SUSTAINABLE WASTE MANAGEMENT SYSTEM IN ABATTOIR DESIGN.

BY

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DEPARTMENT OF ARCHITECTURE AHMADU BELLO UNIVERSITY, ZARIA
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NOVEMBER, 2014.

DECLARATION

I declare that the work in this thesis entitled Sustainable waste management system in Abattoir design has been carried out by me in the Department of Architecture ABU Zaria.The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree at this or any other institution.

Name of Student	Signature.	Date

CERTIFICATION

This thesis titled SUSTAINABLE WASTE MANAGEMENT SYSTEM IN ABATTOIR DESIGN located in Katsina by Usman Murtala BANYE with Registration No. Msc/EVN-DES/03135/2010-2011meets the regulations governing the award of the degree of Master of Science in Architecture of the Ahmadu Bello University Zaria, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

Waste in whatever form is considered as serious menace to any built environment in both developed and developing countries. In recent years, most developing countries have started taking measures to improve their abattoirs waste management practices. The increase amount of waste generated by abattoirs is usually not properly managed. The research is aim to develop an abattoir waste management strategy through architectural design that utilizes Biogas /Anaerobic digester as a source of sustainable energy for the operation of an abattoir.

Chapter one focuses on introductory part of the study which highlight the background of the study, states the research problem, justify the essence and significance of the study as well as aim and objectives of the study. In chapter two, literature review was done to investigate the potential of abattoir wastes to befoul the environment, or cause hazards to human health, and harm to living resources and ecological systems. Abattoir wastes include animal blood, horns, bones, animal faeces, paunch manure, and abattoir effluent.

Chapter three discuses the various approaches adopted for the research to study the sustainable means of waste management in abattoir design by proper utilization of waste to produce energy. For this research, the instrument used to collect data include: structured interview, checklist, photographs, sketches and notes. Chapter four analysis the case studies result that shows abattoir wastes have the potential to pollute surface waters, underground waters, abattoir environment, and consumables around the abattoir, especially when abattoir wastes are not properly treated and disposed off.

In conclusion, it is recommended that abattoir wastes should be sustainably managed in a modern way through Architectural design to achieve allowable standards, drive renewable energy and exploit the benefits locking in the wastes before safely and economically disposing the ultimate wastes. In order to develop abattoir wastes management strategies that would ensure reduction in environmental pollution in Nigeria, this research proposes some architectural considerations on the potential of abattoir wastes through creating anaerobic digester within abattoirs that can generate a remarkable energy for optimum utilisation.

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GLOSSARY

A glossary of terms relating to Anaerobic Digestion and Abattoirs

Abattoirs

Slaughter house/ meat production factory.

Acetogenesis

A process where anaerobic bacteria produce acetic acid, carbon dioxide and hydrogen from volatile fatty acids.

Acid Fermentation

The breakdown of compounds into acetic acid by bacteria

Acidogenesis

A biological process converting simple monomers e.g amino acids into volatile fatty acids.

Anaerobic

Without oxygen

Biogas

Gas formed from anaerobic digestion, being about 60% methane and 40% carbon dioxide, but also containing free amounts of hydrogen sulphide, and ammonia

Bio methane

Purified methane from biogas

Bovine

Big animals like cattle, camels

Butcher

Cutting off.

Cleaned Biogas

The biogas has been cleaned by removing: water, hydrogen sulphide, silicon compounds; trace components such as halogenated hydrocarbons

Digestate

The material left following anaerobic digestion

Digester

A tank in which the anaerobic digestion process takes place

Dry AD

Where the feedstock is stackable dry matter.

Effluent

Liquid waste

Feedstock

The material that feeds the digester

Fibre

The solid dry matter component of the digestate

Hydrolysis

Process that breaks down the long chain carbohydrates into simpler soluble organic compounds (such as alycerol).

Liquor

The liquid component of the digestate

Mesophilic

A type of anaerobic digestion operating at between 30 and 45^{o}C

Methanogenesis

Process where microbes (methanogens) form methane by binding hydrogen and carbon molecules

Renewable Heat Incentive (RHI)

This will provide a fixed income (per kWh) to generators of renewable heat and producers of renewable biogas and biomethane. The details of the scheme are currently being produced with initial tariff levels being announced March 2011. AD plants that combust the biogas to generate heat are entitled to claim 6.5p/kwH when the scheme is implemented.

Retention Period

The time the feedstock spends in the digester going through the AD process.

ROC

A renewable obligation certificate (ROC) is a green certificate issued to an accredited generator for eligible renewable electricity generated within the UK and supplied to customers within the UK by a licensed electricity supplier. Two ROCs are issued for each megawatt hour (MWh) of eligible renewable output generated via AD.

Ruminant

Smaller animals like ships, goats etc

Substrate

Another term for feedstock

Thermophilic

A type of anaerobic digestion that operates in excess of $50^{o}C$

Upgrading

Purification of biogas into biomethane

Upgraded Biogas

Biogas which has had the carbon dioxide removed to enhance the calorific value of the fuel. This can be undertaken by gas scrubbing, adsorption, membrane separation process and $C0_2$ liquefaction.

Vertical Tank

A type of digester tank

Wet AD

Where the feedstock and digestate are handled as a pumpable liquid

CHAPTER ONE

INTRODUCTION

1.1 Background

Despite modern methods of processing meat, most Nigerian abattoirs use ancient methods leading to significant waste generation. Waste is a serious environmental problem in both developed and developing countries. In recent years, most developing countries have started to improve their municipal waste management practices. The increase amount of waste generated by abattoirs is usually not properly managed. In addition to good abattoir housekeeping, abattoir waste management should be progressively implemented commencing with low cost, low technology practices and thereafter progressing to more sophisticated technologies. Waste management system in abattoirs must deal with many difficulties, including lack of good technical experience, improper organization and low financial resources which often cover only collection, leaving no resources for safe final disposal (Moghadam, 2009).

Abattoir waste originates from slaughtering, hide removal or dehairing, paunch handling, rendering, trimming, processing and cleanup operations. Therefore, abattoir wastes often contain blood, fat, organic and inorganic solids, salts and chemicals added during processing operations are the required byproduct for producing another sustainable energy source through Anaerobic Digestion. Abattoir are a major source of water pollution and greenhouse gas emissions, especially in the developing world. Specific regulations for abattoirs do often not exist or are poorly enforced. This represents an immediate environmental problem, affecting the development of aquatic life. Abattoir waste also often carries diseases that can be transferred to humans. Communities depending on polluted water for consumption and agriculture face significant health risks. Moreover, the anaerobic degradation of wastewater generates methane and carbon-dioxide and thus accelerates climate change. The National Environmental Sanitation Policy identified Abattoir sanitation as one of the key policy issues to address the enormous problems of Environmental Sanitation in Nigeria (Mohammed,2011). Examples of overwhelming sanitation problems in abattoirs include, but not limited to, improper refuse disposal, inadequate water supply, gross-inadequacy of sanitary facilities that results in open defecation and urination, overcrowding and the exposure of flood to flies, rodents and contaminants. The identified reasons for these problems as highlighted in the National

Environmental Sanitation Policy are improper for planning of abattoirs; the springing up of illegal abattoirs (including private slaughter houses); lack of provision of adequate facilities such as portable water, lack of appropriate institutional regulations, enforcement and monitoring and above all, corrupt and sharp practices by the supervisors of abattoirs. Waste issues have been brought to the attention of Nigerian government through its various agencies over the years. Prior to the establishment of the Federal Ministry of Environment, the National Council on Health during its meeting in Jos in 1994 recommended that all States in the Federation should reintroduce market and abattoir sanitary inspection in all Local Government Areas (LGAs) as a means of raising the level of Environmental Sanitation, promoting and protecting the health of all the citizens of this country.

1.2 Statement of the Problem

Waste in whatever form is considered as serious menace to any built environment. In addition there is a problem with ineffective meat production in the existing abattoirs in the country to meet the fast growing demand for consumption. Despite the effort by many researchers to improve in the design approaches of hygienic abattoirs, there is still minimal consideration on waste utilization especially during design stages.

In order to reduce the environmental pollution and increase energy potential, there is need to design a sustainable means of containing and recycling most byproduct of our activities. The is a notion that abattoir produces one of highest environmental pollution.

1.3 Aim and Objectives

1.3.1 Aim

The aim of the study is to develop an abattoir waste management strategy through architectural design that utilizes Biogas /Anaerobic digester as a source of sustainable energy for the operation of an abattoir.

This aim can be achieved through the following objectives :

1.3.2 Objectives

i. To explore sustainable design strategies in abattoir.

ii. To study existing abattoirs design, waste and energy management strategies in Nigeria.

iii. To propose a sustainable abattoir design that combines management and energy efficiency in Katsina.

1.4 Research Question

This research is focus to answer the following questions;

i. What are the basic requirements in designing a sustainable abattoir?

ii. Why is the existing situation of abattoir design, waste and energy management in Nigeria?

iii. How can sustainable architectural design guide the design of improve waste and energy management in Nigeria?

1.5 Scope and Limitation Of The Study

This reseach highlights examples of existing abattoirs in Nigeria. But it does not deal with residues in meat deriving from environmental pollutants, veterinary drugs, growth-promoting agents and illegal preservatives, which might be found in meat. The concern of this project is the poor waste disposal handling of many country abattoirs before and after routine slaughtering as it relates the following;

i. Effective production and storage of meat products.

ii. Improving waste management exercises through the provision of Anaerobic/bio-gas digester.

iii. To provide functional facilities for disposal/removal of offensive wastes.

1.6 Justification of the Study

The National Environmental Sanitation Policy identified Abattoir sanitation as one of the key policy issues to address the enormous problems of Environmental Sanitation in Nigeria (Mohammed, 2011). Examples of overwhelming sanitation problems in abattoirs include, but not limited to, improper refuse disposal, inadequate water supply, gross-inadequacy of sanitary facilities that results in open defecation and urination, overcrowding and the exposure of flood to flies, rodents and contaminants. The identified reasons for these problems as highlighted in the National Environmental Sanitation Policy are improper for planning of abattoirs; the springing up of illegal abattoirs (including private slaughter houses); lack of provision of adequate facilities such as portable water, lack of appropriate institutional regulations, enforcement and monitoring and above all, corrupt and sharp practices by the supervisors of abattoirs.

Katsina is an urban city in Nigeria and sit on the border to Niger Republic adding to local meat requirement of about 250-350 per head of large animals daily. In addition abattoir waste has a complex composition and can be very harmful to the environment. Therefore the importance of knowing the pollution potentials of abattoir wastes and various solutions cannot be over-emphasized.

CHAPTER TWO

LITERATURE REVIEW

2.1 Historical development of abattoir

Abattoir meaning "slaughter house" is a building where animals are killed for human consumption. Abattoirs are usually the starting point of the meat industry, and in these places, stock come through farms/market to go into food chain. Abattoirs have existed since there have been settlements housing more individuals to rear their own stock for personal consumption.

Research has shown that an effort to make abattoirs more humane for the animals was made by Dr. Temple Grandin (Deesing, 2008). In more recent part of the 20th Century, the layout and design of most U.S abattoirs has been greatly influenced through the work of Dr. Temple Grandin, It was her state of intense interest with patterns and flow that first enabled her to rebuild the layout design of cattle holding pens as shown in Plate 2.1, and are intended to provide relief on animals being led to slaughter.



Plate 2.1: Curved cattle holding pens Source**:** food and agricultural organization fao, (2013).

Since the major aim and objective of Grandin's work is to help the operators of slaughterhouses to improve their productivity and also to maximize profit, she proposed that the stress and sufferings of animals to be slaughtered may help achieve this aim and objective. Particularly, she applied an understanding of animal behavior to design pens and corrals which funnel a herd of animals coming to the abattoir into one row ready for slaughter. The corrals are made up of very long sweeping curves such that one animal cannot see what lies in front and just focus on the hind quarters of the animal in front of it. The design concept also tries to override the animals'

survival instincts and stops them from reversing direction. According to the United States Department of Agriculture USDA (2007), Grandin now claims to have designed over 54% of the abattoirs in the United States as well as many others around the world.

Generally, abattoir has standards and regulations governing its design and construction and varies considerably around the world. The slaughtering of animals in some countries is guided by customs and traditions in a particular community rather than by law. In many societies, animals screened out to be slaughtered perhaps are guided by religious laws, commonly known as Halal for Muslims and Kashrut for the Jewish world. The two religious require that the animals selected to be slaughtered should be conscious at the time of death, and as a result, the animals are not allowed to be stunned before they are slaughtered. This generated a lot of disagreements with national regulations where abattoir processes in many parts of the Western nations. The captive bolts and the different other methods of pre-slaughter paralysis are generally not allowed in both Islamic and Jewish laws, because it is being prohibited for every animal to be killed before slaughtering.

Many halal food governments in the modern time embrace the use of the recently formulated fail-safe system where only the head is stunned. The shock is less painful and non-fatal. The result gotten through scientific experiment reveals that it is a two way process which is practicable to reverse the procedure and revive the animal after passing of the electric current.

Some countries stipulate laws that ban the slaughtering of certain species or grades of animals for human consumption, in particular the ones that are considered taboo food. The former Indian Prime Minister; Atal Behari Vajpayee 2004 , formulated a legislation banning the slaughter of cattle (cows) in the whole of India, believing that the slaughtering of cows is unreasonable and offensive since, Hinduism holds cows as sacred. This belief was always criticized on the bases of religious freedom. The butchering of cattle (cows) and the movement of beef into the nation of Nepal are generally prohibited. According to (FAO, 2010), many U.S states have banned the slaughtering of dogs as food for human consumption. Also, the trading and consumption of horse meat is not permitted in the United States, but horses are slaughtered for meat export to Europe and Japan for human consumption and for the U.S pet food market.

2.1.1 Meat as food

Meat is a general term used to describe the edible products of any animal after slaughtered. For example; beef and veal (Cattle), lamb and mutton (Water Buffalo, Sheep), Pork (Goats, Pigs), horse meat (Horses) and fowl largely (Chickens, Turkeys, and Ducks), and increasingly fish from the agriculture industry (Fish farming).

2.1.2 Average consumption of various meats

In this section, livestock production, consumption is limited to some species of animals which includes Cattle, Sheep and Goats. The three animal species are currently recorded on the list of International Livestock Centre for Africa (ILCA's) research agenda. According to FAO (2005) for total meat production data; World Bank (2013) for human population figures, revealed that aggregate meat production and related data for the selected countries are shown in table 2.1.

Table: 2.1 Meat production, human population and per capita in selected countries

Country	Total meat production ('000 tons)	Human population mid-2013 (millions)	Per capita meat production (kilogram)	Per capita (U.S $)
Cote d'Ivoire	127	18.8	18.6	660
Ethiopia	556	72.3	21.1	110
Mali	134	16.5	28.9	150
Nigeria	846	160	26.5	800
Sudan	553	31.7	30.3	300
Zimbabwe	110	12.4	15.1	680
Total,	2326	268.4	18.3	
SSA	4875	516.5	11.7	400

Source: FAO (2005) and World Bank (2013) for population figures.

For this study, the pastoral practices in the selected countries influenced the production of bulk number of ruminant animals. In SSA, 1/per capita meat production varies considerably, ranging from about 8.5kilogram per person in Nigeria to about 25.3kilogram per person in Sudan. The selected countries all together account for almost half the total meat production (by weight), producing a remarkable differences in the growing population and pastoral resources within the selected countries.

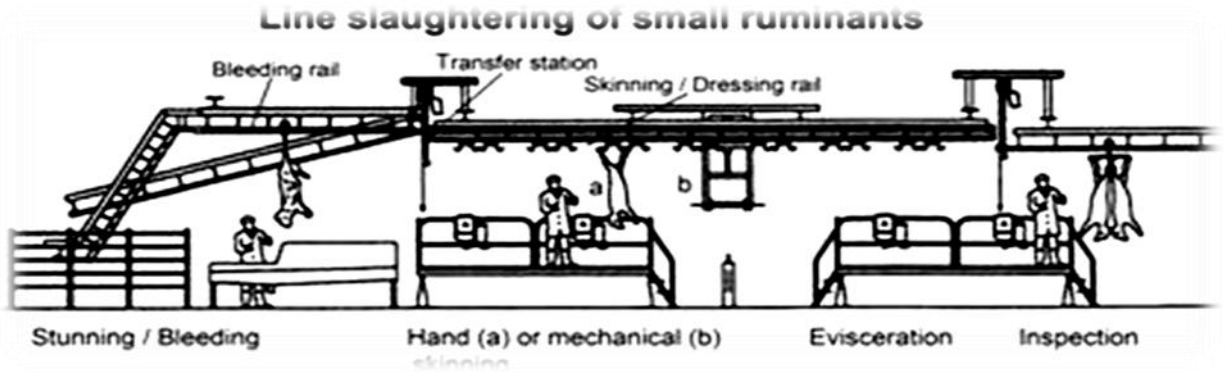
In the selected countries only cattle meat accounts for about 41% (by weight) of total the meat production. Goat meat followed by almost (12%), mutton to about (11%) and the remaining (46%) contained milk production. Therefore, the aggregate meat shares prevent significant country declination in production. The share in total of meat output for cattle meat varies in different countries from almost 29% to about 64%, while goat meat accounts for about 4% to 16% of the total share and for mutton and lamb accounts for almost 1% to 18% of the total share. Cattle meat has the highest share and almost the same in countries such as Sudan and Zimbabwe despite the degree of differences in their production system. In countries of Nigeria and Mali, the share of goat meat is said to be high, but very low in Zimbabwe and Cote d'Ivoire.

2.1.3 Types of abattoirs

Abattoirs are classified based on size which depends on the facilities put in place for various processes in the meat industry.

2.1.3.1 *Line slaughter system*

More recently abattoir operation uses the line-slaughter method for small ruminants. "Line slaughter" required that the carcass should be hoisted up at the first stage and it is recommended to begin with the slaughtering (bleeding). All slaughtering and dressing procedures at a time later are carried out by hanging the carcass off the ground and driving through the overhead rail or ''line''. Therefore, line slaughter is preferable for cattle and small ruminant as shown in figure



2.1

Figure 2.1: Line slaughter system Source: fao (2013).

Several campaigns for upgrading of abattoir have been introduced in many developing nations, and the use of a line-slaughter facilities were embraced by the abattoirs at reasonable cost. However, countries like Indonesia, Pakistan and many more opposed the line slaughter approach. The opposition groups includes abattoirthat are not ready to accept the modern practices, this is a great challenge to food safety and consumer protection.

2.1.3.2 *Booth slaughter system*

Booth slaughter system as shown in figure 2.2 have the areas are separated into different spots called 'booths'. Both permit simultaneous slaughtering of an estimated number of animals in'batch'. A team of abattoir workers attend to every slaughtering spot. The animals in a booth system are each transferred to a confined floor area of which are slaughtered and dressed in that spot. The repeated slaughtering of the animals usually causes congested conditions and health related problems. The facility is generally insufficient in many places with just a knife and axe employed. In some abattoirs, the carcasses are lifted up by the use of hoists as shown in plate 2.2

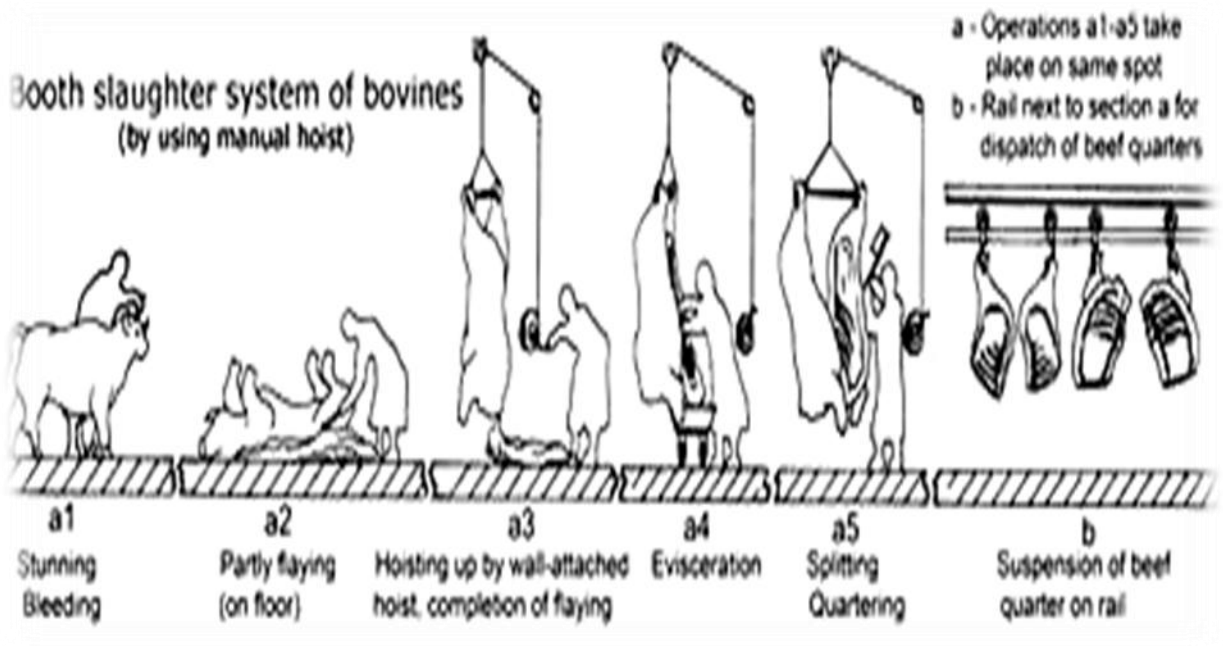


Figure 2.2: Booth slaughter system FAO (2013).

Slaughtering and dressing of animals in small – scale operations, is done on the same area and can be done hygienically provided the required facilities are put in place to includes, hoists and skinning cradles. These equipments are to be used in combination with an overhead railing to make easy the removal of the skin or dispatching of the carcasses. The skinning cradles for removal of skin are processed with cattle, and they help to prevent the carcasses contact with the floor.

Large – scale batch slaughter facilities with a daily output of thousands of small ruminants could be found operating in contrast to the batch slaughter of large animal (Cattle), in different population centers of Asia's developing countries, particularly the Muslim communities and in these places the demand of sheep and goat meat are high. Fortunately, batch operation of small animals can be carried out more hygienically so that, after bleeding, the carcasses can be hanged vertically on hanging racks with hooks or suspension devices.



Plate 2.2: Batch-slaughtering system for small ruminants FAO (2013).

2.1.3.3 *Modified booth slaughter systems for bovines*

Many slaughterhouses or operators in Nigeria do not have the means for proper carcass suspension and this causes a multitude of hygienic problems in bovine slaughtering. Carcass suspension is regarded as one of the basic principles of hygienic slaughtering which involves the lifting of carcasses off the floor at the first stage with bleeding. Therefore, bovines mainly cattle

in Nigeria have to be lifted up mechanically. Farm or field slaughtering of cattle is uncommon, but may occur, in an emergency situation as a result of drought and/or disease infections.

2.1.3.4 *Mobile slaughter facilities*

The efforts made in the past to build mobile slaughter facilities involve the construction of a mobile container for the production chickens. But, since the procedures in large animal slaughtering involved the use of line-slaughter methods, the use of mobile container would limited considering the amount of solid wastes discharges in butchering. In an event where the mobile slaughter facility is required to perform field operations, the preferred alternative method to adopt is to construct line-slaughter components in a way that the hoists and the railing can be mantled and dismantled easily.

The circular rail holds several manual hoists and initial skin removal and hock cutting can be done on the ground once the animal bleeding is completed. The carcass can be hoisted up from the slaughtering spot immediately and conveyed along the rail to another area so that the remaining processes to includes, flaying, eviscerating and splitting is achieved in a vertical position. The circular rail allows the mobile hoists to return to the slaughtering and bleeding area to allow the hoisting of the subsequent carcasses. The circular rail involved manual lifting as shown in plate 2.3 and can be achieved using a wall-attached hoist. The circular rail system is recommended for the simple manual chain block and where possible the electric hoist can be used instead of the manual hoists. Some modification of the booth (batch) system can be done to give a different approach to the booth system as shown in Plate 2.3.



Plate 2.3: Modified booth-slaughtering system: FAO (2013)

2.1.4 Changing consumer preference in abattoir

Generally, meat products are predisposed under cold chain in many developed nations, where all the carcasses are refrigerated once the butchering is completed. In developing countries of Asia and Africa, the traditional customs of purchasing recently slaughtered (hot) meat is prevalent. However, in some member countries of the Animal Production and Health Commission for Asia and the Pacific (APHCA), remarkable differences are recorded to this traditional way of butchering animals with the introduction of meat retailing in supermarkets or in a well-established shops where refrigerated meat only sold, to improve tenderness and the growing popularity for beef.

According to Food and Agricultural Organization (2010), abattoirs that produced meat for export or well established meat shops require the carcasses be refrigerated for not less than 24 hours for pig and not less than 48 hours for cattle. Some Asia countries such as Malaysia and China have since started adopting the developed-country approach. It was gathered from study that, as long as the price differences of cold and hot meat remain possibly small and its cleanliness found appealing, the previous biased attitude of the consumers against meats that are subjected to cold chain may decrease.

In most African countries however, the night-time butchering operations cannot be replaced within a shortest possible term. Since the night-time butchering formed the only means of the traditional meat-marketing system. The simple infrastructure prevailing in the meat sector of these countries formed the bases for the systems financial sustainability. Since the meats are not refrigerated and requires short maintenance periods and also, short time is required to transport these meats from where they are slaughtered (abattoirs) to where they can be marketed mostly in a wholesale packages (meat markets) and lastly the final consumers. Because of the short time operations that normally take between meat production and consumption, spoilage by micro-organisms cannot be of any effect, even if the meat gets heavily contaminated.

One more reason for the high demand of freshly butchered meat is the common and known practice in many Asian countries of processing meat products, which includes meat balls, meat loaves or emulsified sausage products for which “prerigor” meat is particularly well suited due to its pronounced binding capacity. .

2.1.5 Waste in Abattoirs

Waste management is the collection, transport, processing or disposal, managing and monitoring of waste materials. The term usually relates to materials produced by human activity, and the process is generally undertaken to reduce their effect on health, the environment or aesthetics. Waste management is a distinct practice from resource recovery which focuses on delaying the rate of consumption of natural resources. All wastes materials, whether they are solid, liquid, gaseous or radioactive fall within the remit of waste management

Waste management practices can differ for developed and developing nations, for urban and rural areas, and for residential and industrial producers. Management of non-hazardous waste residential and institutional waste in metropolitan areas is usually the responsibility of local government authorities, while management for non-hazardous commercial and industrial waste is usually the responsibility of the generator subject to local, national or international controls.

Waste management concepts

There are a number of concepts about waste management which vary in their usage between countries or regions. Some of the most general, widely used concepts include the hierarchy in figure 2.3:

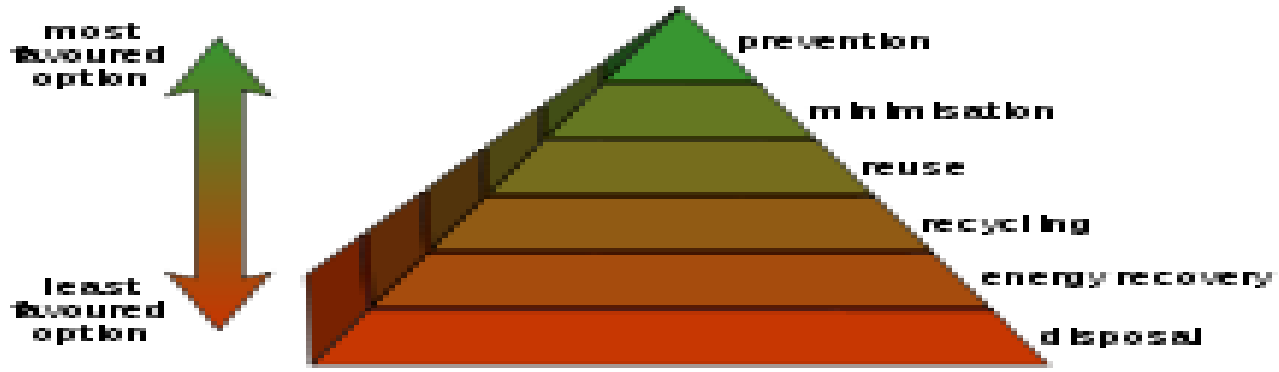


Figure 2.3; Diagram of the waste hierarchy

i. Waste hierarchy - The waste hierarchy refers to the "3 Rs" reduce, reuse and recycle, which classify waste management strategies according to their desirability in terms of waste minimization. The waste hierarchy remains the cornerstone of most waste minimization strategies. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.

ii. Polluter pays principle - the Polluter Pays Principle is a principle where the polluting party pays for the impact caused to the environment. With respect to waste management, this generally refers to the requirement for a waste generator to pay for appropriate disposal of the unrecoverable material.

The policy Guideline seeks to promote and protect the health of all Nigerians by ensuring the standard of sanitation within and in the surroundings of all abattoirs throughout the country, through the establishment and enforcement of adequate standards of sound sanitation in abattoirs. Therefore, construction and management of abattoirs shall be made sustainable in Nigeria and this shall be achieved in the following ways;

i. In cities where private sector participants are available, Government shall provide for them an enabling environment for the construction and management of abattoirs.
ii. In rural and semi-urban areas where private sector is not feasible, government shall be involved in the construction of abattoirs while the management is franchised.
iii. As much as possible, infrastructure and services to abattoirs shall be made self-sustaining.
iv. Public-private partnership shall be explored in securing needed funds for abattoir provision.
v. Government shall build capacity of veterinary practitioners at all levels for effective take-off of the programme.
vi. Government shall build capacity of Environmental Health Officers at all levels for effective take-off of the programme.

The waste materials generated in the course of meat production are known as by-products with high value in both the domestic and overseas market that fetch the meat dealers more profits if properly handled. Practical examples of some of the by-products include; the hides, the horns

and the feet. However, what are subject to more research are the products of pharmaceuticals and industrial importance gotten from blood, intestine and bones.

2.1.6. List of equipments for slaughtering operations

- Stunning gun, electrical head tongs or simple stunning equipment for direct blow; or ritual slaughtering device.
- Breast bone saw
- Dehider (circular disc)
- SIG knife dehider
- Horn cutter
- Leg cutter
- Loin dropper
- Beef splitting saw
- General purpose reciprocating saw
- Breaking saw
- Dehider blade reconditioned
- Knife grinding machine
- Disinfection box (sterilizer)
- Oesophagus closing device
- Knives:
    - sticking: 16 cm sharpened on both sides
    - skinning: 16 cm curved
    - a sharpening steel
    - oil or water sharpening stone
    - scabbard and belt for holding knives
- Meat saw (hand or electric) and cleaver
- Block and tackle or chain hoist strong enough to hold the weight of the animal to be slaughtered
- Pitch, chocks or skinning rock (dressing cradle)
- strong beam, tripod or track 2.4-3.4 m from the floor
- Spreader - gambrel or metal pipe
- Several buckets
- Working platforms.

Other useful additional equipment includes:

- Stunning pen
- Bleeding hooks (for vertical bleeding)
- Blood-catching trough
- Wash trough (for tripe).

The following items are necessary for sanitation of hands and tools:

- Hand wash-basin
- Sterilizers
- Disinfectant

. List of equipments for cutting and boning operations

- Circular saw machine
- Various sets of cutting knifes
- Security clothes
- Manual labeller
- Skin hammer
- Stainless steel hooks
- Pneumatic cutter
- Hand spraying pump
- Mobile belt conveyor
- Cutting tables
- Knife sterilizer
- Hand wash basins
- Ice machines
- Angle meat grinder
- Frozen meat cutter
- Floor and suspended wall amounted weighing scales
- Small wagons
- Cabinets
- bag loaders
- vacuum packaging machines
- steam shrink tunnels

- Bag blow-off tunnels.

2.1.7. Abattoir and sanitation

The term "sanitation" refers to the cleaning and disinfecting of abattoirs as well as the controlling of insects and rodents through the use of chemical substances.

Necessary conditions for efficient cleaning and sanitation;

i. Premises and equipment must be "cleaning-friendly", which means they must have easy and practical access to all contaminated areas and as well as smooth surfaces and adequate materials for building structures and equipments to be cleaned.
ii. Proven method for meat plant cleaning and sanitation must be available.
iii. Personnel must be regularly instructed and trained in cleaning and sanitation methods.

"Cleaning" refers to the removal of dirt and organic substances, such as fat and protein particles, from surfaces, walls, floors, tools and equipments. To improve the cleaning and sanitation situation in abattoirs, physical structures needs to be upgraded to make them "cleaning-friendly" as shown in Plate 2.4

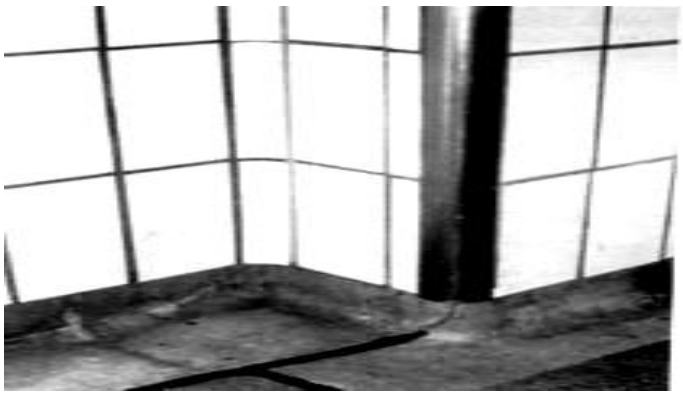


Plate 2.4: Smooth and impermeable surfaces of typical abattoir floors and walls FAO (2013).

2.1.8. Proper cleaning

i. Dry cleaning (physically remove scrap, such as coarse solid particles, with a dry brush or broom).
ii. Wet cleaning (Using brushes and water hose).
iii. High-pressure cleaning (pressurized water is applied with high pressure units and special spraying lances);
iv. Use of chemical cleaning solutions (detergents).

"Disinfection" is the complete removal of microorganisms from surfaces, floors and tools. Disinfection is achieved either by using hot water (or steam) or preferably, chemical disinfectant compounds are used in the meat industries as shown in Plate 2.5



Plate 2.5: Disinfection of walls using portable spray equipment Source: fao.(2011).

2.1.9 Common chemical disinfectants;

i. Chlorine-containing compounds
ii. Quaternary ammonium compounds
iii. Oxygen-releasing substances (peroxide compounds).

During the research for this project, workers in a traditional cattle slaughterhouse were seen using kerosene and detergents for disinfecting; most probably it was the commercially available household bleach materials. Chlorine-containing compounds are suitable and efficient for disinfecting such traditional facilities as long as the right concentration is used – because they barely use mechanical metallic equipment or machines. Chlorine compounds, otherwise, react very aggressively (corrosion) on the metal. However, the chlorine compounds do not affect floor and wall tiles or stainless steel equipments, such as scraping tables. Highly mechanized abattoirs should use quaternary-ammonium compounds or oxygen-releasing substances when disinfecting.

2.1.10. Improving sanitation in abattoir

Abattoirs aim at optimizing the recovery of edible portions from the meat processing cycle for human consumption. Significant quantities of secondary waste materials not suitable for further consumption are however, generated. Since water is often used to wash excessive waste solids to drain, waste solids should be carefully managed to promote water conservation. The most widely used and recommended route for disposal of abattoir-waste is municipal sewers as best management practices which broadly applies in terms of pre-treatment to proposed project. But in most cases, abattoirs normally have difficulty in meeting municipal by-laws for fats, oils, greases and suspended solids. A degree of on-site pre-treatment is therefore preferable (adequate drainage layout and a biogas plant).

i. Proper Drainage Layout:- Satisfactory drainage with traps for solids and oil/fat shall be provided in proper working order for all floors in Lairage, slaughter halls, workrooms, hanging rooms and any rooms for the retention shall be laid to have a step down of 50mm for every 3,000mm to ensure the free flow of waste water by gravity.

ii. Biogas Digester Plant:- Biogas digesters breakdown organic substances that make up almost 100% of the pollutant load of farm or abattoir effluents, primarily to methane gas, but also to CO_2 (to a minor extent) and traces of other gases through the activity of anaerobic bacteria. Anaerobic conditions are created through the construction of air-tight chambers, usually submerged in the ground as shown in plate 2.6.



Plate 2.6: Construction of a biogas digester: An anaerobic baffle reactor under construction. Source: fao. (2013).

Biogas digesters are relatively inexpensive to be constructed. They require little maintenance and generate energy (gas to be used for energy requirements at the abattoir) and the solid residues can be used as fertilizer.

The construction materials used are hollow blocks, cement, sand, gravel, rebar and pipes. The capacity of the digester chamber depends on the volume of effluent to be treated and the retention time; but generally for small-to-medium-sized abattoirs it holds 30 cubic meters. When biogas digestion is completed, most organic matter is broken down to methane, CO_2 and water. Remaining solid materials are primarily sludge.

2.2 History Of Waste Management

Historically, the amount of waste generated by humans was insignificant due to low population density, coupled with insignificant exploitation of natural resources. Common waste produced during early human history was mainly ashes and human biodegradable waste, and these were released back into the ground locally, with minimum impact. Before the widespread use of metals, wood was widely used for most applications. However, reuse of wood has been well documented. Nevertheless, it is once again well documented that reuse and recovery of such metals have been carried out by earlier humans.

With the advent of industrial revolution, waste management became a critical issue. This was due to the increase in population and the massive migration of people to industrial towns and cities from rural areas during the 18th century. There was a consequent increase in industrial and domestic wastes posing threat to human health and the environment. The living conditions of rural areas in England during this time forced society to propose solutions and bring about change. The understanding of good hygiene was important in order to maintain a desired lifestyle.

Waste has played a tremendous role in history. The Bubonic Plague, cholera and typhoid fever, to mention a few, were diseases that altered the populations of Europe and influenced monarchies, they were perpetuated by filth that harbored rats, and contaminated water supply.

It was not uncommon for Europeans to throw their waste and human wastes out of the window which would decompose in the street.

France, specifically Paris seems to have been a leader in poor waste management. The famed Paris sewer system was created over a long period of time in the second half of the 19th century. The long delays were largely due to the virulent opposition of property owners, who did not want to pay to install sanitary piping to their buildings. The Prefect of Paris, Monsieur Poubelle, succeeded in forcing garbage cans on the property owners in 1887 only after a ferocious public battle. This government interference in the individual's right to throw his garbage in the street - which was, in reality, the property owner's right to leave his tenants no other option - made Poubelle into the 'cryptosocialist' of the hour. In 1900 owners were still fighting against the obligations to put their buildings on the public sewer system and to cooperate in the collection of garbage. By 1910 a little over half of the city's buildings were on the sewer system and only half of the cities in France had any sewers at all.

2.2.1 Methods of disposal

Mechanical (digester plant) and biological (chemical disinfectants) treatment plants are employed to manage waste in developed abattoirs high cost in the initial installation and day to day operations. Traditional treatment plants which include solid pits or septic tanks cost less but do not provide the required results and are not efficient to significantly reduced pollution.

Avoidance and reduction methods

An important method of waste management is the prevention of waste material being created, also known as waste reduction. Methods of avoidance include reuse of second-hand products, repairing broken items instead of buying new, designing products to be refillable or reusable (such as cotton instead of plastic shopping bags), encouraging consumers to avoid using disposable products (such as disposable cutlery), removing any food/liquid remains from cans, packaging, and designing products that use less material to achieve the same purpose.

2.2.1.1. *Landfill*

Disposal of waste in a landfill involves burying the waste, and this remains a common practice in most countries. Landfills were often established in abandoned or unused quarries, mining voids or borrow pits. A properly designed and well-managed landfill can be a hygienic and relatively inexpensive method of disposing of waste materials. Older, poorly designed or poorly managed landfills can create a number of adverse environmental impacts such as wind-blown litter, attraction of vermin, and generation of liquid leachate. Another common product of landfills is gas (mostly composed of methane and carbon dioxide), which is produced as organic waste breaks down anaerobically. This gas can create odor problems, kill surface vegetation, and is a greenhouse gas.

Design characteristics of a modern landfill include methods to contain leachate such as clay or plastic lining material. Deposited waste is normally compacted to increase its density and stability, and covered to prevent attracting vermin (such as mice or rats). Many landfills also have landfill gas extraction systems installed to extract the landfill gas. Gas is pumped out of the landfill using perforated pipes and flared off or burnt in a gas engine to generate electricity.

2.2.1.2. *Incineration*

Incineration is a disposal method in which solid organic wastes are subjected to combustion so as to convert them into residue and gaseous products. This method is useful for disposal of residue of both solid waste management and solid residue from waste water management. This process reduces the volumes of solid waste to 20 to 30 percent of the original volume. Incineration and other high temperature waste treatment systems are sometimes described as "thermal treatment". Incinerators convert waste materials into heat, gas, steam and ash.

Incineration is carried out both on a small scale by individuals and on a large scale by industry. It is used to dispose of solid, liquid and gaseous waste is a controversial method of waste disposal, due to issues such as emission of gaseous pollutants.

Incineration is common in countries such as Japan where land is scarcer, as these facilities generally do not require as much area as landfills. Waste-to-energy or energy-from-waste is

broad terms for facilities that burn waste in a furnace or boiler to generate heat, steam or electricity. Combustion in an incinerator is not always perfect and there have been concerns about pollutants in gaseous emissions from incinerator stacks. Particular concern has focused on some very persistent organics such as dioxins, furans, PAHs which may be created which may have serious environmental consequences.

2.2.1..3. *Reuse*

Recycling is a resource recovery practice that refers to the collection and reuse of waste materials such as empty beverage containers. The materials from which the items are made can be reprocessed into new products. Material for recycling may be collected separately from general waste using dedicated bins and collection vehicles are sorted directly from mixed waste streams. It requires the owner of the waste to separate it into various different container prior to its collection.

2.2.1.5. *Energy-from-waste*

A number of broad studies have indicated that administration, source separation and collection followed by reuse and recycling of the non-organic fraction and energy and compost/fertilizer production of the organic material via anaerobic digestion to be the favored path. Recoverable materials that are organic in nature, such as plant material, food scraps, and paper products, can be recovered through composting and digestion processes to decompose the organic matter. The resulting organic material is then recycled as mulch or compost for agricultural or landscaping purposes. In addition, waste gas from the process (such as methane) can be captured and used for generating electricity and heat (CHP/cogeneration) maximizing efficiencies. The intention of biological processing in waste management is to control and accelerate the natural process of decomposition of organic matter.

The energy content of waste products can be harnessed directly by using them as a direct combustion fuel, or indirectly by processing them into another type of fuel. Thermal treatment ranges from using waste as a fuel source for cooking or heating and the use of the gas fuel (see above), to fuel for boilers to generate steam and electricity in a turbine. Pyrolysis and gasification are two related forms of thermal treatment where waste materials are heated to high

temperatures with limited oxygen availability. The process usually occurs in a sealed vessel under high pressure. Pyrolysis of solid waste converts the material into solid, liquid and gas products. The liquid and gas can be burnt to produce energy or refined into other chemical products (chemical refinery). The solid residue (char) can be further refined into products such as activated carbon. Gasification and advanced Plasma arc gasification are used to convert organic materials directly into a synthetic gas (syngas) composed of carbon monoxide and hydrogen. The gas is then burnt to produce electricity and steam. An alternative to pyrolysis is high temperature and pressure supercritical water decomposition (hydrothermal monophasic oxidation).

2.3. Anaroebic / Biogas Digester

An Anaerobic digester also known as Bio-gas digester is a simple system which produces biogas, via the natural anaerobic decomposition of organic material. The biogas digester, once its "starter culture" of methan (CH_4 producing) organic bacteria has been established (usually several weeks after initial loading with animal manures or lake mud) can be fed regularly with waste. The ecosystem of bacteria in the biogas digester extracts energy from the organic material and generates methane gas. The digested organic material exits the system as a high-quality fertilizer in liquid form. This liquid anaerobic "compost" still contains all the minerals and other soil nutrients of the animal waste, including the nitrogen that can be lost through aerobic composting. Richards, B.; Herndon, F. G.; Jewell, W. J.; Cummings, R. J.; White, T. E. (2011).

2.3.1 Biogas Plant Designs

Depending on the nature of waste and amount of energy required, the plant is categorized in accordance with the design specification some of which are shown in figure 2.4,2.5 and 2.6. To give an overview, some fictitious designs have been chosen as they could be found in for example, Europe. The designs are selected in a way that all the typical elements of modern biogas technology appear at least once. All designs are above-ground, which is common in Europe. Underground structures, however, do exist.

Mixing pit varies in size and shape according to the nature of substrate. It is equipped with propellers for mixing and/or chopping the substrate and often with a pump to transport the substrate into the digester. At times, the substrate is also pre-heated in the mixing pit in order to avoid a temperature shock inside the digester.

Fermenter or digester is insulated and made of concrete or steel. To optimize the flow of substrate, large digesters have a longish channel form. Large digesters are almost always agitated by slow rotating paddles or rotors or by injected biogas. Co-fermenters have two or more separated fermenters. The gas can be collected inside the digester, then usually with a flexible cover. The digester can also be filled completely and the gas stored in a separate gas-holder.

Gas-holder is usually of flexible material, therefore to be protected against weather. It can be placed either directly above the substrate, then it acts like a balloon plant, or in a separate 'gas-bag'.

Slurry store for storage of slurry during winter. The store can be open (like conventional open liquid manure storage) or closed and connected to the gas-holder to capture remaining gas production. Normally, the store is not heated and only agitated before the slurry is spread on the field.

Gas use element is in Europe in 95% of the cases a thermo-power unit which produces electricity for the farm, the grid and heat for the house, greenhouses and other uses. The thermo-power unit has the advantage, that the required energy can be produced in any mixture of gas and fossil energy. It can, therefore, react to periods of low gas production and high energy requirements or vice versa.(Richards, B. 2011).

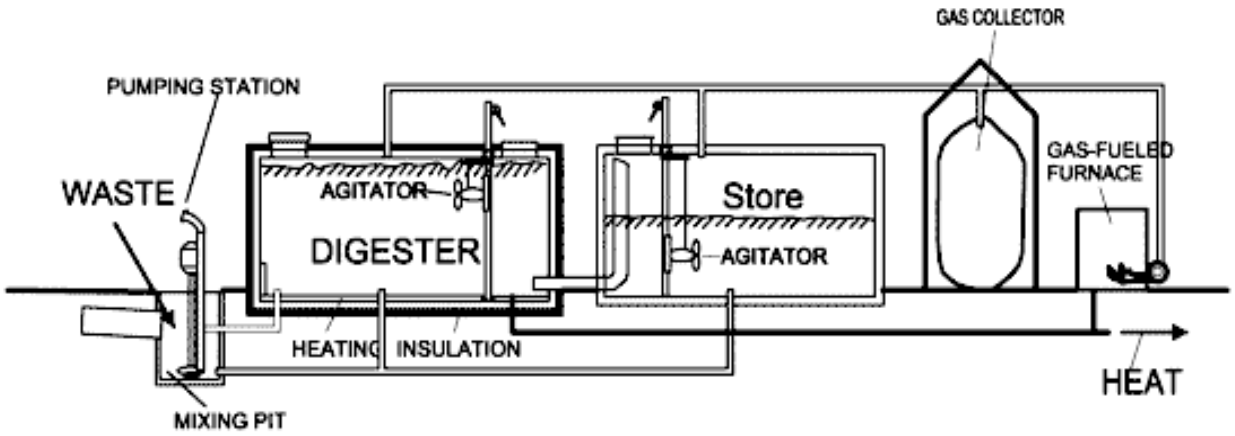


Figure 2.4; Concrete digester with two chambers (one heated, one unheated for storage**)**

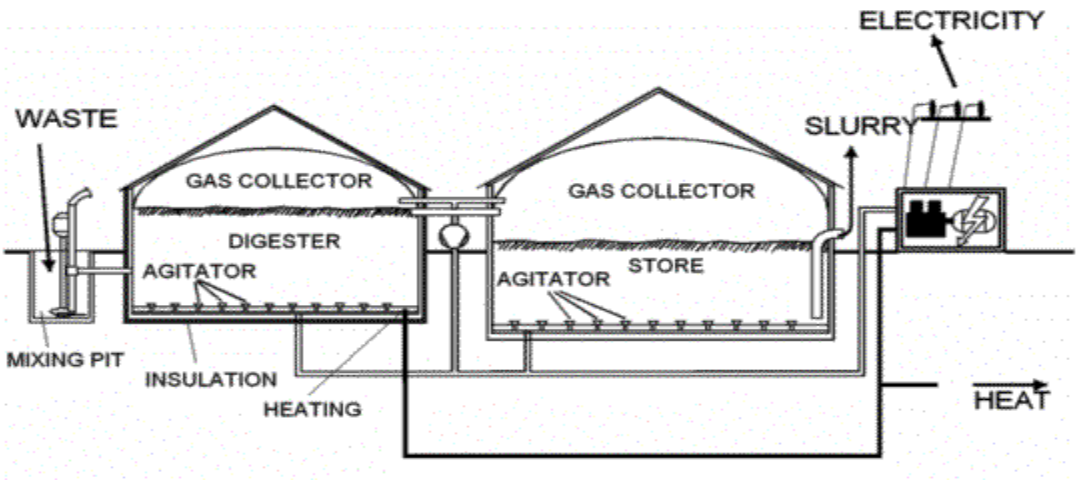


Figure 2.5; Concrete digester with integrated plastic gas-holder

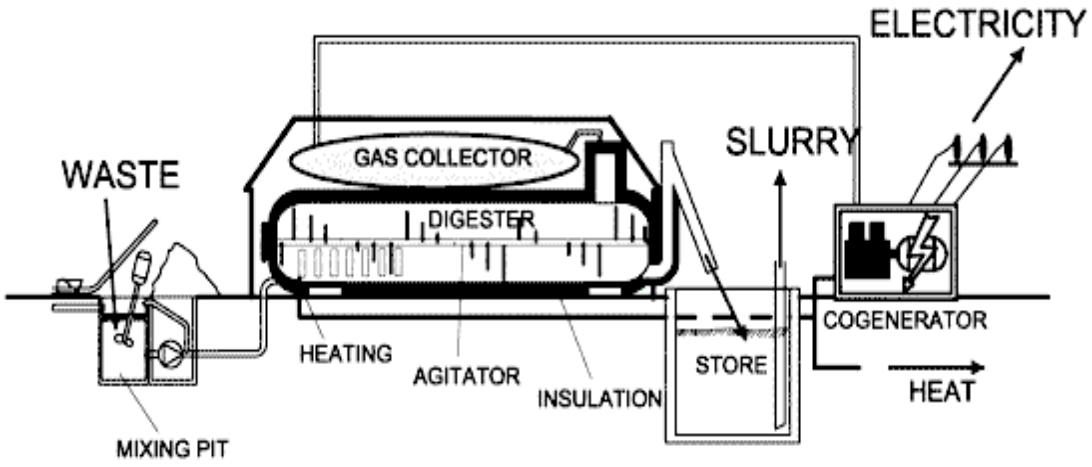


Figure 2.6; Steelvessel fermenter with seperateballon gas-holder

2.3.2.2 *Selection of Appropriate Design;*

The design selection is determined largely be the prevailing design in the region, which, in turn takes the climatic, economic and substrate specific conditions into consideration. Large plants are designed on a case-to-case basis. Typical design criteria are:

Space: determines mainly the decision if the fermenter is above-ground or underground, if it is to be constructed as an upright cylinder or as a horizontal plant.

Existing structures may be used like a liquid manure tank, an empty hall or a steel container. To reduce costs, the planner may need to adjust the design to theses existing structures.

Minimizing costs can be an important design parameter, especially when the monetary benefits are expected to be low. In this case a flexible cover of the digester is usually the cheapest solution. Minimizing costs is often opposed to maximizing gas yield.

Available substrate determines not only the size and shape of mixing pit but the digester volume (retention time!), the heating and agitation devices. Agitation through gas injection is only feasible with homogenous substrate and a dry matter content below 5%. Mechanical agitation becomes problematic above 10% dry matter.

2.3.2. Energy from anoerobic digester

Biogas is only one of many types of biofuels, which include solid, liquid or gaseous fuels from biomass. Any combustible fuel derived from recent (non-fossil) living matter (biomass) may be considered a biofuel, including ethanol derived from plant products, biodiesel from plant or animal oils, as well as, biogas from biomass. All biofuels are produced from sources which are renewable and are included as a subset of renewable energy sources that also include energy produced from solar, hydro, tidal, wind, and geothermal sources as in table 2.3. Biogas, like natural gas, has a low volumetric energy density compared to the liquid biofuels, ethanol and biodiesel. However, biogas may be purified to a natural gas equivalent fuel for pipeline injection and further compressed for use as a transportation fuel. Methane, the principal component in biogas, has four times the volumetric energy density of hydrogen (H_2) and is suitable for use in many types of generators. (Richards, B. 2011).

Table 2.2 Energy Content of Biofuels

Biofuel	**Btu/lb**	**Btu/cu ft**	**Btu/gal**
Biogas (60% CH_4)	13,142	600	80
Purified Biogas (98% CH_4)	21,466	980	131
Pressurized Biogas (3000 psi, 98% CH_4)	21,466	196,000	26,205
Ethanol	11,535	568,956	76,069
Biodiesel	18,163	819,350	109,547

2.3. 3. Bio-Fuel

Biofuel is principally a mixture of methane (CH_4) and carbon dioxide (CO_2) along with other trace gases. Methane gas, the primary component of natural gas (98%), makes up 55-90% by volume of biogas, depending on the source of organic matter and conditions of degradation. Biogas is produced in all natural environments that have low levels of oxygen (O_2) and have degradable organic matter present. These natural sources of biogas include: aquatic sediments, wet soils, buried organic matter, animal and insect digestive tracts, and in the core of some trees. Man's activities create additional sources including landfills, waste lagoons, and waste storage structures. Atmospheric emissions of biogas from natural and man-made sources contribute to climate change due to methane's potent greenhouse gas properties. Biogas technology permits the recovery of biogas from anaerobic digestion of organic matter using sealed vessels, and makes the biogas available for use as fuel for direct heating, electrical generation or mechanical power and other uses. Biogas can often be made from animal wastes in the proportion of energy yield per animal as shown in table 2.3. Finstein, M. S. (2006)

Table 2.3 Waste in-put and Energy Yield out-put of Anaerobic digester

IN-PUT WASTE	Average Solid and Liquid Waste/ head (Kg)	(CH_3 +CO_2) Biogas (m^3/kg)	Energy /electricity OUTPUT Kw
Bovine	45	1.232	0.0261
Ruminant	20	0.638	0.0144

Source; Finstein, M. S. (2006)

2.4 Design Consideration For Sustainable Abattoirs

According to FAO (2010), the classification of criteria based on minimum standards, basic facilities, spatial design and process have an impact on the sustainability in abattoirs as classified in table 2.3, one of the main principles of slaughtering process is to avoid contact between a carcass and the floor. The carcass needs to be off the ground as soon as possible during the first steps of the slaughtering process. This requirement is best fulfilled if carcasses are already off the ground at the point of bleeding. In the absence of supporting technical devices to hoist up carcasses for bleeding, that step can be done on the ground because the carcass is still fully covered by the skin. Once the protective cover of the animal skin is cut open or removed, it is absolutely necessary to prevent any contact with the floor.

Table; 2.4 Abattoir design strategies

BASIC FACILITIES	SPATIAL DESIGN	MINIMUM STANDARDS
• Water Supply • Toilet Facility • Solid Waste Management • Effluent Treatment Facility • Incinerator • Protected Temporary Storage Bins • Percolating Filter • Activated Sludge • Roofing materials • Walls • Floors	• Layout-Adequacy of space and facilities • Lairage-Separate accommodation provided for healthy and sick animals. • Accommodation (administrative unit) • Lighting and Ventilation • Contaminant of Sewage and refuse • Hand washing facilities • Equipment and fittings • Excreta disposal • First Aid Post • On-Site Waste Treatment	• Access points • Proposed parking areas and walkways. • Buildings setbacks • Proposed loading bays • Proposed off-loading bays • Water discharge

2.4.1. Site selection

There are various criteria to be considered when choosing the site for abattoir which include environment, geology, dimensions and services.

i. Environment
ii. Geological structures and features
iii. Site dimensions.
iv. Services

2.4.1.1. *Environment*

No source of contamination (e.g. objectionable odors, smoke, flying ash, etc) should occur in the environment where an abattoir is placed. E.g. a paint factory, foundry, sewage farm, river, residential area, etc. Abattoirs are classified as light industries and can cause water pollution. Therefore, abattoirs should be located at reasonable distances away from any river.

The site where an abattoir is going to be established must be free from big trees that may harbor scavenging birds.

2.4.1.2. *Geological structures and features*

Drainage is affected by the nature of the soil e.g. sandy or loom, by the water table and the slope of the surface. Therefore, the site which is selected for the establishment of an export abattoir must promote good drainage systems.

2.4.1.3. *Site dimensions*

An abattoir site must be large enough to allow abattoir and allied activities to be correctly situated and oriented and provide also possibilities for future extensions.Lairages must not be situated on higher ground than the buildings, nor must they be closer than 10 meters so as to avoid wash down or cross contamination.

Multiple building establishments of an abattoir must be located within one piece and self enclosed.

2.4.1.4. *Services*

Factors under services include Water supply, Effluent disposal, Power source, Access roads, Isolation, Abattoir compound and Abattoir boundary fence.

Water supply: An adequate supply of potable water must be available. Consideration should also be given to the storage and treatment of water.

Effluent disposal: An effective system for the disposal or removal of effluent and satisfactory means of garbage disposal must be provided.

Power source: There must be a reliable source of stand-by power for cooling, heating of water, lighting, as well as for the partial or total mechanization of the abattoir.

Access roods: Access roads to abattoirs should be at least compacted grovel road .Roadways on the premises must be properly graded, compacted, dust proofed, and drained. The building verge, main internal access road, loading bays and all areas serving vehicular traffic must be either paved or tarred.

Isolation: An abattoir should be far from residential areas, social services and airfields. A minimum buffer distance of 500 m downwind of an abattoir and 1000 m for a rendering plant is recommended to the nearest residence or residential area.

Abattoir compound: There has to be a separation either through fence or wall between the clean and dirty areas of the abattoir compound corresponding with the abattoir's internal separation.

Abattoir boundary fence: The abattoir boundary fence must be either masonry wall or wire mesh with iron poles of about 2 meters high.

CHAPTERTHREE

RESEARCH METHODOLOGY

The chapter focus on the research strategy from data collection through analysis and presentation of information on abattoirs in Nigeria. Various approaches are adopted for this research to study the sustainable means of waste management in abattoir design by proper utilization of all byproduct along the meat production to produce energy.

3.1 Case Study Approach

The cases studied for the purpose of this research are in form of qualitative descriptive method. Qualitative research involves an interpretive, naturalistic approach to its subject matter thereby seeking to understand phenomena within specific contexts. Qualitative research identifies the relationships between variables, and generalizing those results to the world at large. (Denzin and Lincoln ,2003),

According to Meyer, the approach enables the researcher to study many different aspects, examine them in relation to each other and view the process within its total environment. The case study approach is considered suitable for this study as it makes use of multiple methods of data collection such as interviews, document reviews, archival records, direct and participant observations etc. (Yin, 2003). Field survey was adopted to validate the data that cannot be collected through other means because of the nature of the research. All the three selected abattoirs were visited. Field visits were supported by comprehensive notes and photographs taken, giving an insight on their physical presence and spatial relativities of each case.

3.2 Population Of Study

Population of study comprises the totality of all subjects that have a set of specifications and characteristics that are of interest to the researcher and to whom the research results can be generalised (Polit and Hungler, 1999). The research population for this study is abattoirs in Nigeria.

3.3 Sampling

Sampling involves a subset of the research population selected to represent the research population. (LoBiondo-Wood and Haber, 2006). For the purpose of this research, a non-probability sampling is used and the selection is purposive where three abattoirs are selected

after careful consideration. The sampling ias limited to three abattoirs; Zango abattoir, Kaduna, Minna abattoir, Niger and Zaria abattoir,Kaduna.

3.4 Instrutment Of Data Collection

Case study for theoretical research in architecture may require the use of general methods for data collection. (Oluigbo, 2010). For this research, the instrument used to collect data include: structured interview, checklist, photographs, sketches and notes..

3.4.1 Interview

The interview in each of the three selected abattoirs were repeated; the same questions were asked on the information of the abattoirs and were answered by the management. The questions were direct, receptive and were decided in advance on what areas to cover. The direct nature of the interview provided the opportunity for both the researcher and the interviewees to discuss the history on relevant information.

3.4.2 Checklist

Checklist was in form of field forms outlining the variables of sustainability. It contained the list of variables which were observed and noted during the survey.

3.4.3 Photographs

Photographs were taken to support the notes taken during the visit and for record. The photographs also provided a significant source of visual data about the case to outside observers. The photographs of relevant areas were taken in order to show the features of sustainable waste management the cases possessed as well as the extent to which they were applied.

3.4.4 Sketches

Sketches showing the selected case studies were made during the field survey. These sketches were considered vital to form an opinion on the physical setting and spatial organisation of the case studies.

3.4.5 Notes

This instrument of data collection was adopted to back-up information discussed during the interview and what was observed during the field survey. Comprehensive notes were prepared as an ongoing record of what was happening as the research progressed.

3.5 Variables Of Study

The variables used in the study were classified into two categories as follows: Architectural features, Waste management strategy and electricity demand.

The parameter selected as indicators of abattoir wastes are solid and liquid waste . Abattoir effluents includes; slaughterhouse garbage, filth and refuse. While solid waste includes; fat/oil, blood solids, hair, stomach fibers/residues, hooves and hides. All the wastes listed in both categories constitute overall abattoir wastes.

The data presented in this research is related to the procedure of analysis of the cases and variables listed in the checklist table.

Table 3.1 check list on Sustainable waste management system

. Scale Factor: Excellent=5, Very Good=4, Good=3, Fair=2, Poor=1				
Variables	**Features**	**Method Adopted**	**Scale Factor**	**Remarks**
Architectural features				
Waste management strategy				
Energy requirement				

CHAPTER FOUR

DATA PRESENTATION AND DISCUSSION

4.1 Case Studies

This is the primary sources of research information that forms the basis for the proposed design. Field work is conducted in the selected abattoirs through which detail accounts of their architectural features, waste management strategy and energy demand are obtained and analysed.

4.1.1 Case Study One: Zango Abattoir, Tudun Wada, Kaduna.

The abattoir is located in Zango road, Tudun Wada, Kaduna North Local Government, Kaduna State, Nigeria. The abattoir was constructed by Kaduna state government, assisted by the United Nations in 1992 as illustrated in figure 4.1.

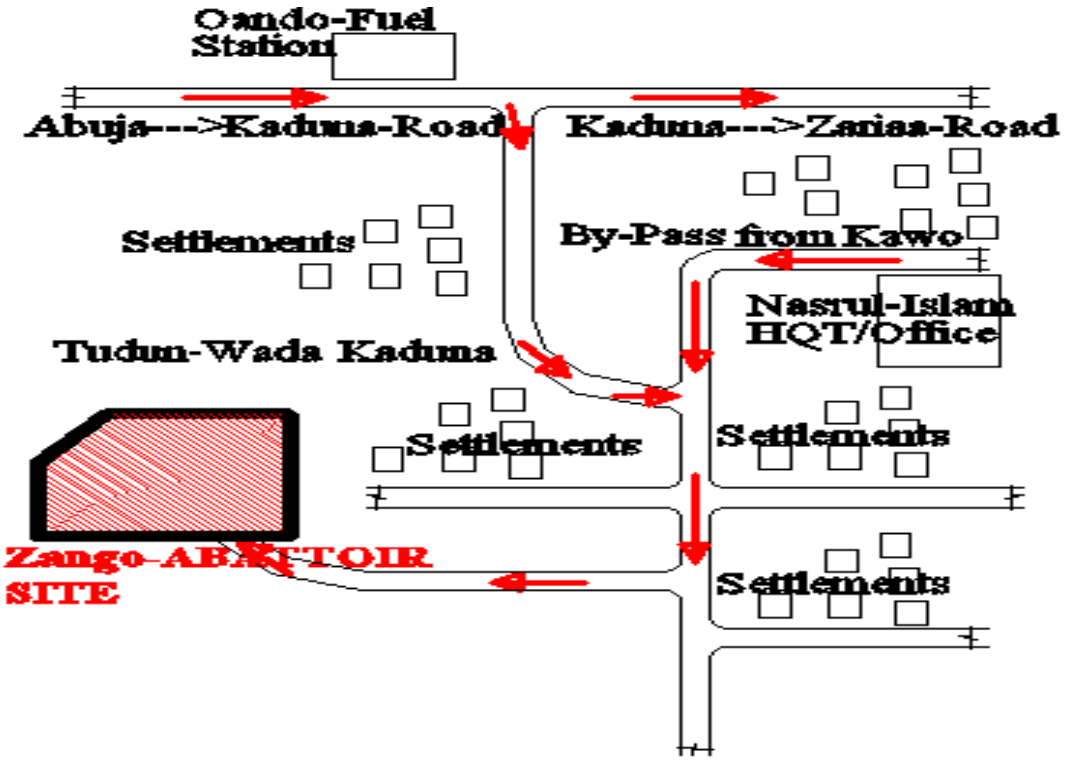


Figure 4.1: Site Location of Zango Abattoir, Tudun Wada Kaduna- Kaduna State, Nigeria (Source**:** Author's field work, (2013)

4.1.2. Architectural features:

These are further classified under site planning and landscaping, spatial organization and design, material and finishes.

4.1.2.1.*Basic facilities;*

The abattoir houses the following facilities: Lairage, cold room, washing areas, manager's office, consideration room, equipment store, weighing area, conveniences, hides and skin washing, slaughtering hall, federal obligation office, washing of residual and slaughtering as illustrated in figure 4.2

4.1.2.2 *Site planning;*

The abattoir site lacks a parking lot to differentiate heavy vehicular movement from cars, walkways. The site is characterized by scattered trees and shrubs as such the absence of landscaping elements exposed the site to erosion and flooding.

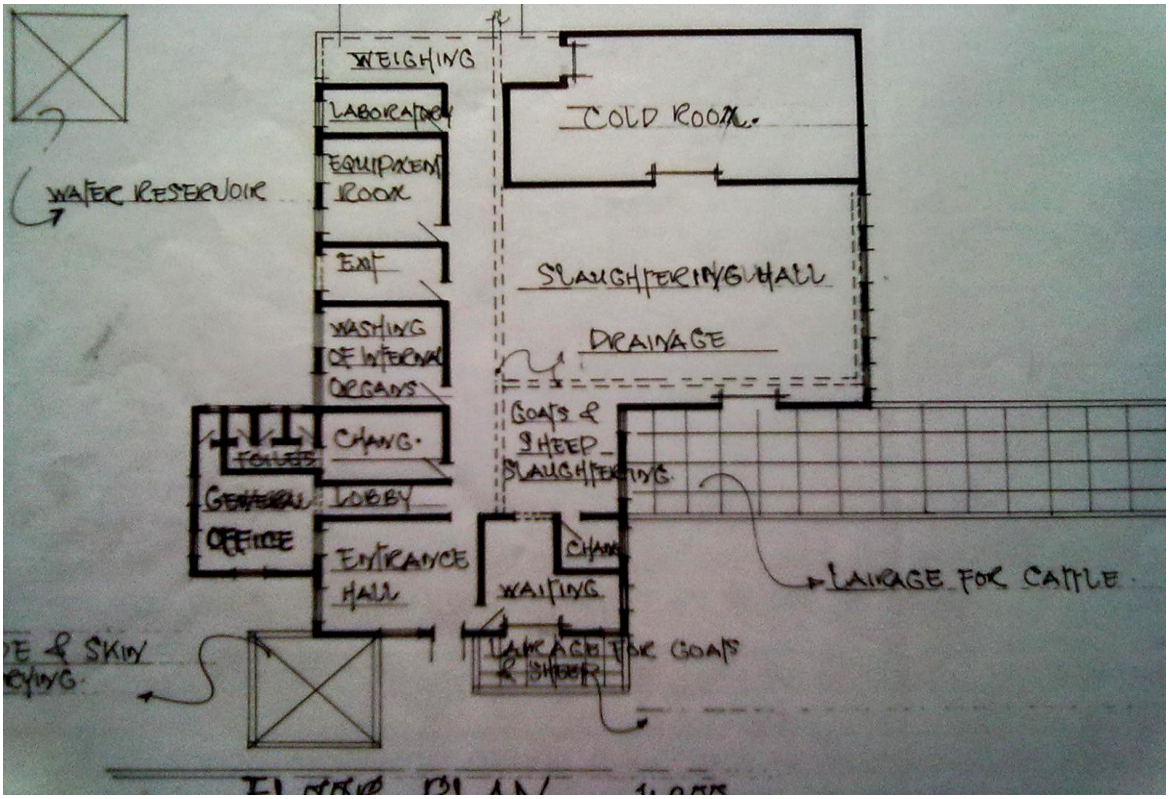


Figure 4.2: Floor plan of Zango Abattoir, Tudun Wada Kaduna- Kaduna State, Nigeria (Source: Author's field work, 2013).

4.1.2.3. *Materials and Finishes;*

Building materials and finishes used in the construction includes; hollow sandcrete blocks, glass, steel rafter, concrete floor, aluminum roofing sheets and paints. The abattoir roofing members is made of steel rafters covered with galvanized aluminum roofing sheets which is resistance to corrosion as shown in plate 4.1



Plate 4.1: Zango Abattoir- Roof members seen from the interior of the abattoir (Source: Author's field work, 2013).

The abattoir's Lairage is turned into slaughtering ground as shown in plate 4.2



Plate 4.2: Zango Abattoir- Lairage used for slaughtering of animals in the abattoir (Source: Author's field work, 2013).

The abattoir interior surfaces of all walls and roof are deteriorating which increases chances of diseases coming in contact with the meat products as shown in plate 4.3



Plate 4.3; Zango Abattoir- Unhygienic interior space for meat production (Source: Author's field work, 2013).

4.1.3. Waste management strategy.

Some adopted features for waste disposal are pit to bury inedible wastes and condemned animals and functional drainage system to take care of effluents generated from the abattoir processes most of which are not functional.The abattoir has good sources of water supply from the town mains distribution, borehole and a well-positionedoverhead water tank for effective day to day activities in the abattoir as shown in plate 4.3



Plate 4.3; Zango Abattoir- Overhead water tank (Source: Author's field work, 2013).

The abattoir lacks adequate waste management facilities such as functional drainage system and waste treatment plant to take care of the effluents generated from the abattoir activities as illustrated in plate 4.4



Plate 4.4: Zango Abattoir- Poor drainage layout, laid against the wall (Source: Author's field work, 2013).

4.1.5. Renewable energy sources

The survey carried out indicated that the abattoir does not used any renewable source of energy despite the potential of waste generated as shown in table 4.1 . They depends on electricity.

Table 4.1 Waste out-put of Zango abattoir, Kaduna.

NATURE OF WASTE	Average Bovine waste (B/Kg)	Average Ruminant waste (R/Kg)	Average Slaughter per day (Kg) B= 25, R= 50	Combine waste OUTPUT per day (Kg) (B + R)
Solid Waste	25	10	B= 625, R= 500.	1,125
Liquid Waste	20	10	B= 500, R= 500	1,000
Solid By-Product	15	7	B=375, R= 350	725
Liquid By-Product	5	2	B= 125, R=100	225

The slaughtering hall of the abattoir building has adequate natural ventilation and day lighting which aids effective meat processes in the day time as shown in plate 4.7



Plate 4.7: Zango Abattoir- Presence of high level windows (Source: Author's field work, 2013).

4.1.6. Summary of the study

The assessment on sustainable waste management and the results obtained during the researcher's field survey at Zango abattoir Kaduna is scaled in the following table.

Table 4.2 Checklist of Zango abattoir

Scale Factor: Excellent=5, Very Good=4, Good=3, Fair=2, Poor=1				
Variables	**Features**	**Method Adopted**	**Scale Factor**	**Remarks**
Architectural Features	Rectangular plan and some cubic attachments	Orientation of the longer axis of the building along the east-west direction	3	Acceptable
Waste management strategy	Waste were exposed Some waste were dumped in water ways	Use of pit and ditch close to the main hall.	3	Averagely managed
Energy requirement	No renewable energy sources	Electricity.	1	Improper

4.2.1 Case study two: Zaria abattoir, Kaduna state, Nigeria

The abattoir is located in Zaria Kaduna. Field work is conducted in the selected abattoirs through which detail accounts of their architectural features, waste management strategy and energy demand are obtained and analysed.

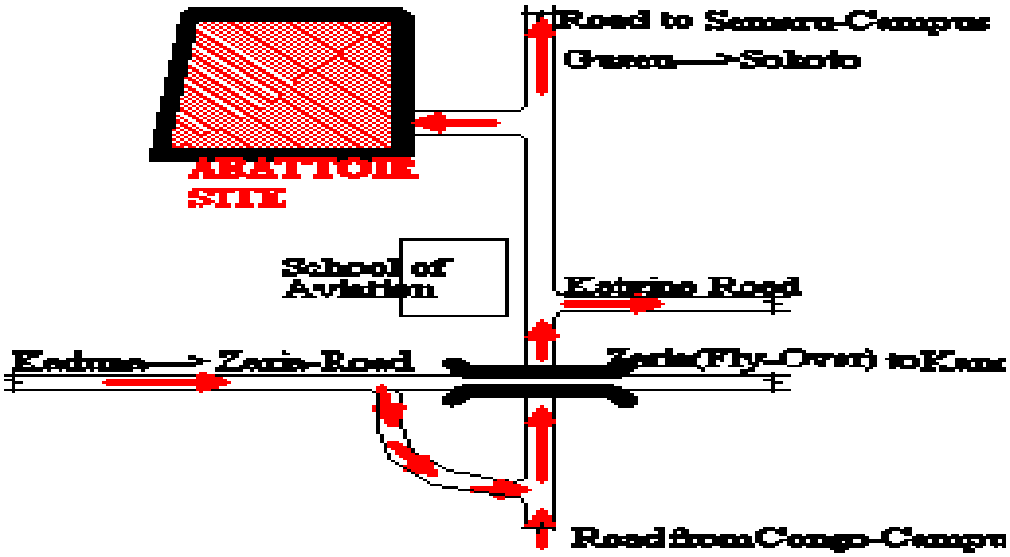


Figure 4.3; Site Location of Zaria Abattoir, Kaduna State, Nigeria (Source: Author's field work,2013).

4.2.2 Architectural features

The abattoir site has problems of parking to differentiate heavy vehicular movement from cars, walkways. Building materials and finishes used in the construction includes; hollow sandcrete blocks, steel rafter, steel columns, concrete floor, aluminum roofing sheets and paints. Also the site is characterized by scattered trees and shrubs as such no landscaping features found as illustrated in below

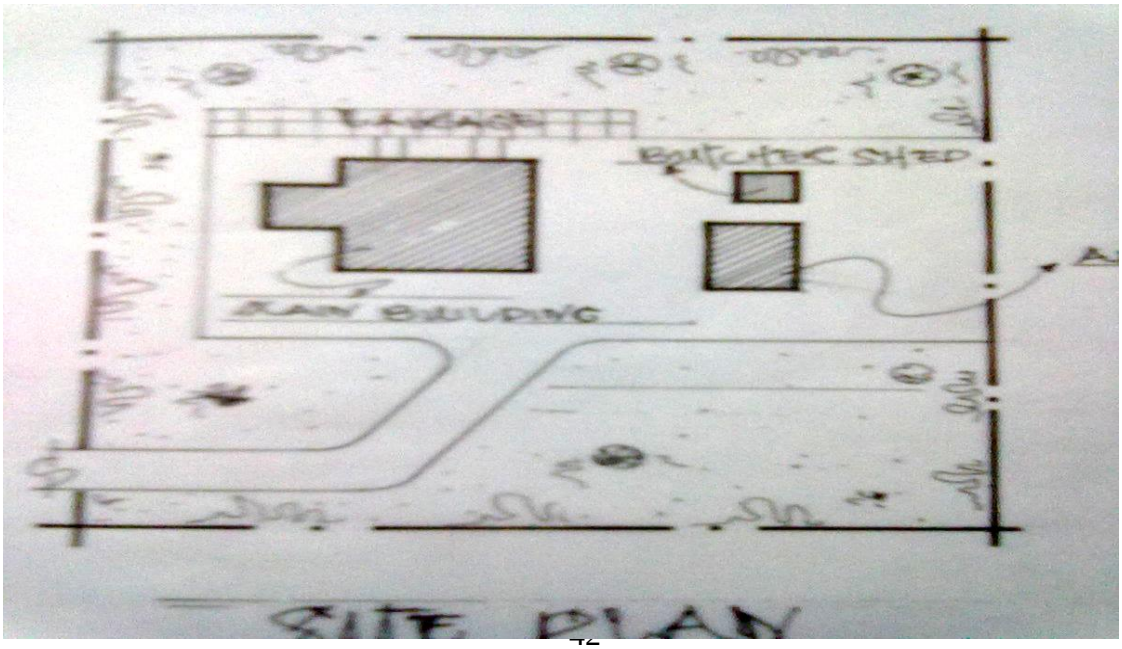


figure 4.4; Site plan of Zaria Abattoir, Kaduna State, Nigeria (Source: Author's field work, 2013).

The abattoir has adequate production area which houses its various activities as in plate 4.8



Plate 4.8; Zaria Abattoir- Interior view of the abattoir's production area (Source: Author's field work, 2013).

The abattoir site layout (if any) lacks defined parking areas to separate cars, long vehicles from the pedestrian as shown below



Plate 4.9; Zaria Abattoir- No defined parking area for cars and trucks (Source: Author's field work, 2013).

4.2.3. Waste management strategy

Absence of on-site waste disposal pit. Drainage lines discharged the abattoir effluents and solid wastes directly into the surrounding water ways.



Plate 4.10; Zaria Abattoir- Cow dung found just by the lairage (Source: Author's field work, 2013).

The abattoir houses facilities which includes; Lairage is turned into slaughtering ground, Administrative block, water reservoir and sheds for meat sellers. Presence of cattle market around the abattoir premises throw out the challenges of new diseases without an effective control as in plate 4.11



Plate 4.11; Zaria Abattoir- Cattle market found around the abattoir premises (Source: Author's field work, 2013).

The abattoir complex lacks adequate drainage layout as a result, cow dung is found just by the Lairage as shown in plate 4.12



Plate 4.12; Zaria Abattoir- The drainage lack adequate slope to drain waste water (Source: Author's field work, 2013).

4.1.4. Renewable energy sources

The survey carried out indicated that the abattoir does not used any renewable source of energy despite the potential of waste generated as shown in table 4.3 . They depends on electricity.

Table 4.3 Waste out-put of Zaria abattoir, Kaduna.

NATURE OF WASTE	Average Bovine waste (B/Kg)	Average Ruminant waste (R/Kg)	Average Slaughter per day (Kg) B= 15, R= 40	Combine waste OUTPUT per day (Kg) (B + R)
Solid Waste	25	10	B= 375, R= 400.	775
Liquid Waste	20	10	B= 300, R= 400	700
Solid By-Product	15	7	B=225, R= 280	505
Liquid By-Product	5	2	B= 75, R=80	155

The abattoir production hall lacks natural ventilation and day lighting which makes meat production difficult even in the day time as shown in plate 4.13



Plate 4.13; Zaria Abattoir- Lack of adequate natural ventilation and day lighting (Source: Author's field work, 2013).

The abattoir lacks proper openings that will allow natural lightening as shown in plate 4.14



Plate 4.14; Zaria Abattoir- showing no existence of power supply Source: Author's field work, 2013).

4.1.6. Summary of the Study

The assessment on sustainable waste management and the results obtained during the researcher's field survey at Zaria abattoir Kaduna is scaled in the following table.

Table 4.4 Checklist of Zaria abattoir

Scale Factor: Excellent=5, Very Good=4, Good=3, Fair=2, Poor=1				
Variables	**Features**	**Method Adopted**	**Scale Factor**	**Remarks**
Architectural Features	Rectangular plan and some cubic attachments	Orientation of the longer axis of the building along the south-north direction	3	Acceptable
Waste management strategy	Waste were exposed Some waste were dumped in water ways	Dump solid waste on site and poorly manage liquid waste.	1	Improper
Energy requirement	No renewable energy sources	Electricity.	1	Improper

4.3.1 Case Study Three: Minna Modern Abattoir, Niger State, Nigeria

The abattoir is located at Tayi village along Niger State School of Health road, behind Bahago Secondary School, Minna-Niger State, Nigeria as illustrated in figure 4.4

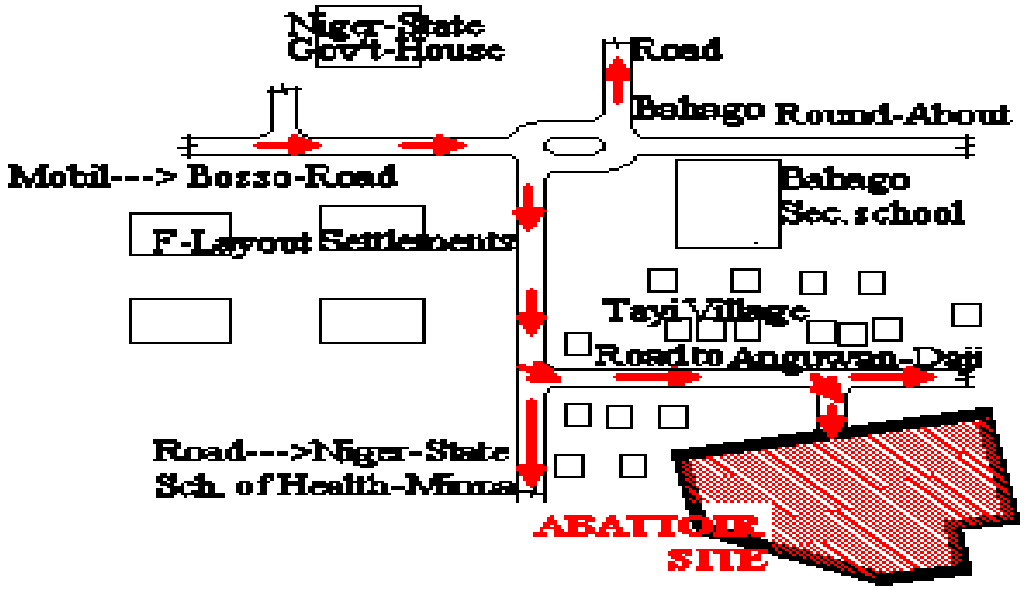


Figure 4.5: Site Location of Minna Modern Abattoir, Tayi Village, Niger State, Nigeria (Source: Author's field work, 2013).

4.3.2. Site planning and landscaping

The abattoir site has some elements of good planning, but with distorted parking lot to differentiate heavy vehicular movement from cars, walkways, absence of on-site waste disposal pit. Drainage lines were found covered with sand particles through erosion activities carried by rainy water on the site. Also the site is characterized by scattered trees and shrubs as such the absence of landscaping elements exposed the site to erosion and flooding as illustrated in figure 4.6

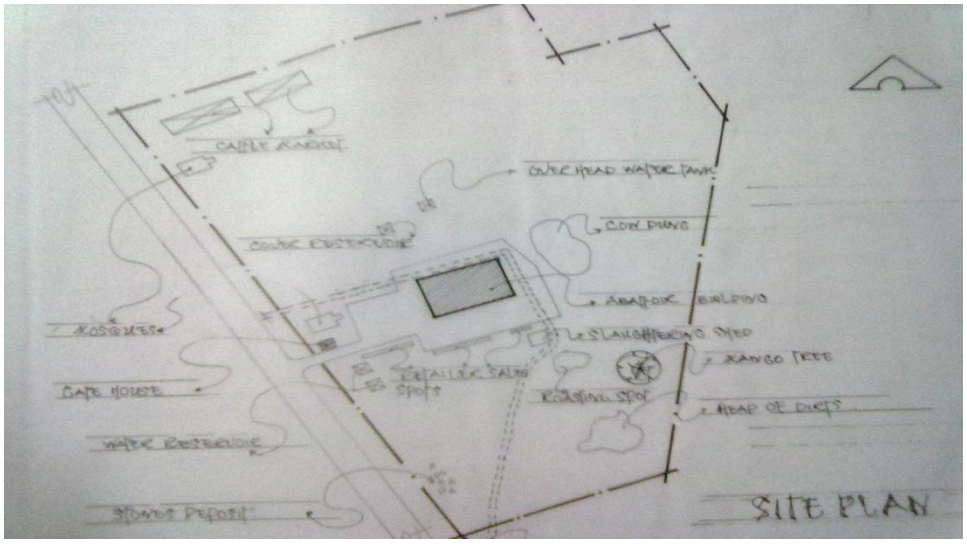


Figure 4.6: Site plan of Minna Modern Abattoir, Niger State, Nigeria (Source: Author's field work, 2013).

4.3.3. Spatial organization and design;

The abattoir houses the following facilities: The main slaughter hall, cattle market, covered water reservoir, gate house, over head tank, open mosque and sheds for meat sellers as illustrated in figure 4.6

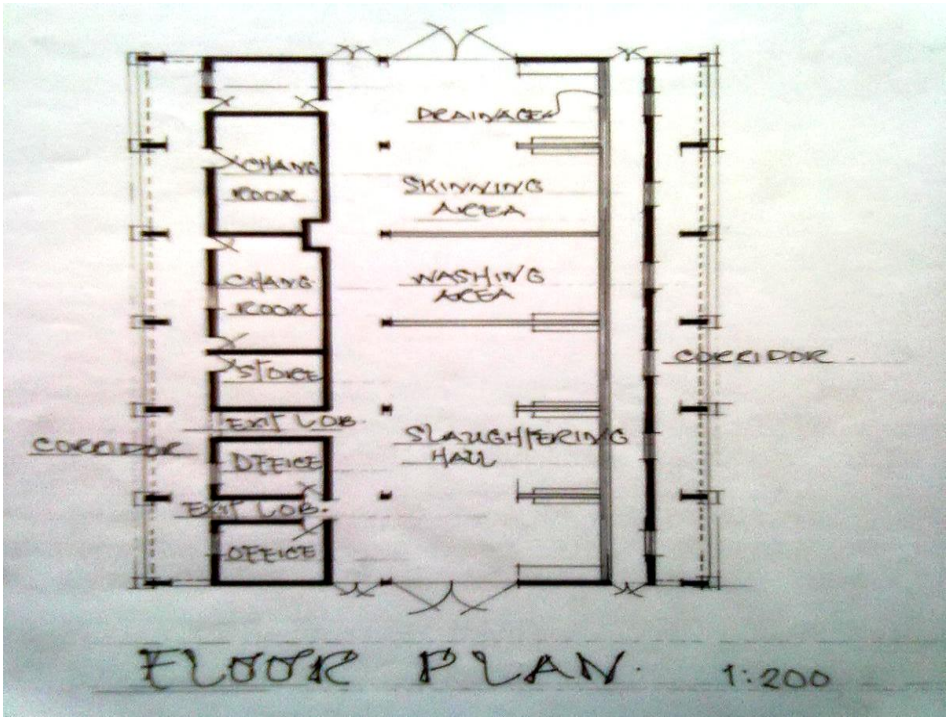


Figure 4.7: Floor plan of Minna Modern Abattoir, Niger State, Nigeria (Source: Author's field work, 2013).

4.3.4. Materials and Finishes;

Building materials and finishes used in the construction includes; hollow sandcrete blocks, steel rafter, steel columns, concrete floor, aluminium roofing sheets and paints.

4.3.5. Merits

i. The abattoir is located at Tayi village off Niger State School of Health road, behind Bahago Secondary School, Minna and is accessed by both cars and trucks as shown in plate 4.15



Plate 4.15: Minna Modern Abattoir- Access road to site of the abattoir (Source: Author's field work, 2013).

ii. The presence of cattle market in the abattoir provides relief of cow scarcity facing other abattoir in some locality as shown in plate.



Plate 4.16: Minna Modern Abattoir- Cattle market at the site of the abattoir (Source: Author's field work, 2011).

iii. The abattoir's building has adequate slaughtering hall with sufficient natural ventilation and day lighting which aids effective meat processes in the day time as shown in plate 4.16 and figure 4.8



Plate 4.16: Minna Modern Abattoir- Openings along left side of the abattoir building (Source: Author's field work, 2013).

4.3.6. Demerits

The abattoir over head water storage tank is being abandoned, likewise the borehole source, which hindered effective waste management practice in keeping the abattoir's surrounding clean as shown in plate 4.17:



Plate 4.17; Minna Modern Abattoir- Abandoned over head water tank on the site of the abattoir (Source: Author's field work, 2013).

i. Cow dung is found just by the rear side of the abattoir due insufficient drainage layout system as shown in plate 4.18.



Plate 4.18: Minna Modern Abattoir- Cow dung at the rear side of the abattoir (Source: Author's field work, 2013).

III. The burning processes of animal's heads, tails and legs polluted the whole surrounding environment of the abattoir which is dangerous to human health as shown in plate 4.19.



Plate 4.19: Minna Modern Abattoir- Burning activities in the abattoir (Source: Author's field work, 2013).

4.3.7. Summary of the study

The assessment on sustainable waste management and the results obtained during the researcher's field survey at Minna abattoir Niger is scaled in the following table 4.5.

Table 4.5 Checklist of Minna abattoir

Scale Factor: Excellent=5, Very Good=4, Good=3, Fair=2, Poor=1				
Variables	**Features**	**Method Adopted**	**Scale Factor**	**Remarks**
Architectural Features	Rectangular plan	Orientation of the longer axis of the building along the east-west direction	4	Acceptable
Waste management strategy	Waste were exposed	Dumped on site but not close to hall, Improper drainage system	2	Manageable
Energy requirement	No renewable energy sources. No carcass	Electricity. Manual operation	1	Improper

4.3.8. Renewable energy sources

The survey carried out indicated that the abattoir does not used any renewable source of energy despite the potential of waste generated as shown in tableb4.6 . They depends on electricity.

Table 4.6 Waste out-put of Minna abattoir, Niger.

NATURE OF WASTE	Average Bovine waste (B/Kg)	Average Ruminant waste (R/Kg)	Average Slaughter per day (Kg) B= 20, R= 45	Combine waste OUTPUT per day (Kg) (B + R)
Solid Waste	25	10	B= 500, R= 450.	950
Liquid Waste	20	10	B= 400, R= 450	850
Solid By-Product	15	7	B=300, R= 315	615
Liquid By-Product	5	2	B= 100, R=90	190

4.2. Conclusion on the three selected case studies

Comparative analysis of results/findings were summarized and compared in table 4.7, of the results obtained from the three selected cases. All the three cases possess the potential of utilising waste as source of energy

Table 4.7: Comparative Analysis of the Cases on Energy Demand and Potentials

VARIABLES	Zango Abattoir	Zaria Abattoir	Minna Abattoir
ENERGY REQUIREMENT	**30kw** in full capacity operation	**15kw** in full capacity operation	**20kw** in full capacity operation
BOVINES (B)	25	15	20
RUMINANTS (R)	50	40	45

ENERGY OUT-PUT/HEAD AT OPTIMUM YIELD STAGE (KW)	B=0.0261 , R=0.0144	B=0.0261 , R=0.0144	B=0.0261 , R=0.0144
(OPTIMUM YIELD STAGE) NUMBER OF BOVINES /30 DAYS	750	450	600
(OPTIMUM YIELD STAGE) NUMBER OF RUMINANTS /30 DAYS	1,500	1,200	1,350
AVERAGE WASTE/30DAYS (OPTIMUM YIELD STAGE) (KG)	63,750	44,250	54,000
EXPECTED ENERGY FROM WASTE AT OPTIMUM YIELD STAGE (KW)	31.78	22.06	26.92

CHAPTER FIVE
DESIGN DEVELOPMENT

5.1. Site Selection

Site selection is one of the most critical part of Abattoir development. Two alternative sites were chosen for this research. In Accordance with the standard of Food and Agricultural Organization, FAO (2010) criteria for abattoirs design as described in section 2.4 in chapter 2

5.1.1. Site 1

Site 1 is located at Makera along Daura road in Katsina. It is about 2.5km away from the Umaru Musa Yar'Adua airport, 1 kilometers away from the mobile police compound, the 252 housing units for junior and middle cadre workers and 3.6km away from the Katsina state Hajj transit camp (see fig 5.2). The site is a virgin land with large site area..



Figure 5.1 Site 1 Google map
(source: Google earth, 2013)

5.1.2. Site 2

Site 2 is situated at the new commercial lay-out, Gidan Dawa (see fig. 5.3.) It is easily accessible by the well connected road networks constructed recently and it is linked by tarred road to popular IBB way and the new Katsina bye-pass. The site is centrally located between the urban

settlement and the airport and the land use was purposely allocated for hotel development. The mapped out area for the proposed site was approximately 2.5 hectres. Services like electricity, water supply, well designed drainage system, tarred roads etc are all available.

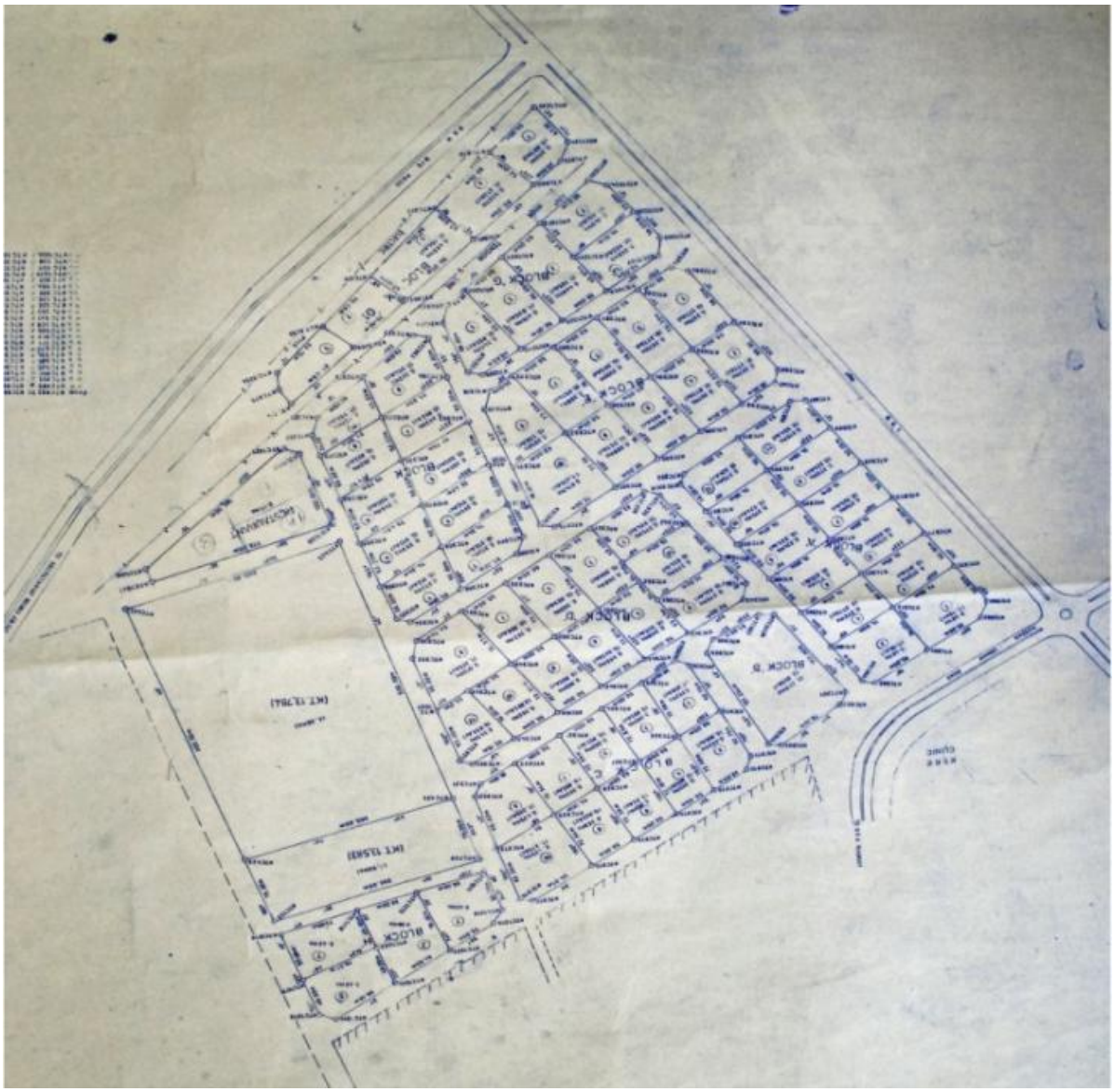


Figure 5.2 Site 2 (Source: KTURPB, 2013)

5.1.3. Comparative Analysis Between Site 1 And Site 2

Preliminary analysis is conducted on the sites base on the various criteria for site selection as explained in chapter 2 section 2.4.2. of this research which includes environment, geology, dimensions and services. Using a rating scale 5-1, with 5 as the strongest rating and 1- as the

weakest as shown in table 5.1. According to the analysis, site 1 being the site with most suitable features ranking a total of 23 as compared with site 2 with 15 was therefore selected for the design of the proposed abattoir.

Table 5.1: Assessment of alternative Sites

Selection Criteria	Sites		Remarks
	Site I	Site II	
Environment	5	3	Most preparable in site I
Geological structures and features	4	5	Site I is considered better option
Site dimensions	4	3	Both complied
Services	5	2	All sites are accessible from major roads
Prompt removal/reuse of abattoir solid waste	5	2	Most preparable in site I
Total	23	15	Site I is considered to be the most appropriate for the development.

5.2 Proposed Site Location

The proposed Abattoir is to be located at Katsina, Katsina state of Nigeria as shown in fig. 5.3. The city is lying between $12^0$15'N of the equator and $7^0$30'E of the Greenwich Meridian and it is

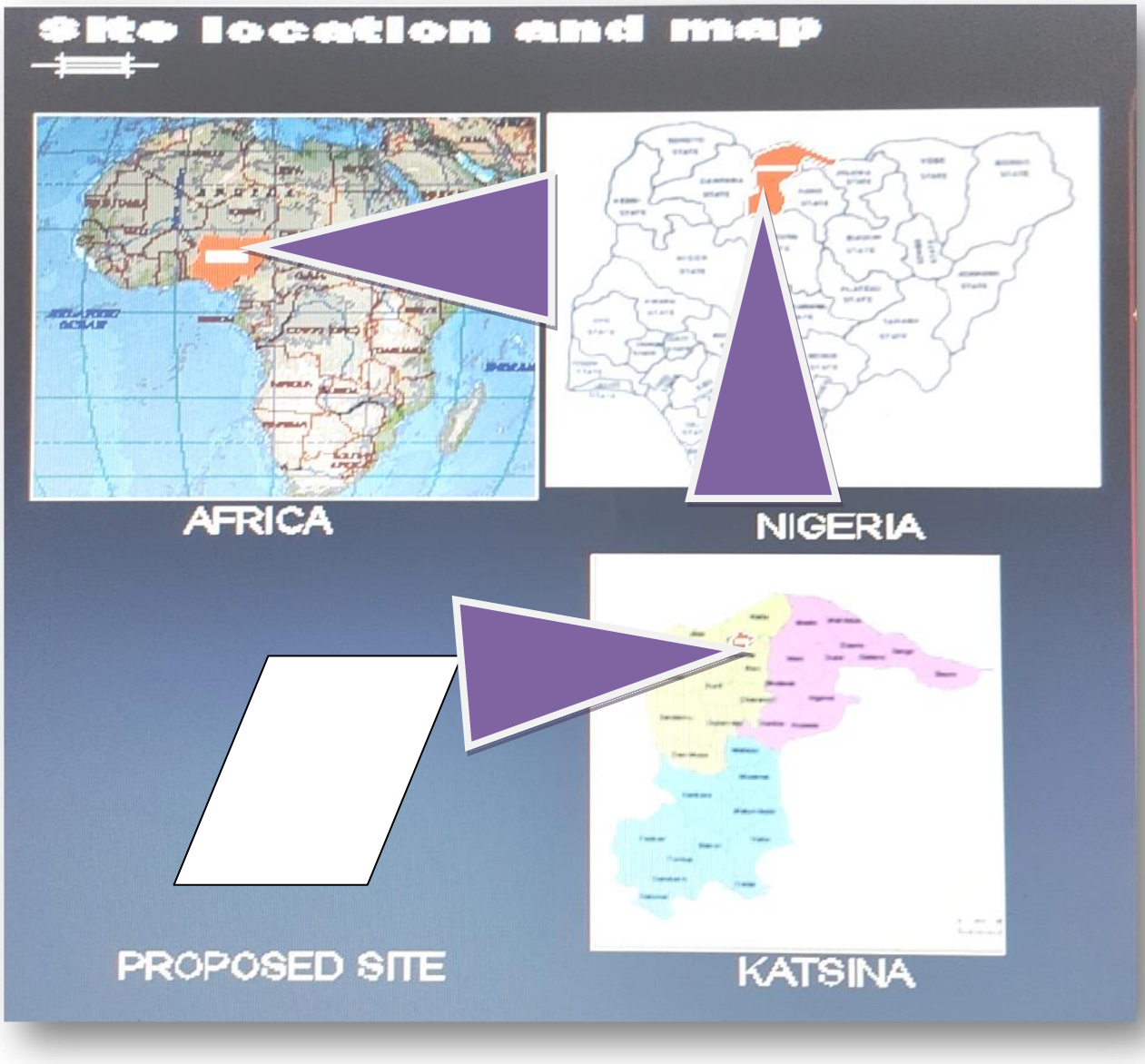


Figure 5.3 Site Location.

5.3 Site Analysis

The analysis covers climate, temperature, wind, relative humidity, precipitation, solar radiation, vegetation, topography and soil.

5.3.1 Climate

The climate of Katsina varies considerably with months and seasons .During the month of December to February a cold and dusty hammattan season is witnessed and hot dry season from the month of March with temperatures ranging from 32^0c to 40^0c (see fig. 5.5). The hot dry season is followed by a raining season from June to September.

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	5.51	6.58	7.01	7.20	7.18	7.06	6.52	6.07	6.12	6.13	5.79	5.21
Clearness, 0 - 1	0.66	0.71	0.70	0.69	0.68	0.67	0.62	0.58	0.60	0.65	0.67	0.64
Temperature, °C	21.89	23.95	28.43	31.07	29.97	27.40	25.37	25.24	26.36	28.35	26.39	22.90
Wind speed, m/s	5.05	4.98	5.04	4.92	4.69	4.35	4.15	3.80	3.49	3.88	4.52	5.11
Precipitation, mm	0	0	0	5	30	80	174	212	91	10	0	0
Wet days, d	0.0	0.1	0.1	1.2	3.9	8.0	12.5	14.3	8.8	1.4	0.0	0.0

Figure 5.4 Solar energy and surface meteorology of Katsina

(Source: www.gaisma.com)

5.3.2.Temperature

The study area climate record temperature of up to 40^0c with the months of April/May as the hottest months of the year. The temperature range is between 32^0c to 40^0c with a mean temperature of 28.88^0c as shown in fig 5.6. During the cold month January, the mean temperature is about 21.89^0c. However, the mean monthly temperature varies between 25^0c and 32^0c throughout the year.

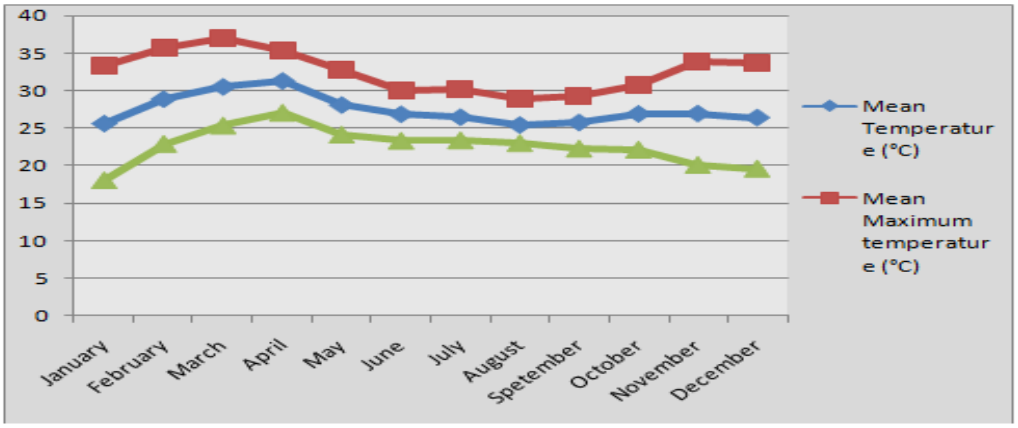


Figure 5.5 Temperature chart of Katsina

(Source: www.gaisma.com)

5.3.3.Wind

The average wind speed of the study area varies with the time of the day with average from 2.2m/s to 4.3m/s. The strongest wind occurs at about 15:00 hours and relatively low at morning hours. The region is characterised by the South-West and North-East trade winds attributed to the displacement of inter-tropical convergence zone.

5.3.4 Relative humidity

The study area is characterised by relatively low humidity, the recorded mean relative humidity for an average year is 30% and the mean monthly humidity ranges from 1% in March to 68% in August as shown in fig 5.7.

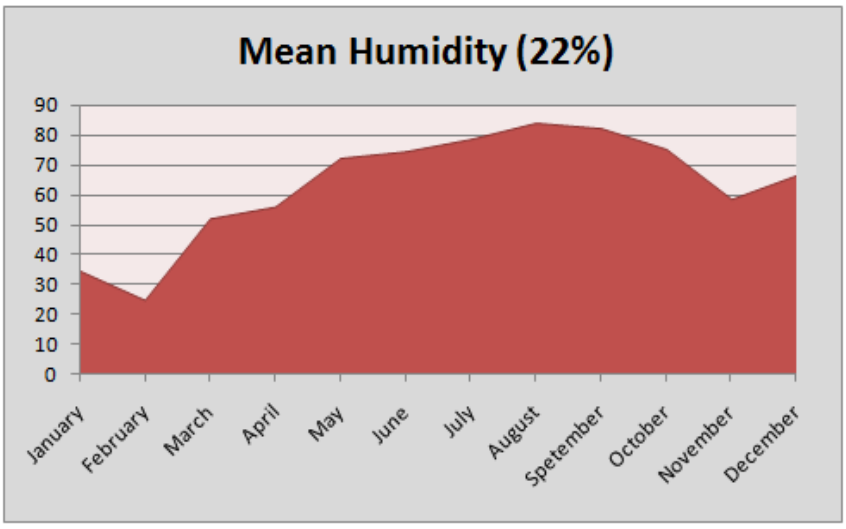


Figure 5.6 Relative humidity chart of Katsina

(Source: www.gaisma.com)

5.3.5.Precipitation

Average rain recorded is 0mm in the month of March to 212mm in the month of August and 0mm in the harmattan period. January and December are the month with the driest weather with no rainfall and August is the month with highest rainfall of up to 212mm (see fig 5.8).

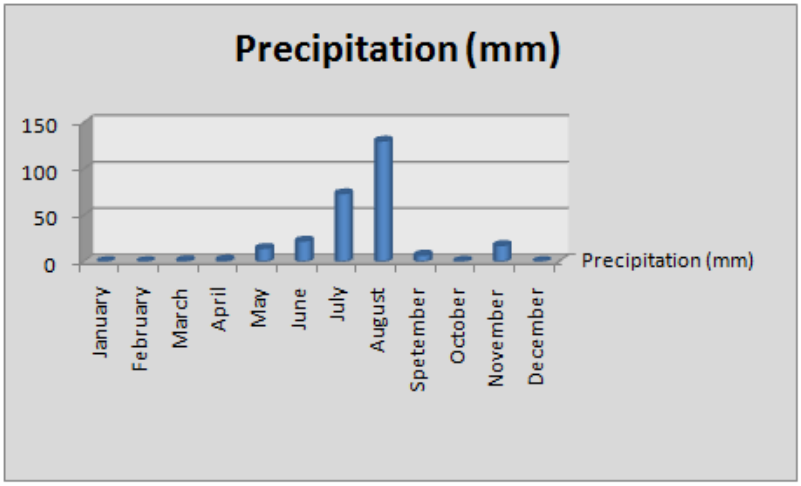


Figure 5.6 Relative humidity chart of Katsina (Source: www.gaisma.com)

5.3.6. Solar Radiation

The hours of sunshine vary considerably with time of the year with estimated average of 6.5 hours per day in August (cold season) and 10 hours per day in November (hot season) see fig 5.10. Also, the study area has relatively high daily radiation that ranges from 25MJ/m^2 during the dry season and 19MJ/m^2 in early August. Meanwhile, the angle of elevation of sun at noon is 73^0 as shown in fig 5.9.

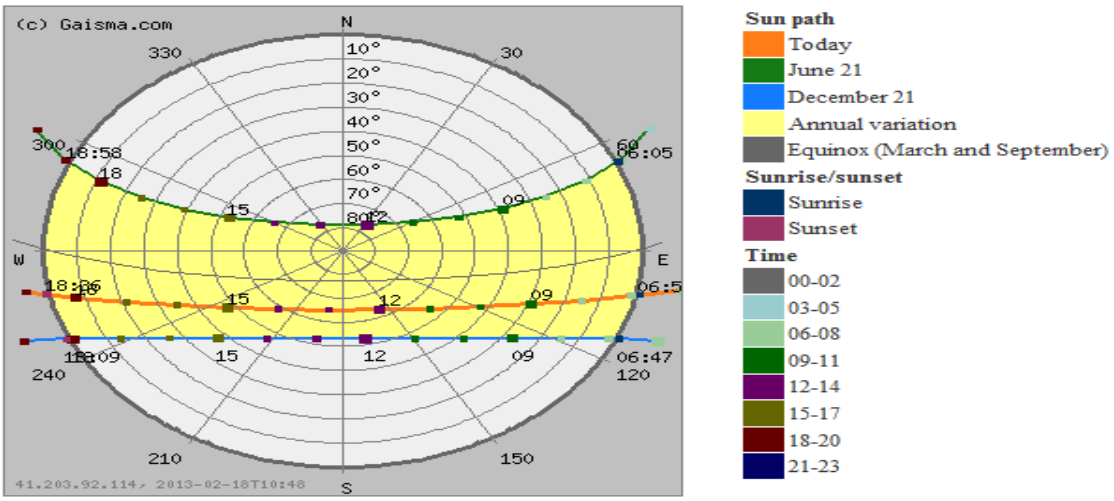


Figure 5.8 Sun path diagram of Katsina

(Source: www.gaisma.com)

Date	Sunrise	Sunset	Length	Change	Dawn	Dusk	Length	Change
Today	06:51	18:36	11:45		06:29	18:58	12:29	
+1 day	06:50	18:37	11:47	00:02 longer	06:29	18:58	12:29	00:00 equal length
+1 week	06:48	18:38	11:50	00:05 longer	06:26	18:59	12:33	00:04 longer
+2 weeks	06:44	18:39	11:55	00:10 longer	06:22	19:00	12:38	00:09 longer
+1 month	06:34	18:40	12:06	00:21 longer	06:13	19:02	12:49	00:20 longer
+2 months	06:15	18:43	12:28	00:43 longer	05:53	19:05	13:12	00:43 longer
+3 months	06:03	18:49	12:46	01:01 longer	05:41	19:12	13:31	01:02 longer
+6 months	06:18	18:48	12:30	00:45 longer	05:56	19:10	13:14	00:45 longer

Figure 5.9 Sunrise, sunset, dawn and dusk time table

(Source: www.gaisma.com)

5.3.7 Topography and Soil

The topography of the site relatively flat and has a gentle slope towards the south-west of the site. Site drainage would take this direction in order to use the concept of natural gravity. While the water supply should come from North-eastern direction in order to also use the principle of natural gravity.



Plate 5.1 Site soil and topography

The site is relatively flat with no undulating or hilly areas. The soil is laterite (see plate 5.1) which has good bearing capacity but the hydrological and geological survey will confirm the actual load bearing capacity of the site. But for the purpose of this research and based on the observation carried out, the site soil shown strong indication of good load bearing capacity.

5.3.8 Vegetation

The vegetation of the study area (Katsina) is Sahel savannah characterised by few trees (see plate 5.2) scattered around the site and small grass distributed sparsely.



Plate 5.2 Site vegetation

5.3.9 Services

Services like electricity power lines, water supply lines, telephone services, well constructed tarred roads and pedestrian paths, well designed drainages are all available on site (see plate 5.3).



Plate 5.3 Site Services

5.4 Site Zoning

The zoning of areas on site was carried to appropriately allocate areas best suited for specific facilities. The analysis of the site was done to check the extent of noise penetration, physical features, best views, areas that can be categorised as public and private areas and other site features in order to determine the best areas for development.

5.5 Concept Development

The concept development considers the functionality and site using the form follows function concept. This concept explains how the author came about using different forms in achieving the intended plan. The concept emphasize on functionality and the total integration of the various spaces within the enclosed space.

5.5.1. Functionality concept

The design concept, gives an explicit clue on the ideas behind the arrangement of the facilities in the design. It is based on simplicity, functionality and total integration of the various spaces in the abattoir.

5.5.2. Site concept

Zoning concept is adopted in the proposed site planning . The concept separates vehicular circulation from pedestrian and offers a direct access to the interior buildings in the abattoir, through defined and articulated entrances.

Grid type of planning is employed to represent the idea of an organic growth, which is typical of a commercial venture. The growth will conform to the site-zoning concept, so as to achieve the aim of this project.

5.6 Schedule Of Accommodation

A functional design is one which suitably accommodates the facilities it is meant for and hence a spatial analysis is made for an efficient meat production of the proposed abattoir complex as shown in Table 5.2 A and B

Table 5.2(A) schedule of accommodation

UNIT	S/NO	FUNCTIONS	NO	DIMENSIONS (m)	AREA COVERED (m^2)	TOTAL AREA(m^2)
PRODUCTION SECTION	1.	Main entrance porch		6.8*3.0	20.4	20.4
	2.	Reception/ security		6.4*6.8	43.5	43.5
	3.	Lairage/ante- mortem		12.8*17.6	225.3	225.3
	4.	Cattle slaughter area		40.8*11.7	477.4	477.4
	5.	Sheep/Goats slaughter		12.8*17.6	225.3	225.3
	6.	Washing of internal organs	2	8.2*5.0	41.0	82.0
	7.	Cold room	2	7.6*5.6	42.6	85.1
	8.	Triperry		4*5	25	25
	9.	Digester		7*11	77	77
SERVICES SECION	1.	Entrance		11.0*3.0	33.0	33.0
	2.	Whole sale hall		17.4*11.4	198.4	198.4
	3.	Changing room		5.0*3.7	18.5	18.5
	4.	First aid room		5.2*6.0	31.2	31.2
	5.	Laboratory		3.3*2.6	8.6	8.6
	6.	Store		2.5*2.6	6.5	6.5
	7.	Cashier's counter		2.6*2.6	6.8	6.8
	8.	Customer's payment stand		5.6*2.6	14.6	14.6
	9.	Research room		6.0*2.6	15.6	15.6
	10.	Manager's office		5.4*2.6	14.0	14.0
	11.	Toilet/ lobby		1.3*1.2+1.3*1.2	3.1	3.1
	12.	Secretary		2.8*2.6	7.3	7.3
	13.	Toilets	5	1.0*1.2	1.2	6.0
	14.	Lobby spaces		6.1*1.2+3.4*1.2+2.8*2.8+5.7*1.2	26.0	26.0

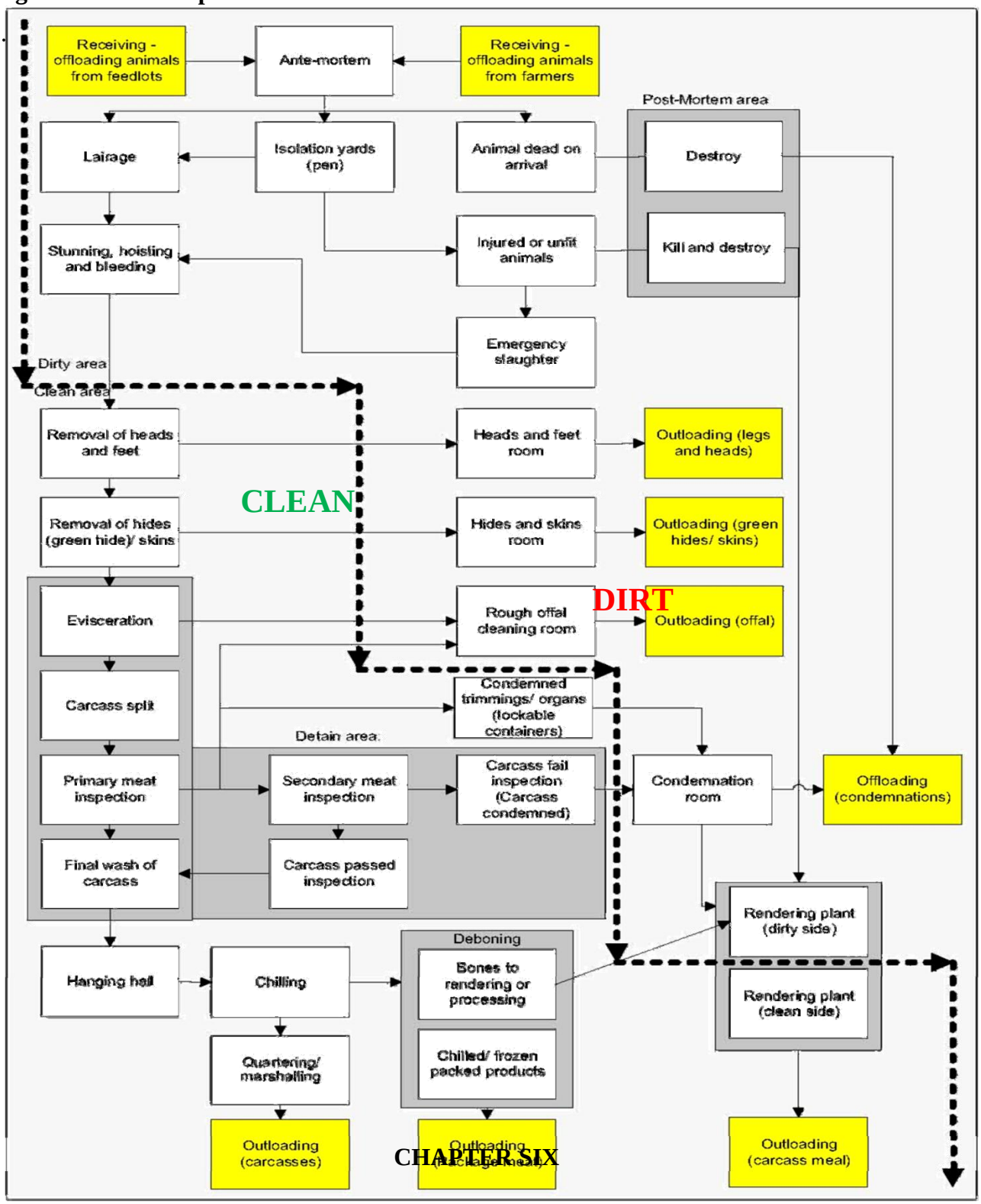
Table 5.2(B) schedule of accommodation

UNIT	S/NO	FUNCTIONS	NO	DIMENSIONS (m)	AREA COVERED (m^2)	TOTAL AREA(m^2)
Source: Author's design proposal (2013).	1.	Entrance porch		6.5*3.0	19.5	19.5
	2.	Reception/ security		5.6*8.8	49.3	49.3
	3.	Office		2.8*3.1	8.7	8.7
	4.	Accountant office		2.8*3.1	8.7	8.7
	5.	Cashier's office		2.8*3.1	8.7	8.7
DMIN. SECTION	6.	Board room		5.8*3.1	18.0	18.0
	7.	Chief Veterinary.		2.8*3.1	8.7	8.7
	8.	Veterinary staff		2.8*3.1	8.7	8.7
	9.	Records room		3.7*4.5	16.7	16.7
	10.	Internal Auditor		3.7*2.8	10.3	10.3
	11.	External Auditor		3.7*2.8	10.3	10.3
	12.	Head of butcher's room		3.7*2.8	10.3	10.3
	13.	Maintenance unit		4.3*2.8	12.0	12.0
	14.	Toilets	3	1.2*1.0	1.2	3.6
	15.	Court yard		17.8*4.7	83.7	83.7
	16.	Corridor		18.*2.4	43.2	43.2
	17.	Lobby		1.4*3.7	5.2	5.2

5.7. Functional Flow Chart

The abattoir should be divided into "Clean" and "Dirty" areas as indicated in the following figure 5.10

figure 5.10 Adopted Functional flow chart



DESIGN REPORT

6.1 Anaerobic Digester

Anaerobic systems can be built on any scale: small and simple or single household, or large and industrial for a whole municipality. In this research we are interested in digesters appropriate for standard abattoir facility, the research focus to make these with inexpensive, widely accessible materials and technology. As previously stated in section 2.3 of chapter 2 of this research, biogas consists of about two third methane and one third CO_2, with some water vapor and trace gasses (principally H_2S) and as such, without any alteration or purification, it can be used in all appliances made for natural gas for example cookers and water and space heaters and electric gensets with minimal modifications. The energy production depend on the capacity of the facility and the amount of waste dung in the plant. Table 6.1 analyses the potential waste and by-product to be generated in the proposed abattoir design.

Table 6.1 Waste out-put of proposed abattoir, Katsina.

NATURE OF WASTE	Average Bovine waste (B/Kg)	Average Ruminant waste (R/Kg)	Average Slaughter per day (Kg) B= 50, R= 150	Combine waste OUTPUT per day (Kg) (B + R)
Solid Waste	25	10	B= 1,250, R= 1,500.	2,750
Liquid Waste	20	10	B= 1,000, R= 1,500	2,500
Solid By-Product	15	7	B=750, R= 1,050	1,800
Liquid By-Product	5	2	B= 250, R=450	700

A basic anaerobic digester will consists of a tank in which the organic material is digested, combined with a system to collect and store the biogas produced. The digesters can be quite simple, and the details vary depending on available materials. The Anaerobic digester will consists of three cylindrical 15,000 liter tank, in which the organic material is digested as shown in figure

6.1 . A second, slightly smaller tank is placed on the larger tank, upside-down. As biogas is produced, the inner tank fills with gas and rises, telescoping out of the outer tank.

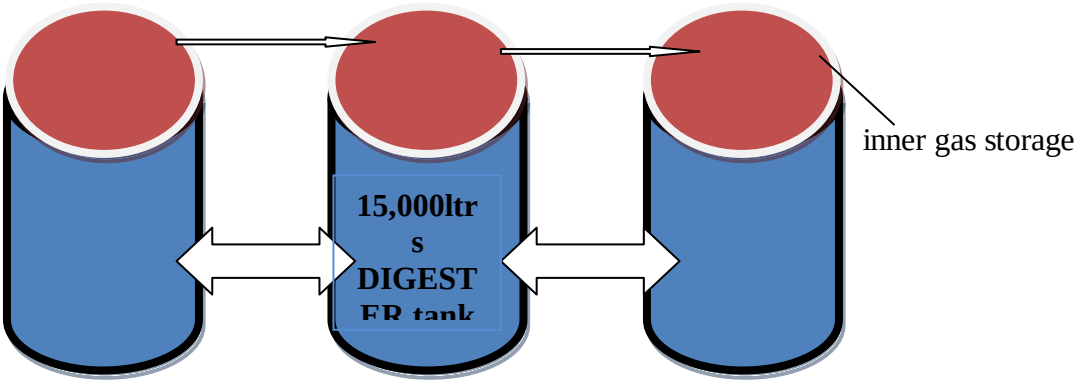


Figure 6.1 Anaerobic digester

As biogas is removed for use, the inner gas storage tank sinks back into the larger, outer tank. In this system, the inner tank acts as both storage, and as a lid for the digester tank. The gap between the tank walls is narrow enough to prevent significant quantities of oxygen from entering the digester, which would kill the anaerobic bacteria that produce the methane. The amount of biogas lost though the gap is negligible. Abattoir's 45,000 liters digesters will typically fed a substantive amount of biomass daily. Solid waste mixed with liquid waste generated from the production processes of the abattoir will be fed into the digester to produce energy as appropriated in Table 6.2 . Before being fed into the digester tank, the biomass is mechanically macerated chewed up with an “Insinkerator” garbage disposal.

Table 6.2 Waste in-put and Energy Yield out-put of Anaerobic digester

IN-PUT WASTE	Waste Kg	Biogas (m^3/kg)	Energy OUT-PUT (Kw)	At Optimum Yield Of 15 Days Total Energy = (Eb+Er)15
Bovine	2,250	61.6	1.31	**52.02 Kw**
Ruminant	3,000	95.7	2.16	

Nowadays these "waste disposal" machines are being rebranded as "feedstock preparation devices" and we call them "compost companions" because they can be used to prepare organic garbage for use in both anaerobic and aerobic decomposition processes. Grinding allows the bacteria to access and digest the organic material more easily; in an anaerobic system the transformation into gas and fertilizer which can take as little as 24 hours while in an aerobic compost pile, the transformation into soil can take as little as three to six days instead of months. For this biogas digester a slurry of ground biomass a warm (40°C) water will be poured into the tank inlet funnel. The inlet for the digester leads down to the bottom center of the digester tank. The digested organic material leaves as a high-quality liquid fertilizer, through an outlet near the top of the outer digester tank. At the top of the inverted, inner tank, there is an outlet for the biogas. Before normal operation, the biogas digester must be "started." This is done by preparing a 1:1 mixture of fresh solid and liquid waste and allowing this to ferment anaerobically for several weeks. The volume of this mixture should be around 12,000 liters for a 15,000 liter digester or roughly 3000-4000 kg of waste in a digester tank space. Less can be used but it would simply take longer to establish the colonies of bacteria to enable feeding (feeding only starts once first flammable gas is produced). The slurry can be prepared in a separate container or in the digester tank. The waste contains the naturally-occurring bacteria that digest organic matter and produce methane.

Note that unlike in cheese making or yoghurt making biogas digesters do not rely on one strain of bacteria but depend on a balanced ecology of many different types of microbes - hydrolytic,

acidogenic, acetogenic and methanogenic.

Fortunately these are all found in animal waste. Human excreta can be used as well, although in this case the fertilizer output of the digester should only be used on trees, or in other appropriate applications. Once the waste-mixture is producing flammable gas, feeding of the digester with biomass can begin. It is best to begin gradually, for example with 1/3 of the expected feeding for the first week, 2/3 for the second, and then onto a normal feeding regime. The maximum ratio is about 525 liters of feedstock slurry for every 5000 liters of digestor space. During normal operation, wastes can still be included in the feed stock. Most energy has already been extracted from manure, but it can help maintain or replenish bacteria populations in the digester and help balance the pH. The pH and temperature of the digester will affect its performance.

Different methane-producing bacteria respond to temperature differently; some prefer cooler temperatures as low as 17°C-20°C (psychrophilic). Others thrive at higher temperatures around 57°C (thermophilic). On the whole, however, biogas digesters well-suited to temperate climates work best at temperatures around 37°C (mesophilic). In most non-tropical climates, it may be worthwhile to insulate and heat the digester tank, for example with a solar hot water system. It can be helpful to put lake mud in the digester to populate the colder bottom regions with psychrophilic (cold-adapted) microbes.

6.2 Component Spaces And Positions

The following guides were to be adopted in positioning the various component as shown in appendix;

6.2.1. Premise

- Abattoir premises is design to be fenced with lockable gates in order to control the unauthorized entry of vehicles, persons and animals.
- Prevailing winds were managed not blow from the "dirty" side to the "clean" side.
- Natural slope allow the rainwater and runoff from the dirty area not flow into the abattoir, nor must they flow from the dirty to the clean side of the premises.

- Biogas digesters for the collection of effluent were situated at the lowest point of the site, on the dirty side for easy collection.
- There should be water storage, chlorination and pressure tanks. These must be on the clean side, preferably at the highest point.
- In order to control access roads and ensure staff separation, the "clean" and "dirty" areas of the premises must be physically separated.
- Vehicles which offload live animals, load intestines, heads and feet as well as vehicles removing paunch contents, condemned material and refuse in the "dirty" area should not have access to areas where meat vehicles and staff who handle meat are to be found.
- Traffic areas in the abattoirs must have a surface that is dust and mud free, readily cleanable and well drained. The traffic zones of abattoirs must have a permanent surface. Planting of grasses and trees is not encouraged as these might attract insects.
- The abattoir compound needs to be partitioned in dirty, clean and hygienic areas with respect to the very internal partition of the abattoir. The partition shall be a properly structured, see-through material and provided with lockable gates to allow authorized cross from one area to the other.
- Specific areas such as collection points for manure from holding pens and paunch contents must also be paved, drained and provided with kerbstones.
- The main gate(s) to the abattoir should have disinfectant tubs 3m X 1m X 10-30 cm (30 cm deep at the centre) to rinse vehicle tyres.
- The length of the disinfectant tub(s) at each entrance gate to the slaughter hall shall be as wide as the entrance door.
- Cold and hot water point, pressure of 0.8 to 1.2 bar or 14 kgf/cm2 at the nozzles must be installed for cleaning meat transporting trucks.
- The truck washing area should be connected to the main drainage canal.

6.2.2. Reception

- The reception area should have offloading platforms alongside the truck reception point.
- The length of the platform should correspond to the total length of all trucks. Docks of different heights or adjustable ramps should be provided to accommodate vehicles of varying heights.
- The unloading facilities shall be so constructed that unloading can be carried out without having a gap between the vehicle and the unloading dock. The sides of any ramps should be high enough to prevent the escape or injury of animals. Ideally, the unloading dock area should be level.
- The angle of ramp slope should not exceed 25^{o} from the horizontal. The platform should slope at the ends to ground level of not more than 8%.
- The sides of any ramp should be high enough to prevent the escape or injury of animals.
- Facilities shall be provided for the unloading and conveyance of crippled animals directly to the bleeding rail in a humane manner. Where these facilities are not practical, suitable facilities shall be provided for the immediate "on-the-spot" stunning and bleeding; or stunning followed by the conveyance of the stunned animal directly to the killing floor for bleeding.

6.2.3. Livestock pens (lairages)

- Livestock pens, chutes and/or squeezes must be provided at all slaughtering establishments.
- Chutes, ramps and inclines should be cleated or "stepped" and have a reasonable incline to prevent slipping, falling or injury.
- All floors, alleyways and chutes must be impervious, paved, properly drained and scored to prevent slipping. The floor area should have rough cement mortar finishing with 1% slope to the drainage canal.
- Covered pens must be provided to ensure adequate protection of livestock received for slaughter; uncovered pens may be used to hold the overflow.
- Separate pens must be provided where mixing of species occurs at the same time.

- Watering and feeding facilities must be provided in all holding pens. There should also be adequate water supply for clean-up. There should be drainage for each pen by means of individual inlets or valley-type drains.
- There should be ample hose and water outlets for cleaning of all pens and runways.
- As ante-mortem inspection requires observation of animals in motion, adequate space must be provided in the form of an alleyway, which can regulate their movement. Adequate covering and protection must be provided in order to facilitate ante-mortem inspection under hot or rainy weather conditions.
- Adequate lighting should be provided with an intensity of at least 540 lux for the ante- mortem inspection points.
- Ante-mortem facilities should ensure protection of inspection personnel against injury.
- Hand wash and boot cleaning facilities must be available for inspection staff upon entry and exit from the livestock area. Adequate facilities for changing and storing outer protective clothing must also be available.
- A small rust-resistant metal cabinet, equipped with lock and key, should be provided for the exclusive use of the inspection staff, for the storage of supplies such as ear tags, thermometers, stethoscopes, inspection documents, etc.
- Partitions and gates of rust resistant metal pipe or tubing are preferred. Smooth sawed lumber is the minimum acceptable. Protruding nails, bolts etc., which might cause injury, are not permitted.
- The partitions of each pen should have tubular iron pipe poles of least 1.8-2 m high for cattle and 1-1.5 m for sheep and goats and purlins spaced at 20-50 cm from the floor to the top as required.
- Gates should be provided with means to prevent reversal of animals.
- Roofing should be weather proof that is against heat.
- If the lairage is to have a wall, the wall should be finished with fine cement mortar.
- There must be an open space between the wall and the roof of the lairage for ventilation.

- Each pen should be supplied with concrete water troughs at about 50 cm from the floor, with 60 cm width and 25-40cm depth across the length of one side of each pen.
- Metallic hayracks should be installed in those pens in which the animals stay until before 24-72 hours of slaughter at about 60-100 cm from the floor across the length on the opposite side of the water supply line.
- Area of about 3.25 m2 and 0.55 m2 per head of cattle and shoats is required, respectively.
- The livestock holding pen capacity at the establishment shall be sufficient to hold the number of animals slaughtered during one half slaughter shift. The capacity of each livestock pen shall indicate on the establishment drawings.

6.2.4. Isolation Pen

- Isolation pen should be shaded and have feeding, watering and cleansing and drainage facilities.
- The drainage of isolation pens should prevent the possibility of spread of infection via fluid waste material.
- The isolation pen for each species of animals shall be constructed at least 50 m away from lairage and slaughter hall.

6.2.5. Pre-slaughter holding pens

- Pre-slaughter holding pens should have a half shift holding capacity, be constructed of acceptable masonry and metal construction with adequate lighting and ventilation.
- To prevent dust and odours from entering the stunning and bleeding areas, pre- slaughter holding pens must be completely separated from the stunning and bleeding areas.
- These pens must be constructed and drained to permit daily floor washing.
- Must be connected to the slaughter hall with race having a minimum length of 10 m.
- The width of the path (race) leading from pre-slaughter holding pens to stunning box or directly to the slaughter hall shall not be greater than 90 cm for cattle and 35 cm for shoats (should not allow the direction reversal of animals).

6.2.6. Stunning, hoisting and bleeding areas

- Stunning and bleeding areas must be constructed to ensure humane treatment of animals, and that the operations can be conducted and maintained in a sanitary manner.
- Stunning boxes should be excluded from the slaughtering floor, except for the door opening, in order to reduce hazards by possible aerosol contamination.
- Stunning and bleeding operations must be separated from areas where beef or shoat blood is collected.
- These areas must be equipped with hand washing and sanitizing facilities.
- Stunning boxes should allow that only one animal at a time be placed in them.
- The design of chutes, stunning boxes, restraining devices and other facilities shall be such that animals are provided with good footing and that direction reversal and injury is prevented.
- The provision of adequate restraining facilities for the ritual slaughter of all slaughter animals is a mandatory requirement. The restraining pen for Islamic slaughter shall be semi-rotary casting pen for cattle while sheep and goats can be slaughtered on a slaughtering conveyor.
- The floor of the stunning box is recommended to be 35 cm raised above the floor and should have a distance of about 0.9 m between the front and back ends of the stunning pen and any wall or obstruction. There should be a clear space of 3 m between the exit door of the pen and opposite wall or blood trough. An area of 4.5 x 3 m is required for safe working.
- A hoist hook should be set 1.8 m from the rotating exit door of the pen towards the back legs of the ejected animal.
- A landing area shall be provided in front of the stunning box, to receive stunned animals.
- An upward curved falling trough at the discharge of the stunning box needs to be provided so as to insure a gentle fall of animals.
- The landing area should be laid to falls of 50 mm in 3 m and should be kept dry as much as possible. It shall be separately drained and sufficiently separated from the bleeding area.

- The bleeding area should allow simultaneous bleeding of 2-3 cattle or 3-6 sheep and goats per line (8 m rail length).
- Bleeding areas shall be curbed and steeply graded to the blood and wash-up drains.
- The blood drain shall be of sufficient size to prevent blockage due to clotting (diameter of 33 cm or more) and sloped not less than 17 cm per meter to the discharge point.
- The bleeding trough should have smooth impervious surface and be made of either smooth concrete or rust resistant metal.
- If blood is to be collected for further use, there must be blood tank. If blood is not to be collected for further use, it has to be led to an open canal that ends up in a cesspool.

6.2.7. Slaughter and dressing hall

- The rooms and areas shall be of sufficient size to provide adequate space for all phases of dressing and inspection operations in proper sequence and relation.
- The equipment and the layout for carcass dressing rooms must provide inspection stations that are accessible by inspectors.
- All equipment should be rust-resistant metal or other accepted material. All equipment should have an acceptable design, sufficient capacity and have a satisfactory layout for all phases of the operation.
- A held rail must be provided for all carcasses requiring inspection or further trimming. A switch off rail, which leads directly to the inedible room, should be provided for condemned carcasses.
- The floor should be finished entirely with grooved glazed tile.
- The wall must be free of pitting, indentations, cracks, cervices and ledges up to the level of rail(s) (3.7m), hard and imperious material (e.g., accepted prefabricated panels or glazed tile) and of smooth finishing to its 2/3 height with the same floor finishing (i.e. epoxy) for cement walls while sandwich panels don't require painting.
- The canal shall be open top covered with stainless steel grill.
- The hook of the hoist should be stainless steel.

- To dress carcasses of more than one compatible species of animals concurrently on the same floor, the facilities should be designed to provide for adequate segregation and physical separation.
- Stationary or elevating type platforms should be located away from the dressing rail to avoid common contact of skinned portions of carcasses. A rust-resistant protective guard shall be provided to prevent footwear contact with carcasses.
- There must be sufficient, strategically located equipment sanitizing units, hand washing facilities with disinfectant, drinking fountains and hot and cold water outlets for clean-up purposes.
- Suitable facilities and floor space must be provided for dehorning, removal and thorough washing of heads and their preparation for inspection.
- The identity of heads and all parts of the animal must be maintained until final disposition of the carcass. There shall be no drip contamination from one head to another.
- Head meat and tongues are frequently exposed to contamination and there should be a system to avoid all such contamination and maintain all portions in a sanitary condition. There should be separate chillers for head meat and tongues.
- All cattle and shoat hides removed from the carcasses on the dressing floor must be removed from the floor to properly constructed and hooded chutes or bins.
- Trimming, fleshing and grading of hides must not be done on the killing floor but in separate rooms designed for this purpose or in the hide-curing room.
- The slaughter hall must be furnished with wash hand basin(s) and disinfectant, pressurized water hoses of 0.8 to 1.2 bar (14kgf/cm2) and knife sterilizing boxes at every work stand (platform).
- Adequate washing and sanitizing facilities for viscera inspection trucks or a stationary inspection table of each about 0.9 m length shall be provided. The hose used for sanitizing inspection trucks shall be equipped with a dial-type thermometer, to ensure that hot water having a minimum temperature of $82^{O}C$ is used.

- Facilities such as racks, or trays, or equivalent means shall be provided to accommodate and maintain the identity of organs and parts detained for veterinary diagnosis.
- A check-trim station shall be provided at a point prior to the final carcass washing station. This check-trim station shall be equipped with an adequate platform, to facilitate trimming of the dressed carcass.
- Facilities on the dressing floor should provide for the prompt removal of edible and inedible offal to their respective destinations.
- Properly constructed trucks or hooded chutes shall be provided for the prompt removal of hides and pelts, as required.
- For both moving-type and gravity-flow dressing rails, carcasses must be adequately spaced to prevent any contact between them at least until post-mortem inspection is completed. Beef carcasses should be spaced using rail stops of at least 1.5 m on centre.
- Adequate mechanical or operational measures must be incorporated to prevent the splashing and cross-contamination of carcass for both moving-type and gravity-flow dressing or bleeding rails.
- Pressure spray-washing equipment shall be used to remove blood and bone dust at the final carcass washing station.

Table 6.3 Carcass spacing on the rail

	Dressing	**Initial Cooling**	**Chilling or Freezing**
Cattle	1.8m	0.5 m	0.5 m
Sheep & goats	1 m	0.3 m	0.3 m

- Rails and rail support systems should be easily cleanable types and constructed from materials which resist corrosion.
- Supporting beams for rails must present surfaces, which are free of crevices.
- The rail heights shall accommodate the following minimum distances from the carcass suspension contact point to the floor. All rails shall have a minimum distance of 2.75 m from walls and pillars for cattle and 2.5 m for sheep and goats in the slaughter and dressing hall.

Table 6.4 Rail height and spacing guidelines

Species	Bleeding	Dressing	Coolers		
	Minimum distance from top of rail to floor	**Minimum distance from top of rail to floor**	**Minimum distance from top of rail to floor**	**Maximum distance from top of rail to shackle**	**Minimum spacing (distance) from walls, pillars, etc**
Cattle	3.7 m	3.1 m	3.1 m	30 cm	60 cm
Calves •	3.7 m	2.4 m (or above level of inspection	2.4 m	30 cm	60 cm
Sheep and goats	2.4 m	2.0 m (or above level of inspection	2.0 m	30 cm	60 cm

The distance between double rails should be 1.5 m in the slaughter hall, but double rails leading to storage, treatment and dispatch facilities shall be spaced at least at 1 meter apart for both species.

- Hangers and hooks for liver, heart, lung, and spleen should be installed in the slaughter hall.
- Platforms, ladders, tables, chutes and similar equipment shall be rust resistant, smooth and have non-absorbent surface.
- The rails of the production room, refrigeration and freezing rooms should be connected with loading ramps for meat transportation vehicles.

6.2.8. Meat inspection points

The following requirements apply to establishments that are registered to slaughter specific classes of food animals.

6.2.8.1. *Head inspection point*

- Head inspection point shall be located immediately after the head preparation and washing operations are performed by a plant employee.
- The minimal unobstructed space (length) for this inspection point is 1.5 m per inspector.

- When racks or conveyors are used for head inspection, the heads shall be spaced at a distance sufficient to prevent the contact of one head with another. A minimal distance of 0.6 m center to center is recommended for beef heads.

6.2.8.2. *Viscera inspection point*

- Viscera inspection point shall be located immediately after the evisceration of the animal.
- Every registered establishment slaughtering cattle at a rate of 25 or more per hour shall provide a moving top evisceration table.
- The minimum unobstructed space (length) for this inspection station is 2.5 m. Where multiple viscera inspection stations can be consolidated, 1.5 per inspection station is acceptable if all other ergonomic factors are met.

6.2.8.3. *Carcass inspection point*

- Carcass inspection point shall be located immediately after the carcass splitting operation and prior to any trimming being performed on the carcass.
- The minimum unobstructed space (length) for this inspection station is 2.5 m.
- The online carcass inspection point shall be adjustable to accommodate inspectors of different heights. The point shall be capable of being positioned so the eyes of the inspector are level with the lumbosacral area (rump) of the carcass.

6.2.8.4. *Veterinary held rail inspection point*

- Veterinary held rail inspection station shall be located as close as possible after the carcass rail inspection station and prior to company in-house trimming, inspection and final carcass wash. This station is to be independent from the operator's carcass trimming/re-processing station.
- The minimum unobstructed space (length) for this inspection station is 2.5 m.
- The veterinary held rail inspection point shall be equipped with an adjustable stand that enables the veterinarian to perform a safe and thorough inspection (visually, by palpation and/or incision) of all carcass surfaces including extremities.

- A switch-off rail, which leads directly to the inedible room or to a suitable truck or chute, should be provided for condemned carcasses.

6.2.9. Detained rooms

- The wall of the detained rooms must be epoxy paint of up to 2 meters high from the floor.
- The floor of the rooms shall be grooved glazed tile.
- There should be a rail system connected directly from the slaughter hall.
- 5-10 head hangers with hooks and 3 x 2 m (L x H) shelf with horizontal partitions at 50 cm intervals.
- Furnished with stainless steel or marble topped inspection table.

6.2.10. Condemned and inedible rooms

- The condemned rooms should be built in such a way that the inspector can have a closer look and control over it.
- The room must be provided with a self closing door.
- The wall and floor of the room shall be epoxy resin surfaced and cement screed respectively.
- The room shall be equipped with clearly marked water tight container(s) to ensure their use for no other purpose and be furnished with hand wash basin, equipment sanitizing facilities and pressurized hot and cold water supply.
- Each room should have adequate space which allows effective segregation of inedible and condemned parts.

6.2.11. Hide, skin and feet rooms

- Hide and skin rooms or storage areas must be properly ventilated so that they do no affect the air quality entering other areas of the plant.
- The floor of each room must be finished with cement screed with a slope of 2% to the drainage canal.
- The wall of the room should be epoxy painted.
- The drainage canal in the rooms shall be open top covered with iron grill.
- There should be hand wash basin(s) with hot and cold water supply.
- The rooms should be provided with stainless sliding metal chute.

- They must be located in the inedible section of the establishment with only the very minimum of connection with the carcass dressing room or area.
- Receiving platforms and fleshing tables should be of suitable metal construction.
- Shipment must be by direct access to the inedible loading dock or to an area designed solely for this purpose and separate from edible areas. Hides must not pass through other storage areas.
- Salt facilities for curing hides should not be part of the plant.

6.2.12. Carcass Coolers

- All coolers have a certain maximum capacity which is dependent, not only on the refrigerating capability of the unit, but also on the provision of an adequate circulation of air. Overcrowding reduces the effectiveness of refrigeration units, not only by being too much heat generated from freshly introduced carcasses but also by interference with air circulation. Therefore, the holding capacity of all carcass chilling and holding rooms shall be indicated on the establishment drawings.
- These rooms must be designed in a manner which ensures that all products are cooled.
- The floor of the cold rooms must be resistant to blood, fat, acid, and non-slippery.
- Polystyrene of corrugated iron sheet roof should be at least 10 cm thicker than polystyrene used for wall and floor.
- The wall must be finished with epoxy.
- The hangers in the cold room should be stainless steel.
- Equipment designed to promote rapid and thorough chilling, such as racks, shallow trays, etc., shall be provided.
- The doors of the cold room shall be resistant to temperature variation and air tight with rubber gaskets and be made of non rusting material.
- The entrance of the cold storage should be along the dispatch hall.
- A suitable area must be designated in a cooler for chilling and storing "held carcasses" and parts. This section should be segregated from the remainder of the cooler and sealed or locked. A sufficient length of side rail, equipped with lockable devices (i.e. lockable rail) may be sufficient for these purposes.
- All cold storage rooms should be equipped with a thermometer, thermograph and alarm systems on the exterior wall next to the door.

6.2.13. Offal Coolers

- When harvested for food, adequately refrigerated and constructed rooms must be provided to lower the internal temperature of offal to $4^{O}C$ or lower as quickly as possible after evisceration.
- When edible offal is stored on the premises for more than 24 hours after harvest, the rooms used to store the edible offal shall be kept at a temperature of 1°C or less, as measured in the warmest spot in the room.
- Equipment designed to promote rapid and thorough chilling must be used when handling offal.

6.2.14. Freezers

- Floors shall be properly insulated and constructed to eliminate possibilities of frost damage.
- Floor and wall racks shall be provided with proper air circulation, as required.
- All sharp (blast) freezers shall be capable of maintaining temperatures of $-25^{O}C$ or lower.
- Holding freezers shall be capable of maintaining temperatures of $-18^{O}C$ or lower.
- All freezer rooms shall be equipped with thermometer and thermographs.

6.2.15. Head preparation rooms

- Should be adjacent to the bleeding and flaying area and possibly connected with a conveyor or with sliding chute.
- The wall of the room must be epoxy paint 2 meter high from the floor.
- The floor of the room shall be grooved rough epoxy paint with 2% slope.
- The room should have an open drainage canal top covered with iron grill.
- 2-3 shielded head washing cabinets and equipment sanitizing facilities should be available.
- There should be hot and cold pressurized water supply.

6.2.16. Offal preparation rooms

- The rooms shall be adjacent to the casing cleaning rooms.

- The floor of the rooms should be grooved glazed tile with 2% slope to the drainage canal.
- The wall of the room must be epoxy paint 2 meters high from the floor.
- The drainage canal of the room should be open top covered with iron grill.
- The rooms should have rust resistant metal sliding chutes to the slaughter hall.
- The room shall be furnished with wash hand basin(s), hot and cold water supply, and pressurized water hose 0.8 to 1.2 bar, sterilizing box(s) and stainless steel or marble topped offal preparation table.

6.2.17. Cutting and de-boning rooms

- The cutting and de-boning room should be sufficient in size to accommodate carcasses from one shift of production.
- Equipment and tools should be food-grade (stainless steel, plastic, or rubber) and not include any wood products.
- The area should be furnished with wash hand basin(s), pressurized water hose 0.8 to 1.2 bar, stainless steel or hard plastic (Akron) food grade-topped table(s), sterilizing box(es) and hot and cold water supply at strategic locations.
- This room should be enclosed and refrigerated to 10°C or less with adequate lighting (540 lux) to safely process meat products.

6.2.18. Vacuum packaging Area:

- The vacuum packaging room is where the boneless beef will be transported, either manually or automatically for packaging.
- Vacuum packaging of small quantities of beef could be done with a simple machine and limited automation.
- Vacuum packaging of large quantities of beef requires the use of automation and conveyors.
- The layout requirement for the vacuum packaging area will include bag loaders, vacuum packaging machines, steam shrink tunnels, bag blow-off tunnels.

6.2.19. Weighing, labeling and pack off rooms

- The pack-off area is where vacuum packaged beef will be transported, either manually or automatically, for boxing.
- This area should be separated from the production area by a wall or “pass-through”

enclosure to maximize sanitation.

- The pack-off area should be refrigerated to 10°C or less, with adequate space.
- Under ideal circumstances, boxes would be delivered to this room assembled and via conveyor belt. Boxes should not be stored in this area.
- The wall should be finished with epoxy paint until 2 meters high from the floor.
- Its floor shall be a grooved cement-tile with a slope of 1% to the drainage canal.
- Weighing machine should be available.

6.2.20. Dispatch

- Carcass in the dispatch area should be hanged on stainless steel hangers directly connected to the loading ramp.
- Shipping areas or docks must be of sound construction, properly drained, and located so that edible and inedible shipping and receiving areas are physically and operationally separated from each other.
- A satisfactory dock seals and a canopy or roof overhang must be provided at edible loading and unloading bays to protect against dust, meat condensation, etc.
- Edible shipping and receiving areas and docks should be refrigerated or designed such that meat products pass directly through to either the truck or holding cooler.
- The whole wall of the dispatch area should be finished with epoxy resin.
- The floor must be grooved cement tile with a slope of 0.5% to the drainage canal.

6.3 Proposed Design Context

6.3.1 Site layout

The site layout includes production section, services section, administration section, mini-tannery, pen/quarantine, water source, mosque and parking lots.

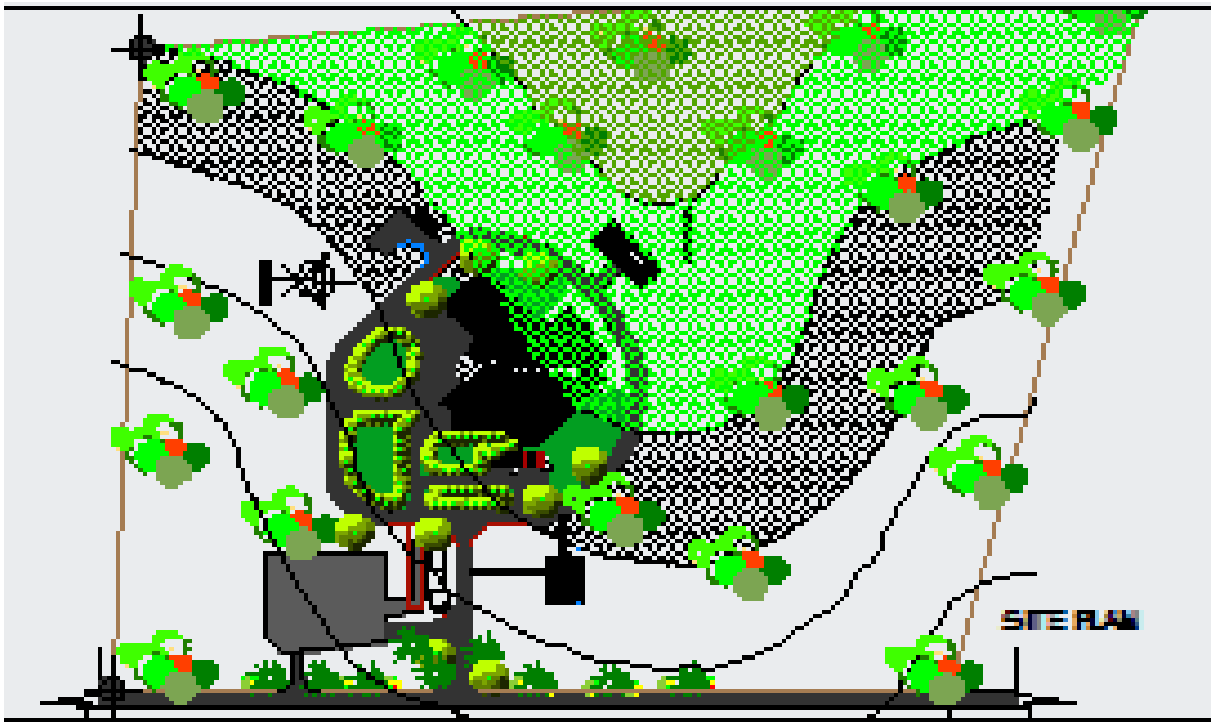


Figure 6.2: site plan of the proposed abattoir, Katsina

The site plan is designed to take full advantage of accessibility/privacy to the abattoir. The parking spacces are designed for easy parking with a 90 degree parking style adopted. Pedestrian route are also hard landscaped with concrete interlocking tiles for easy movement. Ramps were used where there was need for change in level in order to facilitate smooth movement for people carrying meat.

Soft landscaping: large percentage of the site is undeveloped and is used for soft landscaping. As a long term solution, trees with high water absorption quality were planted on different parts of the in an ordered manner. These trees include willows, eastern red cedar, bald cypress and river Bircch. These trees absorb gallons of water on a daily basis and this will help reduce surface run offs.

Site drainage: The drainage channels were designed to follow pedestrian routes and were connected to existing drainage channels.

6.3.2 Floor Plans

The facility has different functions just on the ground with different levels of heights and the buildings are raised 450mm above the ground level.

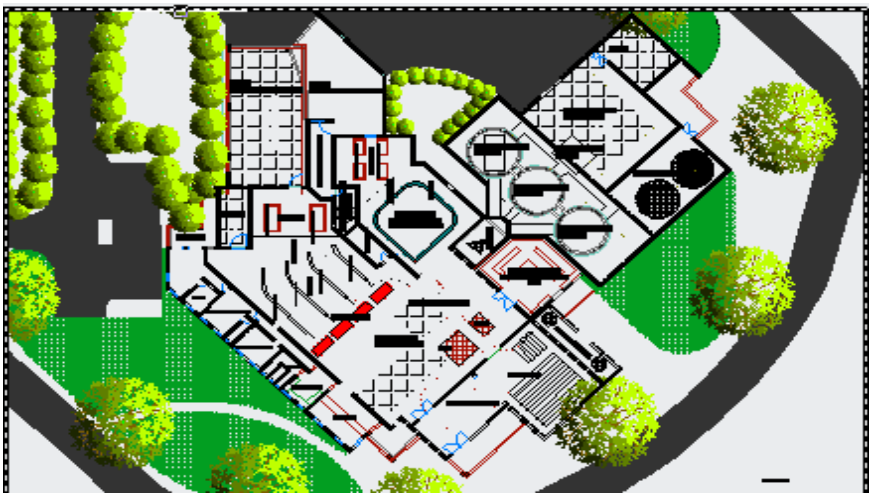


Figure 6.3: floor plan of the production section

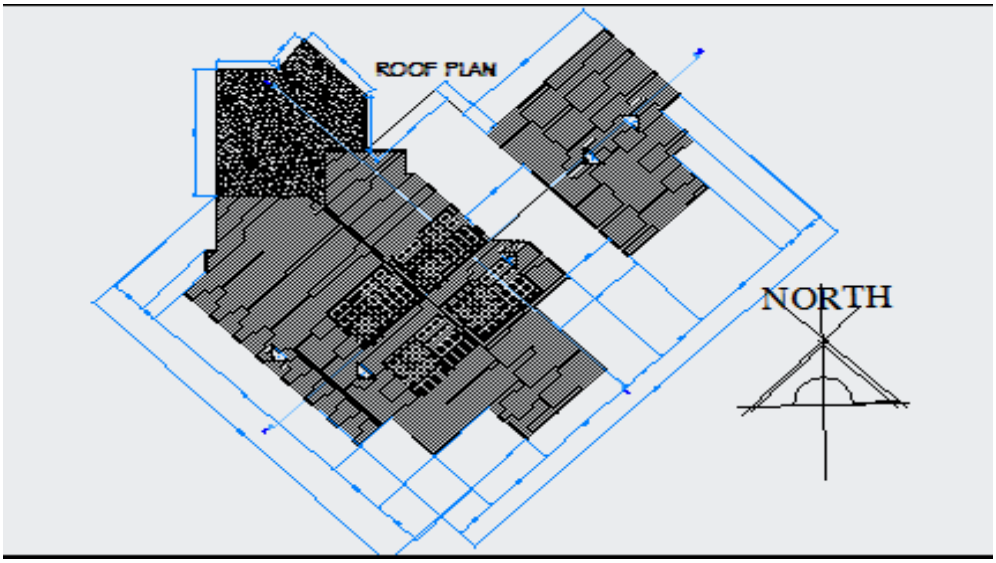


Figure 6.5: Roof plan of the production section

The roof is gable with the inspection chamber decked; solar panel is also used on the roof to harness energy for use on the site.

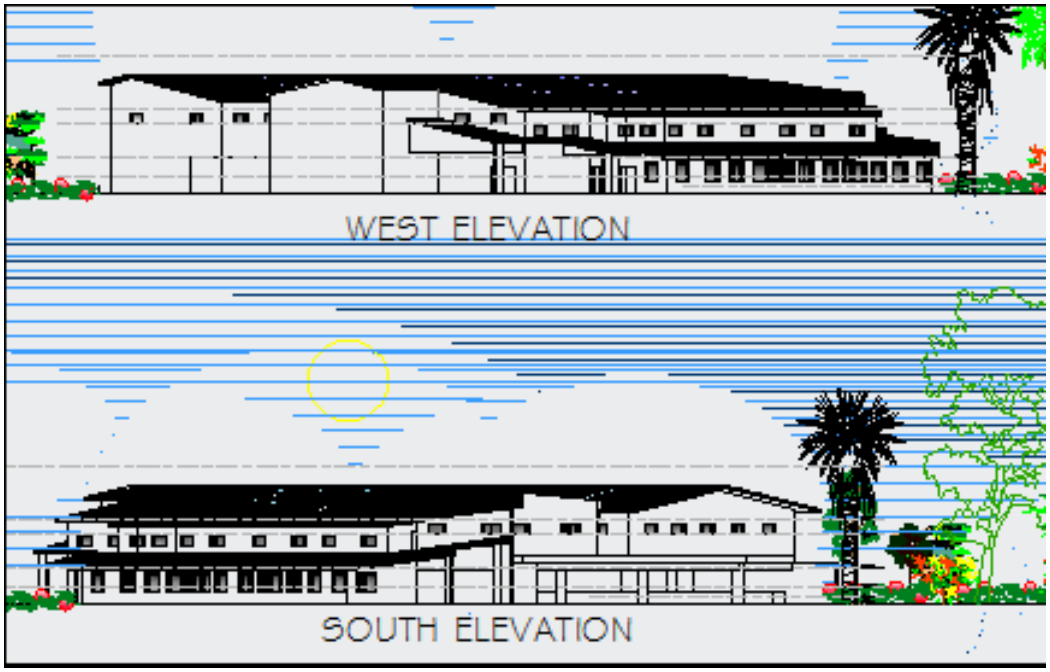


Figure 6.6: West and south elevations of the of the production section

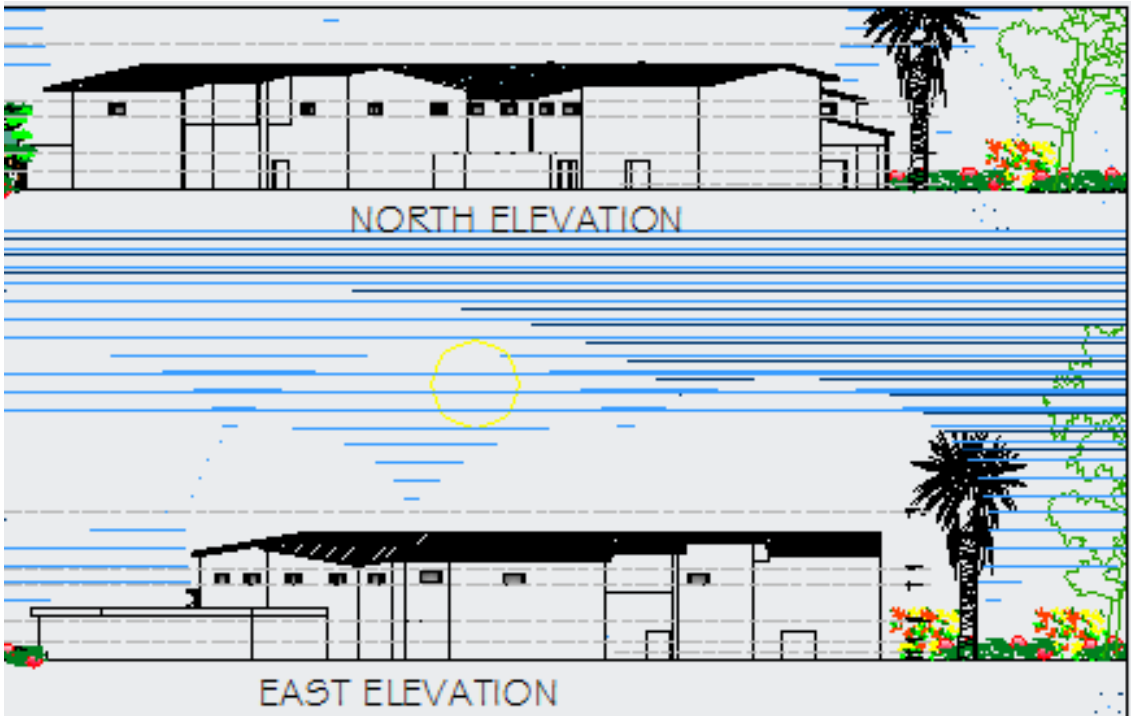


Figure 6.6: North and east elevations of the of the production section

6.4 Construction

6.4.1 Sub-structure:

Research indicates that the site soil ispredominantly derived from granite, guises and magnetile. But the load or size of a building is a determinant of the type of foundation suitable for such structure. Hence, the abattoir building is on a reinforced strip foundation and lay over 450mm hardcore.

i. Foundation

This is the part of the building that has direct contact with the ground and its primary aim is to transmit and spread the loads (dead and live) from the building over a sufficient area of soil to avoid undue settlement because of the failure of the underlying soil. Preliminary site work shows that the site soil posed no construction problems and strip foundation is used for the foundation

type. Also, steel stanchions on concrete base are used as column throughout the construction. Expansion joints are introduced at intervals to allow for expansion and contraction that will take place on the buildings.

ii. Structural system

Owning to the nature of the design and having in mind the structural stability of the building as well as load transmission among structural members, the production hall would be constructed basically of steel portal frame structure through which live, dead and imposed loads will be transmitted to the foundation and consequently to the ground. The infill basically sandcrete block does not transfer load.

6.4.2 Super-structure

Sandcrete blocks make up the walling which is plastered with cement and finished with paintto help reduce heat absorption. It is efficiently ventilated for the comfort of staff. High level windows were introduced to allow light and natural air. The roof members consist of steel rafters covered with long span aluminum roofing sheets.

6.4.3 Building materials

Structural frame: reinforced concrete was used for the main structure of the building. These include the arches, columns, beams as well as pad foundations for the substructure.

Facing: Small pieces of red brick of 100 x 50mm dimensions were used for facing in different surfaces of the walls.

Partitions: Sancrete block work was used to partition most of the buildings' interior. The opaque nature of this material creates the required visual and physical privacy needed in some of the spaces.

Finishes: The consideration given to the selection of floor finishes were non-slippery surfaces considering possible water spillage in different areas of the production section, so, terrazzo floor finish was used for most of the spaces while the interior spaces of offices and stores were finished with vitrified porcelain floor tiles. Also granolithic floor finishes were used in some parts of the building with various variables in color and texture.

For the wall finish, the major consideration was sound absorption to curtail the necessary noise from animals, so, rough texture finishes such as Tyrolean was used for the walls while acoustic ceiling boards were used for the ceiling.

6.5 Summary

The result of the above analysis shows that sustainable waste management system in abattoir have been fully employed for both production section of the abattoir and the entire site. The outcome also reveals that proposed abattoir has its most integrated space within the site and functions for direct manufacture at the production section.

CHAPTER SEVEN
CONCLUSION

7.1 Summary

In conclusion, the research carried out shows that waste generated in abattoirs can be harmful to the environment, therefore abattoir waste should be managed to achieve a balance between sustainable disposal and energy supply in order to optimize abattoir waste management strategies that will ensure reduction of environmental pollution, there is the need for intensive research in all aspects of the problem.

However, this thesis looked at the contemporary ways of achieving a sustainable waste management system with special focus on Anaerobic digester. Research was carried out on the architectural design requirement of abattoirs and anaerobic design requirement in order to achieve the research objectives.

The architectural design of Abattoir was conceptualized to improve the waste management of abattoirs through exploitation of Anaerobic digester, incorporation of renewable energy strategies like the use of generated solid and liquid waste to produce energy as an alternative solution to the high energy demands in Nigerian abattoirs.

This research study and incorporate anaerobic design principles to ascertain the general potential of energy yield from waste generated along the production process of abattoirs. The research however highlights the possibilities of adding and adopting biogas as one of the sustainable energy source being it environmentally friendly .

7.2 Recommendation

Based on the research conducted, the studied needs of the problems of abattoir wastes can be minimized when considering the following:

i. Evaluating the modernized abattoir design strategy and considering the necessary steps in separating product from by-product/waste and directing it to the units where it will be serve as raw materials for biogas production.

ii. The effects of abattoir size, abattoir facilities, types of livestock processed, overall market size, etc. on the pollution potential of abattoir wastes.

iii. Characterization of abattoir wastes which includes the physicochemical and microbiological characterization by extracting usable gases for biogas plants.

iv. Creating more renewable energy means through utilizing the generated waste.

v. Environmental impact assessment of abattoir wastes on surrounding surface waters, surrounding wells and boreholes, the butchers health, and on crops grown with effluent contaminated pond waters, rivulets and streams

vi. The development of the utilization potential of abattoir wastes and the consequent effects on the marketability of the wastes

vii. Appraisal of existing abattoir waste treatment and disposal practices in Nigeria and the recommendation of remedial measures.

7.3 Contribution to knowledge.

i. The research also highlights the economical value of generated abattoir waste and created the balance between the product demand and required waste.

ii. The energy generated could be another means of income to enhance the running cost of the abattoirs.

iii. The research help in redefining the design strategy through considering the necessary steps in separating product from by-product/waste and directing it to the units where it will be serve as raw materials for biogas production.

iv. Helps in creating additional job opportunity in both skilled, unskilled and at professional level.

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APPENDICES