conveyed to various offal processing areas. The head and feet are chuted to the ground floor for further washing and stored or directly sold.

Red offals (hearts, lungs, kidneys, and livers) require only some cold water washing to remove blood and any particles adhered thereto before storage or despatch. The small amount of effluent generated is passed to drain. Rough offal processing comprises opening up of paunches and intestines for washing which is carried out in two stages; a primary wash to remove loose dirt followed by a secondary wash to clean the offal to the requisite standards for human consumption. The paunches and intestines contain large quantities of suspended solids, and the organic strength of paunch contents and associated wash-waters is high. Effluents should be initially screened before discharge into the drains followed by another screening stage using a vibrating screen at the wastewater pre-treatment plant. Nevertheless, both screening stages are out of operation.

Cold storage facilities are provided to store carcasses and offals at temperatures from -20 to +4 °C. Maintaining the required temperature in the cold rooms makes use of an ammonia-cooling plant. Compressors circulate the ammonia gas to the cold rooms where it is required. In the process ammonia gets hot and is subsequently cooled in evaporative condensers where water is evaporated to achieve the desired cooling effect. Cooling coils in the cold rooms are defrosted by water and hot gas.

By-products handling involves the processing of blood, condemned meat and carcass trimmings by rendering them into marketable products as animal feed and fertilisers. By-products include carcass meal, blood meal, bone meal and tallow. Effluents are generated as condensates and floor washings. However, the by-products section is non-functional and awaits rehabilitation. In this regard, condemned animals and carcass trimmings are collected for disposal by the Public Health Department of the Lusaka City Council while blood goes down the drain into the sewer lines.

4.5 Water

4.5.1 Sources and Distribution

There are two sources of water for Kembe Cold Storage Corporation. One source is Lusaka Water and Sewerage Company (LWSC) and the other is on-site ground water supply by way of two boreholes. Only one borehole (B1) is in use, the other (B2) has been shut off due to suspected contamination. Figure 4.5.1 gives the layout of the main components of the plant highlighting water and wastewater pipe networks including the location of the two boreholes.

Water supplied by LWSC was abstracted at three points. The major supply (line 1) was by a 100 mm galvanised iron pipe feeding the new section of the complex (shaded portion in figure 4.5.1); compressors, condensers, slaughter floor, by-products, lairage and the boiler. Before reaching the mentioned processes, water passed through an underground storage reservoir of capacity about 100 m^3. It was then pumped into a ground level cylindrical tank of capacity 25 m^3 , boosted by two pumps in parallel and distributed into the plant. The second abstraction point was via line 2 by a 25 mm diameter galvanised iron pipe which supplied the administration block, clinic and corridors of the old cold-rooms. The third supply (line 3) was a 50 mm pipe serving the meat processing section, laundry and laboratory. The flow from the borehole B1 was split into two branches. Part of the water supplemented the LWSC line 3, while the rest went to the underground reservoir and mixed with water from line 1. Figure 4.5.2 gives a detailed picture of water distribution and wastewater production when the study started.

4.5.2 Water Use

When the study started, there were two water meters on lines 1 and 2 from LWSC designated (as M1 and M2, respectively (Figures 4.5.1 and 4.5.2). Line 3 had no meter. Four additional water meters were installed at various points to closely monitor the water usage in the plant. These were M3, M4, M5 and M6. M3 recorded the amount of water produced by the borehole B1. The quantity of water from the reservoirs going into the plant was recorded by M4. Water for cooling in the engine room was measured by M5 while the amount used in the making of ice blocks was monitored by M6.

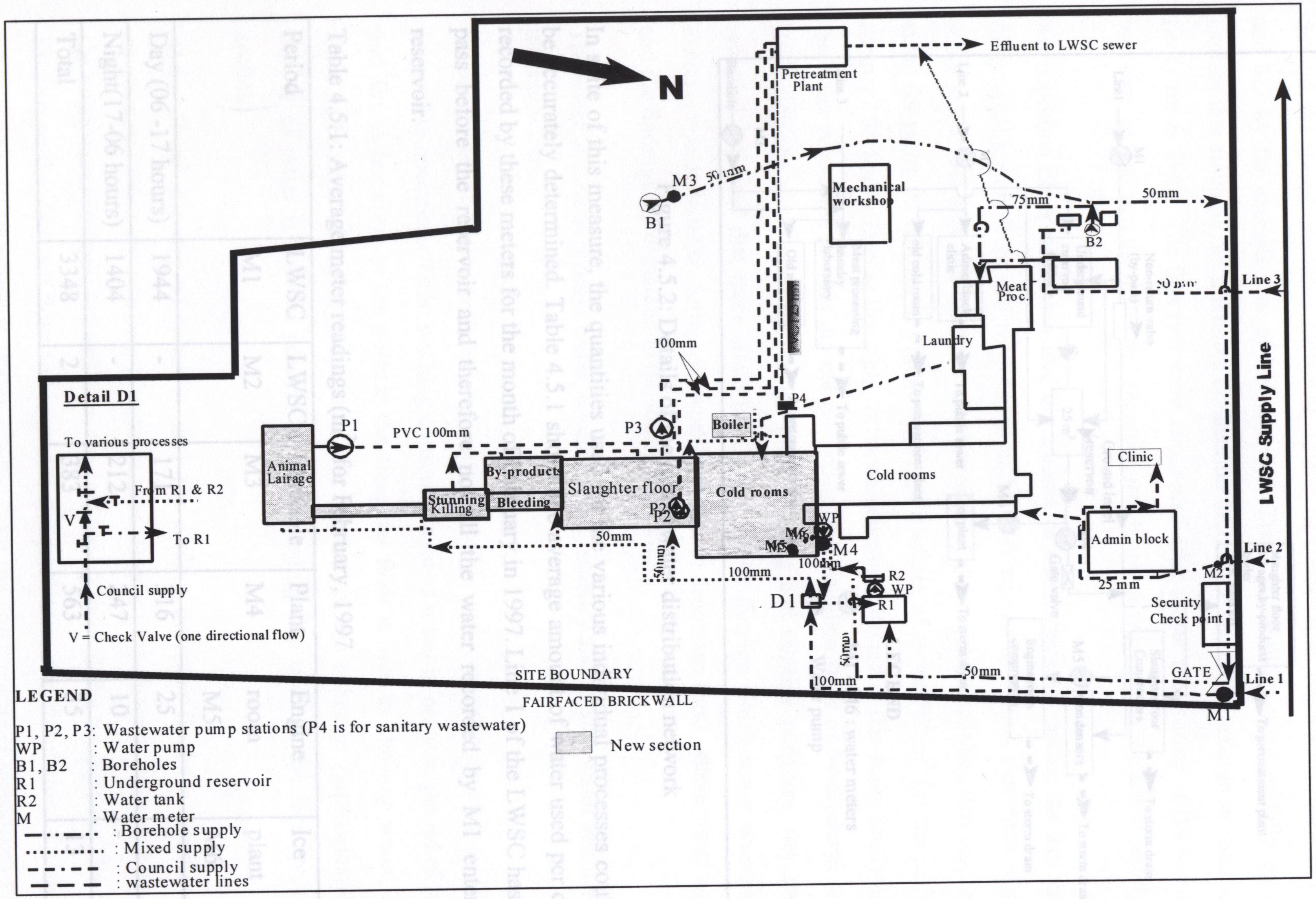

Figure 4.5.1: Layout of the Kembe industrial plant showing water and wastewater reticulation systems.

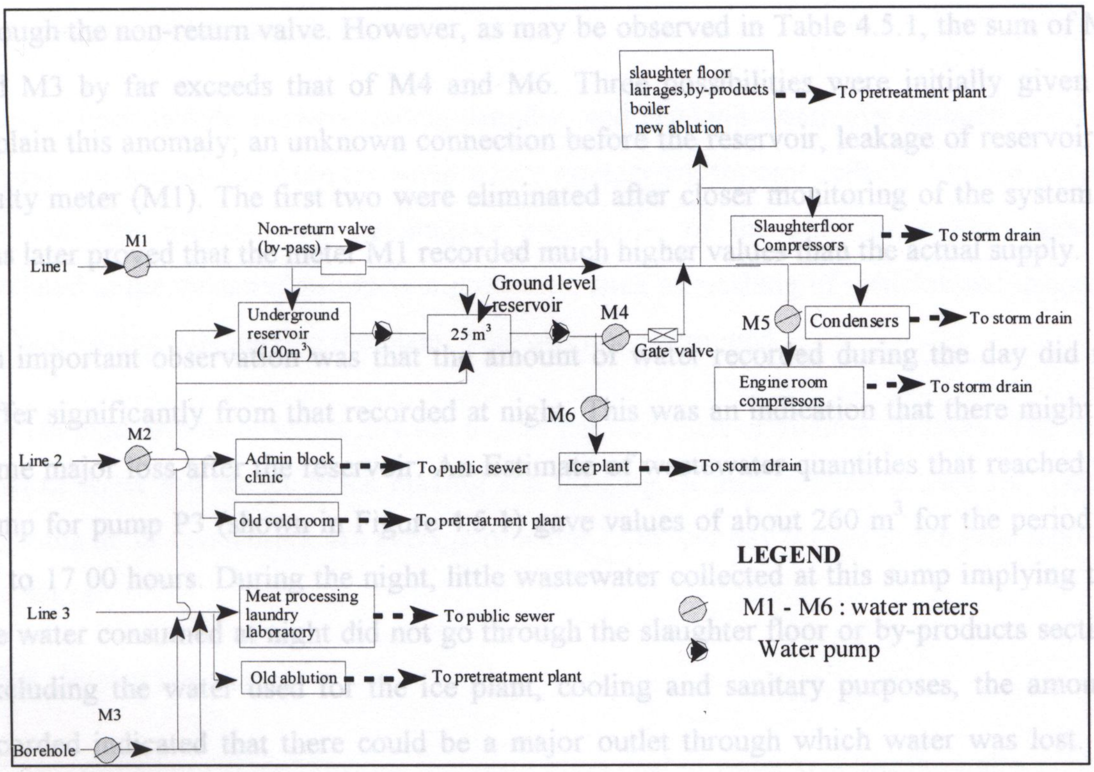

Figure 4.5.2: Details of the initial water distribution network

In spite of this measure, the quantities used for the various individual processes could not be accurately determined. Table 4.5.1 shows the average amount of water used per day as recorded by these meters for the month of February in 1997. Line 1 of the LWSC has a by-pass before the reservoir and therefore not all the water recorded by M1 enters the reservoir.

Table 4.5.1: Average meter readings (m^3) for February, 1997

Period	LWSC M1	LWSC M2	Borehole M3	Plant M4	Engine room M5	Ice plant M6
Day (06 -17 hours)	1944	-	171	316	25	-
Night(17-06 hours)	1404	-	212	247	10	-
Total	3348	2	383	563	35	13

From Figure 4.5.2, it can be assumed that sum of the readings for M1 and M3 should not significantly differ from that of M4 and M6. The difference should account for the water used in the meat processing section, laundry and the amount that bypasses the reservoirs through the non-return valve. However, as may be observed in Table 4.5.1, the sum of M1 and M3 by far exceeds that of M4 and M6. Three possibilities were initially given to explain this anomaly; an unknown connection before the reservoir, leakage of reservoir or faulty meter (M1). The first two were eliminated after closer monitoring of the system. It was later proved that the meter M1 recorded much higher values than the actual supply.

An important observation was that the amount of water recorded during the day did not differ significantly from that recorded at night. This was an indication that there might be some major loss after the reservoir. An Estimate of wastewater quantities that reached the sump for pump P3 (shown in Figure 4.5.1) gave values of about 260 m^3 for the period 06 00 to 17 00 hours. During the night, little wastewater collected at this sump implying that the water consumed at night did not go through the slaughter floor or by-products section. Excluding the water used for the ice plant, cooling and sanitary purposes, the amounts recorded indicated that there could be a major outlet through which water was lost. An exercise was undertaken during off-working hours to determine areas where water was lost and the findings are explained in the following section.

The water is used as process water, cooling water, sanitary and service water and ice block making water.

Process water is the water used for washing offals and carcasses as well as in meat processing operations. Offal washing consumes a lot of water in order to get rid of manure and dirt. A fair share of the water to the slaughter floor is used as clean-up water. This is more so because of high hygiene standards required of the industry. Approximately 260 m^3/day of water is used as process water (excluding that used in the meat processing section).

About 60 m^3 per day of water is used for cooling purposes in the compressors and condensers. There are two sets of compressors. One is in the engine room and circulates the refrigerant (ammonia) to and from the cold rooms through the condensers. The other is situated on the slaughter floor and is used in the production and circulation of compressed air for pneumatic machinery. Water coming from the compressors is discharged to storm drains. The compressors in the engine room operate for 24 hours while those on the slaughter floor operate during the day. The refrigerant is cooled in the condensers where recycling is practised. Additional water is applied as make-up water to compensate for evaporation and blow down.

Sanitary uses include showers, toilets, laundry, and drinking water. An estimate of 40 m^3 per day was established from the sump where sanitary wastewater collects. Service water is that used for maintenance, cleaning or preparation of the plant or support services unrelated to the industrial production processes, such as washing of vehicles and irrigating the landscaping surrounding the plant. This was not determined.

The ice plant produces about 204 ice blocks per day each of volume 30 litres. The main areas of water use are ice block making and thawing. A little amount is used for cooling ammonia in the condensers. An average of about 13 m^3 per day is used in the production of ice blocks.

4.5.3 Water Losses

As was pointed out in the previous section, a great deal of water was lost through a number of ways. The following were established as water loss areas:

- Leakage ; as a result of burst pipes, loose connections and other defects in the pipe network
- Running taps due to defective stop cocks
- Running taps due to negligence
- Compressor room on slaughter floor where water supply was not shut off even after the compressors were switched off after working hours
- Pumping; the high pressure created by pumping from the borehole within the premises may result in supply into the LWSC trunk through line 3
- Overflow from the underground reservoir; supply to the reservoirs was not regulated for both line 1 and the borehole. Whenever the reservoir got full, water overflowed to the storm sewers.

From the foregoing, it was deemed very important to address the above mentioned problems to minimise water losses. The measures given in the following section were agreed upon after consultations with management to try and solve the problem.

4.5.4 Measures Recommended to Rationalise the Water Distribution Network

1. Install a float switch connecting the borehole and reservoir to curtail losses due to overflows in the reservoir.
2. Install a ball valve on LWSC line 1 at the point of entry into the reservoir to prevent losses by overflows
3. Eliminate line 3 from the network
4. Connect the borehole supply to Line 2 from LWSC whose supply was not very reliable. Maintaining Line 2 ensures continuous water supply to the administration block when the borehole pump is off (due to measure No. 1 above). In order to avoid pumping water into the LWSC trunk, a non-return valve was required on this line just before the meter M2.
5. Replace or repair the meter M1

4.5.5 Actions Taken and Observations

- Line 3 was eliminated from the network after it was proved that water from the borehole was leaving the premises. After this measure, it was observed that more water reached the reservoir than before.
- A float switch was installed to control the water level in the reservoir. Although water losses by overflows were curtailed, there was a drawback in that no water reached the meat processing section when the borehole pump was off. This could be overcome by connecting the meat processing section to the reservoir supply.
- There was a continuous supply to the administration block after reinforcing line 2 with borehole supply.
- The meter M1 was replaced and the new meter gave much lower readings than the previous meter. This proved that the earlier meter was indeed mal-functional.

The foregoing measures notwithstanding, the puzzle of a major water loss (indicated by night readings) remained unsolved. The average meter readings (M1, M3 and M4) for February and October shown in Table 4.5.2 indicate the situation before and after the corrective measures were taken. This clearly shows reduced readings at all the meters signifying improved water management.

Table 4.5.2: Comparison of Meter Readings for February and October (1997)

	M1	M3	M4	M1	M3	M4
	Daily "consumption"			Night "consumption"		
February average	3348	383	563	1432	213	248
October average	248	287	364	178	164	194
Difference	3100	96	199	1254	49	54

The Engineering Manager devised a way of preventing water going into the plant at night except for the engine room and condensers for cooling purposes by connecting a pipe directly to these areas just before the gate valve G2 (Figure 4.5.3). After working hours, this valve was shut off leaving only supply for cooling. This further reduced losses at night and during non-operation hours. Figure 4.5.3 also shows the water distribution network after the recommended measures were implemented.

Based on the water meter readings and estimates from collection sumps for process and sanitary water, the water balance in Figure 4.5.4 has been formulated. It has to be stated that the branch from the borehole supply to the meat processing section, laundry and laboratory was not metered and it is questionable whether all that water (158 m^3) could be used in these areas. There is therefore need to install a meter on the pipe that supplies these areas. The same applies for the bypass from Line 1 from LWSC though it has to be stated that the amount might not be much because no water reaches the new section of the plant when the pumps after the reservoirs are off. This shows that the amount of unaccounted for water is high.

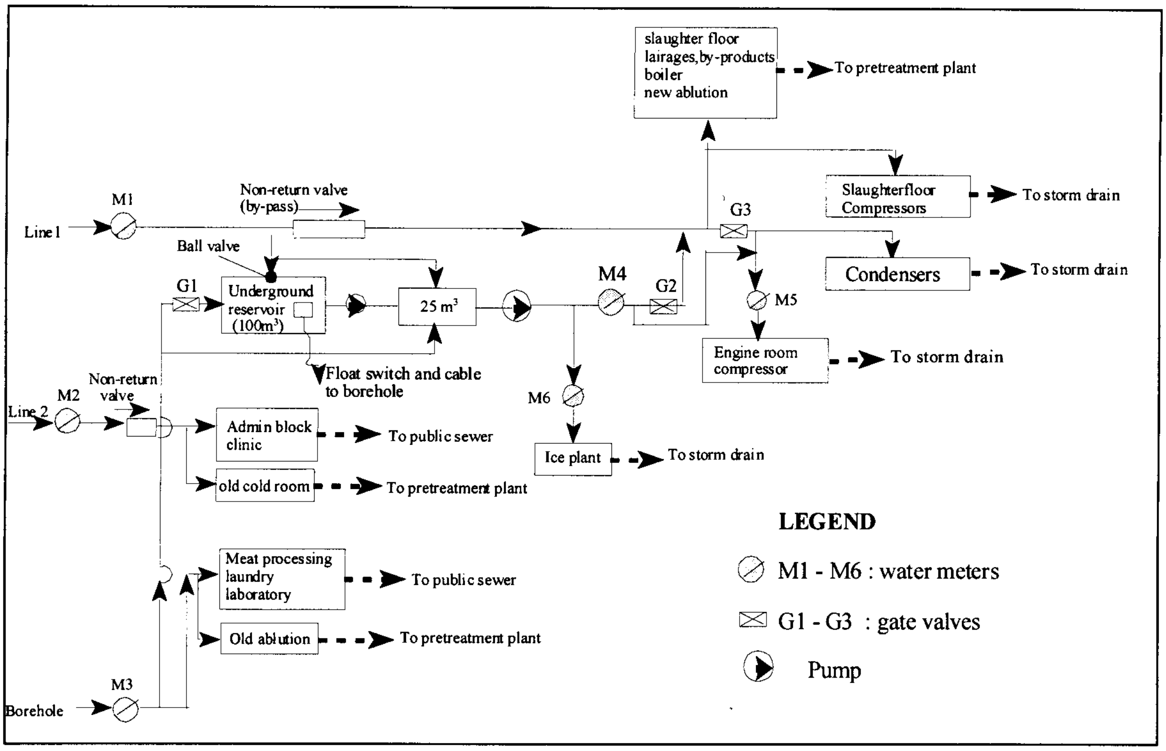

Figure 4.5.3: Detail of the water distribution network after corrective measures

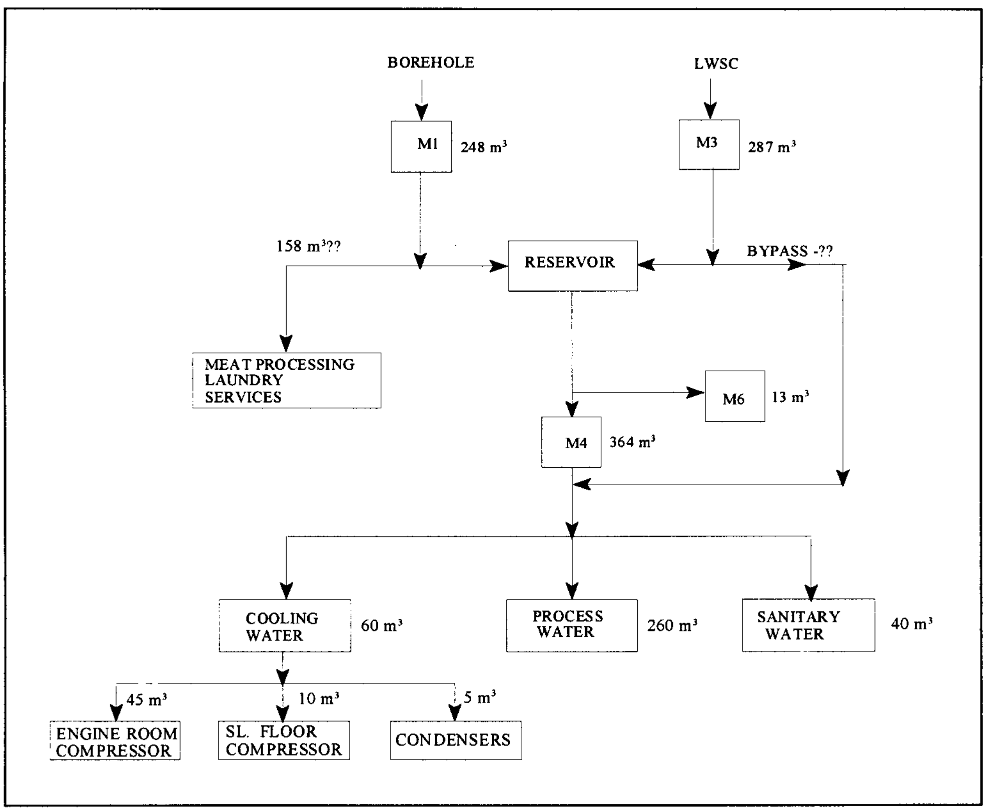

Figure 4.5.4: Water balance for the plant

4.6 Housekeeping

Cooling water from all the compressors goes to waste. This water is relatively clean and can be used in processes that require lower quality water. For instance, it can be recycled or reused in cleaning of floors and walls. The possibility of harnessing this water so that it can be used for tasks mentioned above should be explored. One possibility is to collect it into a holding tank from where it can be abstracted for the intended purpose.

There is a lot of water wasted during the cleaning process. Workers prefer to let water run from a hosepipe until it carries the waste to the sewers. A better way of cleaning is to use much less water by preliminary dry cleanup using a rubber broom. Another area where water can be conserved is in the handling of offal. Paunch manure, which is relatively dry, is dropped into a chute to a collecting pit where it is diluted to facilitate pumping. This same manure is then removed manually at the pretreatment plant. A way of disposing of the manure in its dry state from this pit is advisable.

4.7 Water Charges

The following water tariffs are charged per month for water consumption. In order to discourage consumers from using too much water, the tariffs get higher as the consumption increases (some kind of surcharge) as shown in Table 4.7.1.

Table 4.7.1: Water tariff structure of LWSC (April 1997)

Consumption range (litres)	Charge in Kwacha (per 1000 litres)
0 - 100,000	364
100,001 - 170, 000	574
170,001 and over	854

Taking an average consumption of 248 m^3/d (based on October M1 readings), KCSC falls in the last category (K 854 per 1000 litres)

Monthly consumption = 7440 m^3

Monthly charge = K 6.35 million

This kind of money definitely calls for water conservation measures. This is what Kembe is supposed to pay to LWSC instead of the fixed monthly fee it pays.

4.8 Wastewater

4.8.1 Production

Wastewater emanates from lairages, sticking and bleeding, slaughter floor (comprising carcass and offal washing), meat processing and clean up from all these areas. The wastewater originating from the lairages consists mainly of manure from animal droppings, which is washed into drainage channels. The quantities are higher in the rainy season because the lairages are not covered. Sticking and bleeding operations produce wastewater mainly composed of blood. On the slaughter floor, wastewater is produced from washing of carcasses and offal as well as from the cleanup of the entire section. The main constituents are meat scraps, blood and manure from the rough offal. In the meat processing section, wastewater is mainly from the washing of equipment, walls and the floor. This has a high content of oil and grease. The characteristics of the wastewater that reaches the pretreatment plant are given in chapter five.

4.8.2 Collection and Transport

The design incorporated three collection lines for the process wastewater. Firstly, there was that emanating from the lairage and surrounding areas. This was collected by open channels and flowed to a sump containing a submersible pump (P1) that conveyed the wastewater to the pretreatment plant. The wastewater contains great amounts of manure. Secondly, wastewater from the initial offal handling on the slaughter floor was drained to a rectangular collection tank on the ground floor and pumped by P2 for pretreatment. Thirdly, wastewater from the stunning area, bleeding ramp, slaughter floor, second offal handling (ground floor), cold room corridors and the by-products section was drained to another sump with a submersible pump (P3) from where it was also conveyed for pretreatment. Sanitary sewage was collected at sump P4 and pumped to the pretreatment plant. Figure 4.8.1 gives a flow sheet of the wastewater emanating from the industry as it was designed to be handled.

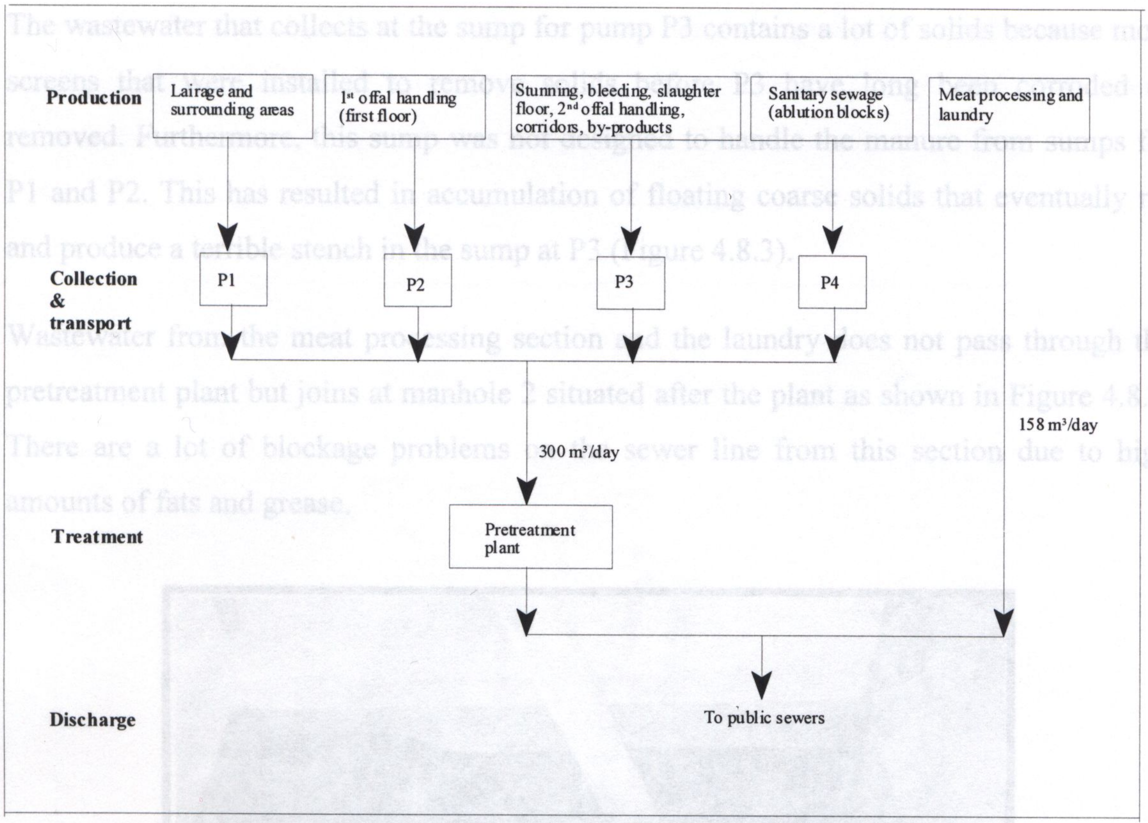

Figure 4.8.1: Wastewater handling flow chart as designed

It has to be pointed out, however, that only pumps P3 and P4 are functional. All the wastewater from the various processes has been diverted by makeshift arrangements to end up at P3 where it is pumped to the pretreatment plant. Figure 4.8.2 shows waste from the first offal handling stage (mainly manure) on the floor before it is forced into collection pits and hence to the sewers that lead to P3.

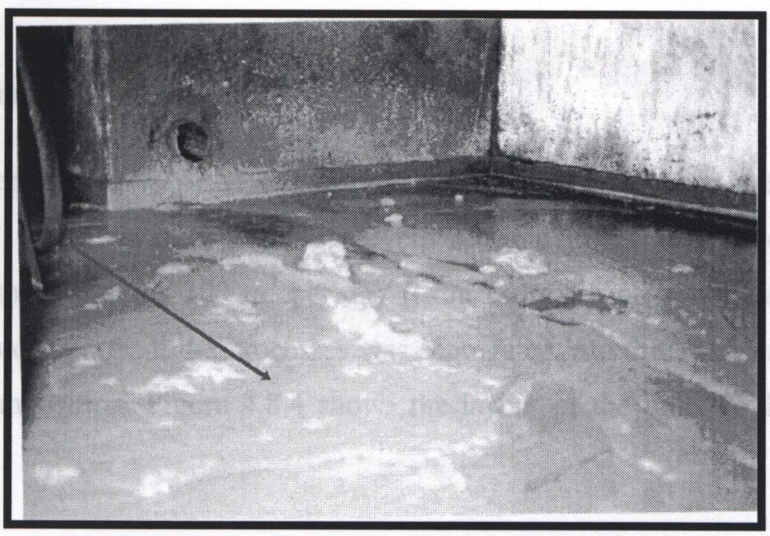

Figure 4.8.2: Waste from offal handling spills on the floor before being forced into sewers

The wastewater that collects at the sump for pump P3 contains a lot of solids because most screens that were installed to remove solids before P3 have long been corroded or removed. Furthermore, this sump was not designed to handle the manure from sumps for P1 and P2. This has resulted in accumulation of floating coarse solids that eventually rot and produce a terrible stench in the sump at P3 (Figure 4.8.3).

Wastewater from the meat processing section and the laundry does not pass through the pretreatment plant but joins at manhole 2 situated after the plant as shown in Figure 4.8.4. There are a lot of blockage problems on the sewer line from this section due to high amounts of fats and grease.

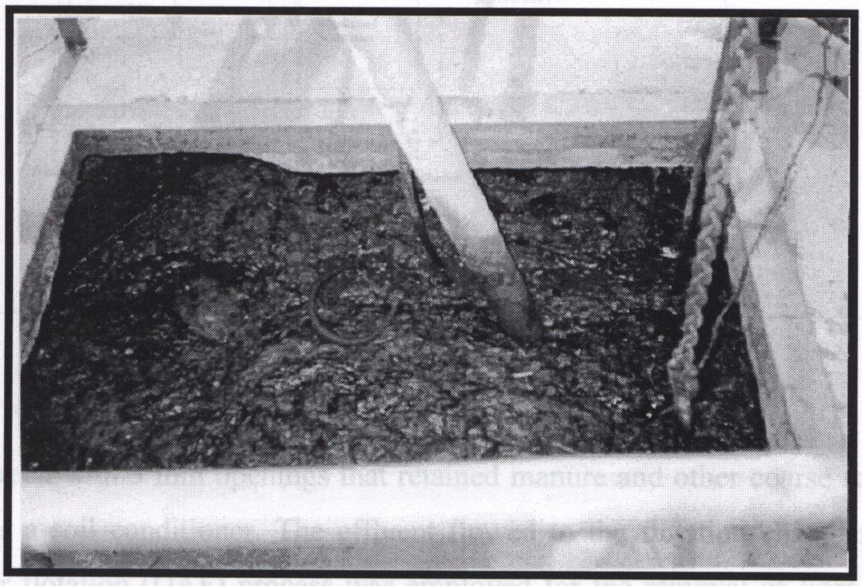

Figure 4.8.3 Accumulation of solids in the sump for pump P3

4.8.3 Pretreatment

The pre-treatment plant comprised a vibrating screen, a grease chamber and a dissolved-air flotation (DAF) chamber incorporating recycle of final effluent. The total amount of wastewater to the plant was 300 m^3 per day (from estimates on water balance of figure 4.5.4). The wastewater from the processes was segregated into three streams based on the sources and composition. Figure 4.8.4 shows the layout of the units of the pretreatment plant.

Wastewater from the lairages was collected at the sump for pump P1 and that from offal handling accumulated at the sump for pump P2. The main components of both of these streams were manure and a lot of other coarse solids. The wastewater was pumped to a

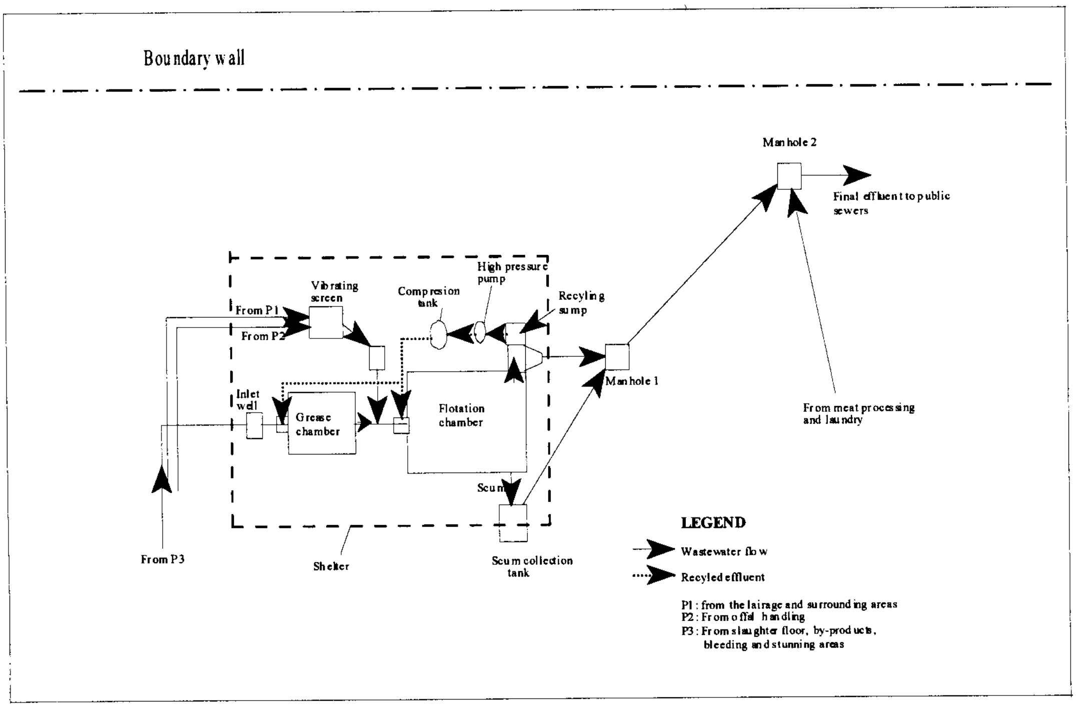

Figure 4.8.4: Layout of the wastewater pretreatment plant

vibrating screen with 3 mm openings that retained manure and other coarse solids, which were sold as a soil conditioner. The effluent flowed to the flotation chamber where the dissolved-air flotation (DAF) process was employed for the removal of light solids. The wastewater from the slaughter floor, sticking and bleeding area, cold room corridors and by-products section collected at the sump for pump P3. This was conveyed to the grease chamber where the DAF process was employed for the removal of fat, oil and grease (FOG) at the surface. Effluent flowed to the flotation chamber. A portion of the flotation chamber effluent (about 10%) was recycled, pressurised and semi-saturated with air. The recycled flow was mixed with the unpressurised main stream just before admission to the flotation chamber, with the result that the air came out of solution in contact with particulate matter at the entrance to the chamber. In this way solids that were lighter, equal to, or slightly denser than water rose to the surface and were collected by a chain-and-flight collector to a trough at the effluent end leading to a scum collection tank. The raw skimmings were then manually removal from this tank and disposed of. Heavy solids that settled to the bottom were scraped to a sludge hopper. From time to time, the sludge was drawn off using compressed air. The flow sheet of the pretreatment plant is given in Figure 4.8.5. The final effluent was discharged, via two manholes, to the LWSC sewers.

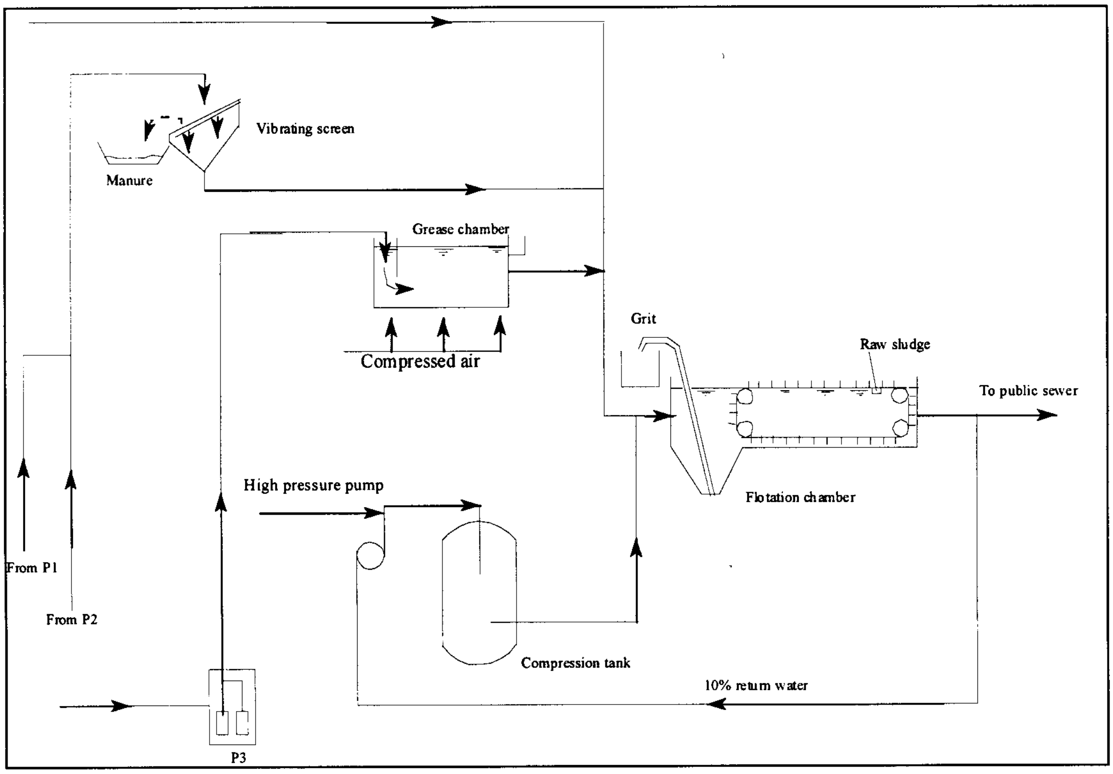

Figure 4.8.5: Flow sheet of the pretreatment plant

Unfortunately, the pre-treatment plant is completely rundown and the wastewater passes through virtually untreated. Firstly, only one pump, P3, is functional. Some makeshift provision was made to direct all the process wastewater to this pump, which feeds what were once grease and flotation chambers. The compressed air supply and the effluent recycle systems have long been removed. The flight mechanism for scum and sludge scraping for the flotation chamber does not exist. By natural flotation in the 'former' grease and flotation chambers, manure and other light materials collect at the surface where they are manually removed and sold as a soil conditioner. Figure 4.8.6 shows what remains of the flotation chamber of the defunct DAF facility. The only unit that is intact, though not in use, is the vibrating screen.

This state of disrepair can be attributed to:

- Inappropriate technology
- High operation and maintenance costs
- High skilled labour requirements

- Non-enforcement of effluent standards into the sewers by the local authority
- Lack of environmental awareness by workers and management.

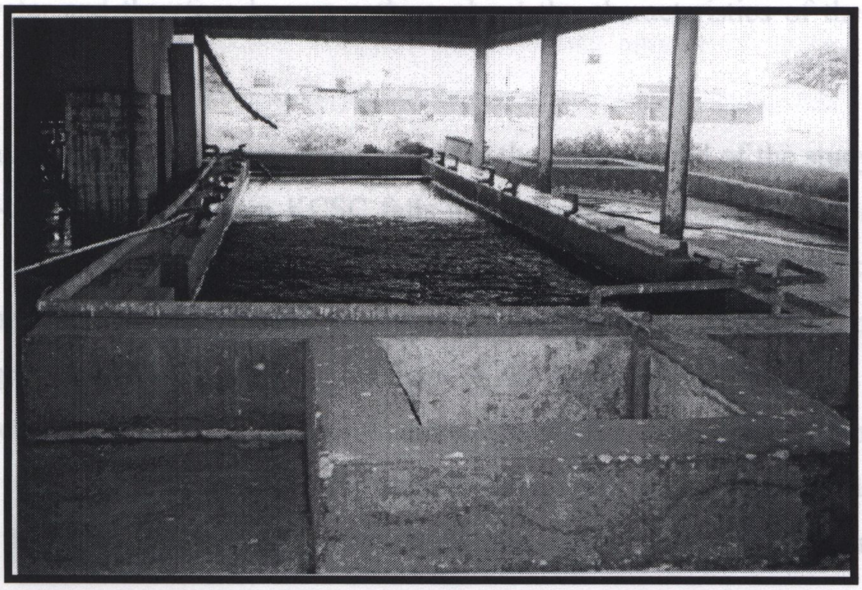

Figure 4.8.6: Remains of the flotation chamber of the defunct DAF facility

It was because of this that an alternative treatment scheme suitable under the prevailing circumstances was sought and the pilot plant study of chapter 5 was the result.

4.8.4 Environmental Impacts

Wastewater originating from this plant contains oil, fats and grease and high amounts of solids. This has a great potential of causing blockages in the sewerage system, giving rise to unsightly sewage spills. The organic content, paunch manure and wide variations in both quantity and quality of the effluent may cause overloading of the public sewage treatment plant and severely affect the treatment process. This in turn means discharge of partially treated effluent from the public sewage treatment plant to the environment. The following section seeks to justify the construction of pretreatment facilities based on the sewerage charges by LWSC for industrial wastewater discharge into their sewers.

4.9 Sewerage Charges, Compliance and Penalties

The sewerage fees charged by the LWSC are based on the volume of wastewater produced and biochemical oxygen demand (BOD). The tariffs are as given in Table 4.9.1. This table illustrates the use of surcharges to penalise industries producing wastewater with high

BOD concentrations. KCSC does not comply with the standards for BOD, COD and TSS as stipulated in the Local Administration (Trade Effluent) regulations principally because there is no enforcement. The company does not have facilities to carry out tests for water and wastewater and therefore knows nothing about the characteristics of the wastewater produced.

Based on the average BOD values determined for the entire period of the study (Appendix D, Table D-1), wastewater from KCSC falls under tariff D. Since no devices have been installed to measure the amount of wastewater produced, LWSC assumes that 90% of the water consumed enters their sewers. Based on this assumption, KCSC is supposed to pay the sewerage fees based on October readings of the meter M4 because that records the amount of water that can reach the pretreatment plant. By way of an example, only the wastewater passing through the pretreatment plant has been considered, excluding wastewater from the meat processing section and the laundry that directly enters the public sewers.

Table 4.9.1: Wastewater Tariff regimes by LWSC (April, 1997)

Tariff*	BOD range (ppm)	Charge in Kwacha (per 1000 litres)
C	up to 1000	644
D	1001 to 2000	938
E	over 2000	1344

* No mention is made of tariffs A and B

Water consumed = 364m^3/day (10920 m^3/month)

Wastewater produced = 10920 * 0.90 = 9828 m^3/month

Monthly charge = (9828 * 938) = 9.22 million Kwacha

This kind of charge can justify the construction of a pretreatment facility to reduce BOD concentrations to levels in tariff C before discharge into the LWSC sewers. However, it has to be stated that KCSC pays a fixed fee based on fixed monthly water consumption figures, which fee is too low to justify putting up of pre-treatment facilities.

Considering the February readings of M4, the following costs should have been incurred by KCSC:

Water consumed = [563 m^3/day (16890 m^3/month)

Wastewater produced = 16890 * 0.90 = 15201 m^3/month

Monthly charge = (15201* 938) = 14.26 million Kwacha

Comparing February and October charges, the following amount of money would have been saved in sewerage fees because of the reduction in water consumption if LWSC had implemented their tarriffs.

Savings = 14.26 - 9.22 = 5.04 million Kwacha

It has to be stressed that the charges computed exclude the wastewater discharged from the meat processing section.

Since there was a fixed charge for wastewater discharge, this saving could not be reflected in the costs at the time. It should be stressed that the situation is likely to change in the near future when LWSC strictly adheres to its tariff structure and industries are forced to pay according to the amount and strength of wastewater they produce. Wastewater charges by the company would increase by more than a hundred times. That would definitely call for water conservation measures and pretreatment before discharge into the public sewers.

4.10 Discussion

Good housekeeping is one area that has to be seriously inculcated in the minds of the workers. From the stunning area through the slaughter floor, offal room, cold-room corridors and meat processing, fully and partially running taps are not uncommon. This is a clear testimony that the workers know little regarding water costs and therefore the need to conserve it. A programme to educate the managers and the workers at large on water conservation is necessary to make them aware that water is a scarce and expensive resource that has to be guarded jealously. For instance, it is common to find a worker washing a carcass using an unregulated supply from a hose pipe rather than the installed water savers (economy spray).

In the wastewater collection pits, the screens in the form of perforated baskets should be designed and installed in such a way that they cannot easily be removed. Mostly, they have been removed to ease the work of having to dispose of accumulated solids separately. Forcing the solids into the sewers has been seen as the better option, for it is said " out of sight, out of mind". This transfers a solid waste problem into a liquid problem and results in wastage of high amounts of water for conveying these solids. These solids give rise to an odour nuisance when they rot in the pit for P3. Most of the solids accumulate in the grease chamber at the pretreatment plant where they are manually removal (Figure 4.10.1).

It has to be reiterated that all personnel should be made aware of the importance to conserve water. Great savings may be realised in the long run, which savings might help towards bettering their welfare.

Figure 4.10.1 Most solids accumulate in the rundown grease chamber

Mention should be made here that Low or Non-waste Technology (LNWT) was applied in the design and construction of the whole industrial complex. Ideally, no waste is supposed to be produced. Nearly all the waste materials were meant to be processed into by-products. Blood was collected in blow tanks and rendered into blood meal; condemned carcasses were rendered into animal feeds, horns used to be exported; the hides were sent to a tannery and paunch manure was sold as a soil conditioner. It is sad to note that the by-products section is non-operational due to equipment break- down. All the blood goes to waste into sewers, condemned carcasses are collected by the City Council's Public Health Department for disposal and horns are incinerated on site. Only hides are sent to a tannery for processing into leather. This means the wastewater has a much higher pollution load than should be the case. If all the by-products equipment were to be put back into working condition, KCSC would have an enhanced public image in the area of waste reduction and environmental pollution prevention.

The foregoing has emphasised the importance of conserving water and reducing waste from the source – this is an aspect of source management and control in the realm of water and wastewater management. The principal components of source management and control are:

- Conservation of water
- Minimisation of waste
- Waste reuse and recycle
- Materials and/or energy recovery
- Process modification or substitution

The major benefits are:

- Reduced water cost per unit of production
- Reduced pollution load per unit of production
- Increased product yield
- Reduced size of the wastewater treatment plant

Figure 4.10.2 illustrates the importance of source management and control in terms of increased product yield and reduced end-of-pipe treatment requirements.

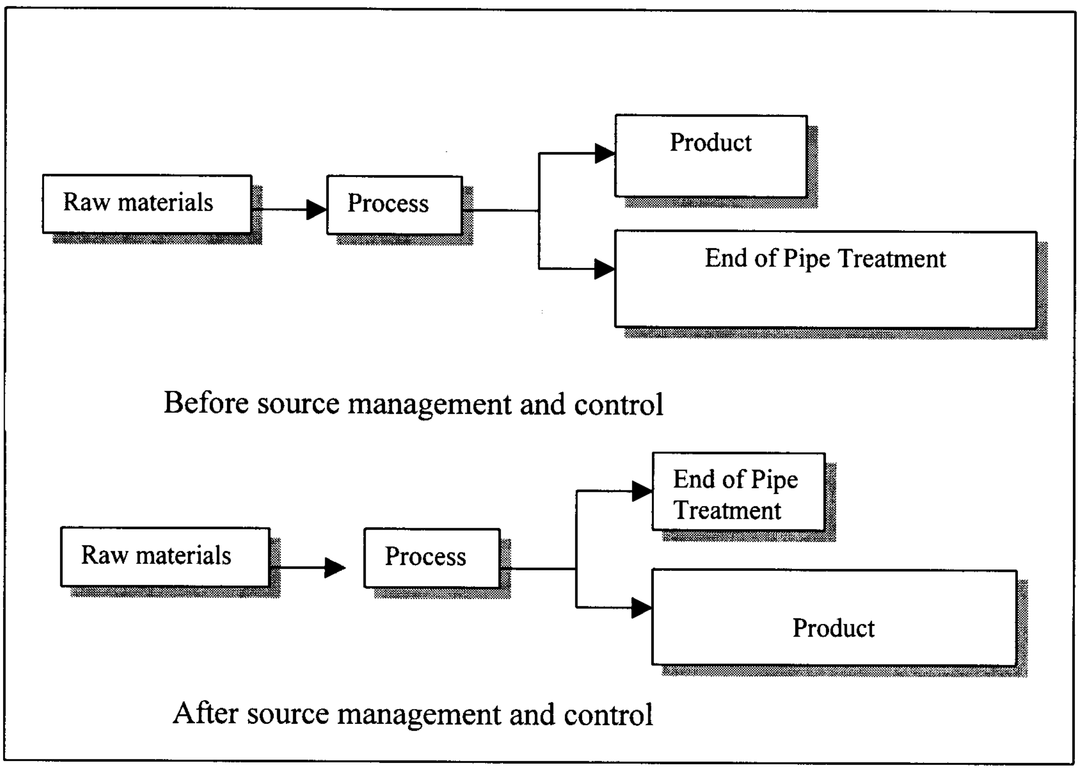

Figure 4.10.2: Industrial water and Wastewater management

(After Appleyard, 1994)

Finally, it has to be stated that a hygienically operated slaughterhouse and meat processing plant makes a "self contained" unit, that is, a plant where only market ready products are dispatched. This means that all inedible raw materials from slaughtering and meat processing, such as condemned carcasses, condemned viscera, lungs, feet, hooves, glands, skulls, jaws, bones and fat trimmings, are rendered into valuable animal food stuffs and fat (as tallow). This greatly contributes to improving the profitability of the plant.

4.11 Summary of Recommendations

4.11.1 Opportunities for Improved Water Management

- All water intakes and individual processing areas should be metered and the results obtained used constructively.
- Lairages should be dry-swept and the sweepings collected for disposal instead of being flushed down the drain
- Paunch contents should be removed dry without initial use of water, and the solids transported separately for disposal
- There should be a water conservation awareness campaign for the workers
- The water distribution pipe network should be checked for major losses and corrected
- The meat processing section should be connected to reservoir supply so that all the water used in the plant comes from a central distribution point
- Explore ways to reuse or recycle cooling water
- The quantity of clean-up required for most areas can be substantially reduced if dry brushing or squeezing techniques are employed initially to collect gross solids. The solids collected should be disposed of to solid waste handling facilities rather than flushed to the drain
- All hoses should be fitted with positive self-closing nozzles to eliminate unattended sluicing as was frequently observed. Where the hoses are in frequent use, pistol grips should be fitted

4.11.2 Opportunities for Improved Effluent Management

- Minimise water use to reduce effluent volume to be handled and disposed of. Although the strength of final effluent increases, handling is facilitated.
- Solid wastes should be prevented from entering the drainage system wherever possible and should rather be disposed of separately.
- Fat, meat and blood from carcass trimming and hide removal should be dry-swept, collected, binned and passed to suitable solids handling and disposal facilities rather than being flushed down the drain
- Lairages should be dry-swept to collect loose solids. The collected solids should not be to forced into the drain but rather passed on for suitable solids handling and disposal
- The effluents from rough offal washing should be separately screened as finely as possible to minimise the loss of solids to drain.
- All effluents should be screened, either separately and/or when combined in the final effluent, to recover gross solid particles. Screens should be designed such that they can easily be cleaned and not readily removable unless under adequate supervision, otherwise the solids tend to be dumped into the drain system.
- The two pumps (P1 and P2) should be reinstalled in order to make use of the vibrating screen and reduce the solids content of the effluent. Pump P2 is more critical and may be installed earlier than P1.

5. Pilot Plant Investigations: Treatability of Slaughterhouse Effluent by Trickling Filtration

5.1 Rationale

The trends in the water and sanitation sector may bring in a more serious approach to the running of wastewater facilities by local authorities. The recent enactment of the Water Supply and Sanitation Act (GRZ, 1997b) facilitates the participation of the private sector in the running of these facilities as commercially viable utilities. This may usher in strict controls of industrial wastewater discharges into sewers by revision of the regulations and enforcement procedures.

In this respect, there will be need for industries to install pre-treatment schemes in order to comply with effluent standards before they discharge into the sewers operated by these utilities. Non-compliance may mean the wastewater not being accepted into the sewers or imposition of heavy penalties by way of surcharges.

Considering the foregoing, the complete breakdown of the DAF pre-treatment facilities at the Kembe Cold Storage Corporation was a source of concern. It was found necessary to propose an alternative treatment scheme to suit the prevailing situation. In this vein, it was deemed important to firstly review the available treatment methods used for this kind of wastewater before selection of the most favourable option.

5.2 Wastewater Treatment Methods

Most of the slaughterhouses in Zambia discharge their wastewater to a municipal treatment system. Because municipalities mostly operate these slaughterhouses, the discharge of wastewater into the sewers is done without any pre-treatment - typical of a situation where an organisation plays the dual role of discharger and regulator. Operational problems have plagued the running of these slaughterhouses and, as a consequence, programmes are underway to de-link them from municipalities to the private sector. It is envisioned that the new operators of slaughterhouses will have to apply adequate pre-treatment to comply with water pollution control standards stipulated by the municipalities or, as the case may be, the commercial utilities.

Pre-treatment of red meat packing waste can be broken down into two steps: (1) coarse solids removal and (2) grease and suspended solids removal. Coarse solids removal is accomplished by screens, or in a catch basin (also known as a mechanised catch basin or gravity grease separator). Dissolved air flotation (DAF) enhances total suspended solids (TSS) and fat, oil and grease (FOG) removals along with the BOD associated with these (McVaugh, 1979).

The secondary treatment processes used on meatpacking and rendering wastewater are those common to most food processing industries. They are almost exclusively biological and include anaerobic, facultative, aerobic, or aerated lagoons; trickling filters, either conventionally loaded or " high rate" roughing filters; and activated sludge. Sayed (1987) mentions the use of high-rate anaerobic processes such as the anaerobic filter, the downflow stationary fixed film reactor, the anaerobic attached film expanded bed, and the fluidised bed reactor. All these systems employ carrier materials to prevent biomass washout. In the same category but without carrier materials is the upflow anaerobic sludge blanket (UASB). Combinations of the secondary treatment systems may be required in case of discharge into surface water.

5.3 Selection of Treatment Process

Treatment options appropriate to this industry that would suit the Zambian scenario had to be sought. Of immediate interest were the stabilisation ponds and lagoon systems. These could not be used because of their large land requirements. Demands for operation and maintenance coupled with high skilled labour requirements eliminated treatment techniques such as activated sludge and anaerobic systems. The trickling filter was chosen as the most suitable based on the selection matrix in Table 5.3.1. Although trickling filters cannot always achieve the high degree of BOD removal characteristic of alternative processes such as activated sludge, it is claimed that they are particularly suitable for partial or roughing treatment because of their simplicity of operation, low operating costs, and resistance to shock loads (Moodie and Greenfield, 1978). As the effluent has to be discharged into a public sewer, the trickling filter would provide suitable pre-treatment.

Figure 5.3.1: Comparison of treatment systems (Veenstra and Polprasert, 1995)

Criteria	Activated sludge	Trickling filter	Waste stabilisation pond (including anaerobic units)	Waste stabilisation pond (excluding anaerobic units)	Anaerobic processes
BOD removal	**	**	***	***	**
SS removal	***	***	**	**	**
Simple & cheap construction	*	*	***	***	*
Simple operation	*	**	***	***	*
Land requirement	***	***	*	*	***
Maintenance costs	*	**	***	***	*
Energy demand	*	**	***	***	**
Weighting	12	15	18	18	12

KEY: *** good; ** fair; * poor

(NOTE: Lack of adequate space eliminated the waste stabilisation pond system)

5.4 Theoretical Background of Trickling Filters

Trickling filters have been in use for over 100 years in the biological treatment of municipal and industrial wastewater. A trickling filter is a heterogeneous bioreactor in which the biomass is fixed on inert packing such as stones or plastic media. The wastewater flows downward and trickles over the packing surface allowing a progressive colonisation of the support. As the wastewater flows, the organic materials get in contact with the microbiological slime layer growing on the media surface. The organic matter in the liquid is adsorbed onto the slime layer. In the outer portions of the biological slime layer, aerobic micro-organisms degrade the organic matter. As the micro-organisms grow, the thickness of the slime layer increases and the diffused oxygen is consumed before it can penetrate the full depth of the slime layer. Thus, an anaerobic environment is established near the surface of the media. As the slime layer increases in thickness, the adsorbed organic matter is metabolised before it can reach the micro-organisms near the media surface. The lack of external organic source for cell carbon makes the micro-organisms near the media face enter into an endogenous phase of growth and lose their ability to cling to the media surface. The liquid then washes the slime off the media, and a new slime layer starts to grow. This phenomenon of losing the slime layer is called sloughing and is mainly a function of organic and hydraulic loading on the filter. A cross section of the biological slime layer and the processes that occur are illustrated in Figure 5.4.1.

Filters are constructed with an underdrain system for collecting the treated wastewater and any sloughed biological solids. The underdrain system also serves as a porous structure through which air can circulate. Figure 5.4.2 shows a typical rock filled trickling filter.

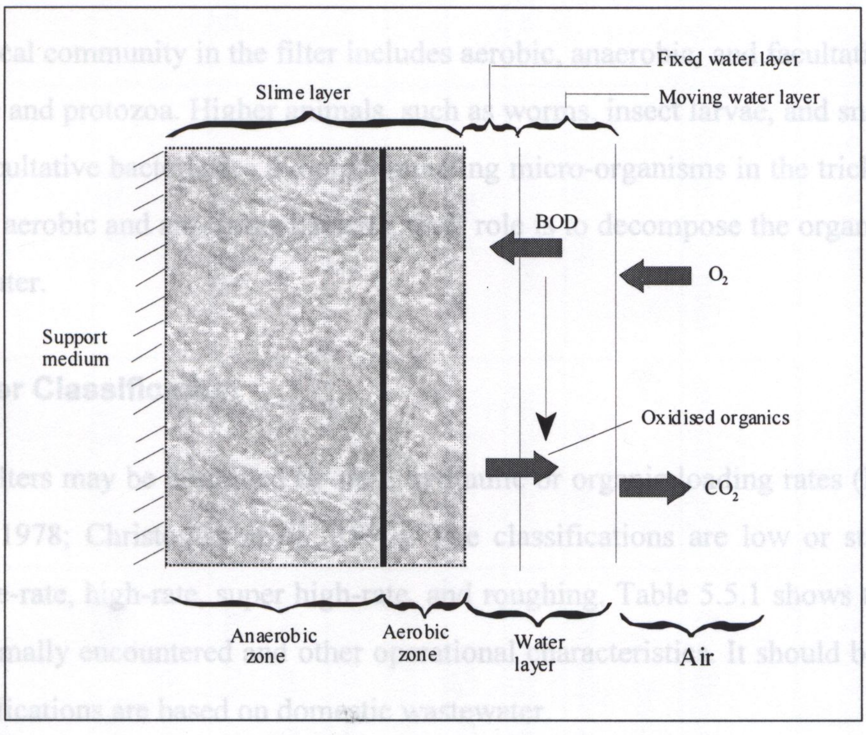

Figure 5.4.1: Schematic representation of the cross section of biological slime in a trickling filter (After Steel and McGhee, 1979).

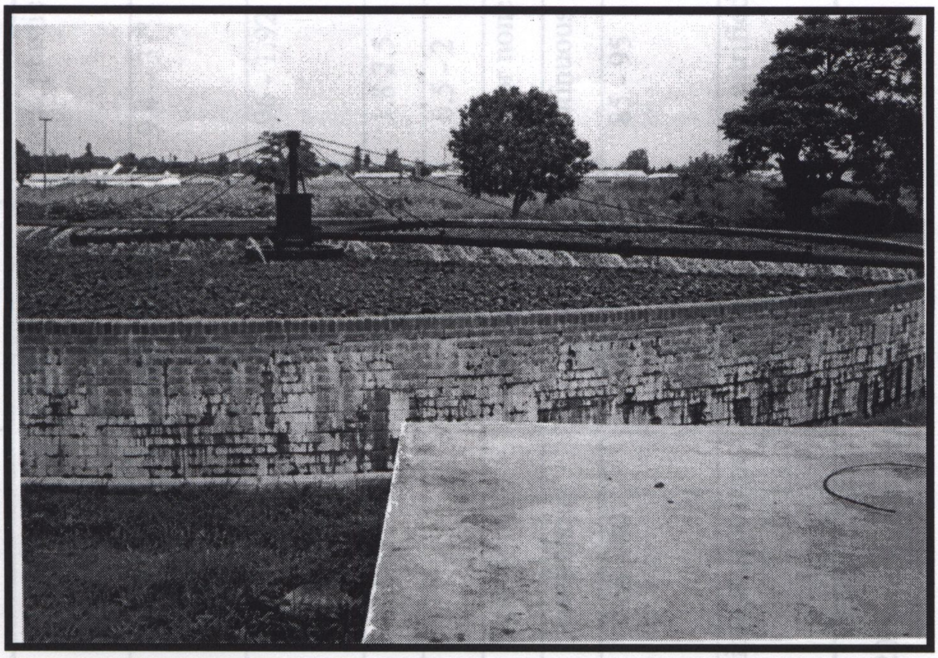

Figure 5.4.2: Typical trickling filter, conventional rock-filled type

(Courtesy of Lusaka Water and Sewerage Company)

The biological community in the filter includes aerobic, anaerobic, and facultative bacteria, fungi, algae and protozoa. Higher animals, such as worms, insect larvae, and snails are also present. Facultative bacteria are the predominating micro-organisms in the trickling filters. Along with aerobic and anaerobic bacteria, their role is to decompose the organic matter in the wastewater.

5.5 Filter Classification

Trickling filters may be described by their hydraulic or organic loading rates (Moodie and Greenfied, 1978; Christoulas *et al.*, 1990). The classifications are low or standard-rate, intermediate-rate, high-rate, super high-rate, and roughing. Table 5.5.1 shows the range of loading normally encountered and other operational characteristics. It should be noted that these classifications are based on domestic wastewater.

Figure 5.5.1: Typical design information for trickling filters (Metcalf and Eddy, 1991)[a]

Item	Low rate	Intermediate rate	High rate	Super high rate	Roughing	Two stage
Filter media	rock, slug	rock, slug	rock	plastic	plastic, redwood	rock, plastic
Hydraulic loading (m^3/m^2.day)	0.9 - 3.7	3.7 - 9.4	9.4 - 37	14 - 84	47 – 187[b]	9.4 – 37[b]
Organic loading (kg BOD/m^3.day)	0.08 - 0.4	0.24 - 0.48	0.48 - 0.96	0.96 - 1.6	1.6 - 8	0.96 - 1.92
Depth (m)	1.8 - 2.5	1.8 - 2.5	0.9 - 1.8	3 - 12	4.5 - 12	1.8 2.5
Recirculation ratio	0	0 - 1	1 -2	1 - 2	1 - 4	0.5 - 2
Filter flies	Many	Some	Few	Few or none	Few or none	Few or none
Sloughing	intermittent	continuous	continuous	continuous	continuous	continuous
BOD removal efficiency (%)	80 - 90	50 - 70	65 -85	65 - 80	40 - 65	85 - 95
Effluent quality	Well nitrified	partially nitrified	little nitrification	little nitrification	No nitrification	Well nitrified

[a] Classification based on domestic wastewater at an operational temperature of 20°C

[b] Excludes recirculation flow

5.6 Design of Physical Facilities

Factors that must be considered in the design of trickling filters include (1) the dosing rate, (2) the type and dosing characteristics of the distribution system, (3) the type and physical characteristics of the filter medium, (4) the configuration of the underdrain system, (5) provision of adequate ventilation and (6) the design of the required settling tanks. Prior to trickling filtration, there has to be adequate preliminary treatment by screening, grit removal and primary settling.

To optimise the treatment performance of trickling filters, there should be continual and uniform (1) growth of biomass and (2) sloughing of the excess biomass as a function of the organic loading.

Distribution systems may employ either rotary or fixed nozzles. The rotary systems consist of a hollow arm, pivoted at the centre and fitted with nozzles so sized and placed that they provide an essentially uniform distribution of liquid over the filter surface. The arm may be driven by the liquid discharge if sufficient head is provided, or may be turned by an electric motor. Fixed nozzle distribution systems consist of a series of spray nozzles located at the points of equilateral triangles covering the filter bed. A system of pipes placed in the filter is used to distribute the wastewater uniformly to the nozzles. The underdrain system serves to carry away the liquid effluent and sloughed biological solids and to distribute air through the bed.

Settling tanks follow trickling filters and their function is to produce a clarified effluent. The sludge from high-rate filters need further stabilisation to prevent odour release whereas that from low-rate filters is highly stabilised and can be directly dewatered and dried in drying beds. Design of the settling tanks is based on a combination of overflow rate and retention time which are in the ranges 0.7 - 1.0 m/h and 1 - 2 hours, respectively. Suggested overflow rates during peak loading periods are in the range 1.7 - 2.0 m/h (Metcalf and Eddy, 1991).

5.7 Advantages and Disadvantages of Trickling Filters

Trickling filters have several disadvantages as a means of wastewater treatment. Their advantages, nonetheless, outweigh the disadvantages. The major advantages are:

- low operation and maintenance costs
- simple operation requirements
- ability to absorb shock loads
- low energy consumption

Of particular concern are the following disadvantages:

- proliferation of filter flies
- odour nuisance
- lower treatment performance

5.8 Review of Design Methods

Although they have been used for a long period, no unifying theory has been developed for trickling filters (Moodie and Greenfield, 1978; Christoulas *et al.*, 1990; Crine *et al.*, 1990). Most of the models proposed in the literature are totally or partially empirical and may be grouped into three classes (Crine *et al.*, 1990):

1. The empirical models which try to reproduce globally the relationships between performance of industrial installations and the applied operating conditions (hydraulic and organic loads)
2. The semi-empirical models which are based on macroscopic mass balance in which some empirical correction factors are introduced in order to obtain a better agreement with the experimental observations
3. The mechanistic models which describe the couplings between mass transfer and biochemical kinetic processes at the level of the biofilm, leading to different expressions for the apparent reaction rate for consumption of organic matter or oxygen

The following are the equations developed for some of these models:

The National Research Council (NRC) or The Ten State Equations consider such factors as the effective number of passes of wastewater over the media, the reduced treatability of wastewater on each successive pass through the filter, and the organic load applied to the filter. The reduced treatability reflected, according to NRC, the fact that with each successive pass through the filter, the proportion of the remaining BOD was weighted toward a more resistant species of biodegradable material. The formulas are primarily applicable to single-stage and multi-stage rock systems. For a single stage rock filter, the equation is

$$E_1 = \frac{100}{1 + 0.4433\sqrt{\frac{W}{VF}}} \tag{5.1}$$

where

E_1 = efficiency of BOD removal at 20°C, including recirculation and sedimentation, percent

W = BOD loading to the filter, kg/day

V = volume of filter media, m^3

F = recirculation factor

The recirculation factor is calculated using the equation

$$F = \frac{1+R}{(1+R/10)^2} \tag{5.2}$$

where

R = recirculation ratio Q_r/Q

Q_r = recirculation flow

Q = wastewater flow

For the second-stage filter, the equation is

$$E_2 = \frac{100}{1 + \frac{0.4433}{1-E_1}\sqrt{\frac{W'}{VF}}} \tag{5.3}$$

where

E_2 = efficiency of BOD removal for the second-stage filter at 20°C, including recirculation and sedimentation, percent

E_1 = fraction of BOD removal in first-stage filter

W'= BOD loading applied to second-stage filter, kg/day

Robertson *et al.*(1968) report that of the two types of loading, organic and hydraulic, the organic load was found to have a greater influence on efficiency. These equations are based solely on the results of low-rate and standard-rate rock filters operated with domestic wastewater.

Probably the earliest mechanistic theory is that of Velz (Robertson *et al.*, 1968; Moodie and Greenfield, 1978) who postulated that " The rate of extraction of organic matter per interval of depth of a biological bed is proportional to the remaining concentration of organic matter measured in terms of its removability." This basic theory has been expanded by many others, incorporating other variables such as hydraulic loading, specific surface area, and so on to predict the performance of trickling filters packed with plastic media. Examples are those of Ekenfelder (Moodie and Greenfield, 1978; Metcalf and Eddy, 1991) and Germain (Metcalf & Eddy, 1991).

Ekenfelder proposed the expression given below:

$$\frac{S_e}{Si} = \exp[-KS_a^m D(Q_v)^{-n}] \qquad (5.4)$$

where

S_e = Total BOD_5 of settled effluent from filter, mg/l

S_i = Total BOD_5 of wastewater applied to the filter, mg/l

K = observed reaction-rate constant for a given depth of filter (value usually obtained from pilot plant studies), m/day

D = filter depth, m

S_a = specific surface area of filter medium = A_s/V, m^2/m^3

Q_v = volumetric flow rate applied to filter, m^3/m^2.d

Q_v = (Q/A)

Q = flow rate applied to filter, m^3/d

A = cross sectional area of filter, m^2

m, n = empirical constants

The general form of the equation proposed by Germain is as follows:

$$\frac{S_e}{S_i} = \exp[-k_{20} D (Q_v)^{-n}] \qquad (5.5)$$

where

S_e = Total BOD_5 of settled effluent from filter, mg/l

S_i = Total BOD_5 of wastewater applied to the filter, mg/l

k_{20} = treatability constant corresponding to a filter of depth D at 20°C, $(m^3/min)^n$

D = filter depth, m

Q_v = volumetric flow rate applied per unit volume of filter, $m^3/m^2.min$

Q_v = (Q/A)

Q = flow rate applied to filter without recirculation, m^3/min

A = cross sectional area of filter, m^2

n = experimental constants, usually 0.5

It should be pointed out that trickling filters fell out of favour in Europe and the US because they could not meet the stringent effluent standards for, among other things, nutrient removal. In the USA, however, the trickling filter has re-emerged through the development of the Trickling Filter/Solids Contact (TF/SC) process (Parker *et al.*, 1990). This uses physical and biological flocculation features to transform the poor quality of the trickling filter effluent into an effluent equal to the best activated-sludge system. The further development of the Biofilm-Controlled Nitrifying Trickling Filter (BCNTF) permitted higher rate operation and rendered the process less costly than the activated sludge system for nitrification.

5.9 Limitations for Slaughterhouse Effluent

Moodie and Greenfield (1978) assert that the agreement between the various design equations is not good. They argue that for a given load and efficiency, the NRC and

Eckenfelder equations can vary by a factor of eight in their predictions of required filter volume. This is the case with domestic wastewater treatment; the situation for the design of trickling filters treating abattoir effluent is even worse. The differences caused by the characteristics of abattoir wastewater mostly accounts for this. Furthermore, the BOD value of the waste fluctuates widely throughout the day depending on the operating conditions within the abattoir. A comparison of typical diurnal variations of domestic wastewater and abattoir waste is given in Figure 5.9.1. As well as having much higher BOD's than domestic wastewater, abattoir wastes also have much higher levels of fat, colloidal and suspended solids.

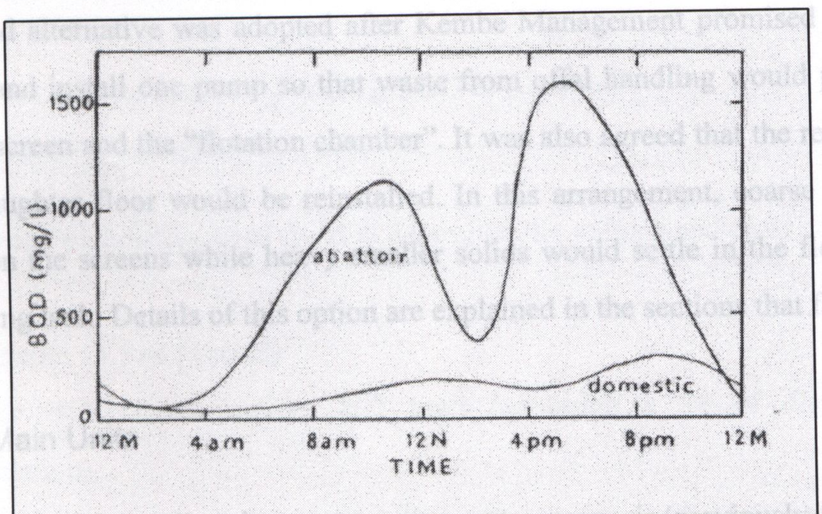

Figure 5.9.1: Diurnal variation in BOD of abattoir effluent and domestic wastewater (After Moodie and Greenfield, 1978)

Because of these significant differences, Moodie and Greenfield further argue, it would appear that existing empirical equations such as the NRC equation are of little use for abattoir applications. Pilot scale studies can help in developing design equations, but an attempt should be made to choose the appropriate model on which to base the equation. The choice of the model depends on how closely the model's assumptions agree with the observed behaviour of the filter, and on the accuracy and spread of the data collected.

5.10 Description of the Pilot Plant: Design, Construction and Operation

5.10.1 Process Selection

Two alternatives for the trickling filter process were proposed. The first alternative involved designing a complete pilot plant comprising screening, primary settling, trickling filter and final settling incorporating recirculation of the final effluent. The second alternative involved partial rehabilitation of the existing pretreatment plant with additional units being abstraction pump, flow control and stilling tanks, trickling filter and final settling with recirculation of final effluent.

The second alternative was adopted after Kembe Management promised that they would purchase and install one pump so that waste from offal handling would pass through the vibrating screen and the "flotation chamber". It was also agreed that the removable screens on the slaughter floor would be reinstalled. In this arrangement, coarse solids would be retained on the screens while heavy smaller solids would settle in the flotation chamber-cum-settling tank. Details of this option are explained in the sections that follow.

5.10.2 Main Units

The main units of the pilot plant were a wastewater reservoir (previously flotation chamber for the defunct DAF facility), abstraction pump, flow control tank, stilling tank, mixing tank, trickling filter, humus tank (final clarifier) and recirculation pump. In the design process, more attention was given to the trickling filter than on the other units, which were constructed using the rule of thumb. It was assumed that pump P2 would be purchased before the pilot plant became operational so as to put the vibrating screen to use. The other assumption was that the removable screens on the slaughter floor and other areas would be reinstalled to prevent coarse solids from entering the sewers. Details of the design considerations are given hereunder.

5.10.3 Trickling Filter Design

A BOD value of 800 mg/l was selected based on an assumed value of 1500 mg/l for the influent and at least 100 percent recirculation of highly treated final effluent. By varying the flow rate, the volume and area of the filter was computed using the following relationships (Veenstra and van Duijl, 1995):

$$L_v = \frac{load(kgBOD/d)}{Volume_{filter}(m^3)}(kgBOD/m^3 filter/d) \quad (5.6)$$

and

$$HSLR = \frac{flowrate}{Area_{filter}} = \frac{Q(m^3/h)}{A_f(m^2)}(m/h) \quad (5.7)$$

where

Lv = volumetric organic loading rate, kg BOD/m^3filter/day

HSLR = hydraulic surface loading rate, m/h

The following parameters were fixed to determine the volume and cross section area of the filter.

- Filter depth : 1.5 m (typical)
- Influent BOD concentration: 800 mg/l (assuming a lot of dilution occurs by recirculation)
- Organic loading rate : 0.4 kg BOD/m^3filter/day (maximum for low rate)

From these conditions and varying the flow rate, the hydraulic load calculated was 0.031 m/h, which is just about the minimum for a low-rate filter (Table 5.10.1). The flow rate selected was 0.1 m^3/h giving a square section of sides 1.8 m.

Table 5.10.1: Extract of spreadsheet used to determine filter dimensions

Flow (m3/h)	BOD kg/m3	Lv (kgBOD/m3.d	Area (m2)	V (m3)	HSLR (m/h)	Q (m3/d)	Sq side (m)
0.05	0.8	0.4	1.6	3.2	0.031	1.2	1.26
0.1	0.8	0.4	3.2	6.4	0.031	2.4	1.79
0.15	0.8	0.4	4.8	9.6	0.031	3.6	2.19
0.2	0.8	0.4	6.4	12.8	0.031	4.8	2.53
0.25	0.8	0.4	8.0	16.0	0.031	6	2.83

On construction, it was found easier to use the full length of the provided steel sheets (dimensions 2.4 by 1.25 m). The depth of media packing was set at 1.8 m leaving a free board about 0.50 m. The other 0.10 m was taken up by the welding provision and overlap for strength.

A fixed flow distributing system was adopted over a rotary distributor because it was easier to operate. A square cross section for the filter was selected because it was found simpler to fabricate than a circular section. Due to anticipated clogging problems, open distribution channels were selected to facilitate cleaning.

5.10.4 Final Clarifier Design

The final clarifier design was based on surface loading rate and retention time at a flow of 1.1 m^3/h. Previously, it was felt that the clarifier be made in such a way as to be adjusted according to the flow rate. This was turned down because of anticipated construction complications. The fabricated clarifier was trapezoidal in shape with a volume of about 0.8 m^3, water depth 0.75 m and liquid surface area 1.65 m^2. It had a provision for sludge removal by way of a gate valve at the bottom. Scum was skimmed from the surface manually.

5.10.5 Construction Materials

All the units that required fabrication works were constructed in steel. These were the trickling filter (including distributors and underdrain), final clarifier and flow mixing tank. Rusting of these structures was minimised by painting the surfaces with two protective layers of red oxide. The flow control and stilling tanks and the recirculation sump were ready-made 210 litre PVC containers. High resistance to corrosion was the main factor that favoured the use of PVC.

The wastewater conveyance and drainpipes were either of rubber or PVC to resist corrosion. Brass gate valves were used at the drainage and sludge removal outlets.

5.10.6 Layout and Construction Details

The flotation chamber for the rundown DAF facility was used as a wastewater reservoir and also helped in sedimentation. Abstraction was done by a submersible pump placed in the sump that had previously been used for recirculation in the DAF process. Wastewater was pumped to the flow control tank located on a wooden platform about 4.5 m high. The flow to the subsequent units was by gravity. The required flow was regulated by means of a drop gate and an overflow arrangement that maintained a constant head. Overflowing wastewater from the flow control tank returned to the abstraction sump. In the stilling tank, floatable solids accumulated on the surface by natural flotation and were removed manually. The mixing tank facilitated the combination of the influent and the recycled final effluent before being conveyed to the trickling filter for biological treatment. Biologically treatment effluent from the trickling filter entered the final clarifier for removal of sloughed biomass. The final effluent passed though a recirculation sump where part of it was pumped to the mixing tank and the rest discharged to the public sewer. A bypass was provided before the final clarifier to convey wastewater directly to the recirculation pump if the need arose. The tanks for flow control, flotation and mixing all had bottom drains for removal of any accumulated solids and emptying in case of repair works. Figure 5.10.1 gives the layout of the pilot plant units in relation to the defunct DAF pretreatment facility.

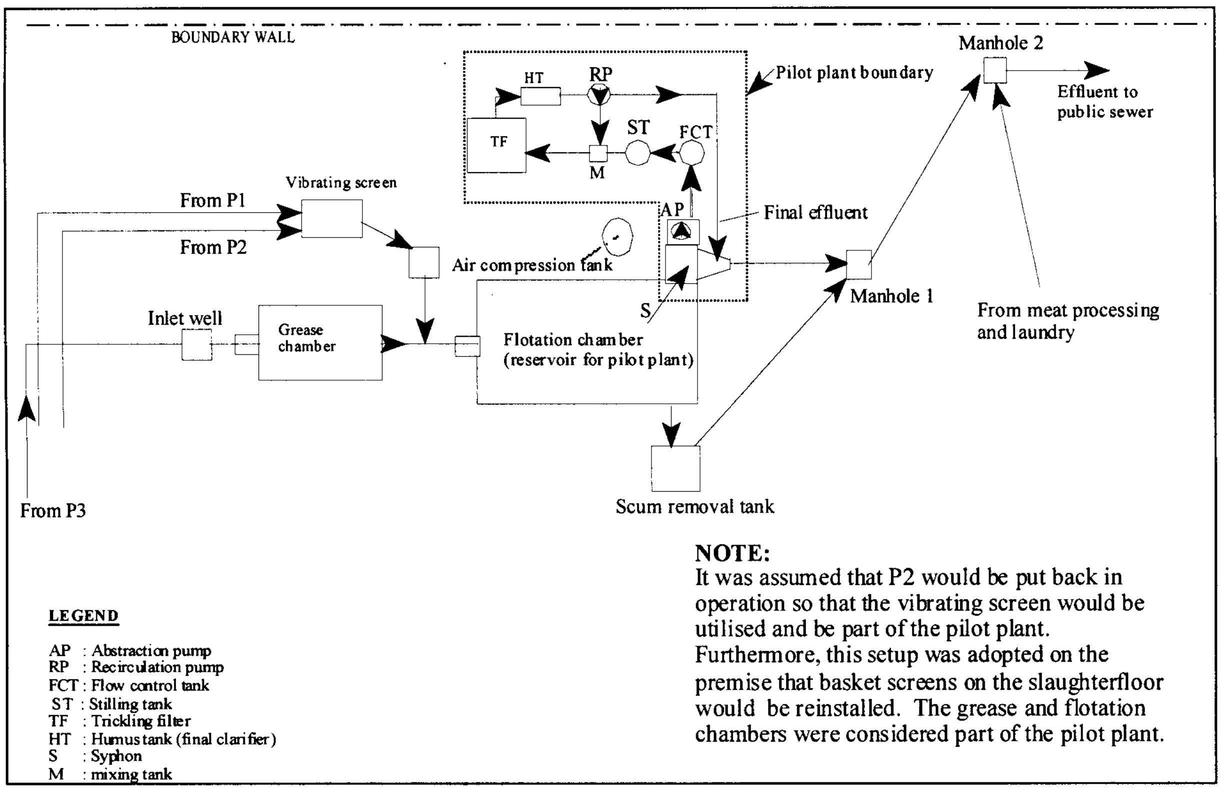

Figure 5.10.1: Layout of pilot plant units in relation to the defunct DAF pretreatment facility

The pilot plant installation is schematised in Figure 5.10.2. Wastewater left the defunct flotation chamber at an outlet located at the same level with the liquid surface when this chamber was full. The wastewater only reached the abstraction sump when there was pumping from the operations within the slaughterhouse. In this respect, a siphon (50 mm hosepipe) was provided to ensure a continuous supply of wastewater from the flotation chamber to the abstraction sump.

The main treatment unit of the pilot plant was the trickling filter and its main features are explained below.

The trickling filter consisted of a steel angle framework with 4 mm thick steel cladding. It had a depth of 1.8 m and a square section plan of side 1.8 m giving an effective plan surface area of 3.24 m^2. The distribution system was located 50 cm above the filter media and comprised a 50 by 50 mm central channel connected to eighteen 25 by 25 mm channels covering the whole filter area.

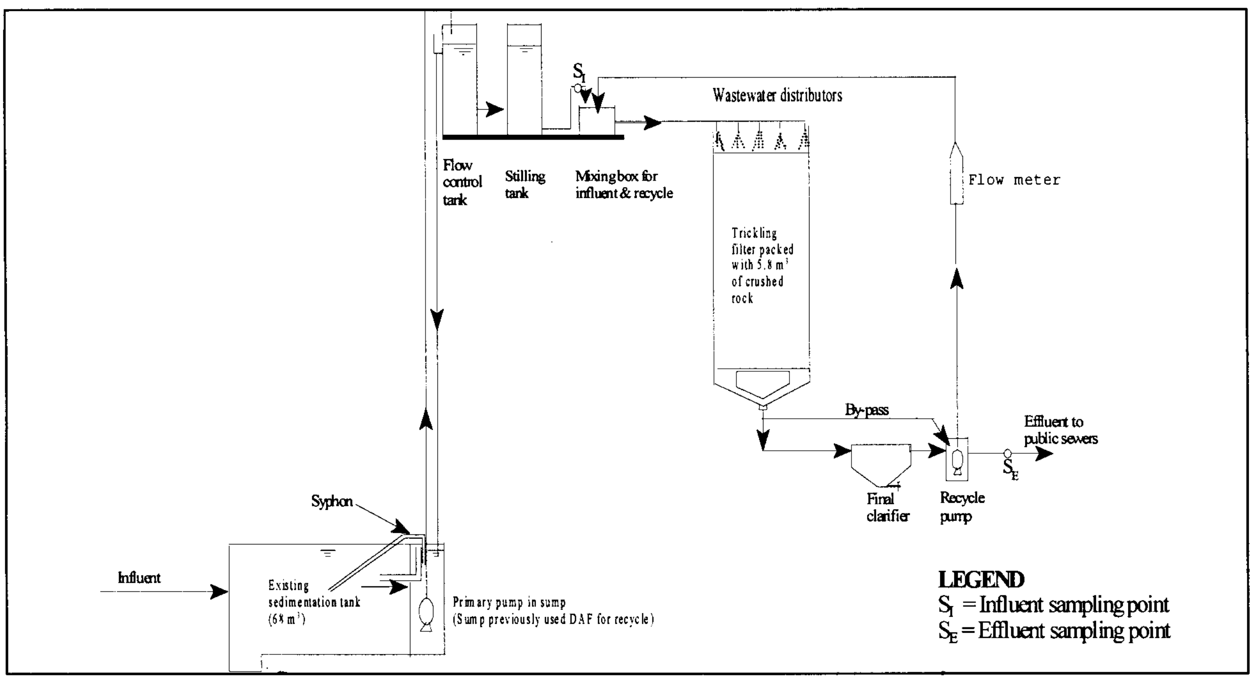

Figure 5.10.2: Schematic representation of the pilot plant

There were 5 mm perforations on the sides of the smaller channels to let the wastewater flow onto the media. Each of these channels received wastewater from the central channel and distributed it over the entire filter area. The distribution arrangement had provisions for horizontal adjustment by way of six screws – two on the central channel and the other four at the corners as depicted in Figure 5.10.3. An aerial view of the trickling filter illustrating the arrangement of the distribution system is shown in Figure 5.10.4.

The filter media was supported by a grid of square mesh of 5 cm made from 12 mm steel bars which were in turn supported by 100 X 50 mm steel channels. The ratio of openings to total area at the filter support was about 40 percent, which meets the recommended value of at least 15 percent (Steel and McGhee, 1979). Filter media composed of crushed rock of sizes ranging from 60 to 100 mm with the bigger ones placed at the bottom.

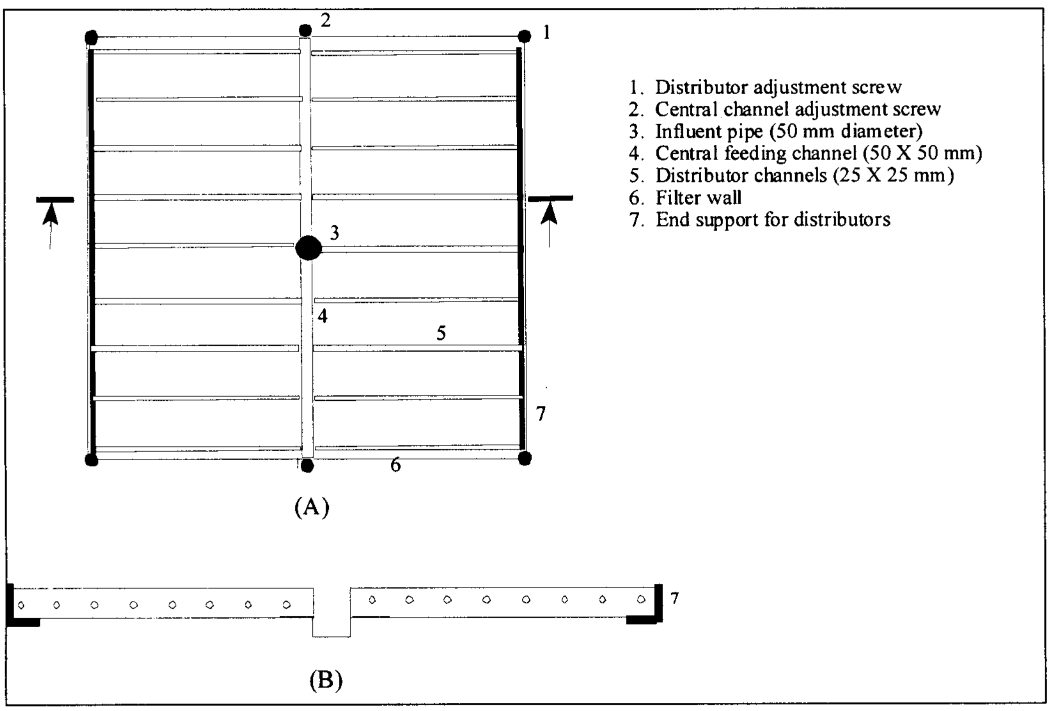

Figure 5.10.3: Flow distribution configuration: (A) plan and (B) cross section of central channel and distributors

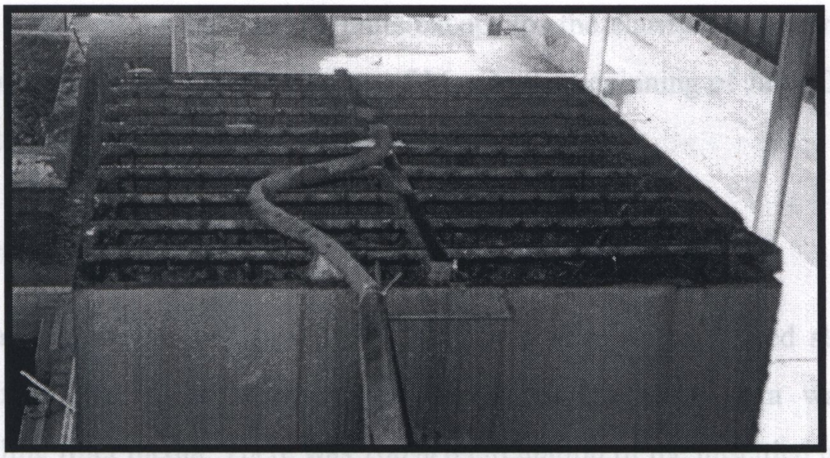

Figure 5.10.4: Flow distribution system for the pilot plant trickling filter

Ventilation was accomplished by two openings in the underdrain system located on opposite sides of the filter. The whole trickling filter arrangement was supported on concrete brickwork columns placed at the four corners. Figure 5.10.5 shows the cross-section of the trickling filter highlighting the salient constructional features.

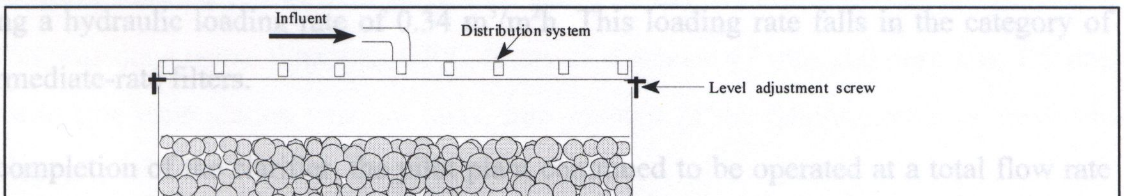

Figure 5.10.5 Cross-section of the pilot plant trickling filter

Construction of the pilot plant (all the units except for the clarifier) was carried out in a period of two months - from the beginning of May to the beginning of July. Other features of the pilot plant are presented in pictures in Appendix E.

5.11 Experimental Programme

The plant start-up was on 10th July 1997. Five days after start-up, seed sludge from a humus tank (final clarifier) at Chunga Sewage Treatment Plant in Lusaka was introduced onto the trickling filter media. There was 100% recirculation of the unsettled trickling filter effluent for 24 hours after seeding to ensure adequate colonisation of the media by bacteria (the final clarifier was by-passed). It took about two weeks after seeding to notice an appreciable amount of slime layer development on the media.

It was observed at start-up that wastewater distribution over the filter surface was very poor at low flow rates. The minimum hydraulic loading required for good wastewater distribution over the filter and to ensure that the whole area was wet was about 1.1 m^3/h giving a hydraulic loading rate of 0.34 m^3/m^2h. This loading rate falls in the category of intermediate-rate filters.

On completion of the clarifier, the pilot plant continued to be operated at a total flow rate of 1.1 m^3/h with a recirculation ratio of 0.5. The main purpose of recirculation was to dilute the influent. Influent flow was determined by a stopwatch and a graduated container while the recirculation flow was measured by a flow meter. From time to time, the flow meter reading was counterchecked by the stopwatch and graduated container.. On October 15, the flow rate was increased to 1.6 m^3/h due to a high proliferation of filter fly larvae on the media. This gave a hydraulic loading rate of 0.49 m^3/m^2h and thereby changing the operation regime to the high-rate range. The recirculation ratio was 1.0.

The larvae consumed the slime layer leaving the media bare and the flies became a nuisance in the vicinity of the filter. Measures to control the flies were therefore sought. Houston *et al.* (1989) state that various methods of control (physical, chemical and ecological) have been tried with none of them being a complete success. They investigated the effectiveness and suitability of the entomopathogenic bacterium, *bacillus thuringiensis var. israelensis (Bti)* and found that it was suitable for use on sewage filter beds to control nuisance flies. In this study, the physical control by increasing the hydraulic rate was applied. This helped in flushing out larvae from the media and resulted in satisfactory development of the slime layer after about two weeks. Covering the top of the filter using a fly screen was pursued as a further fly control measure and prevented flies from accessing the media. However, the fly nuisance around the trickling filter did not reduce and made it even more difficult to clean the distribution system.

All the analyses were performed according to " Standard Methods" (APHA, AWWA, WEF, 1995). Treatment performance considerations were based on removal efficiencies of organic matter in terms of the biochemical oxygen demand (BOD). However, because of the long time required to get BOD results, the chemical oxygen demand (COD) was used. A few samples were analysed for the BOD to establish a correlation with COD. For BOD, dissolved oxygen was determined by the Winkler method. COD was determined by using the closed reflux titrimetric method in standard 10-ml ampules. Standards were used at all times to guarantee reliability of the analyses. The other parameter examined, though on a much lower frequency, was total suspended solids (TSS). Filtration for the determination of TSS was done using Whatman GF/C filters of diameter 47 mm and pore size 1.5 μm. The effect of recirculation was not taken into account in the determination of treatment efficiency.

Sampling and analysis began towards the end of September, about ten weeks after start-up, and went on until 31st December. An exercise was carried out to determine whether to use grab or composite samples by taking samples every hour during the day for one week. There was a very high variation in COD concentration between the hourly samples and no pattern emerged for all the days. Figure 5.11.1 depicts the high level of variations of the wastewater to the trickling filter for one day. In this regard, composite samples were found to be more appropriate. Initially equal volumes of grab samples were taken hourly for twelve hours from 07:00 hours to 18:00 hours. Each sample was preserved with 2 ml of concentrated sulphuric acid for every litre of sample and stored in a fridge at about 4 °C. The twelve samples for each day were poured into a bigger container to make one composite sample before analysis. A peristaltic pump was afterwards installed to facilitate sampling to obtain 24-hour composites. Two rubber tubes were connected to the pump to facilitate continuous collection of influent and effluent samples at the same time. No preservation was done during the 24-hour sampling period. Figure 5.11.2 shows the peristaltic pump used for sampling. Samples were taken every day except for the weekends and public holidays.

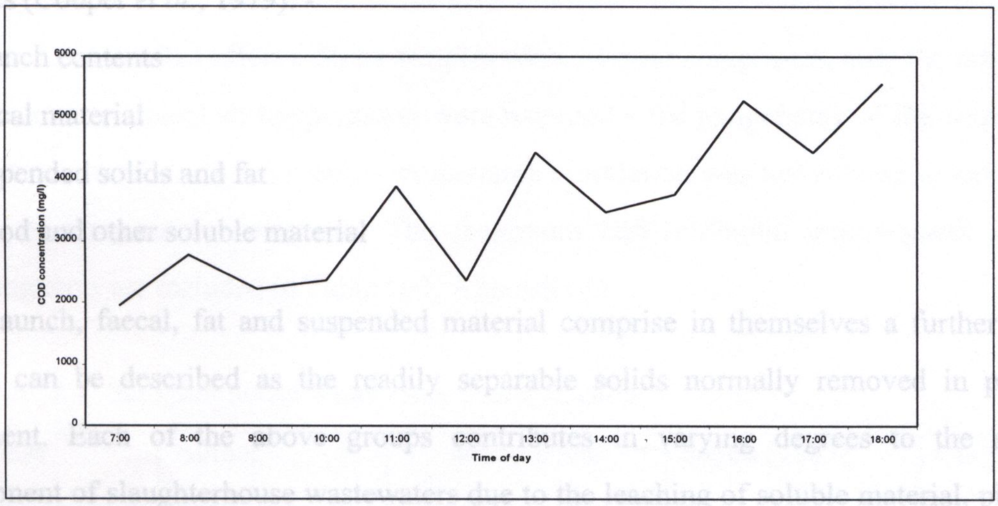

Figure 5.11.1: Hourly variation in COD of wastewater to the filter

Figure 5.11.2: The peristaltic pump used for sampling

(Note the two tubes for sampling of the influent and effluent simultaneously)

5.12 Results and Discussion

5.12.1 Characterisation of Wastewater

The organic constituents of wastewater from a slaughterhouse come from four main sources (Cooper *et al.*, 1979): -

- paunch contents
- faecal material
- suspended solids and fat
- blood and other soluble material

The paunch, faecal, fat and suspended material comprise in themselves a further group which can be described as the readily separable solids normally removed in primary treatment. Each of the above groups contributes in varying degrees to the soluble component of slaughterhouse wastewaters due to the leaching of soluble material, physical breakdown of solids, and emulsification which occurs during the passage of such material through drains.

The analysis of slaughterhouse liquid wastes before primary treatment is difficult because of the presence of large amounts of readily separable material. It is more meaningful to describe slaughterhouse effluent on a settled or post primary treatment basis (Cooper *et al.*, 1979).

The slaughterhouse wastewater underwent some kind of primary treatment in the grease and flotation chambers of the defunct DAF facility to remove solids (mainly manure) by natural flotation and manual skimming. More solids were removed by flotation from the stilling tank. Samples for the influent were taken just before the wastewater entered the mixing box. Table 5.12.1 shows the characteristics of the influent, along with results obtained from other studies on slaughterhouse wastewater.

Samples of filter influent and effluent were analysed for COD and BOD to determine the correlation between the two. The mean COD/BOD ratio was 2.09 for the influent and 2.19 for the effluent, with standard deviations of 0.93 and 0.84, respectively. The minimum and maximum COD/BOD ratios were 1.03 and 4.53 for the influent and 1.38 and 4.20 for the effluent.

5.12.2 Temperature Effects

The temperature of the wastewater in the filter changed from day to day because of process variations and weather effects. Since samples were 24-hour composites, only the maximum and minimum ambient air temperatures were recorded – the temperature of the wastewater was not measured. In this respect, a temperature correlation was not applied to reduce the effects of temperature variations. The maximum and minimum temperatures for the sampling days are included in Table D-1, Appendix D.

Figure 5.12.1: Slaughterhouse wastewater characteristics

Parameter	Author	Moodie and Greenfield (1978)	Sayed (1987)	Cooper *et al. (1979)*
pH	6.8 – 7.6	6.7 - 7.8	6.8 - 7.1	-
Temperature (°C)		30.5 - 32.0	-	-
T.S.S (mg/l)	280 - 990	530 - 1640	-	200 - 1000
BOD_5 (mg/l)	860 - 3100	1460 - 1925	490 - 650	700 - 1800
COD (mg/l)	900 - 5310	2550 - 4980	1500 - 2200	1200 - 3000

5.12.3 COD Removal Efficiency

The influent and effluent samples were analysed for total COD and therefore the overall efficiency is based on the total COD of the influent and settled effluent. The proper functioning of the final clarifier in terms of surface loading rate and retention time was therefore fundamental. No analyses were done for soluble, settleable and nonsettleable components of COD. The uncorrected results are given in Appendix D, Table D-1, together with the graphs (Figure D-1) showing COD of the influent and effluent and Figure D-2 depicting the efficiency removal. Some corrections were done by leaving out all the negative efficiencies and the values obtained for the first three weeks after changing the hydraulic loading rate. The operating conditions and the COD treatment performance results are presented in Table 5.12.2. Figure 5.12.1 shows the level of treatment attained by comparing the influent and effluent COD concentrations. The relationship between the influent COD and treatment efficiency is depicted in the scatter plot of Figure 5.12.2. To distinguish the treatment efficiencies obtained for the two hydraulic loading rates applied, a graph of time against treatment efficiency was plotted (Figure 5.12.3).

Table 5.12.2: Operation conditions and results

Treatment unit	Item	Period 1 Intermediate- rate	Period 2 High-rate
	Period of operation	10/7/97 – 14/10/97	15/10/97 – 31/12/97
	No. of Samples	13	32
	Influent flow rate, Q (m^3/h)	0.74	0.8
Trickling filter	Hydraulic loading rate ($m^3/m^2.h$)	0.34	0.49
	Organic loading rate (kg BOD/ m^3.d)*	1.7 – 8.2*	4.9 – 14.6*
	Recirculation ratio	0.5	1.0
Final clarifier	Surface loading rate ($m^3/m^2.h$)	0.7	1.0
	Retention time (minutes)	44	30
COD Treatment efficiency (%)	Range	5.6 – 62.5	6.3 – 54.0
	Average	37.8	23.9
	Standard deviation	17.5	12.2

* The BOD loading is based on the average COD/BOD ratios (2.09 for the influent and 2.19 for the effluent) as well as the recirculation ratio.

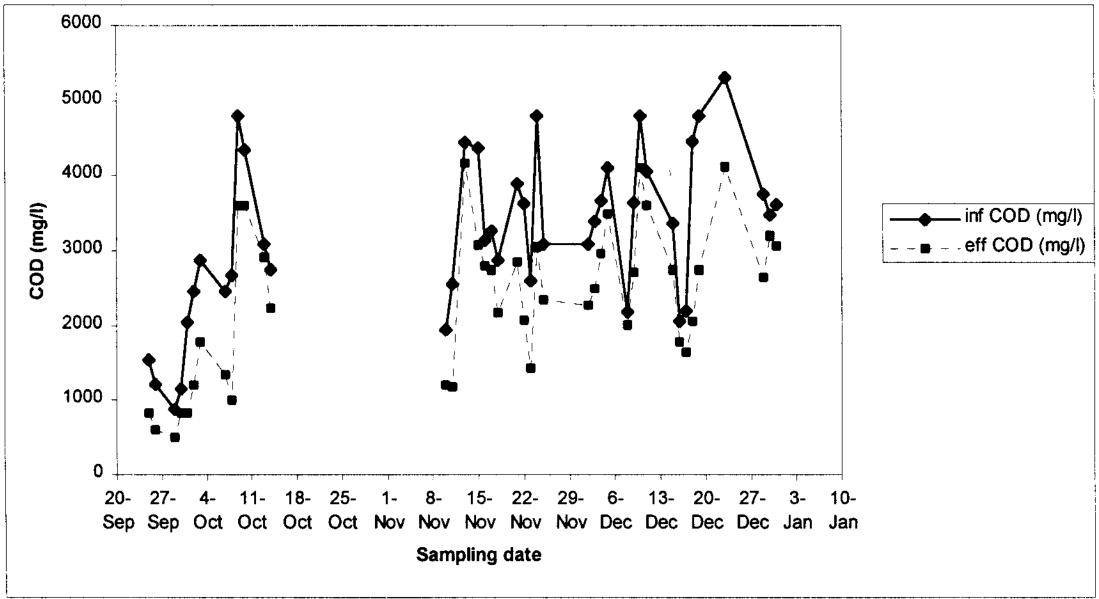

Figure 5.12.1: Overall COD removal efficiency under varying influent COD

(The break in the graph shows the adaptation period after adjusting the hydraulic rate)

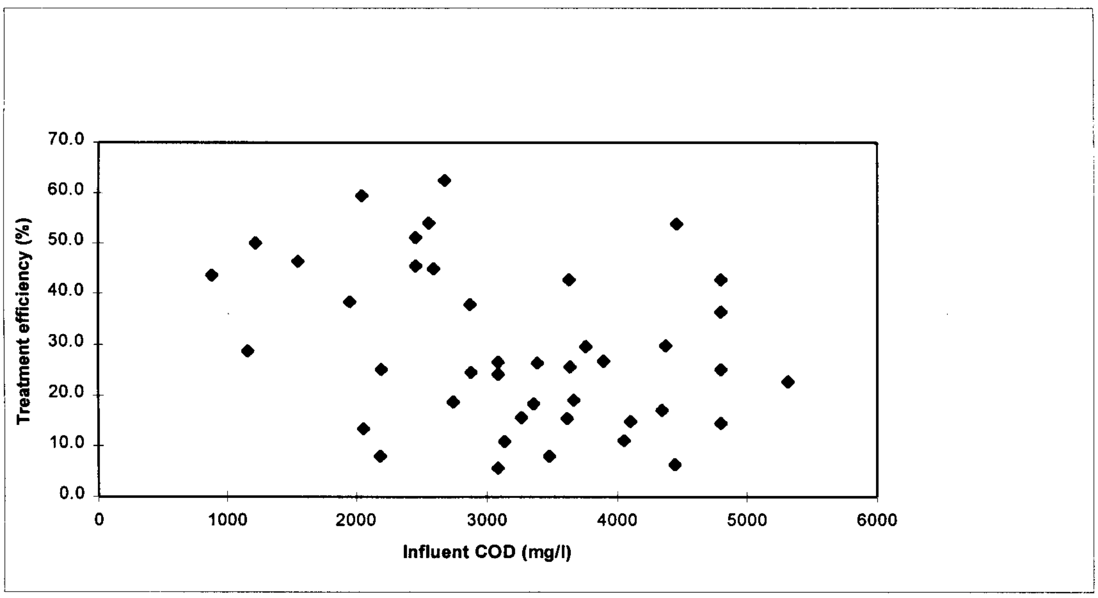

Figure 5.12.2: Relationship of overall COD efficiency to influent COD

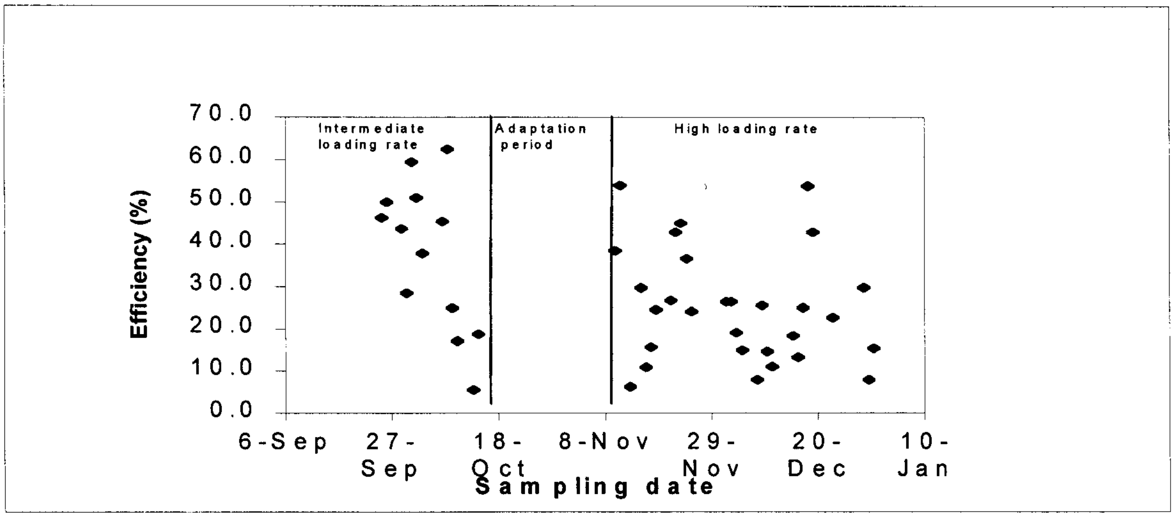

Figure 5.12.3: Variation of COD removal efficiency with time

A period of about three weeks is needed for operation to stabilise and adapt to a new loading rate before sampling can resume (Moodie and Greenfield, 1978). There was no break in the sampling and analysis programme to allow for the adaptation period. In order to allow for this adaptation period, the results of the first three weeks after the change of flow rate were disregarded. The following reasons may account for the streak of negative efficiencies observed after the change of hydraulic rate:

- high hydraulic loading rate to the final sedimentation tank resulted in a low retention time of about 30 minutes, which is much less than the stipulated range of 1 - 2 hours. The surface loading rate was, however, within the acceptable range of 0.7 to 1.0 m/h.
- high accumulation of sloughed biomass from the trickling filter, especially at night when no sludge was removed from the final clarifier. The biomass sloughed off from the filter contributed significantly to the high COD concentrations of the final effluent.

These two problems were overcome by subjecting the collected composite samples to a further 30 minutes of settling. This resulted in an improvement of the final effluent quality.

The scatter plots of Figures 5.12.2 and 5.12.3 do not exhibit any ability of the filter to absorb shock loads. Moodie and Greenfield (1978) found that efficiency was almost constant for COD concentrations varying from 1800 to 3200. For this investigation, the great variation in efficiency is most likely due to the rapid and very high fluctuations in the influent COD that made it impossible to obtain steady conditions within the filter. The high variability of the influent COD may be attributed to the absence of an equalisation step and lack of proper primary treatment by screening and sedimentation. High contents of suspended solids were present in the wastewater as evidenced by the values of TSS (280 to 900 mg/l) obtained from the analyses. Settleability tests on this influent gave values in the range 1.0 to 6.5 ml/l, indicating that there was no proper primary settling. Ideally, there should be no settleable matter after primary sedimentation. In addition, there was a high incidence of clogging in the distribution system due to the accumulation of solids, which solids should have been removed by primary treatment.

5.13 Conclusions and Recommendations

It has to be pointed out that this study solely looked at the removal efficiencies without any attempt to explore the kinetics at the slime layer level or even establish the agreement with the proposed models. It was simply a black box approach. All in all, it can be stated that the pilot plant investigations were successful to some degree with the following major conclusions:

1. The study revealed that the treatability of slaughterhouse wastewater by trickling filtration is good but needs lower organic loading rates to achieve higher removal efficiencies. An average COD removal efficiency of 37.8 at a recirculation ratio of 0.5 was obtained at hydraulic and organic loading rates of 0.34 m^3/m^2h and 1.7 to 8.2 kg BOD/m^3d, respectively. For a hydraulic rate of. 0.49 m^3/m^2h (recirculation ratio 1.0) and organic loading rate in the range 4.9 to 14.6 kg BOD/ m^3d, an average COD removal efficiency of 23.9 percent was obtained.
2. The level of treatment attained did not reduce the COD concentrations to meet the requirements for discharge into the public sewers.
3. The results were not conclusive enough to provide a basis for the design of a full-scale trickling filter plant as explained below.

The results obtained do not give a definite picture of COD removal efficiencies: there is a poor consistency with respect to treatment performance. This treatment efficiency can be improved and made stable by providing an equalisation step with mixing arrangements as well as proper primary treatment by screening and settling. The screening stage (basket screens and vibrating screen) was not incorporated into the pilot plant as had been envisioned at the outset. These measures would considerably improve performance and thus probably achieve high treatment efficiencies. It is therefore recommended that the research should be ongoing and that the pilot plant should be operated under clearly defined conditions. The emphasis should be on the following:

- inclusion of an equalisation step to dampen influent COD fluctuations
- provision of proper primary treatment by screening and sedimentation
- provision of adequate secondary sedimentation
- analysis of more parameters like Kjeldahl nitrogen, pH, temperature and, oil and grease
- collection of composite samples should be confined to the day time (12-hour composites)

Christoulas *et al.* (1990) state that the biological filter can successfully compete with the suspended biomass processes provided that the "secondary factors" are favourable. The secondary factors being good primary and secondary settling, effective distribution system, proper stone size and configuration and a dosing regime that does not cause overloading.

6. Overall Conclusions and Recommendations

6.1 General

The study is the first major work in recent years in Zambia to highlight the main weaknesses of the current policy, institutional and legal frameworks as it relates to industrial wastewater management. The most outstanding is the high degree of duplication and overlap of functions found in the five major relevant Acts, namely, the Natural Resources Conservation Act, the Public Health Act, the Local Government Act, the Water Act and the Environmental Protection and Pollution Control Act. Worse still, most of these Acts are not enforced let alone well known by the responsible authorities. Only the Environmental Protection and Pollution Control Act seems to have gained ground and has had some aspects implemented through the Environmental Council of Zambia. One of the areas found wanting in the implementation of this Act was information dissemination. Industry knew very little on industrial wastewater regulatory requirements. In order to meet the present and future environmental challenges, the need to reformulate the regulatory framework by shifting emphasis from a system of licences to that of pollution prevention is of utmost importance.

The case study of a Lusaka slaughterhouse revealed how deep the problem of non-enforcement of industrial wastewater effluent standards into the public sewers was. The installed pretreatment facilities were completely rundown because of, among other things, inappropriate technology, lack of enforcement and absence of environmental awareness by all employees. There was generally no knowledge of compliance requirements or the quantity and quality of the wastewater produced. Provisions for monitoring industrial water usage and analytical facilities for water and wastewater were nonexistent.

The pilot plant investigation on the treatability of slaughterhouse effluent by trickling filtration was most probably the first of its kind in Zambia. The defunct DAF facility at Kembe Cold Storage Corporation served as a perfect example of what could happen to designs that do not undergo proper evaluation before construction. Trickling filtration was selected as the best option to replace the DAF process because of its low operation and maintenance costs, less skilled labour requirements and ability to absorb shock loads. Although the trickling filter process does not achieve high treatment efficiencies as the activated sludge process, for instance, it would be suitable as pretreatment before discharging to the public sewers. However, the results obtained did not exhibit consistency in treatment performance and the effluent did not meet the stipulated standards for discharge into public sewers principally because the screening stage was not put into operation as was planned at the outset. The high suspended solids content adversely affected treatment performance.

The detailed conclusions for each of the three aspects dealt with in the study are given below.

6.2 Industrial Wastewater Management in Zambia

1. The relevant legal, policy and administrative frameworks are in place, albeit with a number of implementation problems and overlap of functions by various government authorities. There is therefore need to harmonise the various pieces of legislation to eliminate duplication and overlaps to ensure effective monitoring and enforcement of industrial compliance. The main environmental legislation, the Environmental Protection and Pollution Control Act, is the only Act that seems to be implemented. This Act revolves around the "Polluter Pays Principle" and effluent discharge licences to enforce compliance with the stipulated industrial effluent standards. Be that as it may, it is rare to find an industry that complies with regulations. One major observation was that the regulatory requirements were not well understood by industry mainly due to inadequate information dissemination. To some industries, getting of discharge licences was taken as a certificate of compliance. It is therefore important to introduce the aspect of " Pollution Prevention Pays" by way of a cleaner production drive because that is currently the preferred approach.

   The Local Administration (Trade Effluent) Regulations are unknown even to the local authorities that are supposed to enforce them for discharges into the public sewers and in areas within their jurisdiction. There are cases where industries discharge into the public sewers at no cost at all. Many local authorities do not have the facilities and expertise to monitor and control discharge into the public sewers. From the foregoing, it is evident that wastewater treatment plants run by the local authorities cannot operate efficiently and be able to produce effluents good enough for discharge into the environment. It is therefore recommended that the Environmental Council of Zambia and local authorities develop a very close working relationship in order to control industrial effluent discharge and protect the environment.

2. The industries to which the Acts are targeted know very little, if anything at all, about these Acts and the aspects of industrial environmental management. It is against this backdrop that an aggressive awareness drive is required to educate them on the effects of their wastes on the environment and the need to control pollution in general. They regard pollution prevention as a system of permits, licences and penalties meant to victimise them and minimise profits. Instead a new approach based on environmental management tools, as formulated in the ISO 14000 series, should be promulgated to improve on industrial environmental management. This could be facilitated by introduction of environmental departments or sections in industry. It is very important to note here that a confrontational approach to realising environmental compliance may not yield the desired results. Instead, a cooperative stance should be adopted especially in collaboration with the Zambia Association of Manufacturers and the Zambia Chamber of Commerce and Industry.

All in all, it can safely be stated that part of the groundwork has been set for monitoring and controlling water pollution from industries. What is needed is putting the actors in place so that the relevant Acts and regulations are not condemned to the archives but are actively pursued for the betterment and protection of our environment. Let it be stated that environmental legislation is only as effective as the level of enforcement makes it. A prerequisite to enforcement is that industry is first made aware of the prevailing regulatory requirements.

6.3 Water and Wastewater Management at Kembe Cold Storage Corporation

The following conclusions have been made regarding the case study of water and wastewater management at Kembe Cold Storage Corporation.

1. The installed industrial technology had all the attributes of an environmentally friendly undertaking. The plant deserved a cleaner technology tag because it was designed to produce very little waste. Blood, condemned carcasses and offals, horns, bones and meat scraps were conveyed for rendering into marketable by-products. Hides are taken to a tannery for processing into leather. The breakdown of the rendering plant defeated the essence of industrial environmental management as envisaged in the initial plans and meant much higher pollution loads. Rehabilitation of the rendering plant is deemed necessary in order to reduce pollution from this industry and enhance its public image.
2. The installed DAF pretreatment facilities were completely rundown due to high operation and maintenance costs, absence of skilled manpower, lack of environmental awareness and non-enforcement of effluent standards for discharge into the public sewer by the local authority. What was once a well designed pretreatment facility had been reduced to a state where wastewater passed through virtually untreated to the public sewers.
3. Water is used as process water, cooling water, sanitary and service water and in making ice blocks. There was no programme to monitor the quantity of water used in the plant let alone the amounts for the various processes. A study of the water use patterns revealed that water was not considered as a valuable resource that had to be used wisely. Water meters were installed at some points on the distribution network and helped in estimating the quantities utilised for various activities. It clearly came out that there was no relationship between the number of animals slaughtered and the quantity of water used. This showed that water was misused and needed some control.
4. A number of in-house measures were recommended to minimise on water use. Most prominent among these were the inspection of the distribution network to make good any defects detected, installation of water meters, implementing a water conservation awareness drive, exploring ways of recycling or reusing cooling water, and to curtail the use of water to transport solid wastes from their points of origin. Savings of about 200 m^3 per day were recorded for one important meter after the implementation of some of the proposed recommendations. The potential to reduce pollution is high especially if the rendering plant is rehabilitated and solids prevented from entering the sewer system by effective screening. There was increased awareness on the environment and pollution

issues at management level. It is recommended that this should flow down the hierarchy to all the employees at the plant. This would inevitably lead to the company enhancing its public image in the realm of environmental management.

5. Facilities for water and wastewater quality testing were nonexistent. Before the study the company knew neither the quantity of water used nor the characteristics of the wastewater produced. A laboratory was once operational for examinations of meat and meat products only.
6. Considering operation and maintenance costs, skilled labour requirements and the ability to absorb shock loads, trickling filtration was selected as the best option to replace the defunct dissolved air flotation facility. Even though trickling filtration does not attain high treatment efficiencies, it was considered adequate to meet the requirements for discharge into the public sewers.

6.4 Pilot Plant Investigations

The following salient points emerged from the pilot plant investigations on the treatment of wastewater by the trickling filter process.

1. The study revealed that the treatability of slaughterhouse wastewater by trickling filtration is good and that efficiencies are better at lower influent loading rates. Average COD removal efficiencies of 37.8 were determined for a hydraulic loading rate of 0.34 m^3/m^2h (including a recirculation ratio of 0.5) and organic loading rate of 1.7 to 8.2 kg BOD/ m^3d. For a hydraulic loading rate of 0.49 m^3/m^2h (with recirculation ration of 1.0) and organic loading rate in the range 4.9 to 14.6 kg BOD/ m^3d the average COD removal efficiency of 23.9 percent was obtained. Rapid and very high fluctuations of the wastewater to the treatment plant made it impossible to obtain steady conditions within the filter. There was need for an equalisation step to dampen these fluctuations.
2. The level of treatment attained did not reduce the COD concentrations to meet the requirements for discharge into the public sewers as stipulated in the Local Administration (Trade Effluent) Regulations of the Local Government Act. The main

reasons were the high suspended solids loads, rapid fluctuation of the influent to the filter and inadequate capacity of the final clarifier.

3. The results were not satisfactory and conclusive enough to provide a basis for the design of a full-scale trickling filter plant. It is strongly recommended that the research should be on-going so that the pilot plant could be operated under favourable factors (screening and good primary and secondary settling) before considering design of a full scale trickling filter plant.

References

1. Andreadakis, A. (1997). *Industrial Developments,* Journal WQI, January/February, pp. 41-42
2. APHA, AWWA, WEF (1995). Standard Methods for the Examination of water and Wastewater." 19th Edition, New York, N. Y.
3. Appleyard, C. J. (1994) Industrial Wastewater Management, IHE, Delft, The Netherlands.
4. Battistoni, P., Fava, G. and Gatto, A. (1992). Fish Processing Wastewater: Emission Factors and High Load Trickling Filters Evaluation, Industrial Wastewater Treatment and Disposal, *Wat. Sci. Tech.*, 25 (1),pp. 1 -8
5. Chipungu, P. M, Kunda, D. M., Eds. (1994). State of the Environment Report, Zambia.
6. Christoulas, D. G., Liakos S. N. and Andreadakis A. D. (1990). Performance Relationship for Low and Intermediate rate Biological Filters, *Wat. Res.* 24 (5), pp. 607 - 614
7. Cooper, R. N., Heddle, J. F. and Russell, J. M. (1979). Characteristics and Treatment of slaughterhouse effluents in New Zealand. Proceedings: The Agricultural Industry and its Effects on Water Quality, Hamilton, New Zealand, *Prog. Wat. Tech.* , 11 (6), pp. 55 - 68
8. Crine, M., Schlitz, M. and Vandevenne, L. (1990). Evaluation of the Performances of Random Plastic Media in Aerobic Trickling Filters. *Technical Advances in Biofilm Reactors*, *Water Science and Technology, 22*, (1/2), pp. 227 -238.
9. Houston, J., Dancer, B. N. and Learner, M. A. (1989) Control of sewage filter flies using bacillus Thuringiensis var. israelensis - II. Full scale trials. *Wat. Res.* 23 (3), pp. 379 - 385
10. Lindsey, T., Neese, S., Thomas, D. (1996) *Implications of Pollution Prevention for Water Pollution Control*, Journal WQI March/April, pp. 32 - 36
11. Matilla, M. E. (1989). Clean Technologies - Policy of the European Economic Community, UNEP - Industry and Environment, January/February/March, Volume 12 No. 1, pp. 11- 13

12. McVaugh, J. (1979). Wastewater Treatment in the Meat Packing, Poultry Processing and Rendering Industries. In: Food Processing Waste management, Avi Publishing Company, Inc., Westport, Connecticut, pp. 462
13. Metcalf and Eddy Inc., (1991). *Wastewater Engineering; Treatment, disposal and Reuse.* McGraw-Hill, New York, N. Y.
14. Moodie, S. P., Greenfield, P.F. (1978) *Treatment of Abattoir Effluent by Trickling Filters,* J. Water Pollution Control Federation, pp. 2741-2751
15. Parker, D.S., Lutz, M.P. and Pratt, A.M. (1990). New Trickling Filter Applications in The U.S.A. *Technical Advances in Biofilm Reactors, Water Science and Technology, 22,* (1/2), pp. 215 - 226.
16. Phiri, Z. (1990). Industrial Wastewater Management in Zambia, Programme on Purification of Industrial Wastewater, Regional Meeting, Paris, France.
17. Robertson, P. G., Wilson D. P. and Liebman, J. C. (1968). Statistical Comparison of Trickling Filter Equations Using Papermill Effluent Data. *Journal Water Pollution Control Federation, 40,* (10), pp. 1764 - 1778.
18. Sayed, S. K. I. (1987). Anaerobic Treatment of Slaughterhouse Wastewater Using the UASB Process, PhD Thesis, Wagenigen Agricultural University, Wagenigen, The Netherlands.
19. Steel E. W, McGhee, T. J. (1979), Water Supply and Sewerage, 5th edition, McGraw Hill, Singapore, pp. 490.
20. Steffen, Robertson, Kirsten, (1990). Water and Wastewater Management in the Red Meat Abattoir Industry, Prepared for The Water Research Commission, Republic of South Africa.
21. Taiganides, P. E. (1977). Animal Wastes, Applied Science Publishers Ltd, pp. 236–237.
22. The Government of the Republic of Zambia (1985). Local Administration (Trade Effluent) Regulations -Statutory Instrument No 161.
23. The Government of the Republic of Zambia (1990). Environmental Protection and Pollution Control Act, No. 12
24. The Government of the Republic of Zambia (1993). Water Pollution Control (Effluent and Wastewater) Regulations - Statutory Instrument No. 72.

25. The Government of the Republic of Zambia (1994). The Ministry of Environment and Natural Resources, National Environmental Action Plan
26. The Government of the Republic of Zambia (1997a). The Ministry of Environment and Natural Resources, Environmental Support Programme Document Files
27. The Government of the Republic of Zambia (1997b). The Water Supply and Sanitation Act - Statutory Instrument No. 28.
28. Theodore, L., McGuinn, Y. C. (1992). *Pollution Prevention,* Van Nostrand Reinhold, New York.
29. Tipping, P. and Brooking, J. (1995). *Trade Waste Treatment and Control,* New World Water, Sterling Publication Ltd, London, pp. 107-110
30. UNEP, Industry and Environment (1989), Waste Minimisation, Editorial, January/February/March, Vol. 12 No. 1
31. UNEP, Industry and Environment (1995), Environmental management tools: facts and figures, April – September, Vol. 18 Nos. 2-3, pp. 4 – 10.
32. UNEP, Industry and Environment (1986), Editorial, October/November/December, Vol. 9 No.4, pp.2.
33. Veenstra, S., van Duijl, L. A. (1995) Wastewater Treatment – Part 1, IHE, Delft, The Netherlands.
34. Veenstra, S., Polprasert, C. (1995) Wastewater Treatment – Part 2, IHE, Delft, The Netherlands, pp. 3

APPENDIX A: SAMPLE INDUSTRIAL QUESTIONNAIRE

SECTION I

1. Name of industry ……………………………………………………………..
2. Classification (tick where appropriate)
    - Brewery
    - Cannery
    - Dairy
    - Soft drinks
    - Meat processing
    - Other……………………………………………………………..
3. Capacity of industry
    - Design capacity…………………………………………………..
    - Actual capacity……………………………………………………
4. Major raw materials……………………………………………………
5. Main products……………………………………………………………
6. By - products……………………………………………………………..
7. Provide a process flow diagram…………………………………………..

    ……………………………………………………………………………

    ……………………………………………………………………………

    ……………………………………………………………………………
8. Major wastes
    - Liquids ………………………………………………………………

    Is there any separation of different waste streams ? Yes/ No…………..
    - Solids……………………………………………………………..
9. Provide (estimate) water consumption figures in m^3/d (if possible for each process)

…………………………………………………………………………………………..

10. Wastewater production in m^3/d (estimate) ………………………………

11. Do you have wastewater treatment facilities? (Tick where appropriate)
    - No treatment
    - Pretreatment
    - Full treatment
12. If the answer to the above is No, what are the reasons?
    - Financial
    - Technical
    - Other……………………………………………………………………
13. Status of treatment plant:
    - Fully operational
    - partially operational
    - Non - operational
14. Capacity of treatment plant:
    - Hydraulic……………………………………………………………………
    - Organic……………………………………………………………………..
    - Other……………………………………………………………………
15. Actual loadings:
    - Hydraulic……………………………………………………………………
    - Organic……………………………………………………………………
    - Other…………………………………………………………………..
16. Treatment method
    - Physical
    - Chemical
    - Biological
    - Combination of the above……………………………………………………
17. Specify type of treatment, e.g., screening, sedimentation, dissolved -air floatation, tricking filter, etc. ……………………………………………………………...

………………………………………………………………………………………………

………………………………………………………………………………………………

18. Where is the effluent discharged?

- Municipal sewers
- Directly into stream
- Land
- Other ....

19. Do you have a discharge permit? Yes / No ....

20. Where do you get the permit? ....

21. Are fees high enough to warrant construction of treatment facilities? Yes /No ......

22. Are you aware of the existing environmental legislation? State the legislation you know regarding effluent discharge.

....

....

....

23. Do you feel there is need for seminars, workshops and conferences to explain environmental pollution and the relevant legislation? Yes / No ....

SECTION II - EFFLUENT QUALITY PARAMETERS

1. Physical parameters

Temperature...

Colour..

Smell..

Total suspended solids (TSS)..mg/l

Settleable solids..mg/l

Conductivity ....µS/cm

Other ....

2. Chemical parameters

pH ....

Biochemical oxygen demand (BOD) ....mg/l

Chemical oxygen demand (COD) ....mg/l

Total Kjeldahl nitrogen (TKN) .... mg/l

Total phosphorus (P) .... mg/l

Other .... mg/l

3. Biological parameters

Faecal coliforms .... /100ml

Total plate count.. /100ml

Algae cells.. /100ml

Others..

APPENDIX B: THE LOCAL GOVERNMENT ACT, NO. 22 OF 1991

THE LOCAL ADMINISTRATION (TRADE EFFLUENT) REGULATIONS, 1985

FIRST SCHEDULE
(Regulation 4)

TABLE OF STANDARDS FOR TRADE AND OTHER EFFLUENTS

Column 1	*Column 2*	*Column 3*
SUBSTANCE	TRADE EFFLUENT INTO PUBLIC SEWER	SEWAGE AND OTHER EFFLUENT
A. PHYSICAL		
1. Temperature (Thermometer)	60°C. after mixing of waters, the temperature should not exceed 40°C	40°C at the point of entry
2. Colour Hazen (Spectrophotometer)	The treatment plant ensure discolouration dyestuffs in the wastewater	Must not cause any colouration of the receiving water
3. Odour and taste (Threshold odour number)	The odour must not cause any nuisance	Must not cause any deterioration in taste or odour as compared with natural state
4. Total suspended solids (Gravimetric method)	1200 mg/L (Avoid blockage of sewer, effect free flow)	50 mg/L. Must not form sludge or scum in receiving waters
5. Settleable matter ml/L (Imhoff funnel)	1.0 ml/L in 2 hours (Avoid blockage of sewer, effect free flow)	0.5 ml/L in 2 hours (Must not cause formation of sludge in receiving waters)
6. Salinity/Residue mg/L (Evaporation and Gravimetric method)	7500mg/L. The salinity must not affect the discharge and treatment or installations or their functioning	3000 mg/L. The salinity of the wastewater must not adversely affect surface water
B. CHEMICAL		
7. pH (0-14 scale) (Electro-metric method)	6-10	6-9
8. Dissolved oxygen, mg O_2/l (modified Winkler method and membrane-electrode method)	No requirements	After complete mixing, the oxygen content must not be less than 5 mg/L. Extreme temperatures may result in lower values
9. Chemical oxygen demand (COD) (Dichromate method)	1800 mg/L	COD based on the limiting values for organic carbon 60-90 mgO_2/L average for 24 hours

Column 1	*Column 2*	*Column 3*
SUBSTANCE	TRADE EFFLUENT INTO PUBLIC SEWER	SEWAGE AND OTHER EFFLUENT
10. Biochemical oxygen demand (BOD) (modified Winkler method and membrane electrode method)	1200 mg/L	50 mg O_2/L (mean value over 24 hours). According to self-cleaning capacity of the waters
11. Nitrates (NO_3 as nitrogen) (spectrophotometric method and electrometric method)	80 mg/L	The nitrates burden must be reduced as far as possible according to circumstances: Watercourse<50 mg/L; Lakes<20 mg/L
12. Nitrite (NO_2 as nitrogen/l) (spectrophotometric sulphanilamide)	10.0 mg/L	1.0 mg/L
13. Organic nitrogen (Spectrophotometric method N- Kjeldhal	300 mg/L*	5.0 mg/L mean*(* the % of nutrient elements for degradation of BOD should be 0.4 – 1% for phosphorus (different for processes using algae)
14. Ammonia and ammonium (total) (NH_3 as N/l) (Nesslerization method and electrometric)	50 mg/L	The burden of ammonia salts must be reduced to 10 mg/L (depending upon temperature, pH and salinity)
15. Cyanides (spectrophotometric method)	0.5 mg/L	0.2 mg/L
16. Phosphorous, total (PO_4 as P/l) (Colorimetric method)	45 mg/L	Treatment installation located in the catchment area of lakes: 1.0 mg/L; located outside catchment area: reduce the load of P as low as possible (PO_4 < 6 mg/L)
17. Sulphates (Turbidimetric method)	500 mg/L	The sulphate burden must be reduced to 1500 mg/L
18. Sulphite (Iodometric method)	10 mg/L	1.0 mg/L (presence of oxygen changes SO_3 to SO_4)
19. Sulphide (Iodometric and Electrometric method)	1 mg/L	0.1 mg/L (depending on temperature, pH and dissolved O_2)
20. Chlorides Cl/l (silver nitrate and mercuric nitrate)	1000 mg/L	Chloride levels must be as low as possible (< 800 mg/L)
21. Active chloride Cl_2/l (Iodometric method)	0.5-3.0 mg/L	0.5 mg/L
22. Active bromine (Br_2/l)	0.5-3.0 mg/L	0.1 mg/L
23. Fluorides F/l (Electrometric and Colorimetric method with distillation)	<30 mg/L	10 mg/L
C. METALS		
24. Aluminum compounds (atomic absorption method, AAM)	< 20 mg/L	2.5 mg/L
25. Antimony (AAM)	0.5 mg/L (inhibition of oxidation)	0.5 mg/L
26. Arsenic compounds (AAM)	1.0 mg/L	0.05 mg/L

Column 1	*Column 2*	*Column 3*
SUBSTANCE	TRADE EFFLUENT INTO PUBLIC SEWER	SEWAGE AND OTHER EFFLUENT
27. Barium compounds (water soluble concentration, AAM)	1.0 mg/L	0.5 mg/L
28. Beryllium salts and compounds (AAM)	0.5 mg/L (inhibition of oxidation)	0.5 mg/L
29. Boron compounds(spectrophotometric method-curcumin method)	< 50 mg/L	< 10 mg/L
30. Cadmium compounds (AAM)	1.5 mg/L	0.5 mg/L
31. Chromium hexavalent, trivalent (AAM)	5.0 mg/L	0.1 mg/L
32. Cobalt compounds (AAM)	0.5 mg/L	0.5 mg/L
33. Copper compounds (AAM)	3.0 mg/L	1.0 mg/L
34. Iron compounds (AAM)	15.0 mg/L	<2.0 mg/L
35. Lead compounds (AAM)	1.5 mg/L	1.5 mg/L
36. Magnesium (AAM and flame photometric method)	<1000 mg/L	<500 mg/L
37. Manganese (AAM)	10.0 mg/L	< 3.0 mg/L
38. Mercury (AAM)	0.01 mg/L	0.001 mg/L
39. Molybdenum (AAM)	5.0 mg/L	0.5 - 5.0 mg/L
40. Nickel (AAM)	2.0 mg/L	2.0 mg/L
41. Selenium (AAM)	<1.0 mg/L	< 0.05 mg/L
42. Silver (AAM)	0.1 mg/L (inhibition of oxidation)	0.1 mg/L
43. Thallium (AAM)	1.0 mg/L	< 0.5 mg/L
44. Tin compounds (AAM)	2.0 mg/L	2.0 mg/L
45. Vanadium compounds (AAM)	1.0 mg/L	1.0 mg/L
46. Zinc compounds (AAM)	25.0 mg/L	10.0 mg/L
D. ORGANICS		
47. Total hydrocarbons (chromatographic method)	20.0 mg/L	10.0 mg/L
48. Oils (mineral and crude) (chromatographic method and gravimetric method)	100 mg/L (after installation of oil separators), 20.0 mg/L (after installation of demulsifier)	1-2 mg/L

Column 1	*Column 2*	*Column 3*
SUBSTANCE	TRADE EFFLUENT INTO PUBLIC SEWER	SEWAGE AND OTHER EFFLUENT
49. Phenols,		
(steam distillable)	5.0 mg/L	0.2 mg/L
(non-steam distilled) (colorimetric method)	1.0 mg/L	0.05
50. Fats and saponifiable oils (gravimetric method and chromatographic method)	No requirement but installation of oil and grease separators	20 mg/L
51. Detergents (Anionic) (AAS)	10.0 mg/L. Alkyl-benzene sulfonate not permitted	2.0 mg/L(detergents should contain at least biodegradable compounds)
52. Pesticides and PCB's (total) (chromatographic method)	1.0 mg/L	0.5 mg/L (Reduce to a minimum)
53. Trihaloforms (chromatographic method)	1.0 mg/L	0.5 mg/L (Reduce to a minimum)
E. RADIOACTIVE MATERIALS		
54. Radioactive materials as specified by the International Atomic Energy Agency	No discharge accepted	Not permitted

APPENDIX C: THE ENVIRONMENTAL PROTECTION AND POLLUTON CONTROL ACT, 1990

1. THE WATER POLLUTION (EFFLUENT AND WASTEWATER) REGULATIONS, 1993

THIRD SCHEDULE
(Regulation 5 (2))

TABLE OF STANDARDS (LIMITS) FOR EFFLUENTS AND WASTEWATER

Column 1 PARAMETER	Column 2 EFFLUENT AND WASTEWATER INTO AQUATIC ENVIRONMENT
A. PHYSICAL	
1. Temperature (Thermometer)	40 ° C at the point of entry
2. Colour (Hazen units)	20 Hazen units
3. Odour and taste (Threshold Odour number)	must not cause any deterioration in taste or odour as compared with the natural state
4. Turbidity (NTU Scale)	15 Nephelometer turbidity
5. Total suspended solids (gravimetric method)	100 mg/L. Must not cause formation of sludge or scum in receiving water
6. Settleable matter (sedimentation in 2 hours, Imhoff funnel)	0.5 mg/L in two hours. Must not cause formation of sludge or scum in receiving water.
7. Total dissolved solids (evaporation at 105°C and gravimetric method)	3000 mg/L . The TDS of the waste water must not adversely affect surface water
8. Conductivity (Electrometric method)	4300 μS/cm
B. BACTERIOLOGICAL	
9. Total coliform/100 ml (membrane filtration method)	2500
10. Faecal coliforms/100 ml (membrane filtration method)	5000
11. Algae/100 ml (Colony counter)	1000 cells
C. CHEMICAL	
12. pH (0-14 scale) (Electro-metric method)	6.0 - 9.0
13. Dissolved oxygen, mg O_2/l (modified Winkler method and membrane-electrode method)	5 mg/L after complete mixing, oxygen content must not be less. Extreme temperature may result in lower values.
14. Chemical oxygen demand (COD) (Dichromate method)	COD based on the limiting values for organic carbon 90 mg O_2/L average for 24 hours
15. Biochemical oxygen demand (BOD) (modified Winkler method and membrane electrode method)	50 mg O_2/L (mean value over 24 hours period). According to circumstances in relation to the self cleaning capacity of the waters

Column 1 PARAMETER	Column 2 EFFLUENT AND WASTEWATER INTO AQUATIC ENVIRONMENT
16. Nitrates (NO_3 as nitrogen) (Spectrophotometric method and Electrometric method)	The nitrate burden must be reduced as far as possible according to circumstances: watercourse 50 mg/L, lakes 20 mg/L
17. Nitrite (NO_2 as nitrogen/l) (Spectrophotometric sulphanilamide)	2.0 mg NO_2 as N/L
18. Organic nitrogen (Spectrophotometric method N- Kjeldhal)	5.0 mg/L* (* the % of nutrient elements for degradation of BOD should be 0.4 – 1% for phosphorus (different for processes using algae)
19. Ammonia and ammonium (total) (NH_3 as N/l) (Nesslerization method and Electrometric)	The burden of ammonia salts must be reduced to 10 mg/L (depending upon temperature, pH and salinity)
20. Cyanides (Spectrophotometric method)	0.2 mg/L
21. Phosphorous, total (PO_4 as P/l) (Calorimetric method)	Treatment installation located in the catchment area of lakes: 1.0 mg/L; located outside catchment area: reduce the load of P as low as possible (PO_4 = 6 mg/L)
22. Sulfates (Turbidimetric method)	The sulphate burden must be reduced to 1500 mg/L
23. Sulfite (Iodometric method)	1.0 mg/L (presence of oxygen changes SO_3 to SO_4)
24. Sulphide (Iodometric and Electrometric method)	0.1 mg/L (depending on temperature, pH and dissolved O_2)
25. Chlorides Cl/l (silver nitrate and mercuric nitrate)	800 mg/L
26. Active chloride Cl_2/l (Iodometric method)	0.5 mg/L
27. Active bromine (Br_2/l)	0.1 mg/L
28. Fluorides F/l (Electrometric and colorimetric method with distillation)	2.0 mg/L

D. METALS

29. Aluminum compounds (atomic absorption method, AAM)	2.5 mg/L
30. Antimony (AAM)	0.5 mg/L
31. Arsenic compounds (AAM)	0.05 mg/L
32. Barium compounds ......(water soluble concentration, AAM)	0.5 mg/L
33. Beryllium salts and compounds (AAM)	0.5 mg/L
34. Boron compounds ......(spectrophotometric method-curcumin method)	0.5 mg/L
35. Cadmium compounds (AAM)	0.5 mg/L
36. Chromium hexavalent, trivalent (AAM)	0.1 mg/L
37. Cobalt compounds (AAM)	1.0 mg/L
38. Copper compounds (AAM)	1.5 mg/L

Column 1 PARAMETER	Column 2 EFFLUENT AND WASTEWATER INTO AQUATIC ENVIRONMENT
39. Iron compounds (AAM)	2.0 mg/L
40. Lead compounds (AAM)	0.5 mg/L
41. Magnesium (AAM and flame photometric method)	500 mg/L
42. Manganese (AAM)	1.0 mg/L
43. Mercury (AAM)	0.002 mg/L
44. Molybdenum (AAM)	5.0 mg/L
45. Nickel (AAM)	0.5 mg/L
46. Selenium (AAM)	0.02 mg/L
47. Silver (AAM)	0.1 mg/L
48. Thallium (AAM)	0.5 mg/L
49. Tin compounds (AAM)	2.0 mg/L
50. Vanadium compounds (AAM)	1.0 mg/L
51. Zinc compounds (AAM)	10.0 mg/L

E. ORGANICS

52. Total hydrocarbons (chromatographic method)	10.0 mg/L
53. Oils (mineral and crude) (chromatographic method and gravimetric method)	5.0 mg/L
54. Phenols, (steam distillable) .... (non-steam distilled) (colorimetric method)	 0.2 mg/L 0.05
24. Fats and saponifiable oils (gravimetric method and chromatographic method)	20 mg/L
56. Detergents (atomic) (AAS)	2.0 mg/L(detergents should contain at least biodegradable compounds)
57. Pesticides and PCB's (total) (chromatographic method)	0.5 mg/L
58. Trihaloforms (chromatographic method)	0.5 mg/L

F. RADIOACTIVE MATERIALS

59. Radioactive materials as specified by international atomic energy agency	No discharge accepted; not permitted

2. SAMPLE OF THE ENFORCEMENT NOTICE FORM

The Water Pollution (Effluent and Wastewater) Regulations- 1993

ENFORCEMENT NOTICE No. ______
(Regulations 2)

From: The Chief Inspector – Pollution Control; P.O. Box 35131; Tel:254130/1, Lusaka.

To: Name of premises and Address
....

You are hereby notified that you have contravened the conditions governing the issue of Licence No.:.......... in respect of your premises situated at......................................

a) Failure to submit a record of the licenced activities every six months to the Environmental Council of Zambia from the date of commencement of the said licence.
b) Withholding information from the ECZ Inspectorate
c) Discharging effluent with parameters .... in excess of the prescribed standards set in the regulations.
d) Providing incorrect information to the Inspectorate.
e) Failure to renew your licence(s) No(s) ....
f) Others (as specified) ....

The above condition(s) must be met by the .... day of ....199......

Failure to meet the stated condition(s) within the specified time given in the notice may warrant **withdrawal** of the licence, **termination** of the licenced activities and/or **criminal prosecution.**

Issued by: .... in my capacity as ....

In the presence of .... this ....day of ....199.....

Signature .... **Signature** ....

Legal counsel **Inspector**

Received by: .... In my capacity as ....

In the presence of ....this .... day of ....199.....

Signature................................. **Signature** ....

Licence holder **Witness**

APPENDIX D

TABLE D-1: COMPLETE RESULTS (UNANALYSED)

DATE	INFLUENT				EFFLUENT				COD Removal Efficiency (%)	Absolute removal (mg/l COD)	BOD Removal Efficiency (%)	Sampling period	Air temperature (deg. C)	
	COD (mg/l)	BOD (mg/l)	COD/BOD	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	COD/BOD	TSS (mg/l)					Minimum	Maximum
	Influent				effluent									
25-Sep	1545				828				46.4	717		12 hours		
26-Sep	1214				607				50.0	607		12 hours		
29-Sep	883				497				43.8	386		12 hours		
30-Sep	1159				828				28.6	331		12 hours		
1-Oct	2041				828				59.5	1214		12 hours		
2-Oct	2456				1200				51.1	1256		24 hours		
3-Oct	2874				1786				37.9	1088		24 hours		
7-Oct	2456				1340				45.5	1116		24 hours		
8-Oct	2679				1005				62.5	1674		24 hours		
9-Oct	4800				3600				25.0	1200		24 hours		
10-Oct	4343				3600				17.1	743		24 hours		
13-Oct	3086				2914				5.6	171		12 hours		
14-Oct	2743				2229				18.8	514		12 hours		
16-Oct	2274				842				63.0	1432		12 hours		
17-Oct	2358				1263				46.4	1095		12 hours		
18-Oct	1516				1600				-5.6	-84		24 hours		
19-Oct	1432				1095				23.5	337		24 hours		
20-Oct	2947				1095				62.9	1853		24 hours		
26-Oct	2370				2189				7.6	181		24 hours	23	30
29-Oct	3720				4407				-18.5	-687		24 hours	20	33
30-Oct	2910				4126				-41.8	-1216		24 hours	19	32
2-Nov	863				1187				-37.5	-324		24 hours	19	29
3-Nov	1726				378				78.1	1348		24 hours	22	32
4-Nov	485				378				22.2	108		24 hours	19	32
5-Nov	2211				1079				51.2	1133		24 hours	19	29
6-Nov	917				1240				-35.3	-324		24 hours	22	30
7-Nov	3260				2762				15.3	498		24 hours	22	32
8-Nov	2830				3260				-15.2	-430		24 hours	21	33
9-Nov	1313			280.00	1540			310	-17.2	-226		24 hours	25	35
10-Nov	1947				1200				38.4	747		24 hours	28	35
11-Nov	2558				1177				54.0	1381		24 hours	24	34
12-Nov	1976	1920	1.03		2118	1040	2.04		-7.1	-141	45.83	24 hours	23	34
13-Nov	4447				4165				6.3	282		24 hours	23	34

TABLE D-1 (CONTINUED)

DATE	INFLUENT				EFFLUENT				COD Removal Efficiency (%)	Absolute removal (mg/l COD)	BOD Removal Efficiency (%)	Sampling period	Air temperature (deg. C)	
	COD (mg/l)	BOD (mg/l)	COD/BOD	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	COD/BOD	TSS (mg/l)					Minimum	Maximum
15-Nov	4373				3072				**29.8**	**1301**		24 hours	21	31
16-Nov	3136				2795				**10.9**	**341**		24 hours	20	32
17-Nov	3264				2752				**15.7**	**512**		24 hours	21	39
18-Nov	2880			570.00	2176			416	**24.4**	**704**		24 hours	22	29
21-Nov	3892	860	4.53		2854	680	4.20		**26.7**	**1038**	**20.93**	24 hours	19	29
22-Nov	3632				2076				**42.9**	**1557**		24 hours	19	31
23-Nov	2595				1427				**45.0**	**1168**		24 hours	19	29
24-Nov	4800				3049				**36.5**	**1751**		24 hours	19	29
25-Nov	3088				2344				**24.1**	**744**		24 hours	20	31
2-Dec	3088				2270				**26.5**	**819**		24 hours	20	29
3-Dec	3386	1780	1.90		2493	1300	1.92		**26.4**	**893**	**26.97**	24 hours	20	29
4-Dec	3665				2967				**19.0**	**698**		24 hours	19	29
5-Dec	4102				3491				**14.9**	**611**		24 hours	19	31
8-Dec	2182				2007				**8.0**	**175**		24 hours	20	30
9-Dec	3636	2270	1.60		2705	1960	1.38		**25.6**	**931**	**13.66**	24 hours	19	29
10-Dec	4800			880	4100			725	**14.6**	**700**		24 hours	21	38
11-Dec	4050	1680	2.41	900	3600	1170	3.08	1055	**11.1**	**450**	**30.36**	24 hours	19	29
15-Dec	3360				2743				**18.4**	**617**		24 hours	20	30
16-Dec	2057				1783				**13.3**	**274**		24 hours	19	29
17-Dec	2194				1646				**25.0**	**549**		24 hours	19	29
18-Dec	4457				2057				**53.8**	**2400**		24 hours	18	28
19-Dec	4800				2743				**42.9**	**2057**		24 hours	19	29
22-Dec	4457	2620	1.70		4800	2280	2.11		**-7.7**	**-343**	**12.98**	24 hours	18	25
23-Dec	5314	3100	1.71		4114	2200	1.87		**22.6**	**1200**	**29.03**	24 hours	19	29
26-Dec	7930				5426				**31.6**	**2504**		24 hours	18	28
29-Dec	3757	1900	1.98		2643	1800	1.47		**29.6**	**1113**	**5.26**	24 hours	18	29
30-Dec	3478	1950	1.78	665	3200	1800	1.78	870	**8.0**	**278**	**7.69**	24 hours	19	30
31-Dec	3617	1600	2.26	595	3061	1450	2.11	510	**15.4**	**557**	**9.38**	24 hours	18	28

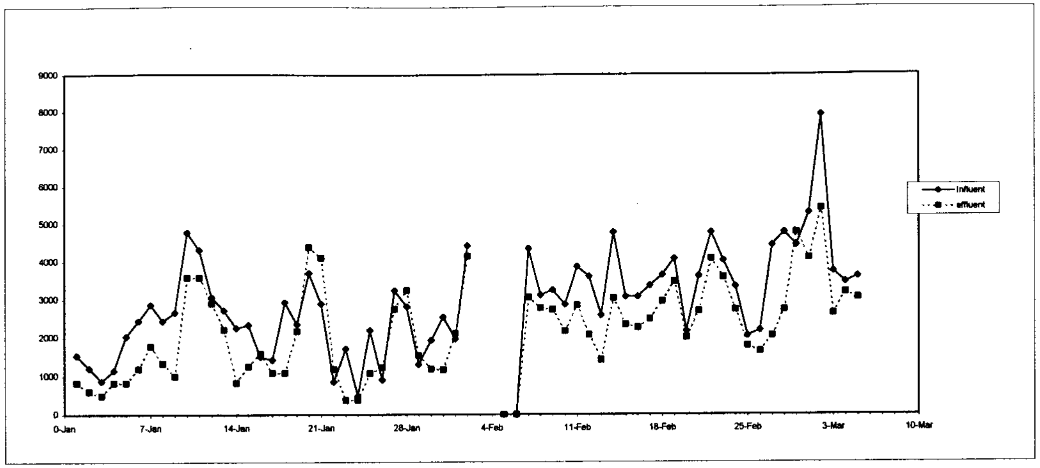

Figure D-1: Overall COD removal efficiency under varying influent COD

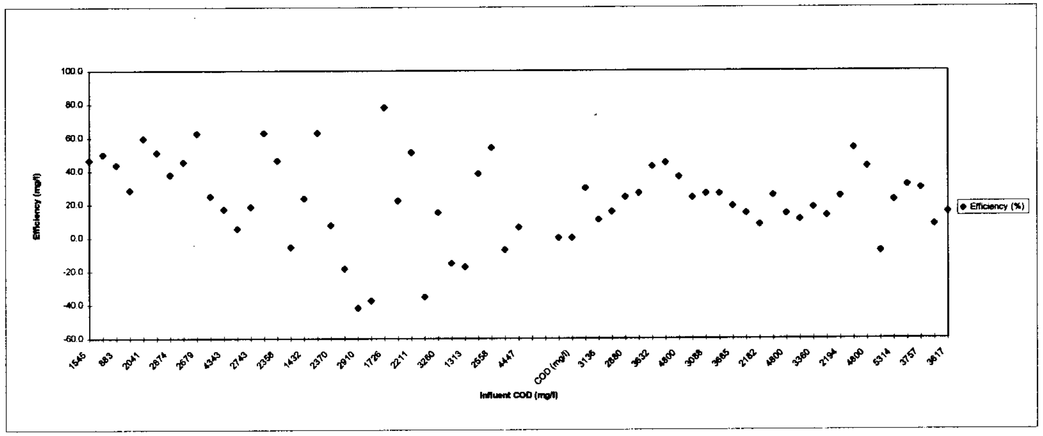

Figure D-2: Relationship of overall COD efficiency to influent COD

APPENDIX E: THE PILOT PLANT IN PICTURES

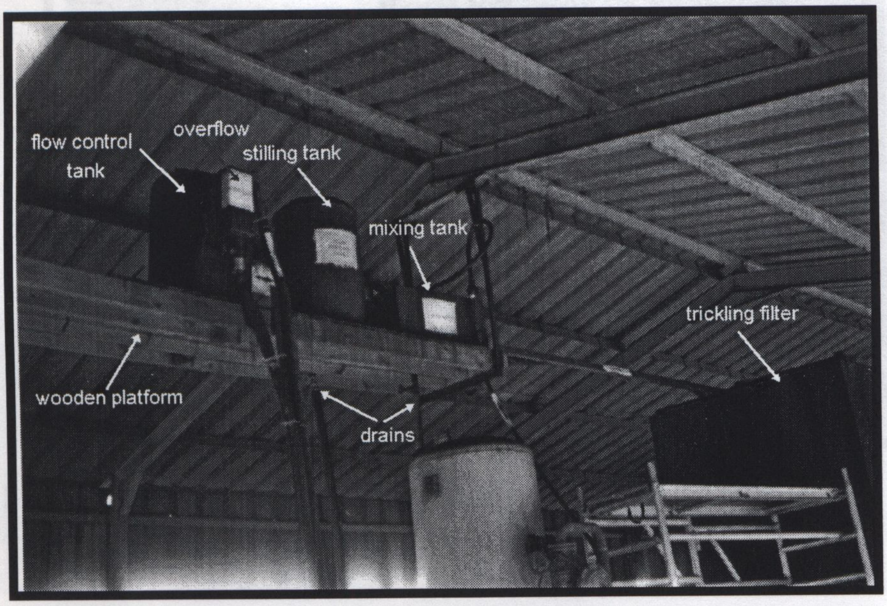

Figure E-1: Some of the pilot plant units

Figure E-2: Some of the pilot plant units (another view)

Figure E-3: The plant operator removing scum from the clarifier

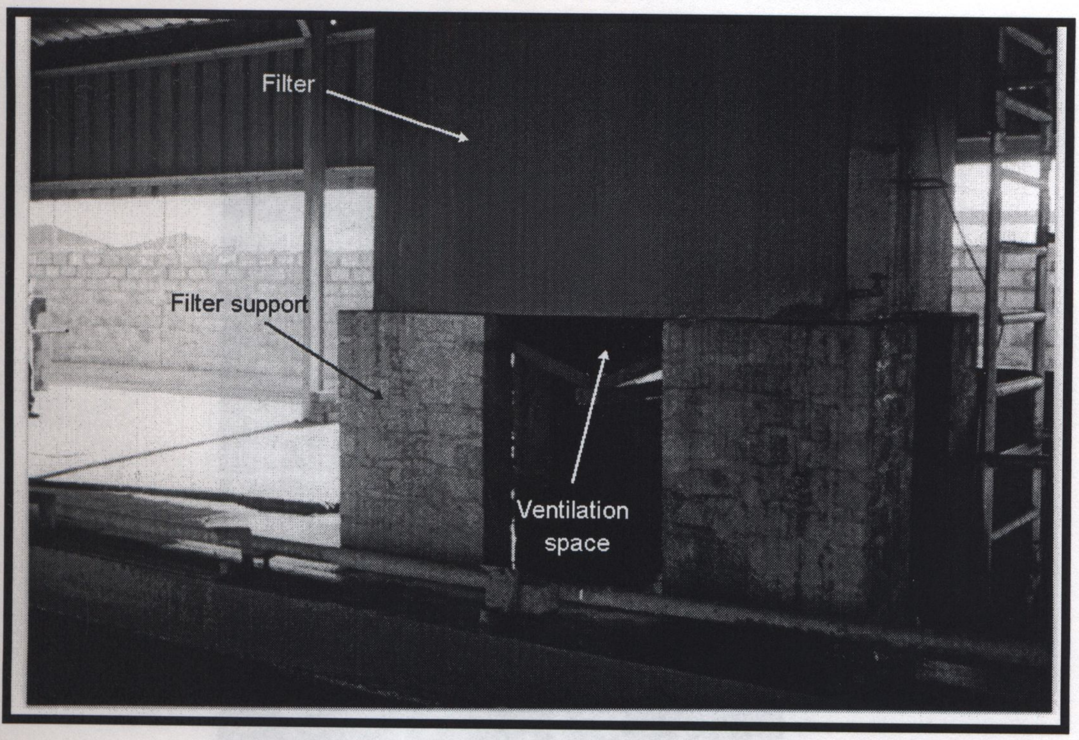

Figure E-4: Ventilation spaces and filter support

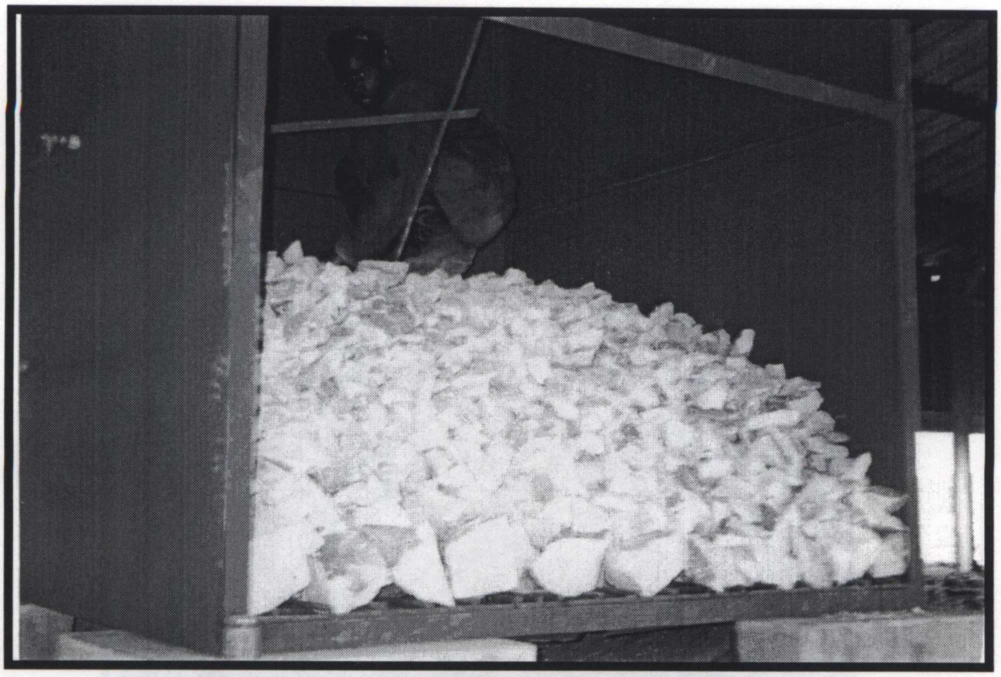

Figure E-5: Placing of filter media

Figure E-6: Lifting the last sheet cladding into place

Figure E-7: The work involved a lot of welding

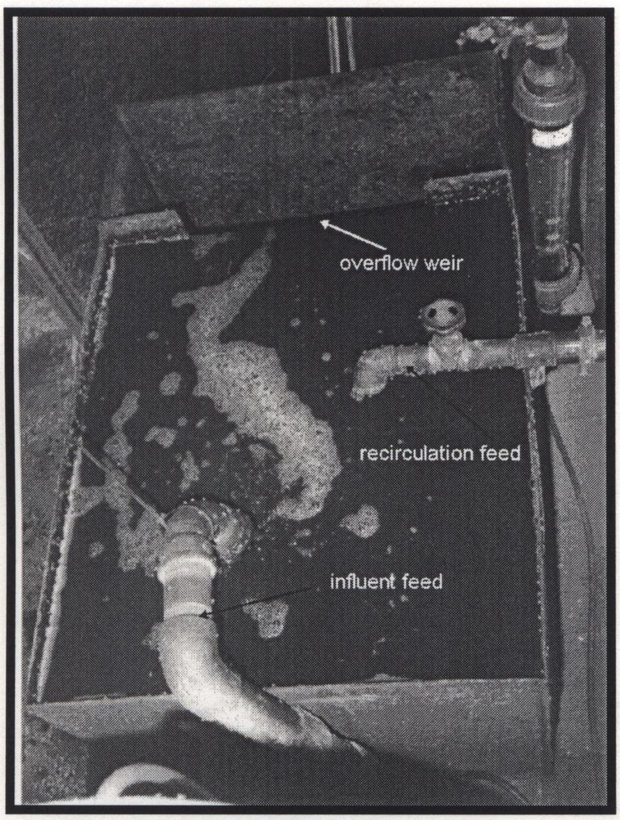

Figure E-8: Mixing tank for influent and recycle