WASTE HANDLING PRACTICES

IN THE

SOUTH AFRICAN HIGH-THROUGHPUT

POULTRY ABATTOIRS

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DECLARATION OF INDEPENDENT WORK

I, **NTAHLI ASHLEY MOLAPO – 20133480**, hereby declare that this research project submitted to the Central University of Technology, Free State (CUT) for the degree MAGISTER TECHNOLOGIAE: ENVIRONMENTAL HEALTH is my own work, and complies with the code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State and has not been submitted before to any institution by myself or any other person in the fulfilment of the requirements for the attainment of any qualification.

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ABSTRACT

WASTE HANDLING PRACTICES IN THE SOUTH AFRICAN HIGH-THROUGHPUT POULTRY ABATTOIRS

The production of poultry meat at abattoirs implies a tremendous amount of organic matter that requires environmentally and biologically safe disposal or utilisation. As a result, waste management is a concern in poultry abattoirs worldwide. Problems with proper storage, handling, management and utilisation of by-products have come to the forefront in planning, establishing and operating of poultry abattoirs.

The rationale for this study centres on the need for the review of poultry abattoir waste management practices, by-product production and environmental implication at South African high-throughput abattoirs. The need for this review stems from the rapid growth of the poultry industry over the past ten years. The industry has responded to this growing demand with larger and faster processing lines and more employees. This has led to the generation of high loads of waste material associated with negative environmental impacts. Poultry waste is of great concern as it plays a major role in environmental affairs over and above the present crisis with waste in South Africa, especially in rural and peri-urban areas.

The primary objectives of the study were to identify the existing waste management practices in relation to the sources, type of waste material generated, and the methods of handling (collection, storage and disposal) as well as to ascertain whether there is any in-house treatment methods practised. In addition, to identify any environmental impacts resulting from waste management practices.

To obtain data, site visits were conducted countrywide and abattoir personnel were interviewed through a questionnaire, in detail about the operation and waste management practices of their respective abattoirs. Their experiences in the industry regarding waste management were determined as well. From a total of thirty-four registered and operating high-throughput poultry abattoirs, twenty-six (76.4%) were visited.

Huge amounts of wastes are generated at South Africa high-throughput poultry abattoirs, and these amongst others includes blood, feathers, feet, intestines, trimmed meat off-cuts, faecal matter, condemned chickens and waste-water. Waste handling practices varies according to abattoir preferences. Different collection facilities are used for different types of waste, 50 - 750ℓ containers and blood troughs are used for blood (table 4.5), crates, wheelie bins, conveyors, black rubbish bags for feathers (table 4.6).

Waste is either stored at the dirty area of the abattoir or in an open space next to the abattoir under strict supervision prior to disposal or by-product processing. Since not all abattoirs dispose off generated waste, some abattoirs have by-products processing facilities either on site or outside abattoir premises. Examples of by-products produced (table 4.3) include poultry (carcass) meal, feather meal, poultry oil and blood meal. Disposal methods used differs from burial, rendering, land application, municipal landfill, collection by farmers (animal feeding), burning, composting depending on waste type. It should however be noted that some of disposal method used are not legally approved in South Africa although legally permitted in other international countries as per literature review.

Three environmental implications were identified by the respondents included in the study (table 4.14) and these included air pollution, water pollution and land/soil pollution.

Recommendations are made to encourage the safe disposal of abattoir waste, minimisation of environmental implications and to limit the methods of disposal to those that are internationally permitted and suggested.

ABSTRAK

AFVAL BESTUURSPRAKTYKE IN DIE SUID-AFRIKAANSE Hoë-DEURSET HOENDER ABATTOIRS

Die produksie van hoendervleis by abattoirs impliseer 'n groot hoeveelheid organiese materiaal wat omgewings- en biologiese veilige wegdoening of verbruik, vereis. As gevolg hiervan is afvalbestuur in hoender abattoirs werêld wyd 'n probleem. Probleme met berging, hantering, bestuur en gebruik van by-produkte het na vore gekom in die beplanning, oprigting en werking van hoender abattoirs.

Die doel van die studie is gehaseer op die behoeftes van die afvalbestuurspraktyke en behandeling daarvan te bepaal. Die behoefte spruit uit die vinnige groei van die bedryf gedurende die laaste tien jaar. Die industrie het gereageer op die behoefte vir groter en vinniger produksielyne en verhoogte hoeveelhede personeel. As gevolg hiervan is meer afval gegenereer wat geassosieer word met negatiewe omgewingsimpak. Hoender afval is van belang aangesien dit 'n hoofrol speel in omgewingssake bo en behalwe die huidige krisis met afval in Suid-Afrika, veral in landelike en semi-landelike areas.

Die hoof doelwitte van die studie was die identifikasie van die huidige afvalsbestuurpraktyke in verhouding met die bronne, hoeveelheid afval wat geproduseer word asook die metodes van hantering (versameling, berging en wegdoening) asook om vas te stel of daar enige behandelingsmetodes gebruik word op die perseel. Addisioneel ook om enige omgewingsimpakte wat deur die afvalsbestuurspraktyke veroorsaak word, te identifiseer. Die hoof fokus is gerig op die Suid-Afrikaanse hoë deurset hoender abattoirs.

Besoeke by die persele is landwyd gedoen en onderhoude is met personeel gevoer om data in te samel rakende die bedryf en afvalsbestuurspraktyke van die onderskeie abattoirs. Die personeel se ondervinding in die bedryf met betrekking tot afvalbestuur is bepaal. Van ‘n totaal van 32 geregistreerde en handeldrywende hoë deurset abattoirs is daar bevind dat 26 (81%) daarvan besoek is as deel van die studie.

‘n Oorsig van die afvalbestuurspraktyke wat in Suid-Afrikaanse hoë deurset hoender abattoirs gebruik word, is in die studie ingesluit. Besondere vordering in sake soos die generasie van afval en afval vloei, afvalbestuurstegnieke, water verbruik, en lokale behandeling op die perseel, word beklemtoon. Operasionele probleme rakende afval-water behandeling, asook afval vermindering en die potensiaal vir die hergebruik of herwinning van soliede afval word bespreek.

Voorstelle is gemaak om die veilige wegdoening van abattoir afval aan te moedig, wat omgewingsimplikasies verminder en die beperking van afvalbestuursmetodes tot die wat in lyn is met goedgekeurde internasionale tendense.

DEDICATION

This dissertation is dedicated to my wonderful parents - Seetsa and M'asenate Molapo who have raised me to be the person I am today. You have been with me every step of the way, through good and bad times. Thank you for all the unconditional love, guidance, and support that you have always given me, helping me to succeed and instilling in me the confidence that I am capable of doing anything I put my mind to. Thank you for everything. To my niece Karabelo Bokang Molapo - you are the reason I rise each morning, ready to face another day and the reason I can smile as I go to bed each night. I love you!!

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LIST OF ABBREVIATIONS

BOD	Blood oxygen demand
COD	Chemical oxygen demand
TSS	Total soluble solids
SPCA	Society for the Prevention of Cruelty of Animals
EPA	Environmental Protection Agency, USA

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CHAPTER ONE

GENERAL BACKGROUND

1.1 BACKGROUND OF THE POULTRY INDUSTRY

1.1.1 Evolution of poultry domestication

World-wide domesticated birds have been raised primarily for use as meat, and to provide eggs and feathers. These include chickens (fowl), ducks, turkey, geese, ostriches, guinea fowl and pigeons. Chickens are the most important birds in poultry production and are classified as either layers or broilers, depending on their intended use (Cooper, 1990). Chickens are kept in two ways: as free range mainly in villages where birds are free to find their own food, and commercially, mainly on the outskirts of towns where birds are confined and continuously fed (King, 1994).

Based on radiocarbon dating of chicken bones at archeological sites, evolution of poultry is considered to have started in Southeast Asia with the earliest record in India dating back to about 3200 BC. The red Jungle Fowl *(Gallus gallus)* (Annexure 3), an Asian breed, is the most commonly wild species found in the world today and is assumed to be the ancestor of our modern poultry breeds (Cooper, 1990; Crawford, 1990; Daghir, 1995; Rose, 1997; Thear, 1999; Scanes, Brant and Ensminger, 2004). Other species of the Red Jungle fowl have been considered as progenitors of the domestic fowl and include the Ceylon Jungle Fowl *(Gallus lafayetti)*, the Grey Jungle Fowl (*Gallus sonneratti),* and the Java or Green Fowl *(Gallus varius)*. Chickens have also been depicted in Babylonian carvings from about 600 BC and were mentioned by ancient Greek writers, particularly Aristophanes in 400 BC (Stevens, 1991). Domesticated chickens have also been thought to have dispersed from their earliest known location in Asia (600 BC) and later spread to western parts of Europe and Africa (Jensen, 2006). The spread of fowls to America is, however, believed to have occurred with the Spanish conquest, followed later by the influx of English, French and Dutch colonisers (Stevens, 1991). The introduction of the domesticated chicken in Africa is not well documented; however it is believed that various domesticated chicken breeds were introduced from Europe during the era of colonisation, leading to extensive mixing of local and foreign chicken populations (MacDonald and Edwards, 1993). The initial reason for poultry domestication was for religious, cultural and recreational purposes, especially in America and Europe where cock fighting provided major recreational activity. This practice continued from early times of domestication until it became illegal in early 1849 (Siegel, 1993). Chickens were then kept in small flocks to provide eggs and meat for human consumption. These birds were allowed to wander freely, foraging for food in the farm yard, though many would have been kept in poultry houses overnight to protect them from predators (Bremner and Johnston, 1996). Moreover, humans also made small clearings in the jungle that attracted insects and other food to feed the Jungle Fowl. This association over centuries gradually led to the domestication of the chicken of today (Crawford, 1990; Scanes *et al.,* 2004).

In developing countries like South Africa the development of poultry industries started some 80 years ago and the major contributing factor to this was the high protein demand because of the increase in the human population (Leeson and Summers, 1997).

In today's systems the poultry sector can be divided into commercial and traditional sub sectors. Each has its own peculiarities which makes chickens special to national food security. The commercial sub-sector comprises layers and broilers of parent and grand parent stock. This sector is mainly confined to the urban and peri-urban areas where the infrastructure necessary for production and marketing exists. These poultry industries need a breed with high egg or meat production for commercial enterprises.

1.1.2 Modern poultry industry

Drastic changes occurred in poultry production in the mid 1900s, which led to the modern poultry industry. Chickens began to be reared in large groups of up to 30,000 birds in environmentally controlled, dimly lit (5 lux) houses. Science and technology are used to assure the well-being of the birds with exact ratios of scientifically determined feed to achieve rapid growth and high production (Jasper, 1996). Well managed breeding, incubation, rearing and nutritional regimes have created birds that are virtual copies of their siblings. Broilers are usually transported from the growing site to the abattoirs at six weeks of age when they weigh about 2-3 kg (Grandin, 1993). This uniformity has allowed poultry abattoirs to develop into highly automated facilities with an efficiency that is unmatched by other livestock processors. With line speeds loading 70 to 140 chickens per minute, uniformity, automation and efficiency are recurring themes which are the key to the success of poultry abattoirs (Sams, 2001).

In addition to the above, the use of power-driven overhead conveyers, brain sticking and agitated water usage for scalding has gradually become common. Some processors began to eviscerate and freeze carcasses at the abattoir facilities. Moreover mandatory poultry inspections have effectively improved the quality of poultry received by consumers as well as improving the industry. As a result of these developments, practically all poultry is marketed or sold to the retailers ready to cook or cut up into parts, or even further processed into products like deboned chicken, chicken polony and chicken viennas (Coetzee, 2005).

1.2 THE SOUTH AFRICAN POULTRY INDUSTRY

Over the past 40 years, poultry production has undergone considerable expansion. The industry has changed from essentially farm-based operations to large commercial producers where economies of scale in rearing and processing have led to a high degree of operational efficiency (Blom, 2006). The industry and the demand for healthy, well bred chickens that deliver quality meat is growing every day as health conscious consumers opt for healthier white meat instead of red meat (Groenewald, 2003).

The poultry meat processing industry has responded to this growing demand by establishing larger plants with faster line speeds and increasing manpower. A typical plant in 2002 produced approximately five times more output than a plant did in 1998 (Mountney, 1989). Traditionally, poultry slaughter facilities mostly produced whole birds, in contrast with slaughter plants today which generate a product composed of whole birds, cut up parts, deboned meat and other further processed convenience products (Blom, 2006).

1.2.1 Number and classification of poultry abattoirs

In February 2006, South Africa had three hundred and twenty-two (322) registered poultry abattoirs, rated and classified as high-throughput (176), low-throughput (67) and rural abattoirs (79) although many abattoirs were not operational. Previously, South African abattoirs were classified as A, B, C, D or E grade abattoirs (South Africa, 2004(a)). Table 1.1 indicates the difference between the old and the new classification of South African poultry abattoirs. About 90% of the poultry abattoirs in South Africa are privately owned, with 5% being government owned (by the Department of Correctional Services) and the remaining 5% are operated as community projects. The owners of the poultry abattoirs are responsible for the daily operation and maintenance of their facilities.

Table 1.1: Old and new classification of poultry abattoirs in South Africa (South Africa. Department of Agriculture, 2004 (a)).

OLD CLASSIFICATION	NEW CLASSIFICATION	
Grading	**Classification**	**Maximum slaughter units per day**
A and B	High-throughput abattoirs	> 2000 units
C and D	Low-throughput abattoirs	< 2000 units
E	Rural abattoirs	< 50 units

*One unit is equal to one chicken, (South Africa. Department of Agriculture, 2004 (a)).

1.2.2 Poultry abattoirs' work force

Most of the processing facilities in the country, except for selected high-throughput facilities, are service-orientated and as such perform only the killing and dressing of chickens without onsite rendering operations. Although the poultry abattoirs industry has become increasingly automated, it still employs a large number of employees (cutters, trimmers and packers). The total number of employees involved in intensive labour differs according to the classification of the abattoir and employees are employed either on a permanent or a temporary basis. Since the work is done indoors under cold and wet conditions (to prolong shelf life and for hygienic purposes), employees are exposed to many physical hazards and stresses such as injury, heat, cold and noise. Therefore, to reduce the risk, employers provide employees with appropriate protective clothing per kind of work involved. Both males and females are employed within the industry. The pre-requisite legislative framework (e.g. Meat Safety Act, Act 40 of 2000; Occupational Health and Safety Act, Act 85 of 1993) is adhered by all poultry abattoirs for the production of wholesome products (meat) for consumers and to ensure compliance to safety in the work environment. Meat inspectors, quality assurance officers and veterinary officers are employed in the abattoirs to achieve high level quality production goals. In addition, good hygiene management practices are also practised for the same reason (Mahrends, 2006: personal communication).

The processing operative hours are usually 37 to 40 hours per week with either single shifts (low-throughput and rural abattoirs) or double shifts (high-throughput abattoirs), from Sunday to Friday. Only a few of the high-throughput abattoirs operate on Saturdays, particularly on selected days such as month end and days before public holidays, due to high demand.

1.2.3 Poultry abattoir waste management

Although poultry abattoirs seem to be increasing production, there are several negative environmental factors associated with this industry. Amongst other things, improperly managed waste is regarded as one of the major contributing factors.

Poultry abattoirs produce considerable amounts of condemned meat tissue, which although it is still rich in proteins and fats, is not used for human consumption and is therefore referred to as waste. Abattoir waste may be classified as high-risk material if it is suspected of presenting a serious health risk, or as low-risk if it does not present a health risk (Salminen and Rintala, 2002). Poultry waste has the potential to contribute to excessive nutrients, pathogens, organic matter, and odorous compounds, which when released into the environment could lead to serious negative environmental impacts such as pollution problems (air, water and soil) and human health hazards. All generated waste needs to be disposed of in a safe and environmentally friendly manner (Mountney, 1989).

Although regarded as waste material, in some cases poultry waste may be considered a valuable source of financial income if processed properly. Such processing could help in minimizing the negative environmental impact (Bremner and Johnston, 1996). Gillespie (1997), reported extensively on certain number of by-products that are produced worldwide, including commercial fertilizers, livestock or pet food and medicines.

Waste does not only concern those who generate it. It is a national concern in most countries and the impact on the environment is preventable but not reversible. In South Africa, legislation is currently being enacted which restricts agricultural activities and penalises producers for exceeding limits related to waste disposal (Groenewald, 2003).

1.3 PROBLEM STATEMENT

Poultry abattoir is a long standing activity and although it is a relatively small-scale industrial sector, its environmental impact has grown considerably due to the increase in number and size of production plants (Coetzee, 2005). Poultry abattoirs can produce large quantities of organic waste which could be used in agriculture to conserve and recycle nutrients; waste could also be used in chemical fertilizers (Salminen, Rintala, Harkonen, Kuitunen, Hogmander and Oikari, 2001). However, without sufficient treatment this waste may pose severe health risks and could cause bad odour, environmental pollution and visual problems if not properly managed.

In South Africa like other developing countries serious problems have been reported in newspapers with red meat abattoirs, whereas no negative publicity has been noted in the poultry industry.

1.3.1 Motivation of the study

In South African poultry abattoirs, the waste disposal problems are widely recognised although efforts to find solutions for different types of waste are not always thorough (Pretorius, 2006: Personal communication). As a result, the study will describe the current waste practices used in South Africa and will recommend possible pollution control measures for the industry as legislation exist but are not always adhered to.

1.3.2 Aims and objectives of the study

The aim of the study was to assess waste management practices in South African high-throughput poultry abattoirs and to recommend best waste management practices that can be applied to all poultry abattoirs grades. Specific objectives were:

- Identification of the types of poultry waste generated at the different high- throughput poultry abattoirs in South Africa (question 8);
- assessment of any in-house treatment methods practiced (by-product production) in South African high-throughput poultry abattoirs (questions 9 -12);
- identification of existing waste management practices in relation to sources, waste generated, methods of handling (collection, storage and disposal used in South African high-throughput poultry abattoirs (questions 13 – 31);
- assessment of any environmental implications resulting from abattoir operations and waste management practices (question 32) and

- recommendation of appropriate waste minimisation strategies for the poultry industry.

1.3.3 Delimitations of the study

Delimitations of the study include the following factors,

- Interviews will be used to collect data regarding poultry waste management practices.
- No attempt will be made to quantify the respective waste outputs of each abattoir.
- It was up to the discretion of senior manager to either answer the questionnaire him/herself or delegate to the person knowledgeable with waste management practices at each respective abattoir.
- The study excluded rural and low through-put poultry abattoirs.
- No additional disposal sites or by-processing sites located outside abattoir premises will be visited.
- Closure of abattoirs due to bird influenza outbreak and
- Denial of access at some government owned abattoirs.

1.4 STRUCTURE OF THE THESIS

This study follows the format as described below, namely;

CHAPTER 1 provides the general background of the poultry industry, the evolution of poultry domestication and the modern poultry industry. It also states the aims and objectives of the study.

CHAPTER 2 contains a review of the literature related to poultry waste management. The methodologies and findings of other studies are identified and discussed.

CHAPTER 3 explains the research methodologies used and measurement of variables. Main focus areas include the compilation of the questionnaires, the collection of data (visits to abattoirs) and analysis of the data.

CHAPTER 4 refers to the interpretation and discussion of the results according to the analysed data. The chapter is divided into four sections, namely biographical information, solid waste handling practices, liquid waste handling practices and associated health and environmental problems.

CHAPTER 5 refers to the general conclusions relating to this study in order to facilitate access and ease of comment.

CHAPTER 6 states general recommendations to the industry and.

CHAPTER 7 contains conclusion and the reflection of the study.

1.5 REFERENCES

Blom, N. 2006. South Africa not at greater risk of bird flu, says poultry association. *Business Day Newspaper*, 30 March. [Online]. Available from: www.dfr.gov.za. Accessed on 16 October 2006.

Bremner, A. and Johnston, M. 1996. *Poultry Meat Hygiene and Inspection*. London: W.B.Saunders Company Ltd. pp. 1- 3.

Crawford, R.D. 1990. Origin and history of poultry species. *In* Crawford, R.D. *Poultry Breeding and Genetics*. Amsterdam: Elsevier. pp. 1 - 42.

Coetzee, Z. 2005. 2004 – a stable to good year South African poultry industry. South Africa. *Poultry bulletin*. pp. 1-2

Cooper, E.L. 1990. Agriscience – fundamentals and applications. USA: Delmars Publishers Inc. pp. 385 – 389.

Daghir, N.J. 1995. Poultry production in hot climates. United Kingdom: CAB International. pp. 1 – 2.

Gillespie, J.R. 1997. Modern livestock and poultry production (5th ed). New York: Delmar Publishers. p. 13.

Grandin, T. 1993. Livestock handling and transport. Wallingford, United Kingdom: CAB International. pp. 274 – 278.

Groenewald, Y. 2003. Checking your chicken's chow. Mail and Guardian, 20 August 2003. p. 3.

Jasper, S.L. 1996. Introduction to livestock and poultry production: *Science and Technology*. Danville, Illinois: Interstate Publishers Inc. pp. 265 – 283.

Jensen, P. 2006. Domestication – From behaviour to genes and back again. *Applied Animal Science*. 97. pp. 3 - 15.

King, A.N. 1994. Agriculture – introduction to Southern Africa. New York: University of Cambridge. pp. 125 – 130.

Leeson, S. and Summers, J.D. 1997. *Commercial Poultry Nutrition* (2nd ed). Canada: University Book. pp.1 – 3.

MacDonald, K.C. and Edwards, D.N. 1993. The importance of chickens in Africa. Qasr, Antequity 67. pp. 584 – 590.

Mahrends, J. 2006. Personal communication. 29 May, Cape Town. Tel: 0825544062

Mountney, G.T. 1989. *Poultry Products Technology (2nd ed*). Binghamton, New York: Food Products Press, Inc. pp. 19 – 20.

Pretorious, S. 2006. Personal communication. 20 March, Kroonstad. Tel; 0735678907

Rose, S.P. 1997. Principles of poultry science. Wallingfort: CAB International. p. 1.

Salminen, E. and Rintala, J. 2002. Anaerobic digestion of organic solid poultry slaughterhouse waste - a review. *Bioresource Technology*. 83. pp. 13 – 26.

Salminen, E. Rintala, J. Harkonen, J. Kuitunen, M. Hogmander, H. and Oikari, A. 2001. Anaerobically digested poultry slaughterhouse wastes as fertilizers in agriculture. *Bioresource Technology*. 78 (1) pp. 81 - 88.

Sams, A.R. 2001. *Poultry meat processing*. Florida: CRC Press LLC. pp. 1.

Scanes, C.G., Brant, G. and Ensminger, M.E. 2004. *Poultry science (4th ed)*. New Jersey: Pearson Education Inc. pp. 1 - 2.

South Africa. 1993. Occupational Health and Safety Act, Act 85 of 1993. Pretoria: Government Printer.

South Africa. Department of Agriculture. **2004 (a).** Grades of and requirements for poultry abattoirs. Pretoria: Government Printer.

South Africa. 2000. Meat Safety Act**,** Act 40 of 2000. Pretoria: Government Printer.

Siegel, P.B. 1993. Behaviour – genetic analysis and poultry husbandry. *Poultry Science*. 72. pp. 5.

Stevens, L. 1991. Genetics and evolution of the domestic fowl. Cambridge: Cambridge Press. pp. 1 -13.

Thear, K. 1999. Starting with chickens – a beginner's guide. Walden: Broad Leys Publishing Company. p. 9.

CHAPTER TWO
LITERATURE REVIEW

2.1 INTRODUCTION

In South Africa, an abattoir in terms of Meat Safety Act (2000) (Act 40 of 2000) means a slaughter facility for which a registration certificate has been issued and grading has been determined. Poultry abattoir houses slaughter, dress, cuts, inspect, refrigerate and manufacture by-products (Figure 2.1) and the basic operational principles are the same in South Africa and other countries as indicated in literature. The construction of an abattoir, drainage, water supply, disposal of waste and all other operations are carried out under government regulations and the Directorate Veterinary Services of the National Department of Agriculture is the custodian for all approvals to anyone intending to construct an abattoir (South Africa, 2007).

2.1.1 Outline of poultry processing

Poultry slaughtering differs from the slaughter process used for red meat animals, resulting in unique by-products and waste types produced. Industrial, large scale poultry slaughter and processing is a multi-stage operation and is virtually the same worldwide. Modern slaughter lines can operate at processing speeds of up to 300 carcasses or more per minute on a single line (Mabe, 2006).

The processing consists of a number of steps (Figure 2.1), where each step entails a specific task which must be performed effectively and hygienically. Each step follows the previous one in a strict sequence. In order to achieve this sequence the layout of the abattoir premises is designed in such a way that the production process moves in a linear flow pattern with no cross flow of products which could adversely affect the quality of the product. Live birds are received at the dirty end of the abattoir and meat is dispatched from the clean site of the abattoir. The two sections (clean and dirty) of the abattoir are separated by distance and physical barriers so that contamination is avoided. In smaller abattoirs (low-throughput and rural) most of the functions are carried out by hand whereas in the larger abattoirs (high-throughput), functions are mechanised (South Africa, 1991). Birds are transported to the abattoir in special containers or crates. On arrival at the abattoir, the birds are taken out of the transport crates and manually hung by the legs onto a continuously moving system of shackles. As the crates are emptied they are conveyed back to the truck on roller conveyers and reloaded.

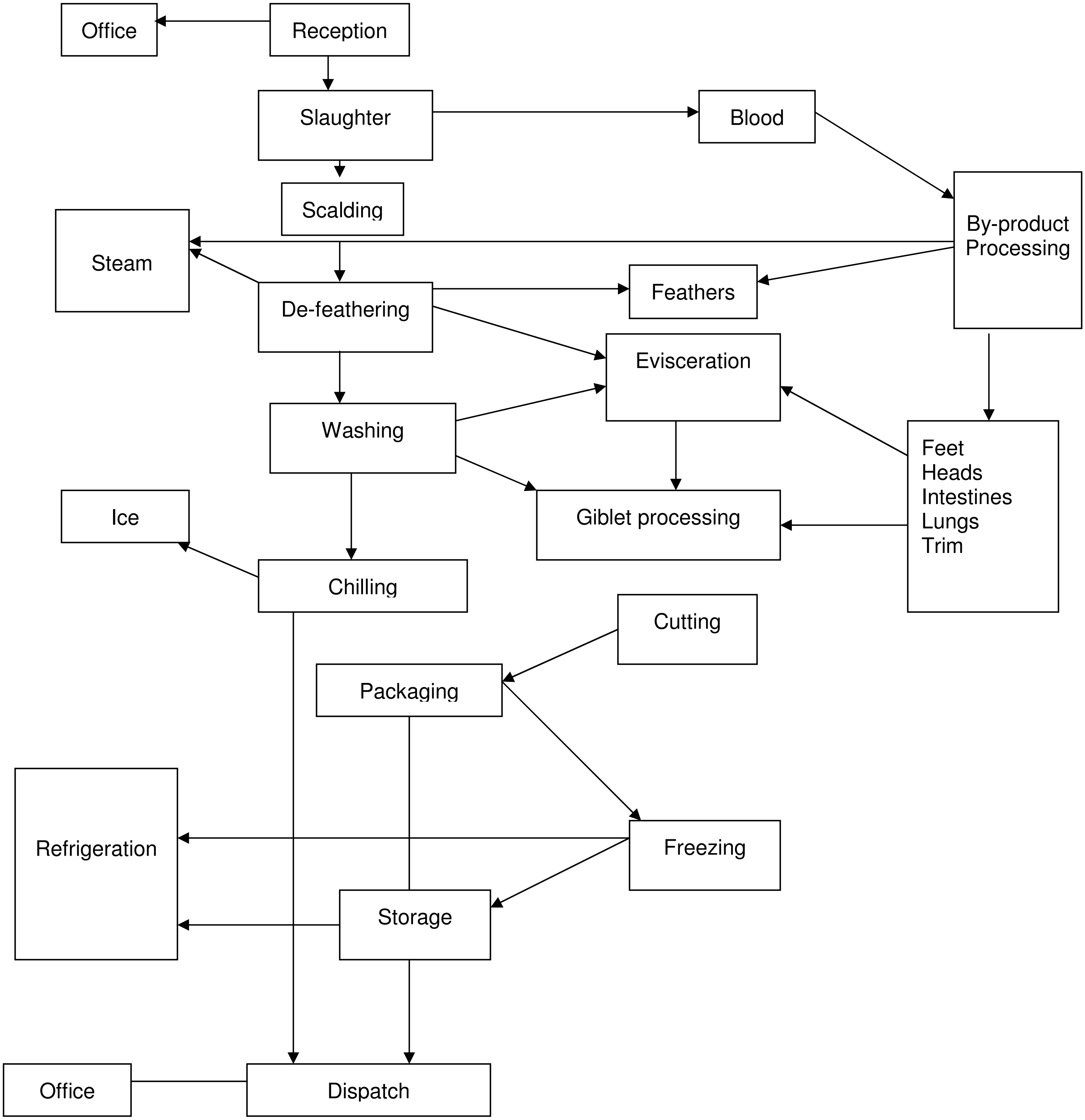

Figure 2.1 Poultry abattoir facility flow diagram (Silverside and Jones, 1992).

Birds are stunned by a low voltage electrical shock when they are submerged into a water bath. Electrical stunning of the birds is effected as their heads touch a brine solution to complete an electric circuit, causing unconsciousness with or without cardiac arrest at the same time (Mountney, 1989).

After electrical stunning, they proceed to a neck cutting and bleeding stage. The neck is partially cut either by hand or automatically with a rotating knife-blade. When a mechanical throat-cutting device is being used, a worker is required to hand cut any bird the machine has missed. Birds are allowed to bleed so that much of blood is reduced. This reduces the internal body temperature of the bird and helps reduce the spread of bacteria. Barnes, (1995) reported that 34 - 50% of chicken blood is lost during the bleeding phase of the killing operation, but a considerable variation exists.

Once bleeding is complete, birds are then immersed into a scalding tank (hot bath) to loosen the feathers for plucking. Two different scalding regimes are used, depending on the type of product, which is either chilled or frozen as reported by Sams (2001). Soft or mild scalding is required for birds that are sold as chilled fresh products. The low water temperature used (49 to 52˚C) softens the skin and prevents damage during the subsequent defeathering processes. Hard scalding as compared to soft scalding is used on birds being sold frozen and the water temperature ranges between 58 and 60˚C to partly soften and loosen the carcass skin (Humphrey, 1991). According to Mountney (1989) high organic and solid pollution loads arise from scalding tank overflows as compared to other poultry processing sections. Following the scalding operation, birds enter the defeathering section and several different types of machines are used. However the most common type of defeathering machine is a continuous type, one that employs rubber fingers attached to a cylinder, which removes the feathers as the cylinder rotates. These rubber fingers do not damage the skin and continuous water sprays are generally used in these machines to flush out the feathers. The feathers fall out of the machine into a trough which serves as a flow-away removal system for feathers (Steffen, Robertson and Kristen Inc, 1989).

Some processing lines include a singeing stage to remove fine hair-like feathers and appendages. On these lines, each carcass passes through a sheet of flames as it moves along the conveyor line (Parkhurst and Mountney, 1997). The feathers can be processed further into a valuable by-product or collected for disposal as solid waste. The waste is collected in a flume and pumped over screens before further processing or dumping. The birds are then sent through the whole bird wash where water is sprayed on the birds as they pass through a washing chamber (Shari, 2002).

After leaving the bird wash, the birds enter the evisceration room which is segregated from the other plant operations. This separation prevents waste from contaminating the eviscerated birds. The evisceration operation involves; the removal of heads, inedible viscera, lungs and any other remaining material from the carcasses, recovery and cleaning of edible products and exposing the bird's viscera for inspection. The birds receive a final wash after all evisceration operations have been completed. This wash is performed in a chamber where spray nozzles cover the birds with a continuous stream of fresh water. The wash removes any remaining particles from the inside and outside of the carcasses (Sams, 2001). The carcasses are then chilled at a minimum of 10˚C to minimise possible microbiological contamination and this as reported by Sams (2001) and Steffen, Robertson and Kristen Inc (1989) can be done by using either cold air or chilled water.

Water immersion chilling involves an in-line process and carcasses move through one or more large tanks of water to which ice or chilled water is added. Air is sometimes introduced at the bottom of the tanks to improve agitation which facilitates the cooling and removes some of the contaminating micro-organisms. Water in the tanks can flow with the direction of carcasses (through-flow system) or the birds can be removed mechanically against the flow of incoming water (counter-flow system). The latter one has the advantage that the carcasses meet the cleanest water when they leave the system, minimising cross-contamination and decreasing bacterial counts on carcasses. Birds have to be re-hung manually when they leave the chilling tank, and an adequate drip-time afterward is essential. This system is very efficient for rapid chilling of small carcasses and is mainly used for hard scalded birds that are sold as frozen products (Richardson, 1991).

Air chilling is basically a dry process, utilising cold air either in a chill-room (batch process) or by continuously moving the carcass through an air blast tunnel at -7 to 2˚C for one to two hours. This can be done with the birds on racks, but it is more efficient and more common to air-chill carcasses on shackles (Steffen *et al.,* 1989). To enhance cooling, the product can be sprayed with water which absorbs heat as it evaporates. Air chilled carcasses have a dried skin appearance which reflects the drying effect of this chilling method. The dried skin rehydrates and the appearance usually returns to normal after packaging. Upon leaving the chilling operation, the carcasses are replaced on the overhead conveyors to allow the excess water to drain. The carcasses are then re-weighted, graded and packed or transferred for further processing (Sams, 2001). In South Africa, feet, heads and intestines (rough offal) and necks, livers and hearts (red offal) are classified as edible products within poultry industry.

2.1.2 Poultry abattoir waste generation

As part of their service to the industry and public, abattoirs perform meat inspections to ensure that only meat products suitable for human consumption are approved and supplied to consumers (Van Zyl, 1995). During these inspections there are a lot of meat trimmings, organs and carcasses that may be condemned and then have to be disposed of as waste material (Salminen and Rintala, 2002).

Moreover the condition of the birds during catching, transportation as well as operational and pathological conditions can also determine the quantities of waste material produced (Wilson, 2002). According to Bilgil, (2004) and Northcutt (2001), the main pathological conditions that increase waste production includes abscesses, bruising, tumours and breast blisters while operational conditions include contamination and over-scalding.

Salminen and Rintala (2002) define poultry waste as carcasses or parts of chickens not intended for direct human consumption as well as all condemned material from abattoir operations. These include parts of bird carcasses such as trimmings, faeces, blood, feathers, condemned material, waste-water and other products not intended for human consumption. This waste can be classified in two categories: **high risk material** - if suspected of posing serious health risk such as the risk of contagious diseases. These materials should be totally destroyed. **Low risk material** - material that presents no risk, such as dead on arrivals, condemned material and spoilt materials. The nature and quantity of waste varies at each processing stage as indicated in Figure 2.2, resulting in either solid or effluent-based waste.
Solid waste includes condemned meat organs and carcass, bone, feathers and manure, while effluent waste is composed of dissolved solids, blood, sludge and wash water (Salminen and Rintala, 2002).

In most modern plants, waste discharged within the abattoirs follows the marked route and containment until disposal. Inedible offal in the form of feathers, feet, viscera and condemned organs are first contained in facilities especially designed for this purpose which include amongst others, troughs, skips or bins. Evisceration waste and wash waste are transferred in waste-water streams. This waste-water normally passes through screens which remove the larger solids until either treatment or final disposal (Bilgil, 2004) takes place. Improperly managed waste can result in both environmental and health hazards to the community.

2.1.3 Environmental impacts associated with waste

While poultry abattoirs generate meat supply and useful by-product production, improperly managed waste generated on the slaughter floor can have serious environmental implications as well as increase the risk of health hazards to humans and animals (Meadows, 1995). Most of the implications are however confined to limited geographic areas around the abattoir. Discharge of waste-water is regarded as the main factor leading to environmental pollution. Waste-water entering surface water leads to a reduction of dissolved oxygen which destroys aquatic life, while nitrogen and phosphorus may cause eutrophication (Brinkman, 1999). Copper and Russel (1992) reported that dust and emissions resulting from combustion are also environmental factors that may be associated with the poultry abattoir industry depending on the scale of the operations and the degree of processing activities carried out. Results recorded in Table 4.14 indicate that respondents thought that air pollution was a problem.

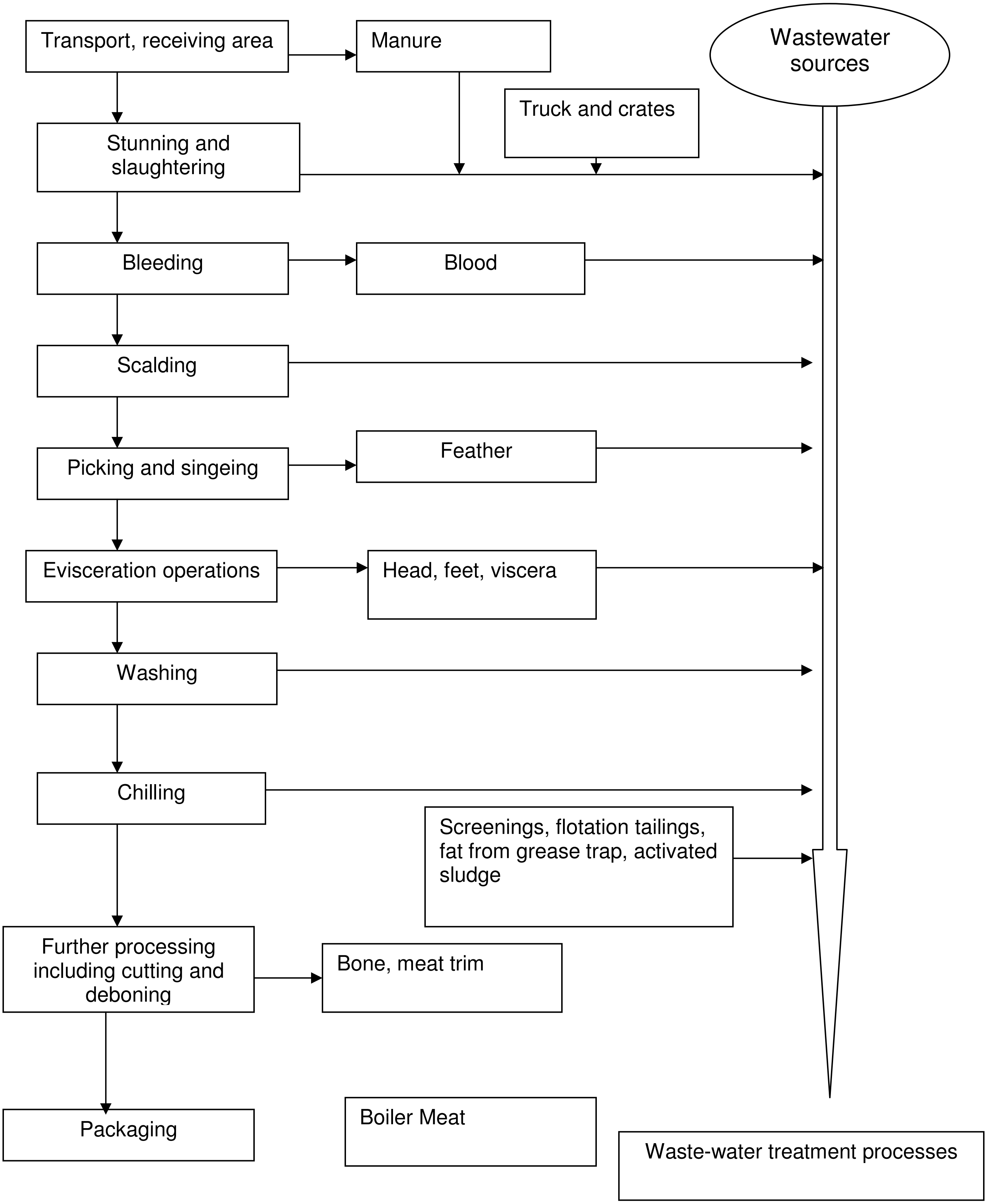

Figure 2.2 Waste production stages and waste material produced in poultry abattoir facility (Salminen and Rintala, 2002).

2.2 POULTRY ABATTOIR SOLID WASTE MANAGENENT

2.2.1 Waste treatment technologies

In poultry abattoirs, poultry wastes resulting from various operations require appropriate management on a daily basis. Suitable methods of disposal are permitted in many areas include burial, incineration and landfill. However these methods are becoming less acceptable or feasible in some areas because of excessive costs and restrictive regulations (Sungwaraporn, 2004). There are also new and emerging waste treatment technologies discussed below, which are able to treat a variety of waste streams.

i. Incineration

Salminen and Rintala (2002) describe incineration as burning of waste at high temperatures, converting it into gaseous emissions into the atmosphere and residual ash released. This is apparently among the most effective methods for destroying potentially infectious agents. It functions as an alternative to landfilling, composting and anaerobic digestion. According to Blake (2004), incineration is probably the safest biological method of disposal. Waste can be disposed of as rapidly as it accumulates, and the resultant residue is easily disposed of. However it tends to be slow and expensive even when highly efficient incinerators are used. This method creates only a small amount of waste (ash) that can be disposed of easily and does not attract pests. The main concerns related to incineration are odours, particulate emissions, slow throughput, expense (maintenance and replacement costs) and the generation of nuisance complaints by the public, even when highly efficient incinerators are used. The most commonly used incinerators are simple incinerators and rotary-kiln incinerators. **Simple incinerators** are brick lined cells with a metal grate over a lower ash pit, with one opening in the top or side for loading, and another opening in the side for removing incombustible solids. **Rotary-kiln incinerators** are slightly inclined cylindrical tubes through which refuse is removed continuously. Waste is first dried and then injected into the refractory-lined cylinder where combustion is completed. Ash drops through the grate although most particles are carried along with the hot gases (Neethling, 2006). As per results recorded in the study this method is not practiced in South African poultry abattoirs.

ii. Composting

Composting refers to controlled biological decomposition of organic solid waste under aerobic conditions (Salvato, Nemerow and Agardy, 2003). It is normally carried out in windrows or reactors (Watts, 1994). Composting is amongst the methods commonly used to treat poultry slaughterhouse waste, which includes screenings, flotation tailings, grease trap residues, manure, litter and feathers (Salminen and Rintala, 2002). This is a relatively fast biodegradation process, typically taking four to six weeks to reach a stabilised form. It can be accelerated by providing the correct temperature, moisture content, density and feedstock mixture (Mittal, 2005).

When properly managed, composting is a bio-secure, relatively inexpensive and environmentally sound method for disposing of poultry waste by converting waste into odourless, humus-like material which is useful for soil enrichment (Blake, 2004). The process reduces the odour, fly problem and reduces the bulk of waste (Watts, 1994). The only disadvantage during composting is cited as loss of nitrogen and other nutrients. This method unfortunately requires significant land, earth-moving equipment and may reduce the value of the land (Kelleher, Leahy, Heniham, O'Dwyer, Sutton and Leahy, 2002).

The simplest method of composting involves the digging of a hole, 1.2m X 1.2m and 1.5 m deep in the ground, in which the waste materials are placed. This hole is then covered with a layer of earthen material. The earthen cover significantly reduces emissions and augments the degradation process. The location of composting ponds should be carefully chosen to prevent them from flooding. The composting ponds should be located at a considerable distance from existing water bays and they should preferably be sited in a downwind direction from residents (Slogan, Kidder and Jacobs, 2005). Composting could be an option at low-throughput or rural throughput abattoirs but is not usually taking place at high-throughput poultry abattoirs.

iii. Burying

According to Damron (2002), burial has been the method of choice for years due to its low cost and convenience. There are similarities between burial and composting, but the main difference is that composted material can be used later as fertilizer while in burial no end product is produced. Burial normally takes place on farm premises where waste material is being filled up in the burial pit. In order to control odour and flies and to discourage scavengers, a covering of at least 1.5 m of earth must be maintained (Damron, 2002). Burial pits used for disposal of poultry abattoir waste cause concerns which include the decline in ground water quality where pits are located (Blake, 2004). According to Salatin (1999), the residue does not decompose readily; they remain jammy and slick for over a year in the soil and can emit a terrible odour. Open-bottom pits are one example of a burying method; it is cheap and easy; though there may be problems such as slow loss of poultry residue, seepage of nitrogen, phosphorus and pathogens into groundwater (Scanes *et al.,* 2004). According to the results recorded (table 4.6) burial is used only for disposal of feathers.

iv. Land application

Waste by-products generated at poultry meat production plants can generally be applied to the land as the final step of the producer's waste management strategy. Under proper land application conditions, the nutrients and organisms in poultry waste pose limited environmental threat. Environmental contamination occurs when land application of poultry waste is in excess of crop utilisation potential or when it is done under poor management conditions, causing nutrient loss from environmental factors such as soil erosion or surface run-off during rainfall.

Environmental parameters of concern are nitrogen (N), phosphorus (P) and certain metals (Cu and Zn in particular) as well as pathogenic micro-organisms that may be contained in poultry waste (Williams, Barker and Sims, 1999). Excessive application of poultry litter in cropping systems can result in nitrate (NO_3) contamination of groundwater. High levels of nitrite in drinking water can cause metheamoglobinaemia (blue baby syndrome), cancer and respiratory illness in humans, as well as fatal abortions in livestock (Kelleher *et. al.,* 2002).

v. Digestion

Digestion is a totally enclosed system utilising a pre-cast septic tank or a large capacity plastic tank to contain condemned poultry carcasses and to promote the growth of microbes that are present in the carcasses. Bacterial cultures with enzymes are added to the dead bird digester to facilitate organic composting (Blake, 2004). Pathogens in the remaining residue are totally destroyed so that the residue can be processed into a feed supplement. The end product of the process includes the generation of methane gas for fuel, liquid nutrients for aquaculture and high-nutrient feed additives (Damron, 2002).

vi. Use as animal feed

As slaughterhouse wastes are rich sources of protein and vitamins, they are preserved with formic acid and used as animal feed, either as such, or together with regular feed (Salminen and Rintala, 2002). Unlike other materials, feathers are not normally used since they are poorly degradable in their natural state (Aro and Tewe, 2006).

vii. Rendering

Kelleher, et.al. (2002) defines rendering as a process that converts highly perishable meat by-products that are unfit for human consumption into useful commodities such as poultry meal, bone meal as well as pet food. Materials that are commonly rendered include inedible offal, dead on arrivals, and poultry that have been classed as condemned as a result of the post slaughter inspection. This technique therefore supports the utilization of waste into useful by-products and helps to prevent air, soil and water pollution since all the material is used. Rendering process can either be for edible products or inedible products. The rendering processes vary from plant to plant depending on the following factors:

- Whether the end products are to be used as human food is based on the type of raw material and the processing method and
- Whether the end products are to be used as animal or pet food.

The material may be processed wet or dry. In wet processing, either boiling water or steam is added to the material causing fat to rise to the surface, while in dry processing, fat is released by dehydrating the raw material. The temperature range used can either be high or low. Processing may be either in discrete batches or in a continuous process. The processing plant may be operated by an independent company that collects the material on the open market, or by the packing plant that produced the material (Jenkins, 1992).

Edible rendering processes are basically meat processing operations and produce lard or edible tallow for use in food products. It is generally carried out in a continuous process at low temperature (less than the boiling point of water). The process usually consists of chopping the edible fat materials (generally fat trimmings from meat cuts), heating them with or without added steam, and then carrying out two or more stages of centrifugal separation. The first stage separates the liquid water and fat mixture from the solids. The second stage further separates the fat from the water. The solids may be used in food products or pet foods, depending on the original materials. The separated fat may be used in food products, or if in surplus, it may be diverted to soap making operations. In an alternative process slaughterhouse offal is cooked to produce a thick lumpy stew which is then sold to the pet-food industry to be used principally as tinned cat and dog foods. Such plants are notable for the offensive odour that they produce and are often sited a distance away from human habitation. **Inedible rendering process** - materials that for aesthetic or sanitary reasons are not suitable for human food are the feedstock for inedible rendering processes. Much of the inedible raw material is rendered using the "dry" method. This may be a batch or a continuous process in which the material is heated in a steam jacketed vessel to drive off the moisture and simultaneously release the fat from the fat cells. The material is first ground, then heated to release the fat and drive off the moisture, percolated to drain off the free fat, and then more fat is pressed out of the solids, which at this stage are called "cracklings" or "dry-rendered tankage". The cracklings are further ground to make meat and bone meal. A variation of dry process involves finely chopping the material, fluidizing it with hot fat, and then evaporating the mixture in one or more evaporator stages. Some inedible rendering is done using a wet process, which is generally a continuous process similar in some ways to that used for edible materials. The material is heated with added steam and then pressed to remove a water-fat mixture which is then separated into fat, water and fine solids by stages of centrifuging and/or evaporation. The solids from the press are dried and then ground into meat and bone meal (Hansen, Christiansen and Hummelmose, 2007).

Although this is widely used there are three major concerns related to this method of disposal, which includes bio-security, proper feather breakdown and suitable on-farm storage method to reduce transportation (Salminen and Rintala, 2002). Moreover, some environmental issues related to rendering include the following, namely:

- Effluent from rendering plants contains very high loads of organic matter, therefore regarded as source of effluent contamination,
- Rendering effluent comprises condensate from dry rendering, stick-waters from wet rendering, decanters and blood coagulation from polisher centrifuges,

- The energy consumption for rendering is very high, especially for the drying step. However modern systems can be quite energy efficient especially when multiple effect evaporators are used,
- Rendering materials are highly putrescible, and if not handled correctly can cause extremely bad odours and or,
- The exhaust fumes from the rendering process are also extremely odorous and consequently often necessary to install odour control system to reduce odour emission to within required limits (Hansen, *et.al.,* 2007).

Figure 2.3 is a flow diagram showing the inputs and outputs from a typical poultry rendering process.

Similar process takes place in South African rendering plants and waste products are generated during percolation, pressing and milling which are later disposed off, while odour produced during sterilisation and drying is regarded as nuisance especially to communities nearer to the abattoirs.

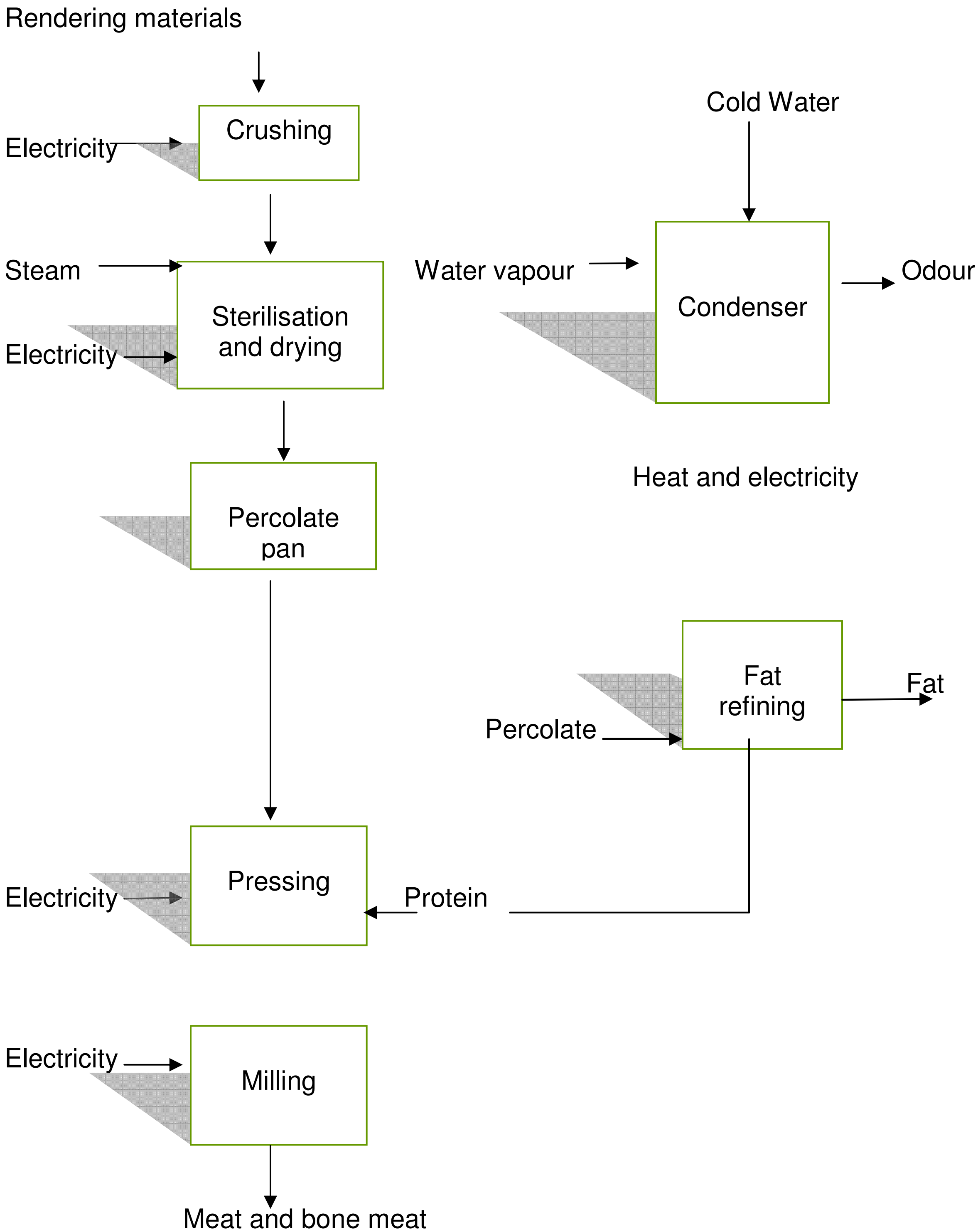

Figure 2.3 Inputs and outputs for the rendering process (Hansen *et.al.,* 2007)

2.3 POULTRY ABATTOIR WASTE-WATER MANAGEMENT

2.3.1 Poultry abattoir water consumption

In poultry abattoirs, a significant amount of water is used for cleaning and washing carcasses, and meat products, sanitation and disinfection of abattoir equipment, transportation of meat products for further processing and transportation of by-products material to by-product recovery operations and waste-water treatment units (El-Boushy, Van der Poel and Walraven, 1990). Water consumption at poultry abattoirs varies with the types of rendering or processing activities used type of equipment used, grading or throughput of the processing facility as well as water and waste minimization practices. Table 2.1 shows the summary of water utilised per section (Kroyer, (1991) and Mittal, (2004)). An estimated amount of 15 – 20ℓ of water is required per bird in poultry abattoirs. The volume of water discharged as waste-water may amount to between 80 and 85% of the waste load (Bremner and Johnston, 1996).

Table 2.1 Typical breakdown of water consumption in broiler abattoir (Kiepper, 2001)

Area	Operations	Range of % encountered	Average %
Processing	Lairages	5 – 12	10
	Slaughter and carcass dressing	12 – 33	20
	Offal handling	11 – 60	25
Utilities	Hot water	14 – 36	25
	Cooling and refrigeration	5 – 11	8
	Steam raising	2 – 9	5
Services	Ablutions, laundry and general washing	1 - 12	7

2.3.2 Poultry abattoir effluent characteristics

As poultry abattoir waste-water are contaminated with fat, viscera, blood, feathers and feaces, it can be characterized and distinguished from other industrial waste-water by their high organic matter, oil and grease and solid content as provided in Table 2.2.

Table 2.2 Poultry abattoir effluent characteristics (Caixeta, Cammarota and Xavier, 2002)

Parameter	Units	Load
pH	mg/ℓ	7.0 – 7.2
BOD	mg/ℓ	700 - 4000
COD	mg/ℓ	1300 - 7500
Total suspended solids	mg/ℓ	200 - 1200
Total nitrogen	mg/ℓ	100 - 250
Total phosphorus	mg/ℓ	100 - 250
Fat, oil and grease	mg/ℓ	100 - 1000

Both the quality and quantity of waste-water generated from poultry abattoir is important for identification and design of technology for treatment. According to Zhang (2001), the oil and grease concentration of this waste-water can reach a level that might adversely affect the subsequent treatment steps. Oil and grease might cause adverse effects in treatment units such as aeration tanks and settlers (Zhang, 2001). If untreated, the disposal of these substances can have significant environmental and public health implications. Therefore any waste-water generated is treated before any discharging or re-use. In South Africa, the degree of treatment required is determined by the specified discharge limitations as defined by the Water Services by-laws as per Municipal Systems Act (South Africa, 2000(b)). The by-laws differ from one province to another.

2.3.3 Poultry abattoir effluent treatment technologies

The method for treatment of poultry abattoir effluent consists of a number of unit processes: primary treatment, secondary treatment and advanced treatment. Primary (pre-treatment) entails the removal of floating materials, coarse solids and grit. Secondary treatment is a biological treatment, generally to remove BOD. The latter is followed by secondary clarification to remove biomass formed in the process prior to further treatment or disposal. Advanced (tertiary) treatment and polishing which is a physical and or chemical removal of pollutants that is not removed by conventional biological processes (Mittal, 2005). After secondary treatment, waste-water can be further processed by tertiary treatment or alternatively, processed waste-water can proceed directly from secondary treatment to the final steps of sludge treatment and disposal (Johns, 1995).

The degree of treatment required by poultry processors will determine which option can be utilised. Figure 2.4, indicates waste-water treatment flow, where each system type posseses unique treatment advantages, as well as operational difficulties (Kiepper, 2001).The treated effluent is partially re-used for truck or floor wash in some cases, and the rest is disposed of by land application such as irrigation. In cases where land application is not possible, the partially treated effluent is discharged to the municipal sewer.

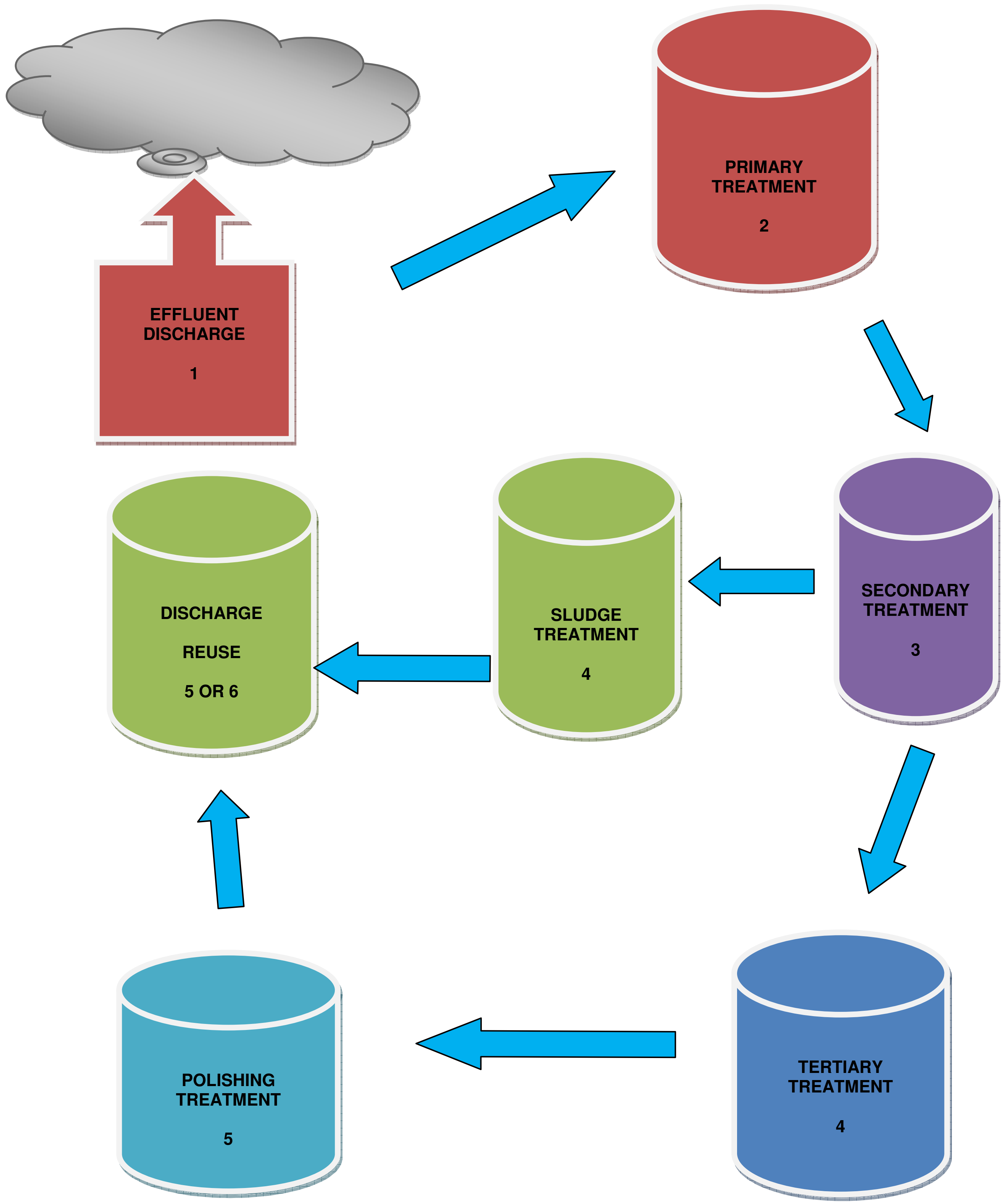

Figure 2.4 Waste-water treatments using various technologies (Shari, 2002)

2.3.3.1 Pre-treatment and primary treatment

Both pre-treatment and primary principles are the same and for the purpose of this study they have been combined into one section. These stages include a broad range of waste-water processing elements, including screening catch basins, gravity separation of solids and air flotation. Before any pre-treatment or primary treatment is considered, an adequate survey is made. Such surveys include flow measurement, composite sampling and chemical analysis to determine the extent of the problem and the possibilities for treatment (Mittal, 2005). Some of the treatment options as practised in poultry abattoirs include the following, namely:

i. Screening

Screening which is often the first, simplest and most inexpensive form of waste-water treatment and serves a dual purpose in a poultry abattoirs waste-water stream (Liu, Xu, Show and Tay, 2002). Firstly, screening recovers offal materials (feathers, viscera, meat particles) that are valuable by-products for the poultry rendering industry. Secondly, screening prepares waste-water for further treatment by removing the larger solids particles from the waste stream that might otherwise affect the operation including maintenance of downstream equipment and treatment processes (Kiepper, 2001).

The size of the screens varies, depending upon the size of the solids to be removed. The well known screen designs which can be used to remove coarse solids, includes amongst others (1) stationery/incline screens, (2) rotary cylindrical screens, (3) brushed screens, and (4) vibrating screens. Vibrating and rotary screens are the most frequently used in poultry waste-water processing (Nielsen, 1989).

The rotary screens on the other hand come in two basic forms, namely internal and external fed. For internal fed screens, waste-water and associated solids are fed into the drum and water drains out of the drum while solids are retained inside.

For external fed screens, waste-water and solids flow over the outside of the drum. The stream of water passes through the drum, while the solids rotate on the outside of the drum and are scraped off on the opposite side of the entry point. Common problems associated with screening include mechanical failures and blanking, due either to the overloading of the screen or to under-sizing of screen gaps (Mittal, 2005).

ii. Fat traps

After the removal of the coarse solids, the effluent stream still contains fine suspended solids, fats and grease. These have high BOD values and form a floating scum, which adheres to the sides of tanks and pipes. The scum causes blockages in pipelines which reduces the efficiency of aeration and blocks the small-bore irrigation outlets on filter beds. Fine solids, fats and grease have financial value in that the scum can be skimmed off and utilised as an animal feed, or processed as a raw material for soap and cosmetics manufacture (Mittal, 2005). The method of removing fatty matter depends upon the amount produced and its quality. For small quantities of low-grade material, a simple fat trap is necessary. However for large volumes of effluent and high-grade fatty waste a more efficient method which works on the principle of gravity separation, by the provision of minimum turbulence, flow-through tank is needed. In the fat traps, settleable solids can remain long enough to settle out to the bottom of the tank, while grease and fine solids rise to the surface. Continuous sludge removal and skimming of the surface to remove scum are essential (Steffen, *et al.,* 1989).

iii. Dissolved air floatation (DAF)

Dissolved air flotation refers to the process of waste-water solids separation by the introduction of fine gas (usually air) bubbles into the waste-water stream. Dissolved air floatation with or without chemical flocculation can be installed to remove oil, grease, fats and other suspended matter in waste-water (Kiepper, 2001; Mittal, 2005). There are several advantages of using the DAF system in the pre-treatment of waste-water. Pre-treatment includes straightforward operations with a high capacity to handle shock loads and require relatively low capital costs, particularly when compared to biological treatment systems (Masse and Masse, 2000).

The waste-water stream is pressurised and injected with compressed air to create supersaturated conditions. The supersaturated waste-water is then allowed to reach equilibrium with atmospheric pressure. The reduction in pressure causes the air to leave the solution as very fine bubbles which adhere to any oil, fat or suspended solids in the waste-water carrying them to the surface. The use of flocculants such as iron salts, sodium carbonate, calcium carbonate and lignin suphonic acid makes the process easier than when DAF is used on its own. The layer of solid materials which results can then be swept off or recovered for rendering and the effluent is now ready to be discharged into the sewer or onto agricultural land as part of an irrigation scheme (Steffen, et al., 1989).

iv. Catch basins/settling tanks

Catch basins are used to remove grease and finely suspended solids by means of gravity. The specially designed tanks allow the water to flow slowly so that the solid particles have time to sink to the bottom of the tank while grease and fine solids rise to the surface. A skimmer is used to remove grease and scum off the top. The particles collect at the bottom to form sludge and from time to time the sludge is removed from the bottom of the tank for further treatment. The water, which is now clearer, leaves from the top of the tank. Primary settling separates most of the solid waste. Sludge from this process is called primary/raw sludge. At a later stage secondary settling takes place after the water from the primary settling tank has been treated biologically (Mittal, 2004).

2.3.3.2 Secondary treatment system

The term biological treatment system refers to the removal of organic compounds and pathogens from effluent using micro-organisms in a controlled environment. The micro-organisms convert biodegradable organic particles and some inorganic materials in waste-water into a more stable cellular mass and other by-products that are later removed from the remaining water. There are two approaches related to this, namely anaerobic and aerobic treatment (Nemerow and Dasgupta, 1991).

i. Anaerobic treatment

This type of biological treatment is carried out in the absence of free oxygen. The system is totally enclosed to prevent the entry of air. The involvement of the micro-organisms enables the utilisation of suitable organic substrates and the system operates as a two-stage fermentation process. Both stages occur simultaneously within the digester, where during the first stage bacteria breaks down complex organic substances into simpler compounds. The most important compounds are volatile fatty acids, carbon dioxide, water, hydrogen gas, hydrogen sulphide as well as ammonia. Maintaining a suitable pH value (7.0 – 7.2) is a very important factor in the process; moreover, temperature also plays an important part in the economic production of methane (Nielsen, 1989).

(a) Fixed film reactors

In this process waste and the micro-organisms move through the reactor, with the micro-organisms constantly suspended in the flow. After leaving the reactor, the suspension flows through a separator which separates the organisms from the liquid. Some of the organisms are discharged as sludge, while the remainder are returned to the reactor. The supernatant is discharged either into the environment or to other treatment units. The functioning of the separator is very important as poor performance of the separator will result in large amounts of solids in the effluent and the reduction of organisms in the recycle (Del Pozo, Diez and Beltran, 2000).

(b) Anaerobic sludge blanket reactor (UASB)

In the UASB reactor, the effluent enters at the bottom of the digester, flows upward through a compact layer of bacteria (the sludge blanket) and exits at the top of the reactor. It operates in three distinct phases: the liquid phase (residual water that is being treated), a solid phase (sludge) and a gas phase. As the gas forms, it flows upwards, transporting particles to the top of the reactor. These return to the sludge blanket so that they remain inside the reactor (Caixeta, Cammarota and Xavier, 2002). Successful operation depends on the formation of bacterial flocs or granules that accommodate and settle easily at the digester bottom. A good fat separator is usually installed to prevent excessive scum layers formation in the reactor (Mittal, 2005).

i. Aerobic treatment

Aerobic treatment involves the degradation of organic substrates by micro-organisms in the presence of oxygen. These micro-organisms require free dissolved oxygen to reduce the biomass in the waste-water. Aerobic treatments are very effective in reducing odours and pathogens. Some of the aerobic treatment methods include: aerobic lagoon, activated sludge processes - extended aeration, oxidation ditches, sequencing batch reactors (SBRs) and trickling filters (Mittal, 2005).

Aerobic treatments can follow directly after primary treatment (pre-treatment) but require daily maintenance. The system also requires a large amount of space, maintenance and energy to ensure artificial oxygenation takes place. The only disadvantage is that abattoir waste-water contains high-concentration of organic carbon which requires high-aeration and this leads to high sludge disposal costs if waste-water is treated using aerobic treatment (Johns, 1995).

(a) Aerobic system

The aerobic system is conducted in a reactor into which oxygen is administered forcibly by pump upon where the effluent passes down a trickling filter to come into contact with the atmospheric oxygen. This system enhances the growth of micro-organisms and the carbohydrates are oxidised into carbon dioxide and water while the nitrogenous wastes are converted into nitrates and sulphates (Kiepper, 2001).

The incoming effluent displaces the treated material which flows over a weir to the settling tanks. Some of the solids are returned to the oxygenation vessel to maintain the microbial culture in peak condition while the sludge is disposed off after treatment if necessary (Mittal, 2006). The effluent can then be discharged into a water course while the sludge can be disposed in the landfill site or spread onto agricultural land (Carawan, Williams, Macon and Hawkins, 1974).

(b) Aerobic lagoons

Aerobic lagoons are large, shallow earthen basins in which algae are used in combination with other micro-organisms to treat water. Oxygen is supplied naturally by the wind, (through photosynthesis) and by mechanical means (Jarvis, Strompl, Moore and Thiele, 1999).

(c) Trickling filters

Trickling filters refers to a tank containing media with a high surface to volume ratio. Waste-water is discharged at the top of the tank and percolates (trickles) down into the media. Bacteria grow on the media utilising the organic matter and nitrogen from the waste-water (Nakhla, Al-Sabawi, Bassi, and Liu, 2003).

(d) Oxidation ditches

Oxidation ditches is an aerobic process in which bacteria consumes organic matter, nitrogen and oxygen from the waste-water and new bacteria is grown. The bacteria are suspended in the aeration tank by the mixing action of the air blown into the waste-water. Physically, an oxidation ditch is ring-shaped and is equipped with mechanical aeration devices (Nielsen, 1989).

(e) Rotating biological contractor (RBC)

The rotating biological contractor is a fixed film aerobic process similar to the trickling filter process except that the media is supported horizontally across a tank of waste-water. The microbial film absorbs and metabolises organic matter and provides energy and nutrients for microbial growth and maintenance (Mittal, 2005). The media upon which the bacteria grow is continuously rotated so that it is in the waste-water and in the air alternately (Mittal, 2007).

2.3.3.3 Tertiary treatment system

Tertiary treatment refers to the removal of suspended or dissolved substances. Nutrients like nitrogen and phosphorus can be removed by biological treatment or physicochemical methods, often within existing treatment plants. Due to high-cost involved, their use in treating abattoir waste-water is limited (Mittal, 2005).

2.3.4 Poultry abattoir treated effluent discharge

Satisfactory discharge of waste-water is dependent on its treatment prior to discharge. There are two types of disposal systems, namely direct and indirect disposal. Direct disposal is defined as the release of waste-water directly into surface water or onto land while indirect disposal refers to the discharge of waste-water into a treatment facility for further treatment prior to disposal into surface water or a land application system (Kroyer, 1991).

However, regardless of whether the discharge is direct or indirect the majority of soluble and particulate matter in waste-water must be removed prior to discharge from the plant in order to achieve compliance with established environmental regulations. There are a number of disposal systems available, and it should be noted that the choice of disposal system is finally selected as the most suitable to the specific poultry abattoir (Nielsen, 1989). These include municipal sewer, land application and infiltration-percolation.

i. Municipal sewer

Abattoirs generally discharge their waste-water into the municipal sewer system after some degree of primary or secondary pre-treatment has taken place at the plant. Here effluent is treated until it meets the required discharge standards. Some advantages when using this option are that there is no need for the processor to invest in costly and complex treatment systems, or to employ more staff to manage and monitor as well as to maintain the treatment system. The sewer needs to be within reach of the processing plant and the capacity of treatment works should be large enough to receive additional flow. The major disadvantage of disposal to municipal sewers is the cost per unit of effluent discharged (Kurup, 2007).

Since most authorities require a balanced flow and often encourage off peak discharge, abattoirs have to have a pre-treatment stage on site consisting of screens to remove coarse solids, grease, fat and fine solids. A balancing or storage tank and controlled discharge could possibly be required (Nielsen, 1989).

Moreover, in South Africa abattoir effluent discharge have to comply with municipal water services by-laws. Each abattoir is expected to comply with the municipal by-laws within its area of jurisdiction.

ii. Land application

Land application encompasses three treatment processes which have been used by food processors of various commodities. The three treatment processes include irrigation, infiltration-percolation and overland flow. The selection of a process is primarily governed by the soil characteristics at the available site, which largely determine the hydraulic loading limitations and the acreage required for effective treatment (De Villiers, 2000, Mittal, 2007).

(a) Irrigation

Irrigation involves applying waste-water to maintain or increase crop production. It ranges from low-volume irrigation, designed to meet the needs of soil and crops, to high-volume irrigation where disposal of large volumes of effluent is the main objective. The processor has to be prudent because if the receiving soil contains clay, the sodium content of the applied waste-water can cause clogging of the soil. High chloride content of the waste-water can also cause damage to crop growth (Mittal, 2007).

(b) Overland flow

The overland flow method requires effluent to run over the surface of the land. Treatment is carried out partly by the soil and partly by aerobic processes as the effluents flow between the stems and roots of crop plants. Treated effluent is collected and discharged into water courses (Nielsen, 1989).

iii. Infiltration-percolation

This system is designed to encourage infiltration into the sub-soil, and its effectiveness depends on the absorption capacity and microbial activity of the soil (Nielsen, 1989).

2.4 ENVIRONMENTAL IMPACTS ASSOCIATED WITH ABATTOIR WASTE

Efforts around the world have been geared towards minimizing or prevention of pollution. Nevertheless, in many parts of the world, human activities such as poultry abattoirs still impact negatively on the environment and biodiversity, especially if waste is not managed properly (Adesemoye, Opere, and Makinde, 2006). In many countries pollution arises from activities in meat production as a result of failure to adhere to good manufacturing and good hygiene practices. The main pollution parameters associated with poultry abattoirs include water, air and soil pollution.

2.4.1 Pollution parameters

i. Water Pollution

Poultry wastes are responsible for many agriculture-related water pollution problems. Large abattoirs produce huge amounts of waste that, if disposed of untreated into the environment, can contaminate water sources. Potential pollutants include organic matter, infectious agents, salts and heavy metals. These pollutants cause turbidity, taste and odour problems, and health hazards to humans or animals drinking or using the water. The contaminants may either leaching to the ground-water or be transported to the surface water by runoff (Hairston, 2001). Discharge of waste-water to surface water affects the quality of water in three ways, namely:

- The discharge of biodegradable organic compounds may cause a strong reduction in the amount of dissolved oxygen, which in turn may lead to reduced levels of activity or even death of aquatic life;
- Macro-nutrients (Nitrogen and Phosphorus) may cause eutrophication of the receiving water bodies. Excessive algae growth and subsequent dying

off and mineralisation of these algae may lead to the death of aquatic life due to oxygen depletion and

- Agro-industrial effluents may contain compounds that are directly toxic to aquatic life.

ii. Air pollution

Air pollution is described as the presence of components that were not found in a clean environment prior to the industrial activity, or substances that are found in unusually high concentrations compared with the natural level. Atmospheric odour and air emission are main air pollution factors associated with poultry abattoirs operations. Atmospheric odour - poultry abattoirs are unlikely to pollute air other than causing to unpleasant odours. The main sources of odour include waste, untreated effluent and cooking activities of by-products. During air emission abattoirs also release large amounts of substances into the atmosphere. These include dust and gaseous emissions such as chlorofluorocarbons which are ozone depleting substances (Masse and Masse, 2000).

iii. Soil or Land pollution

Soil or land contamination basically refers to build-up of excess nutrients and heavy metals in soil. Improper disposal of poultry abattoir waste through land application has been identified as one of the major causes of land pollution due to high organic content (Raymond, 1977).

Commonly identified control measures for soil pollution involve safer land use as well as proper waste management strategies such as collection and categorization of waste, and safe disposal with minimum environmental hazards (Hairston, 2001).

2.5 POULTRY ABATTOIR BY-PRODUCT PRODUCTION

The processing of poultry for human consumption or other human needs inevitably leads to the production of waste. Although described as waste because of its form at the time of generation, new strategies are developed to produce poultry by-products and reduce environmental implications (Mijinyawa and Dlamini, 2006). Poultry by-products can include everything of economic value, other than carcass, obtained after slaughtering and processing. These products are classified as either edible or inedible for humans (Aberle, Forrest, Gerrand and Mills, 2001).

The value of by-products is maximised when processed immediately after slaughter; otherwise edible materials degrade quickly and turn into inedible materials. In addition to the monetary value derived from processed by-products, conversion of inedible parts of the chicken into useful products performs very important sanitary functions. All inedible parts unless processed would accumulate and decompose, causing undesirable conditions in the surrounding environment (Aberle, *et. al.,* 2001).

However, the issue of animal health is always a concern when discussing the use of slaughter waste as animal feed. When fed in wet form, waste has only a very brief shelf-life and there is always the risk of transferring animal diseases. Outbreaks of diseases have been associated with feeding of uncooked waste, and have ultimately led to the requirement to cook waste (Westerndorf, 2000). The disease of concern is mainly hog cholera, but there are several other pathogens of public health significance such as *Salmonella, Campylobacter, Trinchinella* and *Toxoplasma).* Several poultry by-products are produced and amongst others include the following (Barnes, 1995):

i. Offal as pet food

Pet food represents a considerable and expanding market for slaughterhouse offal unfit for human consumption. Offal is used as a source of animal protein as cats and dogs need animal protein in their daily diet. However, because protein is not only supplied from animal waste, all vegetable included in pet food contains varying levels of protein derived from vegetable origin. Therefore during manufacturing, nutritionists balance both animal and vegetable proteins to match the pet's needs as closely as possible. Pet food can be produced in different forms, namely canned soft food, dry food and semi-ousoft dry food (Scanes *et. al.,* 2004).

However, it should still be noted that waste unfit for human consumption that is converted into meat protein meals for pet food, animal feed and other products varies between countries (SPCA, 2008).

ii. Carcass meal

Offal consists of edible (heads, feet, giblets) and inedible organs (intestinal tract, lungs, spleen, wind pipe, and reproductive organs) which are used in the production of carcass meal. Offal is rendered by cooking at high temperature (100˚C) under pressure to destroy pathogenic organisms. The processed material can be used for livestock feed. When prepared, it is a powder with a slight smell and has the pleasant taste of salted meat. The product is a rich source of protein and vitamins (Scanes *et. a.l.,* 2004). Annexure 2.2 indicates a schematic process of carcass meal production.

iii. Feather meal

Feathers constitute up to 10% of total chicken weight, reaching more than 7.7 to 10.0 kg/per year of waste material generated by the poultry industry. This excessive amount of material is discarded and in many cases may become an environmental problem because it does not degrade easily (El-Boushy *et.al.,*1990). Feathers are principally made up of the protein keratin and are not digestible. However, with high pressure cooking at more than 100˚C, hydrolysis occurs which increases the availability of amino acids. Feather meal is produced following drying and grinding of the hydrolyzed feathers. This can be added to poultry, swine or ruminant feed, being a good source of arginine, cysteine and theonine. Feather meal contains 75 to 90% crude protein (Scanes *et al.,* 2004). It is estimated that processed feathers create a livestock feed with approximately the same nutritional quality as soy bean protein (Hasan, Haq, Das and Mowlah, 1997).

iv. Feather fertiliser

Feathers make good fertiliser and mulch and when decomposed, nitrogen is released which nitrifies the soil (Mountney, 1989). However, excess concentration of nitrogen allows multiplication of micro-organisms, leading to very low oxygen tension with water so that animal life cannot survive (North Carolina State University, 1995).

v. Blood fertiliser

Blood is used as fertiliser either in fresh form (mixed with organic manure or alone) or else coagulated with ferric sulphate or lime, or dried. Dried blood is a good supplementary nitrogenous fertiliser containing nitrogen, phosphoric anhydride, potash and moisture. The action of dried blood in the soil is very quick, because the nitrogen nitrifies readily (Bruttini, 1990). However, if over-applied to the soil excessive ammonia content can burn plants. It is also completely soluble and can be mixed with water to be used as liquid fertiliser (Bradley and Ellis, 1997).

vi. Waste-water reclamation

Agriculture is a major user of water, primarily in the food processing industry. This water can be re-used for irrigation, but this requires thorough analysis prior to usage where possible, to avoid any microbial contamination or excess of organic nutrients (Hill, 1997).

vii. Swill

Swill is a product that is prepared daily and immediately after slaughter. Raw offal is boiled at 100˚C for at least one hour before allowing it to cool. After cooling the swill, it may be fed directly to pigs or be fortified (vitamin) after being minced and is then fed as slurry. In areas with dry climatic conditions, the minced product may be sun-dried on open concrete beds and used as fertiliser. The dried product can be broken up or ground before bagging, marketing and final use (Scanes *et. al.,* 2004).

2.6 LEGISLATION GOVERNING ABATTOIR OPERATIONS

2.6.1 South Africa

In South Africa there is variety legislation or acts which relate to abattoir operations. The existing legislation is fragmented into different aspects such as hygiene, occupational health and safety, waste management, handling of condemned materials, animal product safety and waste-water management. Some of the legislation is explained below:

i. Constitution of South Africa, 1996 (Act 108 0f 1996)

Environmental rights are highlighted in section 24(a) of the Constitution of the Republic of South Africa. These rights underline the right of all human beings to an environment that is not harmful to their health and well-being (South Africa, 1996).

ii. Meat Safety Act 2000 (Act no 40 of 2000)

The Meat Safety Act is aimed at promoting safety of meat and safety of animal products. It aims to establish and maintain essential hygiene standards in respect to abattoirs. It also prescribes the methods of disposal and handling of condemned products. The following disposal methods are prescribed under part VIII of the Act:

Total incineration;

Denaturing and burial of condemned material at a secure site, approved by the provincial executive office and local government, by:

- Slashing and then spraying with or immersion in an obnoxious colorant approved for the purpose; and
- burial and immediate covering to a depth of at least 60cm and not less than 100m from the abattoir, provided such material may not deleteriously affect the hygiene of the abattoir, or
- processing at a registered sterilising plant (South Africa, 2000).

Handling of condemned material

Carcass, portions thereof or any edible products in an abattoir, which cannot be passed for human and animal consumption, must be "

- Portioned and placed in a theft proof container which has been clearly marked 'CONDEMNED' in letters not less than 10cm high or conspicuously marked with a stamp bearing the word 'CONDEMNED' using green ink;
- kept in a holding area or a room or dedicated chiller provided for the purpose except if removed on a continuous basis; and

- removed from the abattoir at the end of the working day or be secured in a dedicated chiller or freezer at an air temperature of at least minus 2˚ “.

No person may remove a carcass, part thereof, or any edible product which has been detained or condemned from an abattoir, except with the permission of a registered inspector and subject to such conditions as he or she may impose. The abattoir owner is responsible for complying with the legal requirements or conditions relating to safeguarding and disposal of any carcass, part thereof or any edible product which cannot be passed for human or animal consumption (South Africa, 2000).

iii. Abattoir Hygiene Act, 1992 (Act no 121 of 1992)

Meat is considered to be a perishable source of protein; therefore consumers need to be sure that they receive healthy and wholesome products. The Abattoir Hygiene Act was established to give guidance and regulates:

- The maintenance of proper standards of hygiene for the slaughtering of animals with a view to obtaining meat suitable for human and animal use.
- It forbids the slaughter of animals at any place other than an abattoir with a valid certificate of approval;
- It recommends that at least 15 litres of water is available per poultry slaughter unit and that the water is protected from contamination.
- It ensures that the water is clean, potable and free of suspended material and substance which could put the consumer's health at risk. The water must be subjected to flocculation, filtration, chlorination or other treatments to ensure the following counts:

  Total bacteriological count <100/ml (30˚C/ 48 hrs)

  Coli-form count < 2/100ml

  Faecal coli – absent in 100ml (South Africa, 1992).

iv. National Environmental Management: Waste Bill, 2007

The National Environmental Management Bill enforces the generators of waste to manage their waste according to the hierarchy of waste management in a sustainable way. That is, each industry will have to avoid, minimise, re-use, recycle, treat and dispose of waste as a last resort.

v. Water Act, 1998 (Act no 36 of 1998)

This act regulates the use of water for industrial purposes. This includes poultry abattoirs as these are classified under light industry. The act regulates the protection, use, development, conservation, management and control of water resources in South Africa. It provides for the constitutional demands for pollution prevention, ecological and resource conservation, sustainable utilisation, the precautionary principle, social upliftment, participatory decision-making, transparency and just administrative action. In terms of the act, water resource reserved for human use and maintaining a sound ecosystem take precedence over agricultural and industrial demands. Permits for using water can be obtained for water abstraction; water storage and water discharge in terms of sections 27 to 29 of the act (South Africa, 1998).

vi. Environment Conservation Act, 1989 (Act no 73 of 1989)

The Environment Conservation Act ensures proper management of abattoir waste in terms of protection of the total environment, which includes, for example, water, air, soil, humans, flora and fauna. The protection of water quality and the environment against effects of abattoir waste is regulated by section 20 which prescribes the need for a disposal site permit from the Minister of Water Affairs to establish and operate disposal sites. **Section 19** prohibits discarding, dumping or leaving of any litter on any land or water surface, street, road or site in or on any place which has been specifically indicated, provided or set apart for such purposes. **Section 20 (1)** provides that where an operation accumulates treats, stores or disposes of waste on site for a continuous period, it must apply for a permit from the Department of Water Affairs and Forestry to be classified as a suitable waste disposal facility (South Africa, 1989).

vii. Occupational Health and Safety Act, 1993 (Act no 85 of 1993)

This act is aimed at ensuring health and safety of persons in the work environment, in connection with use of plant machinery, and any hazards arising out of or in connection with activities of persons at work (South Africa, 1993).

viii. Environmental Regulations for Workplaces, (GNR 2281 of 16 June 1987)

These regulations identify environmental factors that need to be adhered to for the sake of the health and safety of employees. Amongst other things, the regulations include factors such as thermal requirements, lighting, ventilation, housekeeping and fire (South Africa, 1987).

2.6.2 European Union

i. Regulation 1774/2002, Animal by-products

The European Union Directive/guidelines govern various aspects of processing, use, disposal, trade and import of animal by-products. The main aim is to prevent animal by-products from posing a risk to animal or public health through the transmission of diseases. It also places strict controls on how meat waste and animal by-products are disposed of (European Union, 2002).

ii. Regulation 2000/76/EC, Incineration of waste

Incineration of waste directive applies to all operators of incinerators, and has the aim of limiting negative effects on the environment caused by incineration of waste. It sets emissions limits and requirements for normal and abnormal operating conditions (European Union, 2000).

2.7 INTEGRATED WASTE MANAGEMENT APPROACH (IWMA)

Integrated waste management approach is defined as a way of managing waste through a participatory process and a holistic approach through multiple techniques to achieve waste reduction, avoidance of health effects and negative environmental implications. Techniques for implementing an integrated waste management approach include waste assessment, waste plan, waste separation, on-site management, waste reduction, waste recovery, monitoring and recording, finally auditing and control. This is a proactive, anticipative and preventive philosophy that can be applied by all abattoir grades (Steffen, Robertson and Kristen, 1989). Figure 6.1 shows a schematic flow diagram of an integrated waste management approach applicable to all abattoir grades (Wells, 1976).

The other important feature of IWMA is that by preventing inefficient use of resources and avoiding unnecessary generation of waste, an abattoir can benefit from reduced operating cost, reduced waste treatment and disposal cost and reduced liability. Some of the aspects which can be included in the IWMA include the following namely, waste assessment, waste plan, waste separation, on site management and auditing and control (Wells, 1976).

2.8 REFERENCES

Aberle, E.D, Forrest, J.C, Gerrand, D.E and Mills, E.W. 2001. *Principles of meat science.* 4th ed.USA: Keendall/Hunt Publishing Company. pp. 311 – 321.

Adesemoye, A.O., Opere, B.O. and Makinde, S.C.O. 2006. Microbial content of abattoir waste-water and its contaminated soil in Lagos, Nigeria. *African Journal of Biotechnology*. 5 (20). pp.1963 – 1968.

Aro, S.O and Tewe, O.O. 2006. Performance and carcass yield of barrows fed dried poultry waste as a replacement for palm kernel cake. *African Journal of Biotechnology.* 6 (4) 19 February. pp. 487 – 492.

Barnes, C. 1995. Animal science in action. London: University of Nottingham. p. 60.

Bilgil, S.F. 2004. Poultry meat inspection and grading. In Sams, A.R. *Poultry meat processing*. Washington DC: CRC Press. pp. 54 – 58.

Blake, J.P. 2004. Methods and technologies for handling mortality losses. *World Poultry Science Journal*, 60 (4) December. pp. 489 – 499.

Bradley, F.M., and Ellis, B.W. 1997. Rodale's all new Encyclopaedia of Organic Gardening: The Indispensable Resource for every Gardener.

Bremner, A. and Johnston, M. 1996. *Poultry Meat Hygiene and Inspection*. London: W.B.Saunders Company Ltd. pp. 1 - 3.

Brinkman, J. 1999. Anaerobic digestion of mixed waste slurries from kitchens, slaughterhouses and meat processing industries. In Mata-Alvarez, J., Tilche, A., and Cecchi, F. (Eds) *Proceedings of Second International Symposium on Anaerobic Digestion of Solid Wastes*, Barcelona. pp. 190 – 195.

Bruttini, A. 1990. *Uses of waste materials*. Westminster, Rome: P.S. King and Sons Ltd. p. 239.

Caixeta, C.E.T., Cammarota, M.C. and Xavier, A.M. 2002. Slaughterhouse waste-water treatment evaluation of new three phase separation system in a UASB reactor. *Bioresource Technology* 81 (1). pp. 61 – 69.

Carawan, R.E, Williams, M.C, Macon, J.A and Hawkins, B.K. 1974. Water and waste management in poultry processing. *Environmental Protection Technology Series*. Pubn.no EPA 660/2-74-031.

Copper, R.N., and Russel , J.M. 1992. Meat industry processing wastes characteristics and treatment. In: Hui, Y. H (Ed). *Encyclopaedia Food Science Technology*. 3. pp. 1683 – 1690.

Damron, B.L. 2002. Options for dead bird disposal [Online]. Available from http://edis.ifas.edu/AN126. [Accessed on 19/02/2006].

Del Pozo, R., Deiz, V. and Beltran, S. 2000. Anaerobic pretreatment of slaughterhouse waste-water using fixed film reactors. *Bioresource Technology*, 71 (2). pp. 143 – 149.

De Villiers, G.H. 2000. Abattoir effluent treatment and protein production: full scale application. *Water SA*. 26 (4). October. pp. 559 – 562.

El-Boushy, A. R, Van der Poel, A. F. B. and Walraven, O.E.D. 1990. Feather meal – a biological waste; its processing and utilization as feedstuff for poultry. *Biological Waste.* 32 (1). pp.39 – 74.

European Union. 2002. Regulation 1774/2002/EC, of the European Parliament and Council of 03 October 2002. Animal By-Products and Regulation. Online [http://europa.eu.int/eur-lex/en/consleg/reg/en_register_035030.html – selected sites [2007-06-15].

European Union. 2000. Regulation 2000/76/EC, of the European Parliament and Council. Incineration of waste Regulation.

Fontent, J.P. 1998. *Feeding poultry waste to cattle*. Blacksburg, Virginia, USA: Virginia Polytechnic Institute and State University. p. 2461.

Hasan, M.R., Haq, M.S., Das, P.M. and Mowlah, G. 1997. Evaluation of poultry feather meal as dietary protein source for India major crop. *Laberonita Fry. Aquaculture* 151. pp. 47 – 54.

Hansen, P., Christiansen, K., and Hummelmose, B. 2007. *Cleaner Production Assessment in Meat* Processing. Denmark: COWI Consulting Engineers and Planners AS,pp. 43 – 45.

Hairston, J.E. 2001. Animal waste and how it affects water quality. California. Alabama: Cooperative Extension System. pp. 1 – 36.

Hill, K.M. 1997. *Understanding environmental pollution*. USA: Cambridge University Press. pp. 148 – 149.

Humphrey, T. 1991. Scald tank hygiene. Proceedings of the workshop: Welfare hygiene and quality aspects in poultry processing. United Kingdom: University of Bristol. p. 45.

Jarvis, G.N., Strompl, C., Moore, E.R.B. and Thiele, J.H. 1999. Isolation and characterization of two glycerol- fermenting clostridia strains from pilot scale anaerobic digester treating high lipid-content slaughterhouse waste. *Journal of Applied Microbiology.* 86. pp. 412 – 420.

Jenkins, D.1992. Towards a comprehensive model of activated sludge bulking and foaming. *Water Science and Technology*, 25(6). pp. 215 – 230.

Johns, M.R. 1995. Developments in waste-water treatment in the meat processing industry: a review. *Bio-resource Technology*. 54 (3). pp. 203 - 216.

Kelleher, B.P., Leahy, J.J., Heniham, A.M., O'Dwyer, D., Sutton, D. and Leahy, M.J. 2002. Advances in poultry litter disposal technology – a review*. Bio-resource Technology*. 83 (1). pp. 27 – 36.

Kiepper, B. 2001. A survey of waste-water treatment practices in the broiler industry. The University of Georgia. Engineering Outreach Program, Driftmier Engineering Centre, Athens, Georgia.

Kroyer, G. 1991. Food processing wastes. – bio-conversion of waste materials to industrial products. In: Martin, M.A (Ed). New York. *Elsevier Applied Science*. pp. 293 – 311.

Kurup, R,G. 2007. An experimental research on application of sub-surface flow constructed wetlands for meat processing industry effluent treatment and nutrient removal. Doctoral Unpublished Thesis. Murdoch University. Western Australia. pp 1-212.

Liu, Y., Xu, H., Show, K. and Tay, J. 2002. Anaerobic granulation technology free waste-water treatment. *World Journal Microbiology. Biotechnology*, 18. pp. 99 -113.

Mabe, E. 2006, Personal communication. 15 June, Rustenburg. 083 476 4799.

Masse, D.I. and Masse, L. 2000. Characterisation of waste-water from hog abattoirs in Eastern Canada and evaluation of their in-plant waste-water treatment systems. *Canadian Agricultural Engineering*. 42 (3) 139 – 146

Meadows, R. 1995. Livestock legacy environmental health perspectives 103 (12), pp. 1096 – 1100.

Mountney, G. T. 1989. Poultry Products Technology. 2nd ed. Food Products Press Inc, New York, London. pp. 140 – 141.

Mijinyawa, Y and Dlamini, B.J., 2006. Livestock and poultry waste management in Swaziland. Livestock and Poultry for Rural Development.18 (6).

Mittal, G.S. 2007. Regulations related to land application of abattoir waste-water and residues. *Agricultural Engineering International*; the GIGR Ejournal.10. Vol IX. pp. 1 - 37.

Mittal, G.S. 2005. Treatment of waste-water from abattoirs before land application - a review. *Bioresource Technology*. 97 (9). pp. 1119 – 1135.

Mittal, G.S. 2004. Characterization of effluent waste-water from abattoirs for land application. *Food Reviews International*. Vol 20. 3. pp. 229 – 256.

Nakhla, G., Al-Sabawi, Bassi, A., and Liu, V. 2003. Anaerobic treatability of high oil and grease rendering waste-water. *Basic Microbiology*. 34. pp. 405 – 423.

Neethling, G. 2006. *The abattoir's view of the material received from the producers*. Menlo Park. Red Meat Abattoir Association. p. 3.

Nemerov, N.L. and Dasgupta, A. 1991. Industrial and hazardous waste treatment. New York: Van Nostrand Reinhold.

Nielsen, V. C. 1989. Treatment and disposal of processing waste. In: Mead, J.C. Processing of Poultry. *Elsevier Applied Science*. New York. pp. 361 – 408.

Northcutt, K.J. 2001. Pre-slaughter factors affecting poultry meat quality. In: Sams, A.R. *Poultry Meat Processing*. Washington DC: CRC Press. p. 10.

North Carolina State University. 1995. Recycled feathers. *Environment.* 37 (2). p. 22.

Parkhurst, C. R. and Mountney, G.J. 1997. *Poultry products technology* (3rd ed) Food Product Press. New York p. 56.

Raymond, C. L. 1977. Pollution control for agriculture. London: Academic Press Inc. pp. 75 – 77.

Richardson, J. 1991. Chilling systems and the EEC water content regulations. Proceedings of the workshop; welfare, hygiene and quality aspects in poultry processing. UK: University of Bristol.

Salatin, J. 1999. *Pastured poultry profits*. Virginia: Polyface Inc. pp. 132 – 134.

Salminen, E. and Rintala, J. 2002. Anaerobic digestion of organic solid poultry slaughterhouses waste - a review. *Bioresource Technology*, 83. pp. 13 – 26.

Salvato, J.A., Nemerow, N.L., and Agardy, F.J. 2003. *Environmental Engineering*. New Jersey. 5th ed. John Wiley and Sons, Inc. pp. 803 – 809.

Sams, A.R. 2001. *Poultry meat processing*. Florida: CRC Press LLC. pp. 13 – 14.

Scanes, C.G, Brant, G. and Ensminger, M.E. 2004. *Poultry Science* (4th ed). New Jersey: Pearson Education, Inc. pp. 147 – 152, 261- 264.

Shari, B. 2002. *Poultry Processing System*. Boca Raton, FL: CRC Press. p. 548.

Silverside, D. and Jones, M. 1992. Small-scale poultry processing. FAO Animal Production and Health Paper. p.98.

Slogan, D.R., Kidder, G. and Jacobs, R.D. 2005. Poultry manure as fertilizer [Online] available of from: http www.epaguyana.org.downloads/poultry%guidelines.pdf. Accessed on 19/02/2006.

South Africa. 1987. Environmental regulations for workplaces. Pretoria: Government Printer.

South Africa. 1989. Environment Conservation Act**,** Act 73 of 1989. Pretoria: Government Printer.

South Africa. 1991. Meat Inspector's Manual poultry meat. Doornfontein: Lexpatria Publishers.

South Africa. 1992. Abattoir Hygiene Act, Act 121 of 1992. Pretoria: Government Printer.

South Africa. 1993. Occupational Health and Safety Act, Act 85 of 1993. Pretoria: Government Printer.

South Africa. 1996. Constitution of South Africa. Act 108 of 1996. Pretoria: Government Printer.

South Africa. 1998. Water Act**,** Act 36 of 1998. Pretoria: Government Printer.

South Africa. 2000. Meat Safety Act**,** Act 40 of 2000. Pretoria: Government Printer.

South Africa. 2000(b). Municipal Systems Act, Act 32 of 2000. Pretoria: Government Printer.

South Africa. 2007. National Environmental Management: Waste Bill. Pretoria: Government Printer.

South Africa. 2007(b). Meat Inspectors Manual Abattoir Hygiene. Doornfontein: Lexpatria Publishers.

Society for the Prevention of Cruelty of Animals (SPCA), 2008. Is waste used in pet food. Online: http://www.spcadbn.org.za/PFI-5.php. Access on 07 September 2008.

Steffen, Robertson and Kristen Inc. 1989. Water and waste-water management in the poultry industry. Pretoria. Water Research Commission. pp. 3, 13.

Sungwaraporn, Y. 2004. Lipid and protein quality of poultry by-products preserved by phosphoric acid stabilization. Unpublished Doctoral Thesis. North Carolina. North Carolina State University. pp.1 -221.

Van Zyl, A.P. 1995. Manual for the abattoir industry. Red Meat Abattoir Association. Pretoria: Sentraaldruk. p. 31.

Watts, N.N. 1994. Dead bird composting. In: Campbell, K.L., Graham, D.W., Del Bottcher, A.B. *Environmentally Sound Agriculture*. Florida: American Society of Agricultural Engineers. pp. 379 – 382.

Wells, W.J. 1976. Inplant waste reduction in meat industry. Environmental Protection Technology Series Pubn. No. EPA 660/2-76-098

Westerndorf, M. L. 2000. *Food waste to animal feed*. United States of America: Iowa State University Press. pp. 8 -11.
(Westendorf, 2000).

Williams, C.M., Barker J.C. and Sims, J.T. 1999. Management and utilization of poultry wastes. *Rev Environ Contam Toxicol*.162. pp. 105 – 157.

Wilson, W.G. 2002. *Wilson's practical meat inspection*. (6th ed). USA: Blackwell Publishing. pp. 261 – 277.

Zhang, R. 2001. *Biology and Engineering of animal waste-water lagoon*. Biology and Agricultural Engineering Department. Davis: University of California. pp. 1 - 9.

CHAPTER THREE
METHODOLOGY

3.1 INTRODUCTION

A survey is defined as the structured or systematic collection of information about the same variables or characteristics from two or more cases that result in the forming of a data matrix (Stuart and Wayne, 1996). Regardless of the survey method used, the goal remains to obtain an accurate description for each defined variable in the survey. Surveys have mistakenly become synonymous with questionnaires, but other techniques such as structured and in-depth interviews, observations and content analyses also fit the survey definition (Coggon, 1995).

Primary data in this study was collected by means of administering written questionnaires. According to McBurney (1994) questionnaires have been proven to be the easiest yet reliable method of ensuring a complete data matrix, permits anonymity and may result in more honest responses, eliminates bias due to phrasing questions differently with different respondents and they are the most common method used in survey research. In addition, this is the speedy and accurate method of collecting data. Although they are one of the strongest measuring instruments used in descriptive relationship research, to be used as a valuable instrument, questionnaires must be reliable, indicate relationships and be applicable to the study (Lues, 2000).

3.2 PROJECT APPROACH

A literature review was first undertaken to obtain background information on poultry abattoir waste management practices worldwide. The manner in which poultry abattoirs operate, types of waste produced and handling thereof were studied.

3.3 SAMPLE REALISATION

3.3.1 Sample identification

The Public Health section of the Veterinary Laboratory in Bloemfontein (Department of Agriculture) was contacted and this body provided a list of all registered poultry abattoirs in South Africa. The list (obtainable from the Department of Agriculture) comprised abattoirs with various throughput levels, from rural, low-throughput to high-throughput abattoirs, depending on the number of slaughter units allowed per day. The directors of Veterinary Services from all the provinces were also contacted to confirm abattoirs that were still operational in their respective provinces.

For the purpose of this study, only high-throughput abattoirs (slaughter more than 2000 chickens/units daily) were selected as large amount of waste is being produced in this grade of abattoirs (Roberts, 2006).

3.3.2 Sample size

As per consultation with a statistician from the Central University of Technology, a random sample was selected as described by Stuart and Wayne (1996). From this consultation a representative total number of 26 abattoirs were included in the study, forming 76.4% of the total number of 34 high-throughput abattoirs in South Africa. The abattoirs included in the study were randomly selected from the list provided by Veterinary Services Directors from different provinces.

3.4 QUESTIONNAIRE DESIGN

A questionnaire to capture content and clarity on waste management practices and experiences in South Africa high-throughput poultry abattoirs was designed (Annexure 1). The order of questions in the questionnaire was developed to address the objectives of the study, background information of the respondents as well as slaughtering and operational status of the abattoir. Questions 1 to 3 covered aspects relating to slaughtering and operational status of each abattoir, questions 4 to 7 covers background information of the interviewee with the aim of being able to evaluate the reliability of information received, question 8 identifies the type of waste material generated, question 9 to 12 assesses if there are any in-house treatment method practices in South Africa while question 13 to 31 covers the current waste management practices and lastly question 32 evaluates the environmental pollution parameters associated with poultry abattoir waste management. A total of thirty-two (32) questions were included in the questionnaire and the questionnaire was compiled in English.

The wording was carefully formulated to eliminate any possible ambiguities (Katzenellenbogen, Joubert and Abdool-Karim, 1997). Open-ended questions which made provision for the respondent's comments and own perceptions were used. Closed-ended questions where the respondents must choose from a list of options available were also included (Collins, Du Plooy, Grobbelaar, Puttergill, Terre Blance, van Eeden, van Rensburg and Wigston, 2000).

To ensure that the questionnaire did not contain any ambiguity and that it could be understood and be easily completed accurately by the respondents as well as to ensure that data can be processed and reported correctly pilot-testing of the questionnaire was done by the researcher. The pilot study also assisted the researcher to assess any possible waste management practices that might occur. The questionnaire was pre-tested in seven (7) low-throughput poultry abattoirs in the Free State Province. These abattoirs were selected randomly, and did not form part of the final group of respondents. After completion, questionnaires were rephrased and refined according to inputs received. The revised version of the questionnaire was then used for data collection for the study.

3.5 DATA COLLECTION

3.5.1 Visits and meeting with the industry

Visits were arranged in order to collect information from abattoirs, based on the waste management practices of each abattoir. Abattoir management was requested in advance to allocate either owner, supervisor (senior employee) or any worker to partake in the visit and be available to be interviewed and to complete the questionnaire. On arrival the researcher introduced the team and clearly defined the purpose of the visit, the objectives, scope of the work, and the details of the project. The respondents (interviewees) were assured that information gathered would be strictly confidential and anonymity was guaranteed.

Formally structured interviews were conducted according to the pre-determined schedule. The same formulated questions were asked in the same order to every respondent. Although the questionnaires were compiled in English, the interviewer translated the questions into the preferred language of the respondent on request, to accommodate Afrikaans, South Sotho and Tswana speaking respondents. All interviews were conducted at the respective abattoirs during working hours.

3.6 GEOGRAPHICAL LOCATION OF THE STUDY

Abattoirs included in this study consisted of high-throughput poultry abattoirs with a slaughter capacity from 800 to 432 000 units per day. A total of twenty-six (26) questionnaires were completed. Figure 3.1 indicates a map of South Africa and the locations of high-throughput abattoirs visited. Eastern Cape: 3, Free State: 2,Kwazulu Natal: 3, Limpopo: 1, Mpumalanga: 4, Northern Cape: 4, North West: 3 Western Cape: 4, Gauteng: 2

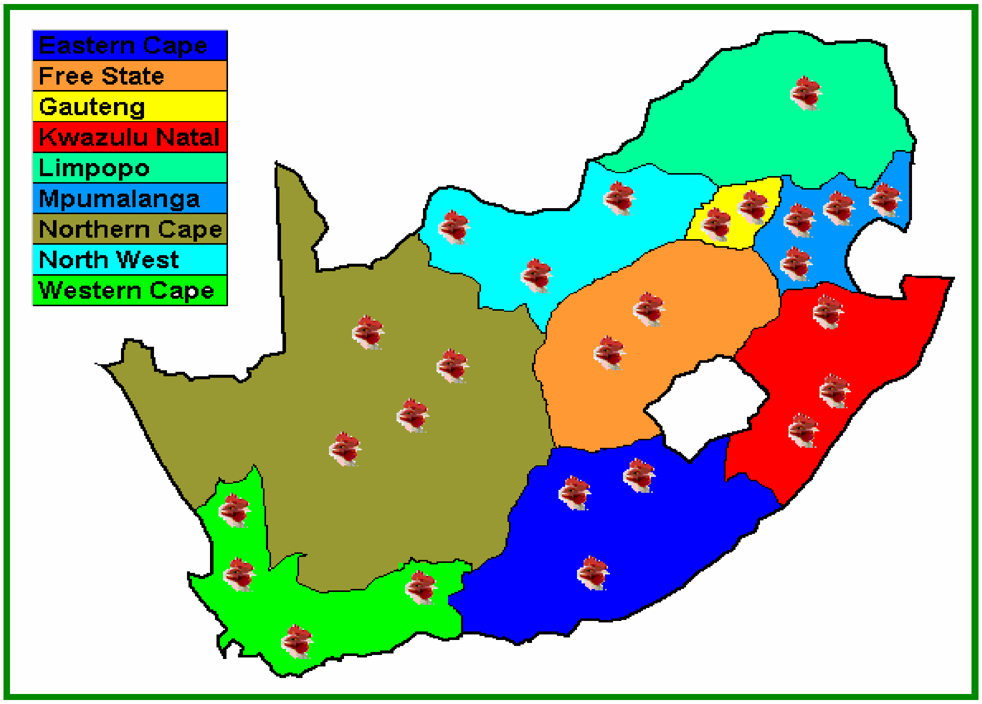

Figure 3.1 Areas in South Africa indicating the location of the high-throughput abattoirs included in the study

3.7 DATA PREPARATION AND STATISTICAL ANALYSIS

The questionnaires were pre-coded by hand and a code list was subsequently drawn up. The data was analysed using SAS/STAT program and frequencies and percentages were calculated (SAS/STAT, 1990).

3.8 CONCLUSION

Primary data in this study was collected by administrating written questionnaires. The order of questions in the questionnaires was developed to address the objectives of the study, background information of the respondents as well as slaughtering and operational status of the abattoirs. Formally structured interviews were conducted according to a predetermined schedule. A total of 26 abattoirs located within nine provinces of South Africa were included in the study. Data was analysed using the SAS/STAT Program.

3.9 REFERENCES

Coggon, D. 1995. Questionnaire based exposure assessment method. *Science of Total Environment.* 168. pp.175 -178.

Collins, K.J., Du Plooy, M.G., Grobbelaar M.L., Puttergill, C.H., Terre Blance, M.J., van Eeden, R., van Rensburg, G.H. and Wigston, D.J. 2000. *Research in Social Sciences*. Pretoria. University of South Africa. p.168.

Katzenellenbogen, J.M., Joubert, G. and Abdol Karims, S.S. 1997. *Epidemiology: A manual for South Africa*. Oxford University Press, Cape Town. p. 85

Lues, J.F.R. 2000. Research Methodology; a modular RBL Approach, Central University of Technology, Free State. p.67

McBurney, D.H. 1994. Research Methods.Brookes/Cole Publishing Company, Pacific Grove, California. pp 193 – 219

Roberts, H.A. 2006. Personal Communication. 07 February, Free State. 051 507 3129

Stuart, M. and Wayne, G.1996. Research Methodology – An introduction for science and Engineering Students. Juta and Company, Kenwyn Cape Town. p.4

SAS/STAT.1990.User's Guide. Version 6, Fourth Edition, Volume 2. Cary, NC:SAS Institute Inc. USA

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

This study presents and discusses the results of an extensive investigation on current waste management practices in South African high-throughput poultry abattoirs on the following objectives;

- Identification of the types of waste generated (Question 8),
- assessment of any in-house treatment processing (by-products production) and (Questions 9 – 12) ,
- Identification of existing waste management practices (collection, storage and disposal) (Questions 13 – 31) and,
- assessment of any environmental implications resulting from waste management practices and abattoir operations (Question 32).

For ease of comment on discussions, the study has been mapped into three sections, namely:

- **Background information of respondents (Question 1- 3)**

Position and work experience of interviewees

Waste management training courses attended

- **Slaughtering and operational status of each abattoir (Question 4- 7)**

Abattoir grading

Units slaughtered

Operation schedule

- **Waste management practices (Question 8 - 32)**

Management of solid and liquid waste in South Africa

By-products production in South Africa and

Environmental Impacts

4.2 BACKGROUND INFORMATION OF RESPONDENTS (Questions 4 – 7)

4.2.1 Position and work experience of the interviewees

Since arrangements were made before visiting the abattoirs, the management of the abattoirs was responsible for arranging for respondents' availability according to the business operations of each abattoir. Results depicted in Table 4.1 indicate the position and work experience of the respondents. Most of the respondents were supervisors (meat inspectors and quality assurance officers) (57.7%), followed by management (owners and shareholders) (34.6%) and then workers (7.7%). Work experience ranges from one to more than five years in the field. About twenty respondents (76.9%) had worked in the abattoir for more than five years. Other respondents had been involved with the abattoir operation for one to five years (19.2%), and six to twelve months (3.8%) respectively. Although the work experience and position differs between respondents, all respondents had knowledge of all activities taking place at the different areas of the abattoirs and waste management practices practiced thereof. This resulted in questions being answered appropriately.

Table 4.1 Position and work experience of the interviewees

	Frequency (n=26)	**Occurrence (%)**
Position of the interviewee in the work place		
Management	9	34.6
Supervisors	15	57.7
Worker	2	7.7
Work experience of the interviewee (abattoir)		
Six to twelve months	1	3.8
One to five years	5	19.2
More than five years	20	76.9

[a] The sub-categories were in some cases only answered by certain respondents and did not always include all 26 respondents. In cases where there were less than 26 respondents the exact numbers (n) are indicated in brackets.

4.2.2 Waste management training received by the interviewees

While the poultry industry employs a high proportion of un-skilled production workers, it also requires highly skilled personnel in research and development to manage and maintain the increasingly efficient and technologically advanced processing operations (Najafpour, Klason, Ackerson and Gaddy, 1994). Waste management within the poultry industry is one of the operations that need to be carefully considered and managed by skilled persons to ensure hygienically safe production of goods. In South Africa the Directorate Veterinary services of the National Department of Agriculture is the custodian of setting standards required for ensuring best hygiene practices at abattoirs (South Africa, 2007).

According to the survey, 34.6% of the respondents attended some waste management courses at different levels and study institutions or organisations, while 65.4% of the respondents have not attended any waste management training or courses (Table 4.2). Courses that have been identified to be completed by the respondents included amongst others Environmental Health (22.2%), Poultry Meat Examiners course (33.3%), and Meat Technology as well as GIMT (11.1%), which are all offered at respective universities of technology in South Africa. In all courses presented waste management is covered in course content either as a module or main subject. The remaining 22.2% stated that although they have been trained in waste management, it was offered as in-house training by a competent person.

Background knowledge of abattoir personnel regarding waste management increases the chance of an abattoir to follow good waste management practices and avoid negative environmental factors associated with improper management of waste.

Table 4.2 Waste management training received by interviewees

	Frequency (n=26)	Occurrence (%)
Undergone waste management courses		
Yes	9	34.6
No	17	65.4
Course and duration	**Frequency (n=9)**	**Occurrence (%)**
In-house training on waste management	2	22.2
B.Tech Environmental Health	2	22.2
Poultry Meat Examiners course	3	33.3
Meat Technology (Diploma)	1	11.1
GIMT	1	11.1

4.3 SLAUGHTERING AND OPERATIONAL STATUS OF POULTRY ABATTOIRS IN SOUTH AFRICA (Questions 1- 3)

The number of birds slaughtered as well as the slaughtering processes practiced at high-throughput poultry abattoirs play an important role on the amount of waste generated daily. The higher the number of birds slaughtered, the more load of waste is generated. Poultry abattoir waste has raised concerns about pollution and environmental safety (Najafpour.et.al., 1994).

4.3.1 Abattoir grading

In South Africa, the grading of the abattoir plays an important role as it determines the number of units (number of birds) that should be slaughtered daily per abattoir. Total of 88% of the respondents were able to classify the grade of their respective abattoirs according to the old classification (A = 46.2% and B = 42.3%) and the remaining 11.5% could not correctly classify their abattoirs grades. However, from the new classification perspective, eighty one percent (81%) of the respondents were able to classify their grade while the other 19% could not identify the grade as per new classification (Table 4.3).

4.3.2 Units slaughtered daily

In South Africa, amongst other requirements that should be considered while grading an abattoir is the number of birds/units to be slaughtered per day. A maximum total of more than 2000 units should be slaughtered for an abattoir to be graded as high-throughput (South Africa, 2006).

Although only high-throughput poultry abattoirs were included in the study, different numbers of slaughter units were recorded from different abattoirs. It was also noted that the difference in slaughter units depended on the market demand and on whether the abattoirs had an export licences or not (Mabe, 2006).

The results displayed in Table 4.3 indicate that 53.9 % of the abattoirs slaughter below and up to 20 000 units daily, 11.6% slaughter 20 001 to 40 000 units daily, 3.8% slaughter 40 001- 100 000 units daily, while the remaining 23.1% slaughter more than 100 000 units per day. Although all abattoirs were graded as high-throughput as per conditions of registration certificate, one respective abattoir slaughter less than the minimum units required per day (table 4.8). The number of birds slaughtered daily as well as the condition of birds, whether bruised, contaminated or diseased, influences the amount of waste generated requiring proper disposal (Mabe, 2006).

4.3.3 Number and days of slaughter per week

Table 4.3 indicates that the majority of abattoirs (73.1%) slaughter five days per week and (11.6%) slaughter six days per week. Other abattoirs slaughtered (7.7%) four days and lastly (3.8%) two or three days per week. Monday and Tuesday are reported to be days whereby 100% of the abattoirs included in the study slaughters, followed by Sunday (96.1%), Wednesday (92.3%), Fridays (84.6%), Saturday (11.5%) and lastly Thursday (3.8%). The days of slaughter vary from two to six days depending on the market demand per abattoir.

4.3.4 Number of shifts daily

Amongst the abattoirs that slaughter five to six days per week 26.9% operated on a 24-hour work schedule (day and night) with eight hour shifts each followed by a single cleaning shift, (table 4.3). The remaining 73.1% operated on a daily single shift.

The twenty-four hour work schedule practised in poultry processing abattoirs in South Africa is unique when compared to a previous study done on red meat abattoirs, which indicated that operation only took place in a single shift (Roberts, 2006). This indicates that poultry meat is in higher demand when compared to red meat.

Table 4.3 Slaughtering and operational status of high-throughput poultry abattoirs in South Africa

	Frequency (n=26)	**Occurrence (%)**
Grade of the abattoir		
Old grading		
A	12	46.2
B	11	42.3
Does not know	3	11.5
New grading		
High-throughput	21	81
Does not know	5	19
Units slaughtered daily		
*800 - 20 000	14	53.9
20 001 – 40 000	3	11.6
40 001 – 60 000	1	3.8
60 001 – 80 000	1	3.8
80 001 – 100 000	1	3.8
More than 100 001	6	23.1
Days of slaughter		
Monday	26	100
Tuesday	26	100
Wednesday	24	92.3
Thursday	1	3.8
Friday	22	84.6
Saturday	3	11.5
Sunday	25	96.6
Number of shifts		
Single shift	19	73.1
Double shifts	7	26.9
Number of days of slaughter per week		
2 days	1	3.8
3 days	1	3.8
4 days	2	7.7
5 days	19	73.1
6 days	3	11.6

4.4 SOLID WASTE MANAGEMENT PRACTICES (Question 8,13 - 31)

Poultry abattoirs generate significant volumes of both solid and liquid waste. Improper disposal of these materials can cause pollution and degeneration of ecosystems, if they are not utilised to produce useful by-products (Kherrati, Faid, Elychioui, and Wahmane, 1998).

4.4.1 Waste material identified (Question 8)

The poultry abattoir waste material identified in literature includes, dead-on-arrivals, feathers, trachea, oesophagus, gall bladder, proventriculus, crop, cloacae, anus, blood, waste-water and manure (small amounts) (Salminen and Rintala, 2002). Although many of these materials are regarded as waste and dumped, considerable progress has recently been made in utilising them (Blake, 1998). According to the study, the same waste materials were identified as shown in Table 4.4 with some additional items such as gizzard contents, trimmed meat off-cuts, caeca and fat. Some abattoirs also mentioned feet and intestines as part of waste materials although regarded as edible products in South African legislation (South Africa, 2000).

Normal abattoir protocol for all condemned materials and wastes which poses possible health threat is held under secure conditions until disposed of in accordance to legislation.

Table 4.4 Waste materials identified

Waste materials identified	Frequency (n=26)	Occurrence (%)
Feathers	26	100
Blood	26	100
Trimmed meat off-cuts	25	96.2
Feacal matter	21	80.7
Condemned chickens (DOA)	26	100
Waste-water	26	100

Waste materials identified	Frequency (n=26)	Occurrence (%)
Feet	7	26.9
Intestines (mala)	11	42.3
Gizzard contents	1	3.8
Caeca	1	3.8

4.4.2 Blood waste management (Question 13 – 16)

Blood waste is a slaughterhouse by-product that has potential for usage in both animal feed and human food, because of its high protein concentration and quality (Gomez-Juarez, Castellanos, Ponce-Noyola, Calderon and Figueroa, 1999). In South Africa blood is regarded as either waste material or an ingredient for by-production within the poultry meat industry. This is mainly because it is used to some extent as a by-product while others dispose of it as waste material. In poultry abattoirs, blood waste requires appropriate management on a daily basis that includes suitable collection and storage facilities to ensure proper hygiene standards especially if blood is intended for use as a by-product. Table 4.5 depicts different blood waste management facilities used by abattoirs in South Africa.

Table 4.5 Blood waste management

	Abattoirs (n=26)	Occurrence (%)
Blood collection facilities		
Blood troughs	14	53.9
50ℓ plastic containers	10	38.5
750ℓ green plastic tanks	2	7.6
Blood storage areas		
Outside abattoir premises (open space)	8	30.8
Dirty area (storage room)	4	15.4
By-product processing	14	53.8
Blood disposal methods		
Municipal sewer	2	7.6
Burial method	9	34.6

Blood disposal methods	Abattoirs (n=26)	Occurrence (%)
Rendering	12	46.1
Collected by contractors (animal fodder)	3	11.5
Run-off onto the fields (Land application)	1	3.8

i. Blood collection and storage systems

Different collection methods are used in different abattoirs as indicated in Table 4.5. According to the recorded results, 53.9% of the abattoirs utilise blood troughs, which pipe blood directly from the collection point into the storage tank, where it is stored until further processing. Some abattoirs, especially those that do not produce any by-products either on-site or on the other premises have blood still collected with blood troughs from the slaughter floor and discharged into containers such as 50ℓ plastic containers (38.5%) and 750ℓ green tanks (7.6%) for storage prior to disposal.

The abattoirs that do not have a by-product processing plant on-site, either store the accumulated blood in the storage room in the dirty area of the abattoir (15.4%) or in open space (30.8%) next to the abattoir premises. This storage arrangement is under the supervision of the meat inspector or dedicated worker until proper disposal takes place or blood is transported to a by-product processing plant.

ii. Blood disposal methods

In South Africa approximately 46% of the high-throughput poultry abattoirs render blood waste into several kinds of by-products as compared to disposal. The most commonly identified blood waste disposal methods are discussed and these include, municipal sewer (7.6%), burial (34.6%), sold to contractors (11.5%), land application (3.8%) and rendering (46.1%) as indicated in Table 4.5. Although rendering is a by-product processing method, it is also classified as a disposal method. It was also observed that in some abattoirs more that one type of disposal method was used depending on quantity of blood available for disposal.

(a) Rendering

Rendering of blood is utilised by total of 46.1% of abattoirs for production of by-products such as blood meal, poultry meal and fertilisers. Rendering of blood in the production of blood by-product involves the cooking of blood in a cooker. A large proportion of the water is evaporated in dry-rendering cookers and the material is reduced to 8% moisture content. The dehydrated material is then pressed to remove the excess fat. Finally the product is ground to a size small enough to pass through size eight to twelve mesh screens. After sieving, the product is weighed and stored in bags until sold to farmers who use it for different purposes such as use as feed supplement and as fertilisers (Mountney, 1989).

(b) Burial

According to the survey, burial is the second (34.6%) most common method of blood waste disposal utilised because of low cost and convenience. However according to literature this method is becoming less desirable since it contributes to potential problems of surface and ground-water contamination due to high organic pollutant (biochemical oxygen demand) and microbial loads (Kherrati, *et.al.,* 1998). In South Africa in order to comply with legislation, the following guidelines must be met when utilising this method. A secure site must be approved by the provincial executive officer or local government and there should be immediate covering to a depth of at least 60cm and not less than 100m from the abattoir (South Africa, 2000).

(c) Municipal sewer

One method for the disposal of blood waste is by discharge into a municipal sewer. Blood waste is transported through the drains from abattoirs into municipal sewers where it is later treated as waste-water. In some abattoirs high proportions of blood leaves the premises raw, while in others it is mixed with other abattoir liquid waste.

There are strict legal requirements (by-laws) that abattoirs must comply with before utilising this method. This method is associated with severe environmental challenges and high financial rates charged by municipality for treating waste-water (Gomez-Juarez *et al.,* 1999). A total of 7.6% of abattoirs according to the survey utilises this method.

(d) Collection by farmers

Presently there is an interest to process abattoir blood waste to present a drier product for animal feeding. This is mainly because dry products have a longer shelf life, are easier to feed and could be included as part of a complete diet. However the collection of fresh abattoir blood waste for feeding animals still continues and will probably continue for the foreseeable future (Westerndorf, 2000). Blood waste is collected and utilised by farmers (11.5%) as an ingredient in animal feed-stuff especially while still fresh although some use it after being sun dried. According Jeffrey (2006) (Blake, 1998) blood is a good source of protein for animals.

(e) Land application

Disposal of blood through land application is practised by a small number of abattoirs in South Africa (3.8%). Hepburn, MacRae and Ogden (2002) indicates that if blood disposed of in this manner contains *E. coli 0157,* there is a possibility of growth and spreading of this organism, which may contaminate nearby crops and water sources ultimately entering the human food chain. This method of disposal is not legally approved in South Africa although some abattoirs utilise it.

4.4.3 Feather waste management (Questions 17 – 21)

Feathers are regarded as one of the most important waste material in poultry production due to different products that can be processed from them. At the poultry abattoirs, feathers are removed from birds by defeathering machines, equipped with rotating rubber fingers so that skin is not damaged (Blake, 2004). The feathers can either be processed to produce a valuable by-product or collected for disposal as waste.

i. Feather collection and storage facilities

Feathers are collected in a flume and pumped over screens to drain water before further processing or dumping. Thereafter several collection facilities as displayed in Table 4.6 are used according to abattoir preferences. These amongst others, include black rubbish bags (15.6%) plastic containers/drums with lids (19.2%), stainless steel drums (19.2%), wheelie bins (11.5%) and crates (3.8%), while the remaining 30.9% of abattoirs use conveyers to transport feathers from the de-feathering area to the by-production facility.

Storing practices of feather waste and blood waste is basically the same. Feathers are also either stored at the dirty area of the abattoir in different kinds of collection facilities or an open space next to the abattoir prior to disposal or further processing.

ii. Disposal methods

Since most abattoirs in the country are service-oriented and only the killing and dressing of chickens takes place on-site, disposal of feathers is a great challenge to these abattoirs. Different disposal methods as displayed in Table 4.6 are used. The most commonly used methods include: composting (7.7%), burning (open fire) (11.5%), sold to other companies (19.2%), rendering (42.3%), and burial (19.2%), respectively, as discussed.

Table 4.6 Feather waste management

	Frequency (n=26)	**Occurrence (%)**
Feather collection containers		
Creates	1	3.8
Wheelie bins	3	11.5
Stainless steel drums	5	19.2
Black rubbish bags	4	15.6
Plastic drums/containers with lids	5	19.2
Conveyors	8	30.9
Feathers disposal methods		
Rendering	11	42.3
Sold to other companies	5	19.2
Burial	5	19.2.
Composting	2	7.7
Burning	3	11.5
Feather processing facility on-site		
Yes	6	23.1
No	20	76.9
	Frequency (n=7)	**Occurrence (%)**
Feather by-products		
Feather meal	2	7.6
By-products meal	2	7.6
Blood and feather meal	1	3.8
Poultry meal	2	7.6

(a) Composting

Composting is used by at least 7.7% of the abattoirs that took place in the study. This method has emerged as an environmentally and biologically safe disposal alternative. It enables on-farm conversion of daily disposal into humus-like soil enrichment (Blake, 1998). Although composting has gained extensive approval as an effective option, it involves heavy equipment, high-cost and attention to detail. Despite its extensive use in this country and worldwide, composting is not a legislated disposal option for poultry and animal waste in South Africa.

(b) Burning (open fire)

Burning of waste is a method of disposal utilised by 11.5% of the abattoirs included in the study. Burning can either be done by means of open fire or by incineration. According to the respondents most abattoirs use the open fire method, whereby feathers are allowed to dry (sun-dried) and are then burned. This indicates that none of the abattoirs utilising this method complies with South African legislation - Meat Safety Act (Act 40 of 2000) (South Africa, 2000) whereby total incineration instead of open fire burning is prescribed.

(c) Sold to other companies

While most abattoirs either dispose of or process feather waste within their territory, 19.2% of abattoirs sell feather waste to nearby abattoirs with rendering facilities. To prevent contamination or any health threats, it was indicated that a transport protocol for collection and transportation of the material existed. There was one exception where the respondents indicated that they sell feather waste to farmers who use it for making fertilisers.

(d) Rendering

The increasing number of birds slaughtered daily has intensified the problem of disposal of feathers. Processing of feathers as a feedstuff has been identified as an advantage in solving the world's protein needs by producing more animal protein (El-Boushy, Van der Poel and Walraven, 1990). According to the study 42.3% of the abattoirs process raw feathers in production of either poultry meal, whereby all condemned waste materials are mixed and cooked together, or as feather meal, where only clean feathers are rendered. These feathers are hydrolysed or pressure-cooked with steam until they form an edible gel which makes them an acceptable feed ingredient. The hydrolysed feather meal is sold to farmers who grow broilers, layers and turkeys. The mixture adds a nutritious value to well-balanced diets without harmful effects as far as production or health is concerned (Mountney, 1989).

(e) Burial

Burial is an original method of disposal and is usually the most convenient. Disposal pits have been used with varying degrees of success by poultry abattoirs (Blake, 1998). According to the study, 19.2% of abattoirs utilise burial to dispose of feathers. Burial pits are either situated on abattoir premises or less than 500 metres outside abattoir perimeters.

4.4.4 Handling of other condemned waste material (Questions 29 – 31)

Condemned waste material refers to dead-on-arrivals, those carcasses and portions of meat condemned by the meat inspector which are regarded as a possible health threat to consumers, and all pieces of debris collected during continuous cleaning (South Africa, 2006). Condemned waste, although still rich in proteins and fats, cannot be used for human consumption due to the presence of pathogenic organisms; therefore it needs to be disposed of in a safe and environmentally friendly manner (Bianchi, Cherubini, De Pascale, Peretto and Elmegaard, 2005).

From the survey it was evident that all abattoirs are responsible for generation of condemned waste during transportation (dead on arrivals), slaughtering process, meat inspections as well as cleaning. This waste is normally handled in a strict manner so as to avoid the spread of diseases and infections to the consumers and the environment. The most commonly identified disposal methods are displayed in Table 4.7.

Table 4.7 Handling of other condemned material

	Frequency (n=26)	Occurrence (%)
Disposal methods		
Rendering	11	42.3
Collected by contractors (Farmers)	6	23.2
Burial	7	26.9
Municipal landfill	2	7.7

i. Disposal methods

Identified methods of disposal for these types of waste as per results of the study include rendering (42.3%), burial (26.9%), contractor collection (23.2%) and municipal landfill (7.7%). However, as mentioned by the respondents some of these methods are currently becoming less acceptable or feasible in certain areas because of excessive costs and restrictive legislation requirements (Mahrends, 2006).

Of all these methods, rendering was the most prevalent method. It recycles the nutrients contained in condemned material into a nutritionally valuable and biologically safe protein by-product meal, and also minimises the risk of environmental pollution. This is followed by burial because of its low cost and convenience. However, this method is becoming less desirable since it contributes to potential problems of surface and groundwater contamination (Blake, 1998). Although burial is a legally approved method of disposal, it is evident that the correct procedure as prescribed by legislation is not followed by most of the abattoirs as, according to the respondents, condemned materials are actually not denatured before being buried (South Africa, 2000). Selling condemned waste to contractors/farmers who utilise it for different purposes from feeding animals and fertiliser's purposes was also identified.

Although municipal landfill is not a legally prescribed method of disposal for abattoirs in South Africa according to the Meat Safety Act 40 (South Africa, 2000), about 7.7% of abattoirs utilise this method. According to the respondents, disposal in landfill was treated as an equivalent to burial. However it should not be treated in this way as the burial requirements are not met. The use of municipal landfills for disposal carries some negative environmental implications and a high probability rate of disease transmission, especially in South Africa, since there are several scavengers living and feeding off landfill sites.

In Canada for instance, disposal at municipal landfills is a regulated method of abattoir waste disposal only used during emergency situations. This refers to natural disasters (fire, flood and extreme weather conditions) or animal disease outbreaks which usually require the mass disposal of infected or potentially infected animals. However, during such outbreaks, decisions are made quickly about where and how to dispose of waste to limit the spread of disease and to prevent danger to the public or the environment (Gilberto, Pilar and Roger, 2003).

4.4.5 Handling of feet, heads and intestines (Question 28)

Although South African legislation classifies feet, heads and intestines as rough edible products (South Africa, 2006), this is not the case with some other international countries in Canada for example, where they are regarded as waste material and are therefore condemned (Bianchi,*et.al.,*2005). Results recorded in table 4.8 indicates that (100%) of abattoirs identified feet, heads and intestines as edible offal, although from the same respondents 42.3% are disposing them as part of waste material especially for by-product processing purposes.

Feet, heads and intestines are therefore like other edible products, washed, packaged, labelled and chilled at -2˚C until dispatched. Vehicles that comply with legislation requirements transport them to respective clients.

Table 4.8 Handling feet, heads and intestines

	Frequency (n=26)	Occurrence (%)
Identify as		
Rough edible offal	26	100
Waste material	11	42.3

4.5 WASTE-WATER MANAGEMENT PRACTICES (Questions 22 – 27)

4.5 1 Magnitude of water used per abattoir

High-throughput poultry abattoirs process much higher numbers of birds than low-throughput and rural abattoirs respectively and therefore utilise great volumes of water on a daily basis. According to Bremner and Johnston (1996), it is estimated that 15 to 20 litres of water is required per bird, resulting in about 80 to 85% of water being discharged as waste-water. This waste-water contains contaminated waste material such as blood, bits of meat, fat, gizzard and intestinal contents and feathers.

Table 4.9 outlines the amount of waste-water generated from different abattoirs included in the study. It is estimated that 7 to 18 litres of palatable water is used per bird. Although the consumption of water used varies widely, the processes used in the abattoir also play a role on the magnitude of waste-water produced (Caixeta, Cammarota and Xavier, 2002). An abattoir slaughtering a large number of birds per day will have increased water intake due to operations that require water such as the cleaning and rendering process (Mabe, 2006).

4.5.2 Sources of water consumption

The same sources of water consumption as identified in literature were identified by the respondents. These include: (i) scalding for feather removal, (ii) bird washing before and after evisceration, (iii) chilling, (iv) cleaning and sanitising equipment and facilities, and (v) cooling of mechanical equipment. However amongst other uses identified, the rendering process was identified as one process that utilises great quantities of water. Water is used for raw material cooking and sterilisation, condensing cooking vapours, plant clean-up, truck and barrel washing when materials from off-site locations are being processed, odour control and steam generation. This leads to a significant amount of waste-water generation (Theron, 2006).

Table 4.9 Amount of water used per high-throughput poultry abattoir

Abattoir	Birds slaughtered / day	Water use (ℓ / bird)
1	240 000	12.5
2	213 000	17
3	37 000	15
4	25 000	14
5	140 000	20
6	25 000	15
7	9 000	7
8	82 000	18
9	15 000	13
10	7 000	16
11	432 000	16
12	7 000	13
13	10 000	16
14	55 000	12
15	4 000	15
16	25 000	12
17	288 000	13
18	15 000	15
19	9 000	13
20	65 000	12
21	31000	16
22	800	10
23	16 000	16
24	10 000	11
25	2 000	12
26	12 000	13
Lowest	**800**	**10**
Highest	**432 000**	**14**

4.5.3 Waste-water treatment processes

The meat industry is characterised by high water consumption and since the waste-water released from the abattoirs is highly loaded with waste material, it should be thoroughly pre-treated prior to discharge. Pre-treatment helps the plant to achieve legal compliance with established state environmental regulations (Bohdziewicz, Sroka and Korus, 2003). Depending on the degree of treatment required, poultry abattoirs have the option of utilising preliminary, primary, secondary or tertiary treatment systems with different alternatives in treatment processes (Shin, 1987). Waste-water treatment processes as displayed in Table 4.9 show that 100% of abattoirs concluded in the survey utilise some form of treatment. Fifteen percent (15.3%) of the respondents reported using a combination of preliminary, primary, secondary and tertiary treatment, 26% utilises primary treatment, 34.6% utilises secondary treatment and 11.5% utilises tertiary treatment. Preliminary treatment, by means of screens of different sizes, fat traps and grit chambers for removal of coarser particles are utilised by all abattoirs. The most popular form of screen is the rotary screen (Mahrends, 2006).

Table 4.10 Waste-water treatment processes

	Frequency (n=26)	**Occurrence (%)**
Pre-treatment	**26**	**100**
Screens, Fat traps, Grit chambers		
Primary treatment	**7**	**26**
Settling tanks, Dissolved air flotation, Chemicals (addition of softners)		
Secondary Treatment	**9**	**34.6**
Naturation dams, Aerobic lagoons, Anaerobic methods		
Tertiary Treatment	**3**	**11.5**
Lipage producing bacteria		
Combination of treatment options	**4**	**15.3**

4.5.4 Use of partially treated effluent

Waste-water pre-treatment is becoming a critical element in the managing of water resources. The researcher therefore, questioned whether pre-treated waste-water was used. Results as shown in Table 4.11 indicate that 50% of abattoirs re-use partially treated waste-water while the remaining half does not. The biggest single use for pre-treated waste-water in poultry abattoirs is irrigation (62%), while the remaining 38% is used to transport feathers and inedible offal for further processing (rendering). The major irrigation activities included: (i) landscape watering and (ii) irrigation of pastures, crops and forest plantation. Effluent irrigation is encouraged when it is safe and practicable and where it provides the best environmental outcome (Visser, 2006).

Table 4.11 Use of partially treated waste-water

	Frequency (n=26)	**Occurrence (%)**
Pre-treatment of waste-water within abattoir premises		
Yes	13	50
No	13	50
Uses of partially treated waste-water	**Frequency (n=26)**	**Occurrence (%)**
Feather transportation	5	38
Irrigation	8	62

4.5.5 Waste-water discharge options

The method of waste-water discharge according to abattoirs included in the study is indicated in table 4.12. These include municipal treatment plants (23%), overland flow (19.2%), French drains (3.8%), constructed wetlands (dams) (42%) and water courses (12%).

Table 4.12 Waste-water discharge options

	Frequency (n=26)	Occurrence (%)
Waste-water discharge options		
Municipal treatment plant	6	23
Overland flow	5	19.2
Constructed wetlands (dams)	11	42
Watercourses	3	12
French drains	1	3.8

i. Watercourses

Twelve percent of the poultry abattoirs dispose of waste-water in running water (river) or dams according to recorded results. In South Africa waste-water discharged into watercourses must comply with the general standards of receiving water quality objectives, based on the appropriate level of reserve determination, to avoid destruction of aquatic life (South Africa, 2001). According to Hairston (2001), abattoirs that discharge waste-water into streams and canals could contribute to the destruction of aquatic life down stream.

ii. Municipal sewer

If the local sewage treatment plant has the capacity for additional hydraulic, organic and nutrient loading from a meat processing, it may accept partially treated or tertiary treated effluent from the plant (Johns, 1995). Abattoirs are expected to keep their solids and feathers to a minimum in order to comply with municipal by-laws. This rate could be typically described as COD≤3000 to 5000mg/ℓ; TSS ≤500mg/ℓ; NH_3 – N ≤ 200 to 300mg /ℓ: pH 6 – 10. The acceptance criteria depend on the distance between the treatment plant and abattoir and the capacity of the treatment plant, annual cost of BOD and nutrient load (De Villiers, 2000). A total of 42% of the abattoirs discharge poultry waste-water into municipal sewers. Although waste-water is treated solely by municipalities, each abattoir that utilises this method is expected by law to pay a municipal levy towards waste-water treatment.

iii. Land application/Irrigation Disposal

Disposal of waste-water by land application is practised by 19% of the abattoirs included in the study. This method is mostly practised in rural areas where there is plenty of space. It was evident that abattoirs that utilise this method are disposing of waste-water in this method with the purpose of fertilising the plants or for soil enrichment. Banana and paw-paw plantations as well as lawn were identified as being watered with abattoir waste-water. Some of the applied water is lost to the atmosphere by evaporation and evapo-transpiration. A part of the nutrients in the water will also be taken up by the plants and used for growth or could be retained in the soils. However, excessive nutrients discharged in the soil can result into groundwater contamination (Kurup, 2007).

iv. Constructed wetlands (dams)

While some abattoirs dispose of waste-water without using it, others (42%) have constructed dams within the abattoir premises where they discharge the waste-water so that it can be re-used later. Most of these abattoirs use this water for agricultural purposes, similar to those mentioned in land application (Visser, 2006).

4.6 POULTRY ABATTOIR BY-PRODUCTS PRODUCTION (Questions 9 – 12)

Abattoirs are facing the task of treating and disposing of waste. Certain treatment methods and techniques have been reviewed and used for production of waste by-products. Some of these new strategies are environmentally friendly and cost effective (Mijinyawa and Dlamini, 2006). Some of the by-products produced according to literature vary from animal feed, human feed, fuel and fertilisers

(Kherrati, *et.al.,* 1998). For instance, in the United States, Conoco Philips and Tyson Foods have joined forces to produce diesel fuel from animal and poultry by-products. Produced renewable diesel fuel supplement petroleum-based diesel fuel supplies (Huntley, 2007).

In South Africa, the increasing number of poultry abattoirs has intensified the problem of disposal of poultry waste as well. Offal and feathers generated have led to the industry opting to process poultry waste into by-products as feedstuff for animals and fertiliser. Table 4.13 shows an overview of by-product production in South Africa. The results recorded in this study indicated that 42.3% of high-throughput abattoirs produce by-products while the remaining 57.7% either dispose of their waste without further processing or give it to farmers (contractors) who feed their animals.

4.6.1 Methods of processing

According to the study, three different processing methods were identified to be utilised in South African high-throughput abattoirs. These include: (i) rendering method (81.8 %), (ii) washing method (9.1%) which mainly involves washing of edible offal before packaging and (iii) boiler operation (9.1%), table 4.13.

4.6.2 Types of poultry by-products

Five different types of by-products that differ according to the composition of the raw materials were identified to be produced at various abattoirs included in the study. These include feather meal (21.4%), poultry meal (57.1%), blood meal (7.1%), poultry oil (7.1%), (Table 4.13). For some abattoirs more that one by-product is produced.

Table 4.13 By-products production

	Frequency	Occurrence (%)
Production of by-products (n=26)		
Yes	11	42.3
No	15	57.7
Types of by-products produced (n=11)		
Blood meal	1	7.1
Feather meal	3	21.4
Carcass meal (Poultry meal)	8	57.1
Poultry oil	1	7.1
Method of processing (n=11)		
Rendering	9	81.8
Boiler operation	1	9.1
Washing, packaging and chilling	1	9.1
Market for rendered end-products (n=13)		
Animal feeds manufactures	10	77
Poultry grower companies	2	15
Fertilisers manufactures	1	8

i. Feather meal

Feather meal refers to the product resulting from the treatment of clean feathers, free from any additives. According to the results recorded in the study, 21.4% of the abattoirs indicated that they produce feather meal. Raw feathers are processed by means of pressure-cooking between 207 and 690kPa, over a time period of 6 to 60 minutes, and with moisture levels ranging from 60 to 70%. This breaks down keratinous material in feathers, resulting in a hydrolyzed feather meal with a 70% digestible crude protein (El-Boushy, *et.al.,* 1990). Some additions to the product, such as dried whey powder, are made to increase the nutritive value of the product (Mahrends, 2006). This product is sold to poultry grower companies.

ii. Blood meal

Maximum recovery of blood within poultry abattoirs is done for the production of blood meal. Recorded results indicated that 7.1% of the abattoirs recover the blood for the production of blood meal. Blood meal is processed by using the rendering method. It has been scientifically proven that blood meal contains a high nutritive value and therefore is being used as a feed supplement for animals (Gomez-Juarez *et. al*. 1999).

iii. Poultry (carcass) meal

Poultry meal is a mixture of blood, feathers and other condemned organic material, in their natural proportions. A mixture of these by-products produces a more nutritionally-balanced product than any other formulations, but entails a longer cooking process because the feathers are harder to decompose than offal. This is a commonly produced by-product in the country as about 57.1% of the abattoirs produce poultry meal. Depending on the processing method involved, poultry meal can be used as animal feed supplement or as a fertiliser. Broiler growers were identified as the main consumers of poultry meal in South Africa. However, in some countries, poultry meal consists of clean, rendered, wholesome parts such as heads, feet, gizzards and intestines but not feathers except the few that might be included in the normal processing and collection practice (Mountney, 1989).

iv. Poultry oil

According to the study one abattoir (7.1%) indicated that they produce poultry oil. Poultry oil is a product of rendering of parts of the carcass of slaughtered poultry. It is light brown in colour and smooth with an oily texture.

4.6.3 Markets available for rendered by-products

Almost all chicken waste have the potential be used to produce a useful commodity. It may not always be possible, however, to find an economic market for all by-products. This will depend on the scale of operation, the cultural and culinary characteristics of the region and the distance to suitable markets. The principal end products from the rendering process are poultry feeds as well fertilisers. The main identified markets as identified in the study (table 4.13) are: (i) animal feeds manufacturers (77%), (ii) poultry growers (15%) and (iii) fertilisers manufacturers (8%) and are discussed

i. Animal feeds manufacturers

The largest market for poultry by-products is animal feeds, as these products are high in protein and other key nutrients. After preparation, by-product meal is mixed with pet meals, pellets or other animal fodder.

ii. Poultry growers companies

The secondary market is chicken growers whereby the by-products, especially poultry meal and blood meal, is mixed in chicken feeds.

iii. Fertiliser manufacturers

To some extent, rendered by-products are being used in production of fertilisers. The treated wastes are rich in nitrogen, calcium, phosphorus and trace elements that may be of great benefit when used as fertiliser.

4.7 IMPACT OF POULTRY ABATTOIR WASTE ON THE ENVIRONMENT (Question 32)

4.7.1 Environmental implications

According to Hairston (2001), abattoirs can contribute towards the pollution of the environment. A question (32) was therefore asked to determine whether the respondents were aware of any pollution or environmental implications caused by the abattoir operation or waste material generated. The responses in Table 4.14 depict that only 15.4% of the respondents indicated that they were aware of the danger to the environment inherent to improper management of poultry waste, though they disagreed that their disposal method constituted a threat to that environment. Most of the respondents (84.6%) disagreed that improper waste management can result in any environmental threat. Of the 84.6% who disagreed that waste material could constitute an environmental threat, 35% agreed that odour from waste rendering facilities and disposal sites could lead to discomfort to the neighbourhood.

Table 4.14 Environmental implications

	Frequency (n=26)	**Occurrence (%)**
Aware of any environmental implications		
Yes	4	15.4
No	22	84.6
Indices of environmental implications in South African poultry abattoirs		
Air pollution	4	50
Water pollution	2	25
Soil/land pollution	2	25

4.7.2 Identified environmental indices in South African poultry abattoirs

According to the results, environmental indices as indicated in Table 4.14 include: air pollution, water pollution and land/soil pollution.

i. Air pollution

According to responses, 50% of respondents identified air pollution as one of the factors associated with abattoir waste. Apart from this, odours from poultry slaughtering, effluent treatment ponds and irrigation areas with inadequate levels of effluent treatment, as well as odours from rendering plants with inadequate maintenance of ducting designed to capture vapours from cookers, were identified and believed to have an impact on human health and the environment. Smoke from open air burning of significant quantities of waste was also identified as a possible source of air pollution that can impact on the environment.

ii. Water pollution

Effluent management is one of the primary environmental issues relating to poultry abattoirs facilities. Water pollution resulting from poultry waste generated was identified by the respondents (25%) as one of the negative indices affecting the environment. It was indicated that disposal of excessive quantities of nutrients into the streams and wetlands as practised by certain abattoirs may contribute to several pollution problems or may lead to environmental degradation. Poorly-operated effluent treatment systems and irrigation areas are considered to be the most likely potential sources of ground-water contamination. Some of the impacts identified by respondents includes;

- High levels of suspended solids can reduce light transmission of water columns, increases turbidity and have deleterious effects on aquatic life such as clogging of fish.
- Waste-water have high biochemical oxygen demand, therefore can use up all available oxygen in waterways. This generates offensive odours and kills aquatic life and,
- Pathogenic organisms such as bacteria and viruses that are harmful to humans and animals can be introduced to waterways.

iii. Land/soil pollution

Soil pollution has been identified by 25% (table 4.14) of the respondents as one of the environmental implications caused by improper management of poultry abattoir waste. It normally occurs when organic poultry waste is applied repeatedly in large amounts and the treated soil accumulates heavy metals and consequently become unable to support plant and soil organism's life.

Soil pollution can lead to water pollution if contaminated run-offs reach streams or lakes and can also lead to air pollution by releasing volatile compounds into the atmosphere (Kurup, 2007).

4.8 CONCLUSION

Despite legislation governing the management of waste poultry abattoirs in South Africa, abattoirs still face serious problems of high volumes of waste, characterized by inadequate disposal technologies leading to environmental and public health implications to nearby communities. Waste material is still not being disposed of properly. Ground water is being contaminated, air pollution exists and disposal sites are health hazards to scavengers.

4.9 REFERENCES

Bianchi, M., Cherubini, F., De Pascale, A. Peretto, A. and Elmegaard, B. 2005. Cogeneration from poultry industry waste-indirectly fired gas turbine application.Energy.31. (10-11) August. 1417-1436

Blake, J.P. 1998. Managing and re-processing of poultry by-products. Department of Poultry Science. Auburn University. Auburn USA. pp 1 – 11.

Blake, J.P. 2004. Methods and technologies for handling mortality losses. *World Poultry Science Journal*. 60 (4). pp. 489 – 499.

Bohdziewicz, J., Sroka, E. and Korus, J. 2003. Application of ultrafiltration and reverse osmosis to the treatment of the waste-water produced by the meat industry. *Polish Journal of Environmental Studies*. 12 (3). p. 269.

Bremner, A. and Johnston, M. 1996. *Poultry Meat Hygiene and Inspection*. London: W.B.Saunders Company Ltd. p. 35.

Caixeta, C.E.T., Cammarota, M.C. and Xavier, A.M. 2002. Slaughterhouse waste-water treatment evaluation of new three phase separation system in a UASB reactor. *Bioresource Technology* 81(1). pp. 61- 69.

De Villiers, G.H. 2000. Abattoir effluent treatment and protein production: full scale application. Water SA. 26 (4). October. pp. 559 - 562.

El-Boushy, A.R., Van der Poel, A.F.B., and Walraven, O.E.D. 1990. Feather meal – a biological waste: its processing and utilization as a feedstuff for poultry. Biological Wastes. Vol 32, Issue (1). pp. 39-74.

Gilberto, I., Pilar,V. and Roger. M.R. 2003. Tequila, slaughterhouse waste and composting. *Biocycle International*. Newspaper, August. pp. 57 – 60.

Gomez-Juarez, C, Castellanos, R., Ponce-Noyola, T., Calderon, V. and Figueroa, J. 1999. Protein recovery from slaughterhouse wastes. *Bioresource Technology*. Vol 70 (2). pp. 129-133.

Hairston, J.E. 2001. Animal waste and how it affects water quality. USA: Alabama A and M University and Auburn University. pp. 1-3.

Hepburn, N.F., MacRae, M and Ogden, I.D. 2002. Survival of Escherichia coli 0157 in abattoir waste products. *Applied Food Microbiology Group*. UK: Department of Medical Microbiology, University of Aberdeen. 35. pp. 233- 236.

Huntley, M.E. 2007. US firms to make biofuel from beef, poultry by-products. *Financial Times Newspaper*, 05 May 2007. p. 6.

Jeffrey. M. 2006. Personal communication. 03 June , Mpumalanga. 013 733 4133

Johns, R.M. 1995. Development in waste-water treatment in the meat processing industry: a review. *Bioresource Technology*. 54 (3). pp. 203 - 216.

Kiepper, B. 2001. A survey of waste-water treatment practices in the broiler industry.

Kherrati, R., Faid, M., Elychioui, M. and Wahmane, A. 1998. Process for recycling slaughterhouse waste and products by fermentation. *Bioresource Technology*. Vol 63.pp. 75 – 79.

Kurup, R.G. 2007. An experimental research on application of sub-surface flow constructed wetlands for meat processing industry effluent treatment and nutrient removal. Published Thesis (Doctor of Philosophy). Environmental Science and Engineering. Murdoch University, Western Australia.

Mabe, 2006. Personal communication.14 June, Rustenburg. 083 476 4799

Mahrends, K. 2006. Personal communication. 30 May, Cape Town

Masse, D.I. and Masse, L. 2000. Characterisation of waste-water from hog abattoirs in Eastern Canada and evaluation of their in-plant waste-water treatment systems. *Canadian Agricultural Engineering*. 42 (3). pp.139 – 146.

Mijinyawa, Y. and Dlamini, B.J., 2006. Livestock and poultry waste management in Swaziland. *Livestock and poultry for Rural Development*. 18(6).

Mittal, G.S. 2004. Characterization of effluent waste-water from abattoirs for land application. *Food Reviews International*. Vol. 20. (3). pp. 229 – 256.

Mountney, G.T., 1989. Poultry Products Technology. 2nd ed. New York: *Food Products Press*. pp.140 – 144.

Najafpour, G.D.T., Klason, M.D., Ackerson, E.C. and Gaddy, J.L. 1994. Biological conversion of poultry waste to single cell protein. *Bioresource Technology*. 48. pp 65 – 70.

Roberts, H. A. 2006. Development of a waste management system model for condemned products at red meat abattoirs in the Free State province, South Africa. Thesis (D.Tech). Free State. Central University of Technology.

Ross, 2006. Personal Communication.02 June, Eastern Cape. 041 398 1123

Salminen, E., Rintala, J., Harkonen, J., Kuitunen, M., Hogmanader, H. and Oikari, A. 2001. Anaerobically digested poultry slaughterhouses wastes as fertiliser in agriculture. *Bioresource Technology*. 78 (1) pp 81 - 88 May

Salminen, E. and Rintala, J. 2002. Anaerobic digestion of organic solid poultry slaughterhouse waste - a review. *Bioresource Technology*. Vol 83 (1). pp.13-26, May

Shin, J.C.H. 1987. Ecological benefit of anaerobic digestion. *Poultry Science* (66). pp. 946 -950

South Africa. 1992. Abattoir Hygiene Act, Act of 1992. Pretoria: Government Printer.

South Africa. 2000. Meat Safety Act, Act 40 of 2000. Pretoria: Government Printer.

South Africa. Department of Water Affairs and Forestry. 2001. Guidelines for handling treatment and disposal of abattoir waste. Pretoria. Government Printer.

South Africa, 2006. Poultry Regulations. No. R. 153. Pretoria. Government Printer

South Africa. 2007(b). Meat Inspectors Manual Abattoir Hygiene. Doornfontein: Lexpatria Publishers.

Theron, C. 2006. Personal Communication.12 June, Klerksdorp. 078 496 2309

Visser, A. 2006. Personal Communication. May. Gordons'Bay, Cape Town. 021 856 1512

Westerndorf, M.L. 2000. *Food waste to animal feed.* United States of America: Iowa State University Press. pp. 8 -11.

Webbstock, B. 2006. Personal Communication. 12 June. North West. 018 293 0202

Williams, C.M., Barker, J.C., and Sims, J.T., 1999. Management and utilization of poultry waste. *Rev Environ Contam Toxicol*. 162. pp.105 -157.

CHAPTER FIVE
GENERAL CONCLUSION

5.1 CONCLUSION

Because of high rates of resource consumption, countries face serious problems of high volumes of waste, characterized by inadequate disposal technologies, high costs of management, and the adverse impact of waste on the environment from various industries (Cooper and Russel, 1992). This study has attempted to provide an overview of waste management in high-throughput poultry abattoirs in South Africa. Findings similar to those published by numerous authors as cited in the literature review were expected as an outcome of this study and have been confirmed.

Form the results captured, it was evident that the principles of basic slaughter practices through all abattoirs are similar, although waste management practices differs according to abattoir preferences, of which some are not always environmentally friendly and do not comply with South African legislation, despite being legally acceptable in other international countries.

5.1.1 Solid waste management practices

According to the study (Table 4.9), total of 800 – 432 000 birds are being slaughtered in South African high-throughput poultry abattoirs per day. Taking into consideration that about 70% of the original weight of the bird represents the finished product and the remaining is waste material, huge amounts of wastes requiring either processing or disposal is being generated in poultry abattoirs. Waste materials commonly identified include feathers, meat off-cuts, condemned chicken, intestines, blood, caeca and gizzard contents. Each of the waste materials is handled differently according to the preference of the abattoir.

However, unlike in red meat abattoirs where most generated wastes are disposed of (Roberts, 2006), poultry abattoirs to a greater extent utilise waste material by using it as raw feed for animals, or in producing by-products. Some of the abattoirs have by-product production facilities (rendering plants) on the abattoir premises while others are located outside abattoir premises. Commonly identified products include poultry (carcass) meal, blood meal, as well as feather meal according to the results of this study. The most common method of by-product production is rendering. Rendered poultry meal is used as a feed supplement for pets and adds nutritional value to growing chickens. Poultry meal is sold directly from the rendering plant to the consumers in powder form. Production of by-products has been associated with greatly reduced environmental implications related to poultry waste disposal and to added profits from rendered waste (Theron, 2006). Waste which is not rendered is sold to farmers (crocodile and lion farmers) and zoo management for feeding animals.

5.1.2 Waste-water management practices

High-throughput abattoirs process much larger numbers of birds and therefore utilise greater volumes of waste-water on a daily basis. The average water used per chicken is 17ℓ according to the study. It is evident therefore that the higher the number of birds slaughtered, the higher the amount of water used resulting also in high waste-water produced.

Because abattoir waste-water is highly loaded with micro-organisms and waste impurities, it requires pre-treatment before disposal or re-use. All of the abattoirs in the study use some form of water treatment, where some abattoirs have installed preliminary treatment devices (screens, fat traps, and grit chambers) to recover solid waste and fats. Others have installed primary, secondary and tertiary treatments methods.

Different discharge methods are available and used in different abattoirs. These include municipal sewer, overland flow, French drains and water courses but the most common method of waste-water discharge is into dams. Abattoirs have constructed wetlands on abattoir premises and discharge water so that it can be used later. Most of this water is used for agricultural purposes such as irrigation of commercial lawn, banana and paw-paw plantations. Waste-water recycling plays an important role in the abattoir industry as, according to the study, abattoirs have also considered to clean or recycle water to be used again within the abattoir in transporting feathers.

5.1.3 Environmental waste management practices

Waste generated in poultry slaughter abattoirs has raised public concern about pollution, health and environmental impacts. According to the results of the survey, the environmental indices associated with poultry abattoirs include pollution, which relates to the contamination of land, water and or air. Air pollution was the most commonly reported type of pollution. The source of air pollution includes the burning of significant quantities of waste, effluent treatment ponds and rendering facilities. Although air pollution was most commonly identified, water pollution is regarded as of most concern.

Waste-water is regarded as the main cause of negative environmental impact in abattoirs in South Africa. There are abattoirs that disposed their waste-water without any means of treatment prior to disposal, either into municipal sewers, land application or into water bodies and therefore causing pollution and affecting aquatic life. If this is not resolved, it may lead to dire consequences such as recent issues (2008) of radioactive contamination in water in the Wonderfontein Catchment Area.

5.1.4 South African legislation

The environmental impact of slaughterhouse waste is a global concern and certain pieces of legislation have been promulgated by governments throughout the world. In South Africa, the Meat Safety Act (2000) is the main Act dealing directly with abattoirs and particularly waste management. This act covers many aspects, such as meat inspections and waste handling. It is however acknowledged that there are a number of loop-holes that still exist as some factors are not clearly elaborated upon. For instance, the act requires meat inspections to be done and all condemned products to be controlled and this is an important aspect of meat hygiene, but meat inspections serve no purpose if the condemned products still find their way back into the food chain. Abattoir waste material is still disposed of without following the legislated methods, at landfills for instance (Roberts, 2006). For that matter there are a number of scavengers found to be living and feeding on condemned meat disposed at South African landfills (Roberts and De Jager, 2004).

Currently, none of the legislation requires application of integrated pollution prevention practices nor do they encourage implementation of substantial measures to avoid, reduce or control pollution.

Financial constraints on abattoirs also play a role in implementing the required waste disposal methods in terms of the Act and as a result incorrect disposal methods are used in many cases leading to failure of complying with legislation.

5. 2 REFERENCES

Cooper, R.N. and Russel, J.M. 1992. Meat Industry processing waste; characteristics and treatment. *In:* Hui, Y (ed) Encyclopidia Food science Tech Vol 3. pp. 1683 - 1690

Roberts, H and de Jager, L. 2004. Current meat-related waste disposal practices of Free State red-meat abattoirs, South Africa. Document Transformation Technologies. ISBN 0-9584663-7-8. February

Roberts, H.A. 2006. Personal Communication. 07 February, Free State. 051 507 3129

South Africa. 2000. Meat Safety Act, Act 40 of 2000. Pretoria. Government Printer

Theron, C. 2006. Personal Communication.12 June, Klerksdorp. 078 496 2309

CHAPTER SIX
RECOMMENDATIONS

6.1 INTRODUCTION

The poultry industry makes a major contribution to the social and economic life of South Africans; however economic development and increased production in the food industry have led to a large waste burden. This in combination with less land available for landfill sites and changes in public attitude has highlighted the need for improvement in waste management practices at poultry abattoirs and in the food industry at large (Sangodoyin and Agbawne, 1992).

As a result of responses recorded after the completion of questionnaires by abattoir personnel and also from researcher's personal observations, certain recommendations on waste management practices and processes were made. The recommended practices and processes are based on current slaughtering processes, waste generated and waste handling (collection, storage, disposal) practices as well as on the utilisation of by-products. For easy comment, recommended practices are grouped into two sections - integrated waste management approach and improved waste practices respectively.

Some of the recommended practices and processes are employed in certain abattoirs in the country while others are used in other countries. The identified processes can be applied to all classes of poultry abattoirs from rural, low-throughput abattoirs to high-throughput plants. The processes are to some extent cost-effective, maximising the use of all identified waste material and most importantly minimising negative effects associated with waste burden.

6.2 INTEGRATED WASTE MANAGEMENT APPROACH (IWMA)

The study indicated that there is a need at abattoirs to adopt an integrated waste management approach. The following aspects should be included in the approach, namely:

i. Waste assessment

Waste assessment is a method of determining what wastes are being generated in what quantities from what activities. This is one of the first steps in starting waste reduction programs. In order to achieve this, abattoir practices/processes must be measured and analysed.

ii. Waste plan

A waste plan should be developed to provide appropriate solutions for managing the entire waste stream within an abattoir site. The objective of the plan should be to reduce volumes of waste for disposal and treatment to reduce the cost of waste without compromising environmental standards. The plan should include recovery, re-use and recycle recommendations. Elements of a proper waste plan include:

(a) Waste management strategies

Industry and control authorities should develop management strategies together that reflect good conservation practices and conform to environmental regulations. Techniques and procedures to integrate all waste management options should be adopted wherever possible. A beneficial re-use strategy should be initiated after the waste management strategy.

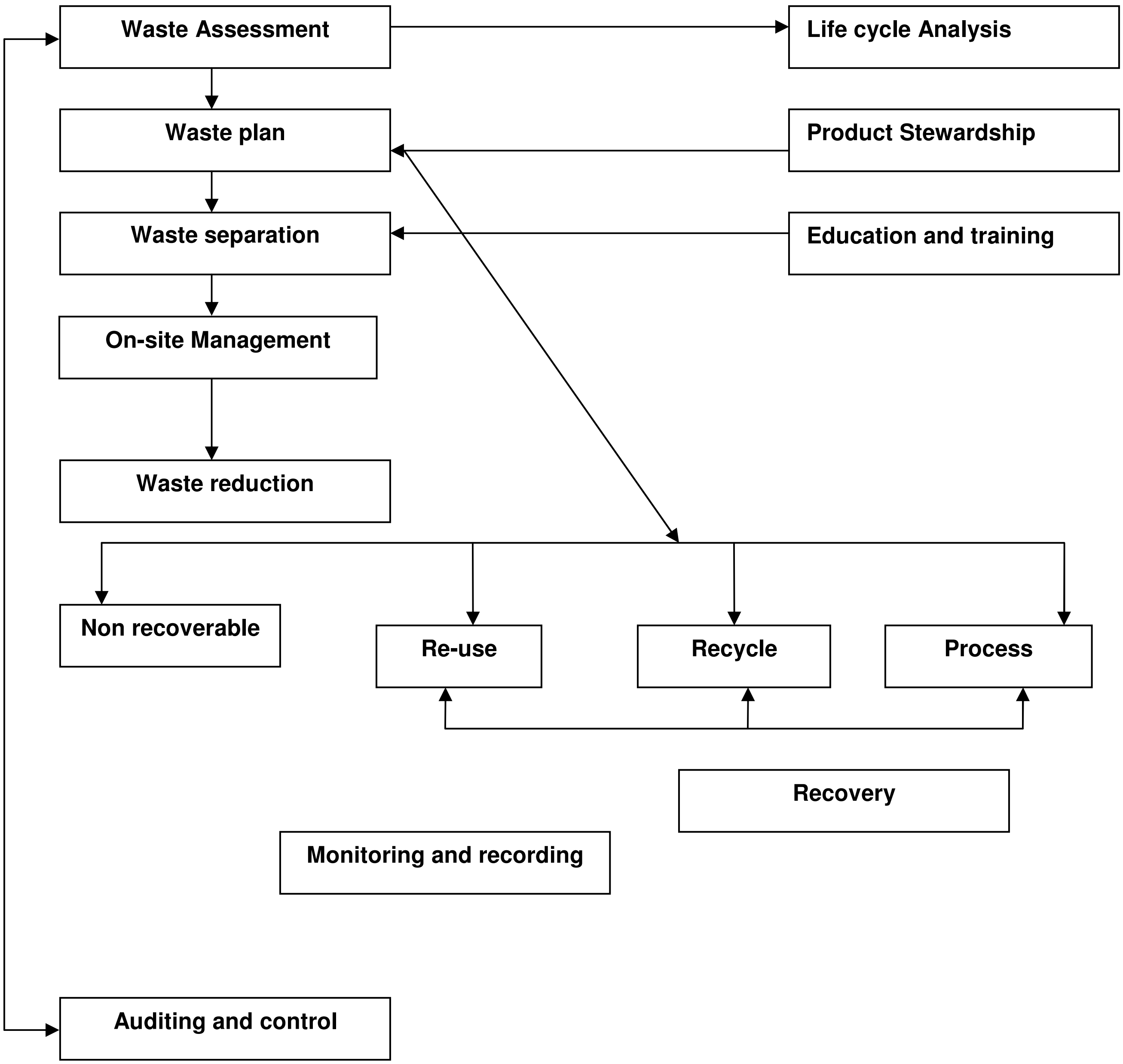

Figure 6.1 An integrated waste management approach (Wells 1976),

Cleaner production and waste minimisation aims directly at the source of waste generation and attempts to eliminate waste before it is produced, or to reduce the amount generated. Waste should be disposed of only after all preventive and minimisation measures have been taken. The abattoir management could develop management strategies for proposed and existing premises. The strategies should aim to:

- minimise the quantity of waste generated;
- prevent pollution arising from the disposal of wastes;
- prevent nuisance pollution such as odours, dust and smoke and
- minimise environmental health risks.

(b) Operational waste management guidelines

Operational procedures and process controls that minimise waste and emissions at the generation point until it reaches disposal site should be developed and implemented. The effectiveness of these controls should be monitored on an on-going basis.

iii. Waste separation

Even the smallest waste generator should implement a waste separation program. This is mostly achieved by separating waste stream close to source rather than at disposal stage. Separation of waste at each stage is essential for maximising product recovery and reducing waste loads.

(a) Identification of waste source and collection point

Proper identification of waste source and collection points should be clearly marked to ensure waste recovery. For example, to avoid environmental implications associated with blood, abattoirs should focus on proper blood collection. Bleeding areas and bleeding time should be clearly identified and adhered to; collection should be done immediately so that its full potential can be utilized (Tritt and Schuchardt, 1992).

iv. On-site management

Good supervision of the waste program within abattoir premises is critical to success. Management of the entire on-site program is critical to ensure smooth operations.

v. Waste reduction

Waste reduction refers to an action undertaken to eliminate or reduce the amount of waste generated before final disposal. This action is intended to conserve resources, promote efficiency and reduce pollution. Examples of waste reduction in poultry abattoirs include;

(a) Waste minimisation

Wells (1976) suggests that abattoir management should ensure full examination of waste to identify options for waste minimisation. In some cases, production of by-products can reduce waste material awaiting disposal. Recovering valuable materials from waste streams can be economically and environmentally sensible. Some waste minimisation options to consider are:

- changing the processes or equipment;
- improving waste material handling and cleaning operations;
- recycling waste internally;
- re-using waste on-site and
- recovering materials from waste streams.

(b) Water conservation enforcement

The capacity of water intake differs per abattoir. And according to Cowan (1998), it is very important to conserve water. This includes a number of factors, which amongst others, includes:

Proper cleaning: For cleaning surfaces a pressurised spray is very effective and uses less water. Fit hoses with spray nozzles for surface cleaning. However, always undertake dry-cleaning before washing with water. Using brooms to sweep up loose dirt and feathers in the reception area, with wash-down taking place using a proportion of recycled water, is recommended as it will also reduce the pollution load.

Measure water use: Have management routinely measure water use by meter on a daily basis, and monitor water use annually. Measuring waste-water can also help in planning for pollution prevention tactics. Flow meters can quickly indicate water overuse. There are some meters in the market that use circular chart recorders to measure water use in meters per second over a 24 hour period. Fluctuations may indicate leaks, wasteful water use or inefficient equipment. Installing meters in high water use areas such as the chillers, scalders, wash cabinets, evaporators and condensers can monitor fluctuations. Regulate meters to avoid unnecessary overfilling and inefficient water use.

Pressure reducers: Install pressure reducers and shut-off valves/automatic shut-off taps to reduce water consumption. This can minimise the amount and cost of water used.

Train personnel: Abattoir management should take the initiative in providing training on water conservation, water monitoring, blood collection and good cleaning practices. Training programmes on how to use the minimum required amount of water needed for the job and on cleaning practices, can save the abattoir money (World Bank Group, 1998).

Equipment modifications: The following equipment modifications were recommended: Fit drains with screens and traps to prevent solid materials from entering the effluent and regularly monitor sprays nozzles (Kupusovic, Midzic, Silajdzic and Bjelavac, 2007). Water loss can also be reduced by repairing all leaks in the facility. Abattoir personnel can make a checklist of all potential sources of leaks and conduct weekly inspections of equipment such as valves, tanks, hoses and nozzles.

(c) Keeping organic materials out of waste-water

Poultry by-products can be cleaned up or moved out using water. Keeping by-products out of the water stream can reduce biological oxygen demand (BOD), total soluble solids (TSS) and phosphorus loading in the waste-water.

Abattoirs should consider replacing water troughs with conveyors for moving organs from the evisceration line to the next process area. Blood and other liquids can be collected from the birds using troughs and curbs to direct their flow. Solid by-products, blood and other fluids can also be collected in holding tanks using a vacuum hopper system which does not require the use of water. These by-products may be shipped to rendering plants and converted to animal feed or for composting or land spreading.

The installation of stainless steel sieves or wire mesh on slaughter floors would also assist in the effective collection of organic materials. This would reduce the sanitary as well as the environmental pollution load. Moreover, regular cleaning of sieves during slaughtering can improve the recovery load (Wells, 1976).

(d) Dry clean-up

The use of dry clean-up methods rather than using water is recommended to save on the amount of water utilised throughout the abattoir. This can also reduce the BOD and TSS loading to the effluent water stream. Some of the most effective dry clean-up methods include the scraping of fat and grease off conveyor belts, installing strainers along the evisceration line and other areas to keep poultry by-products off the floor, and sweeping or shovelling materials off the floor before wet clean-up (Environmental Protection Agency (EPA), 2005).

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6.3 BEST WASTE MANAGEMENT PRACTICES

The preceding section considered possible actions for achieving improved waste management practices that can be applied at abattoirs.

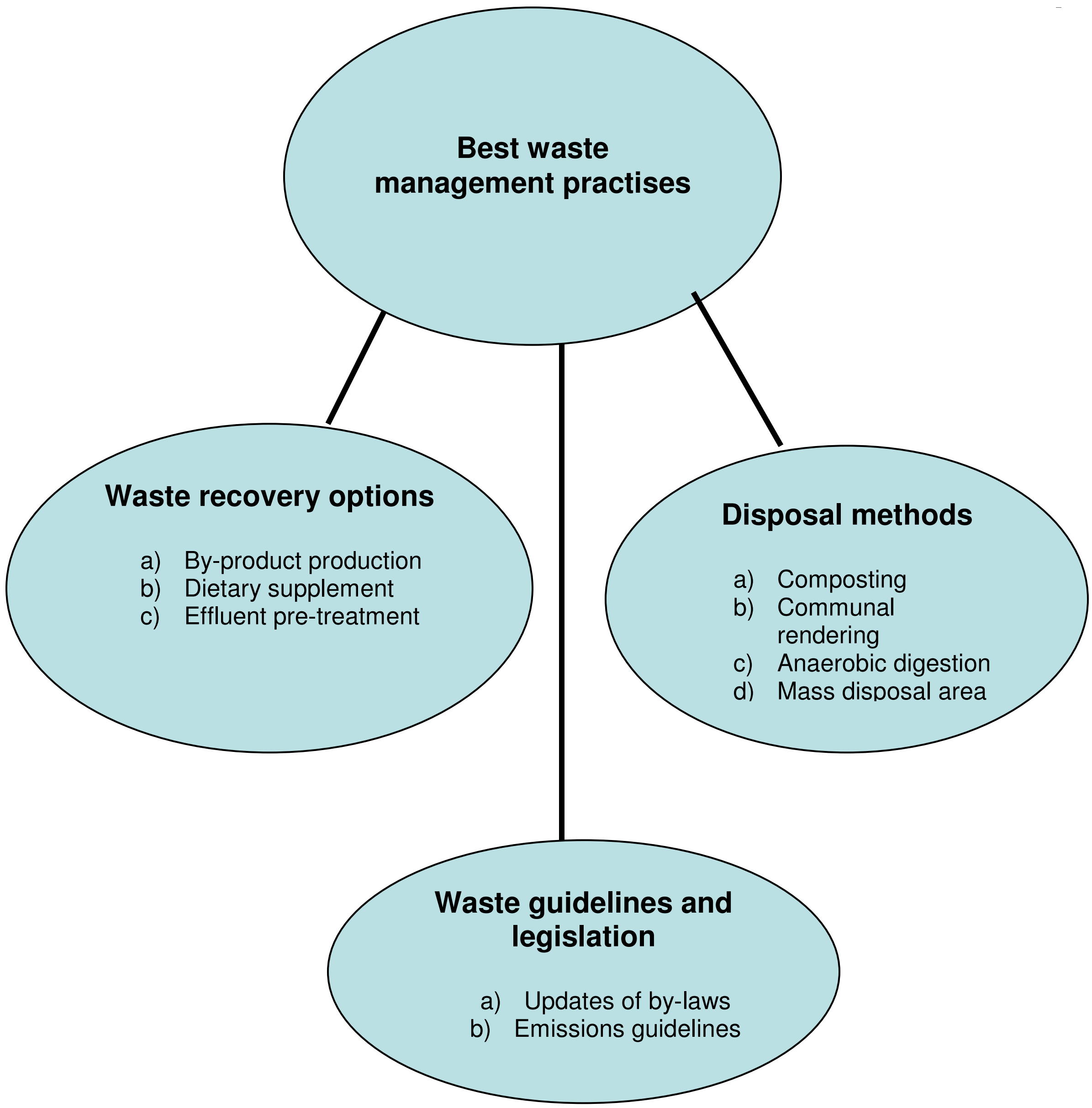


Figure 6.2: Best waste management practices

6.3.1 Disposal methods

Slaughtering of poultry generates waste consisting of non-edible material requiring disposal. If the disposal of this waste is not done in an environmentally friendly way, environmental problems could ensue. Below are some examples of waste disposal methods recommended as practiced locally and internationally;

i. Denaturing and burial

Although prescribed by legislation, denaturing of the condemned material before burial is not always done. Proper denaturing of waste prior to its disposal should be exercised and monitored by abattoir management. The use of this method can reduce health effects to scavengers that normally retrieve condemned materials from the burial pits or landfill sites.

ii. Composting

Composting of solid waste such as turned windrows and aerated static pile are most suited for treatment of poultry abattoir waste. However, waste can be efficiency and economically disposed of by composting as long as offensive odours are not generated (Environmental Protection Agency (EPA), 2005).

iii. Communal rendering facility

Although limited processing of condemned material does take place in South Africa, improvement in this regard can be investigated for implementation. Based on the daily solid waste produced and disposed of without any in-house treatment, it could prove to be very useful to have a communal rendering facility where all abattoirs without rendering facilities could bring waste material to be rendered. This would reduce the disposal pollution load on municipal works from small abattoirs, especially those situated in rural areas where disposal of waste material is problematic.

With the provision of a centralised (communal) rendering facility where geographically feasible, these problems would be largely obviated to the benefit of both abattoir and municipality. The abattoir would benefit financially as by-products would be of considerable value, in addition to the saving on waste disposal costs (Steffen, Roberts and Kristen Inc., 1989).

iv. Anaerobic Digestion

Anaerobic digestion has become an established and proven technology as a means of managing solid organic waste. Besides generating bio-gas for energy use, the process also destroys pathogens and produces stabilised material to be used as fertiliser in land applications (Salminen and Rintala, 2002).

v. Mass disposal area

A mass waste disposal area must be identified for in case there is an outbreak of an exotic disease. This area should be away from watercourses and groundwater. The soil should be suitably friable for digging but also as impermeable as possible (Gilberto, Pilar and Roger, 2003).

6.3.2 Waste recovery options

i. By-products production

Maximising the production of by-products from waste material instead of disposing it off is recommended. The processing of waste in the production of blood meal, poultry meal, and feather meal is recommended as this would also increase the financial benefits for the abattoir (Poopathi and Abidha, 2007).

ii. Poultry waste as a dietary supplement

The use of poultry waste as a dietary supplement in ruminant ration could have a considerable effect on reducing costs, insufficiency of protein in diet and in solving disposal problems. According to a study conducted by Saleh, Elwan, El-Fouly, Ibrahim, Salama and Elashry (2002) the chemical composition of poultry waste and its safe use in ruminant nutrition were investigated prior to its use as a dietary supplement. No appreciable differences in chemical composition were noted in poultry waste between oven and sun-dried forms. The high protein content, energy and minerals in poultry waste indicate its importance as a partial substitute for concentrates in the diet of animals that were used as part of the mentioned study.

Another important point in support of the utilisation of poultry waste is its potential to solve the somewhat nagging environmental problems that cannot be divorced from any poultry enterprise, i.e. the disposal of animal waste (Aro and Tewe, 2006). Egypt is one of the countries that has implemented the option of using poultry waste as a dietary supplement and has not yet had any negative health-related concerns in this regard (Shari, 2002).

iii. Effluent pre-treatment

One of the factors that can contribute greatly in saving water is pre-treatment of waste-water to suitable levels to facilitate its re-introduction into the system either for cleaning purposes or for processing for usage on slaughter floors and for feather transportation.

The waste-water treatment system should essentially comprise of (i) self-cleaning type screening or two-stage screening (Bar type), (ii) primary treatment (anaerobic treatment) and (iii) secondary treatment (aerobic treatment). Preliminary treatment: the use of vibratory and self-cleaning screens can reduce the solids loading in waste-water. FOG removal facilities positioned upstream of waste-water treatment facility can improve the effectiveness of the subsequent treatment process (Al-Mutairi, Hamoda and Al-Ghusian, 2003).

Dissolved air flotation (DAF): after dosing, a protein precipitant will typically remove 60% of the organic load from the effluent (Cowan, 1998).

Effective primary treatment before secondary treatment can increase the overall effectiveness and efficiency of waste-water treatment systems, as it is cheaper to physically remove the fat and solids than to treat them in secondary and tertiary treatment facilities (Adelegan, 2002).

6.3.3 Abattoir waste management guidelines and legislation

Although of legislation is available to govern abattoir operations, it is recommended that by-laws are updated to be in line with existing legislation since certain important issues such as waste minimization, waste recycling, waste information systems, specifically for poultry abattoirs, are not covered.

i. Enforcing environmental laws

Development and implementation of strict environmental by-laws, to monitor and check improper discharge of wastes from poultry abattoirs will be an important factor in reducing pollution caused by poultry operations (Bell and Russell, 2002).

ii. Emission Guidelines

Abattoir management must take into consideration emission levels for the design and operation of the abattoir. These can be established through the environmental assessment (EA) process on the basis of South African environmental by-laws. The key production and control practices that will lead to compliance with emissions guidelines may be summarised as follows:

- Design and operate the production systems to achieve target water consumption levels;
- Dry clean product areas before washing and provide grids and fat traps on collection channels;

- Eliminate wet transport of waste;
- Recover blood and other materials and process into useful by-products;
- Send organic material to the rendering plant and
- Design and operate the rendering plant to minimize odour generation (World Bank Group, 1998).

6.4 REFERENCES

Adelegan, J.A. 2002. Environmental policy and slaughterhouse waste in Nigeria. *Sustainable Environmental Sanitation and Water Services*. 28th WEDC Conference.

Al-Mutairi, N.Z., Hamoda, M.F. and Al-Ghusian, A. 2003. Performance-based characterization of a contact stabilization process for slaughterhouse waste-water. *Journal of Environmental Science and Health*. A38, (10) .2287-2300

Aro, S.O. and Tewe, O.O. 2006. Performance and carcass yield of barrow fed dried poultry waste as a replacement for palm kernel cake. *African Journal of Biotechnology.* 6 (4). 19 February 2007. pp. 487-492.

Bell, R.G and Russell, C. 2002. Environmental policy for developing countries. Issues in science and Technology. Springs. pp. 37 - 42

Cowan, J. 1998. The transfer of waste-water management technology to the meat processing industry. South Africa: Water Research Commission (WRC Report 239/1/98).

Environmental Protection Agency, 2005. Abattoir wastes. South Africa: Department of Environment and Conservation. [Online]. [accessed on 22/11/2006].

Kupusovic, T., Midzic, S., Silajdzic, I. and Bjelavac, J. 2007. Cleaner production measures in small-scale abattoirs industry – a case study in Bosnia and Hezegovina. *Journal of Cleaner Production* . 15 (4). pp. 378 – 383.

Poopathi, S. and Abidha, S. 2007. Use of feather based culture media for the production of mosquitocidal bacteria. *Biological Control* 43 (1). October. pp. 49 – 55.

Salminen, A.E. and Rintala, J.A. 2002. Semi-continuous anaerobic digestion of solid poultry slaughterhouse waste: effect of hydraulic retention time and loading. *Water Research* 36 (13). pp. 3175 – 3182.

Saleh, H.M., Elwan, K.M., El-Fouly, H.A., Ibrahim, I., Salama, A.M. and Elashy, M. 2002. The use of poultry waste as a dietary supplement for ruminants. *International Atomic Energy Agency* (IAEA).1294. pp. 43-51.

Sangodoyin, A.Y. and Agbawne, O.M. 1992. Environmental study on surface and groundwater pollutants from abattoir effluents. *Bioresource Technology*, 41. pp. 193 – 200.

Shari, B. 2002. Poultry processing system. Boca Raton, FL:CRC Press. p. 550

Steffen, Robertson and Kristen Inc. 1989. Water and waste-water management in poultry industry. Pretoria: Water Research Commission., 3. p. 13

Tritt, W.P. and Schuchardt, F. 1992. Materials flow and possibilities of treating liquid and solid waste from abattoirs in Germany. *Bioresource Technology*. 41. pp. 235 – 245.

Wells, W.J. 1976. Inplant waste reduction in meat industry. Environmental Protection Technology Series Pubn. No. EPA 660/2-76-098

World Bank Group, 1998. Meat Processing and Rendering. Washinton DC: Environment Department.

CHAPTER SEVEN

FINAL CONCLUSION AND REFLECTION OF THE STUDY

7.1 REFLECTION OF THE STUDY

Abattoir waste management is a worldwide concern and the impact to the environment is preventable but not reversible. It is not a one-sided issue; government, abattoir management, general labourers and the public should take the initiative in ensuring that best waste management practices are practiced as part of sustainability. Involvement of all parties is important in making any waste reduction effort successful.

Researchers, the public, Department of environmental affairs and tourism (DEAT), Department of Agriculture (Public Health Sector), local municipalities and the poultry industry in South Africa can benefit from this study, as it will give an indication about waste management practices taking place in South African poultry abattoirs. The recorded information about waste management practices in poultry abattoir will be useful for the implementation of best practices and as such will minimise public health risk, environmental implications as well as compliance with legislation.

7.1.1 Study design

Although the study was limited as it only covered high-throughput abattoirs, a study including all levels of abattoirs could have provided a clearer picture of the actual waste management practices throughout the country. However, a positive aspect relating to the study was that information gathered in this study can shed light on current waste practices at South African poultry abattoirs.

7.1.2 Study outcome

Although little information is available in South Africa literature on poultry waste management as compared to red meat abattoirs, the study reached the goal of identifying best waste management practices currently available in the market that can be adapted and practised locally by all grades of abattoirs without endangering the environment. Moreover, as a result of the study, some poultry abattoir staff members became aware of the constraints associated with improper waste management practices and the possibilities relating to by-product production methods which could be economically beneficial to their business.

Furthermore, this study can also provide a guide for bringing changes to South African poultry legislation and waste handling practices, since the void to legislation regarding waste management practices has been highlighted.

The author also benefited by conducting this study, as a higher qualification could be obtained.

7.2 FUTURE RESEARCH STUDIES

This contact with the industry led to the development of a friendly and cooperative relationship with the management of high-throughput abattoirs throughout the country. The close relationship formed could in the future lead to subsequent research being undertaken.

Furthermore, this study could form the basis for further research to shed more light with regards to poultry waste management. Further research opportunities might include:

- a similar research project to be done at low-throughput and rural poultry abattoirs throughout the country;

- investigation of the most appropriate waste-water treatment facility for poultry abattoirs. This would help in identifying and reducing the negative environmental impact the industry is currently facing and so help in water conservation;
- evaluation of other methods of using waste material to produce poultry by-products;
- an environmental impact survey of poultry waste-water and
- waste management policy makers can also re-evaluate disposal methods taking financial constrains into considerations at all levels of abattoirs.

7.3 FINAL CONCLUSION OF THE STUDY

Controlled waste disposal should be implemented throughout the country to avoid both health effects and environmental implications from abattoirs to immediate communities. Participation of government by regular monitoring of abattoirs, providing incentives and encouraging by-products production other than disposal of waste can help in sustainability. Government should also formulate environmental guidelines that shall be incorporated as special conditions in the business license sector.

If the recommendations made in this study are implemented an achievable waste load reduction and reduction of negative environmental impact could be achieved.

ANNEXURES

Annexure 1: Questionnaire

Central University of Technology, Free State

POULTRY ABATTOIR QUESTIONNAIRE

We realize that you have a busy schedule but consider your expertise to be vital for the success of the project.

This research project is being undertaken by Miss Molapo, registered for M.Tech Environmental Health. Ms Molapo is advised by Dr Hester Roberts.

The purpose of this questionnaire is to review the waste management practices at high through-put poultry abattoirs in South Africa with the intention of improving abattoir waste handling practices in South Africa.

The questionnaire to be completed is not a test but contains questions to determine the perceptions, behaviour and knowledge of workers towards waste management practices and the methods practised at the respective poultry abattoirs.

There is no right or wrong answers.

To ensure the best results, please answer the questionnaire truthfully and as accurately as possible.

All the results will be handled in strictest confidence and no names of abattoirs or respondents will be recorded.

Contact details:

Fax No. ………………………………. Tel No. …………………

E-mail address: …………………………………………………..

Date: ……………………………………………………………….

Signature ………………………………………………………….

Mark the applicable box with an X or write the appropriate answer in space provided.

1.Indicate the grade or classification of your abattoir.

Office use

Grade A		1
Grade B		2
Grade C		3
Grade D		4
Grade E		5
Low throughput abattoir		6
High-throughput abattoir		7
Don't know		8

2. Indicate the days on which you slaughter and number of shifts.

Monday		9
Tuesday		10
Wednesday		11
Thursday		12
Friday		13

3. How many units do you slaughter daily?

0 - 20 000 units		14

20 001 – 40 000		15
40 001 – 60 000		16
60 001 – 80 000		17
80 001 – 100 000		18
More than 100 001		19
Please indicate the no. of units		20

4. Indicate the position which you occupy at the abattoir.

Owner		21
Supervisor		22
Worker		23

5. For how long have you been working in the industry?

0 – 3 months		24
3 - 6 months		25
6 - 12 months		26
1 year – 5 years		27
More than 5 years		28

6. Have you had training in abattoir waste management?

Yes		29
No		30

7. If you answered "yes" in question 6, please answer question 7.

Indicate duration of training	**Indicate course attended**	31
		32
		33
		34

8.Identify the waste products disposed of at the abattoir.

Feathers		35
Blood		36
Trimmed meat off-cuts		37
Faecal matter		36
Whole condemned chicken		37
Waste-water		38
Feet		39
Intestines		40
Other (specify)		41

9. Are there any by-products produced at the abattoir?

Yes		43
No		44

10. If you answered "yes" in question 9, please answer questions 10, 11 and 12. Identify the products produced.

Blood meal		45
Feather meal		46
Bone meal		47
Other (specify)		48
		49

11. Describe the method used for processing the products identified.

1.	50
2.	51
3.	52

12. Who is responsible for the production or marketing the products?

Abattoir		53
Private company		54
Other (specify)		55
		56

13. How is the blood collected?

Blood trough		56
Buckets/containers		57
Other (specify)		58

14. Indicate how blood is disposed.

Municipal sewer		59
Burial		60
Land application		61
Rendering		62
Given to animals		63
Other (specify)		64

15. If the blood remains on the premises before disposal or processing, indicate where it is stored.

		65
		66

16. If the blood is buried, indicate the disposal area.

		67
		68

17. Indicate the container used for storage of feathers before leaving premises.

	69

18. Indicate the method used to dispose of the feathers.

Burning (Open Fire)		70
Incineration		71
Burying		72
By-products processing (rendering)		73
Sold to other companies for processing		74
Other (Specify)		75
		76

19. Is there any feather processing facility on the abattoir premises?

Yes		77
No		78

20. If you answered "yes" in question 19, please indicate the products manufactured from the feathers.

	79
	80

21. If the feathers are buried, indicate the area of disposal.

	1
	2

22. Indicate how waste-water is removed from the abattoir premises.

Municipal sewerage system		3
Run off into the fields		4
French Drains		5
Other (Specify)		6
		7

23. Indicate the estimated amount of water used daily (litres).

				8

24. Is there any preliminary waste-water treatment available?

Yes		9
No		10

25. If you answered "yes" in question 24, please indicate how the water is treated.

	11
	12

26. Does the abattoir use recycled waste-water? If you answered yes in question 26, please answer question 27

Yes		13
No		14

27. Indicate for what purpose the abattoir uses the recycled water.

Cleaning the equipment and walls		15
Washing the vehicles		16
Washing meat and products		17
Other (specify)		18
		19

28. Indicate how chicken feet are being handled.

Burial		20
By-product processing (e.g. Crushing)		21
Sold		22
Given to workers		23
Other (specify)		24
		25

29. Indicate the method used to dispose of the condemned products (whole diseased chickens, diseased organs).

Municipal sewer		26
Burial		27
Land application		28
Rendering		29
Incineration		30
Given to workers		31
Given to animals		32
Other (specify)		33
		34

30. In cases where the waste (condemned) products are burnt, indicate which method your abattoir uses.

Open fire		35
Diesel incinerator owned by abattoir		36
Incinerator		37
Do not know		38
Other (specify)		39
		40

31. Indicate the temperature at which your incinerator operates.

	41

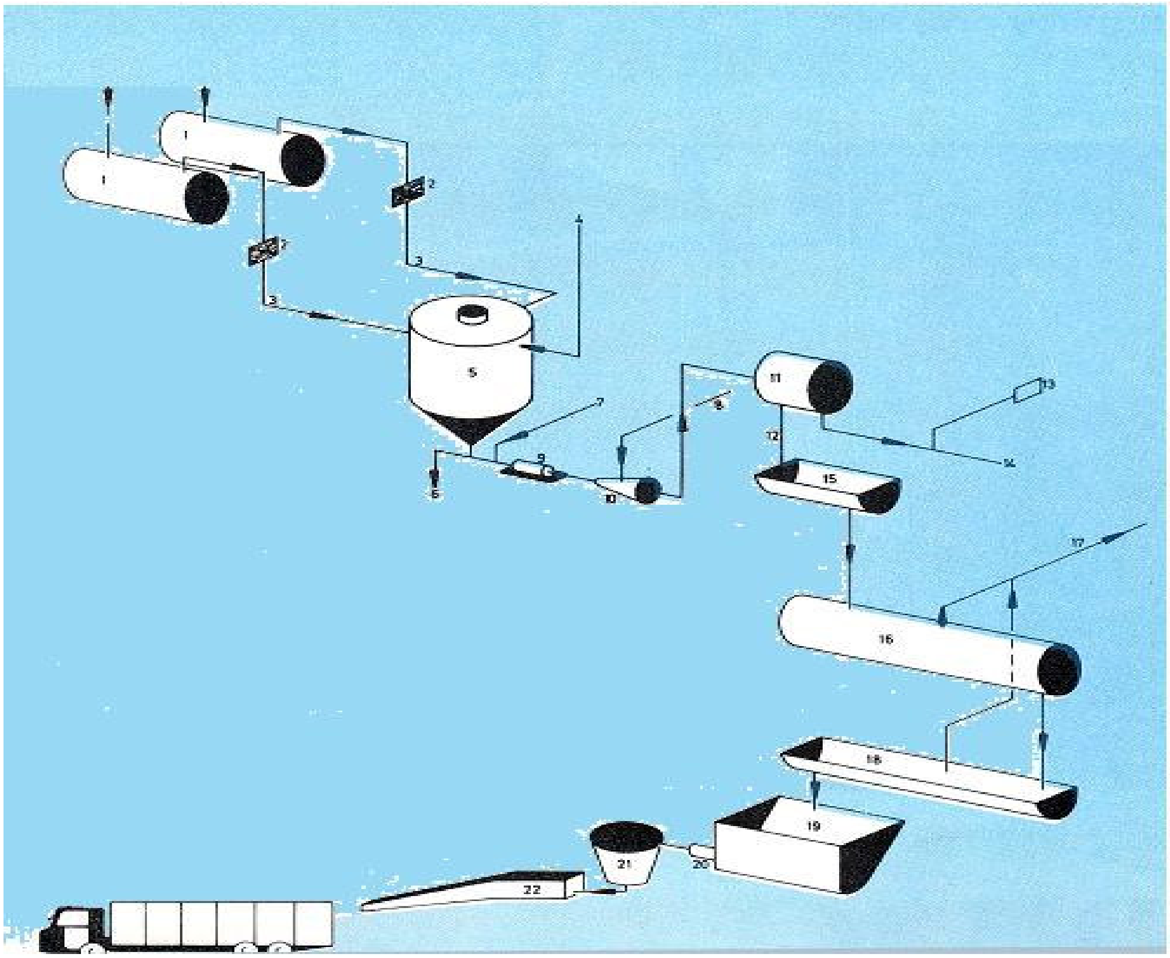
32. **Do you think there are any environmental pollution threats that can occur due to abattoir operations with regard to waste handling practices?**

1.	42
2.	43
3.	44

THANK YOU FOR YOUR HELP IN THE COMPLETION OF THE STUDY!!!

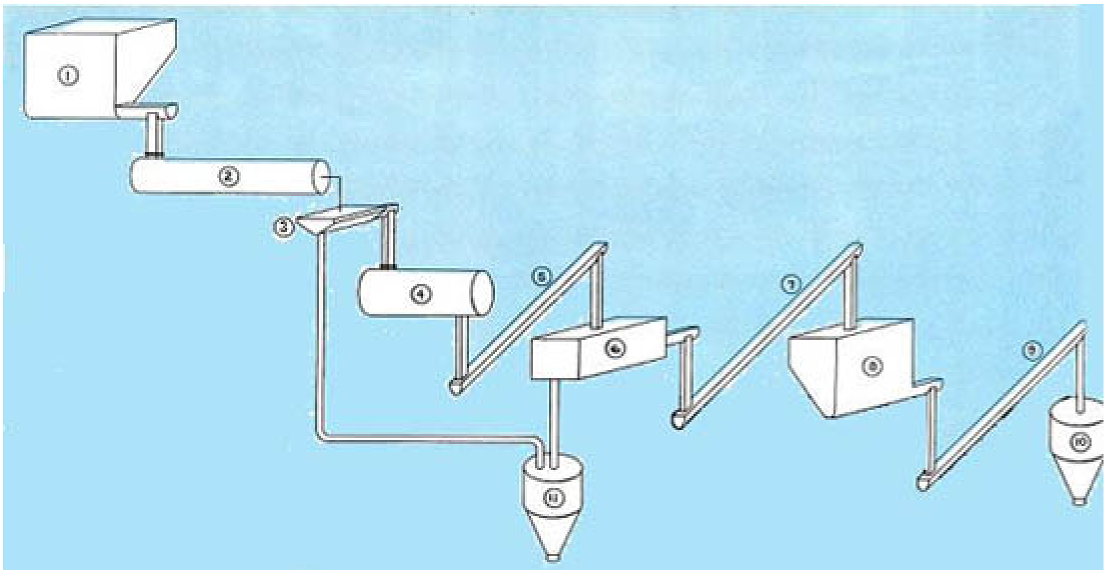
Annexure 2: By-products Production Process

Annexure 2.1: Blood meal production process



1. Blood Blow Tanks, **2**. Strainers , **3.** From Process Block to By-Products, **4.** Cold Water Supply, **5.** Raw Blood Storage Tank, **6.**To Drain, **7.** Cold Water Supply, **8**.Steam Supply Pressure, **9.** Metering Pump, **10.** Continuous Coagulator, **11.** De-watering Centrifuge, **12.** De-watered Blood Line, **13.** Thermostat, **14.** To Drain, **15.** Screw Conveyor ,**16.** Continuous Drier-disc Working Cycle 1/2 - 1 hr, **17.** Vapour to Condensor, **18.** Blood Cooler "If Required" , **19.** Pre-grinding and Cooling Hopper, **20.** Continuous Blood Sieve, **21.** Bag Filling and Weighing Assembly ,**22**.Chute to Dispatch (Gomez-Juarez et. al. 1999).

Annexure 2.2: Carcass Meal production process



(Gomez-Juarez et. al. 1999).

Raw Material Hopper

Cooker

Perc Tank

Disc Drier

Screw Conveyor

Fat Press

Screw Conveyor

Storage Hopper

Screw Conveyor

Bagging Unit & Hammer mill

Fat Setting Tank