INDUSTRIAL ARCHITECTURE; A DETERMINANT OF EFFICIENCY IN THE PALM OIL MILL

by

Afua Asantewaa Temeng (Hons.)

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DECLARATION

I hereby declare that this submission is my own work towards the M.arch and that, to the best of my knowledge, it contains no materials previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement had been made in the text.

Signature …………………… …………………………

(Afua Asantewaa Temeng) Date

Certified by:

Mr. Samuel Owusu Afram …………………… …………………………

(Supervisor) Signature Date

Certified by:

Mr. Samuel Owusu Afram …………………… …………………………

(Head of Department) Signature Date

ABSTRACT

Over the years, the Asian countries have proven that the production of palm oil generates enough income and revenue to aid the development of a nation. It is in view of this that the Ministry of Trade and Industry, Presidential Special Initiative, (PSI), has called for an improvement in the cultivation of oil palm in the country. An increase in the production of raw materials suggests an augmentation in processing facilities to prevent problems associated with inadequate storage practices.

In order to achieve efficiency in the production of oil to meet international demands, a thorough knowledge and understanding of the raw material processing and the infrastructure for the processing must be soughted for. The site for the cultivation of cash crop must have certain requirements for a higher performance in yielding.

Analysis on the raw material must be carried out since this determines the amount of finished goods to be obtained and the various services to be employed for efficiency in production. It is also necessary to have a precedent and/or case studies of existing palm oil processing industries for evaluation in order to develop a functional new industry for sustainability.

This document is a research thesis that reconciles industrial architecture with efficiency in productivity of the production of palm oil in the oil mill. It discusses the factors of efficiency in production and how these factors are directly influenced by the various aspects of industrial architecture.

ACKNOWLEDGEMENT

"Unless the Lord builds the house, they labour in vain, them that build it……….."

An unending praise is given to the Almighty God who through His mercies and grace provided everything needed for this study. It has not been by my might but simply by His Spirit and His grace.

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DEDICATION

This thesis is dedicated to my parents, Mr. & Mrs. Temeng, my sweet sisters, Mrs. Atuahene-Acheampong, Mrs. Tei-Nobi and Maame Yaa Temeng. It also dedicated to my baby Nana

Amponsaah and my niece Pakidi. This is to acknowledge their support and entire role played in my life. May God replace all that you lost for my gain.

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CHAPTER ONE: INTRODUCTION

1.1 PREAMBLE

Efficiency in the Oxford Advanced Learner's Dictionary is defined as the quality of doing something well with no waste of time. In physics, efficiency is expressed as a percentage of work output over work input. Efficiency in production is therefore a measure of the amount of finished goods to that of raw materials used in the production process. Industrially, efficiency to a great deal is determined by the well being of all the machines and the work-force. What is industrial architecture? How does the architecture affect the amount of palm oil produced in the oil mill?

Industrial architecture is a term that refers to the branch of artistic activity that came into being as a result of the need to design machine-made products, introduced by the Industrial Revolution in the eighteenth (18^{th}) century. The purpose of industrial design is to ensure that goods satisfy the demands of fashion, style, function, materials, and cost.

(Source: http://www.britannica.com/EBchecked/topic/286910/industrial-architecture)

It must be noted that the quality of the machines, to a great extent, determine the efficiency in the production of the industry. The configuration and construction of the industrial space suggests the proper functioning of the various machines as well as the well being of the work-force. Inadequate configuration of spaces obstructs circulation, increases the risk of accidents which reduces the outputs of workers among others. If the architecture of the industry has an undeviating impact on the output of workers and all involved machinery, it can be deduced that industrial architecture is directly linked to efficiency as defined in physics and that of the productivity of the industry.

1.2 PROBLEM STATEMENT

The amount of palm oil produced is the major concern of most automated and small-scale palm oil industries. However, factors that influence production rate of the mill are often down-played. The industrial process and routine of production are unconsciously broken by the inadequate arrangement of buildings on site and spaces within the production hall among others. These tend to lower the rate of production of finished good as it reduces productivity's efficiency.

1.3 OBJECTIVE(S)

i. To identify the factors that affect efficiency in production of the palm oil
ii. To establish how architecture affects these determinants of efficiency.
iii. To derive or develop a design response that will make effective use of all aspects of industrial architecture to improve efficiency and productivity in the palm oil mill.

1.4 SCOPE

Industrial architecture in this research will be dealt with in terms of the composition of the overall industrial site and that of the spaces of the individual facilities and the construction of the structure of the site. This research will also tackle the standard configuration of the industry and the extent to which it affects efficiency in the production of finished goods. The capacity of the industry under consideration for the purposes of this thesis is a nine (9) ton/hour automated palm oil mill.

1.5 JUSTIFICATION

The decline in productivity of most industries in Ghana cannot be attributed to any direct factor such as raw materials, labour or machinery. A cursory look at the composition of these factories indicates some weakness in the various aspects of industrial architecture.

CHAPTER TWO: LITERATURE REVIEW

2.0 INTRODUCTION

In order to develop a suitable design for any industry, the production process of the said industry must be studied. For the purposes of this research, the study will be on the production of palm oil.

2.1 PALM OIL PROCESSING

2.1.1 Worldwide available technique

The naturally occurring red palm oil obtained from fresh palm fruit is often acceptable for local consumption without further treatment, or at most, a simple filtering or settling operation to remove any solid impurities. This process is regarded as primary processing.

The satisfactory extraction of crude palm oil from fresh fruit bunches requires specially designed machinery, whether hand or machine operated, and the provision of ancillary equipment for the prior preparation of the fruit for subsequent extraction of the oil.

The methods of production of palm oil can be grouped into

a. Non mechanical traditional methods
b. Small-scale mechanized processing
c. Large-scale automated processing

For the purposes of this study, the large-scaled automated processing will be considered.

In general all crude palm oil extracting methods includes a

- *sterilization process*
- *digesting stage*
- *an extraction process*
- *purification and clarification*

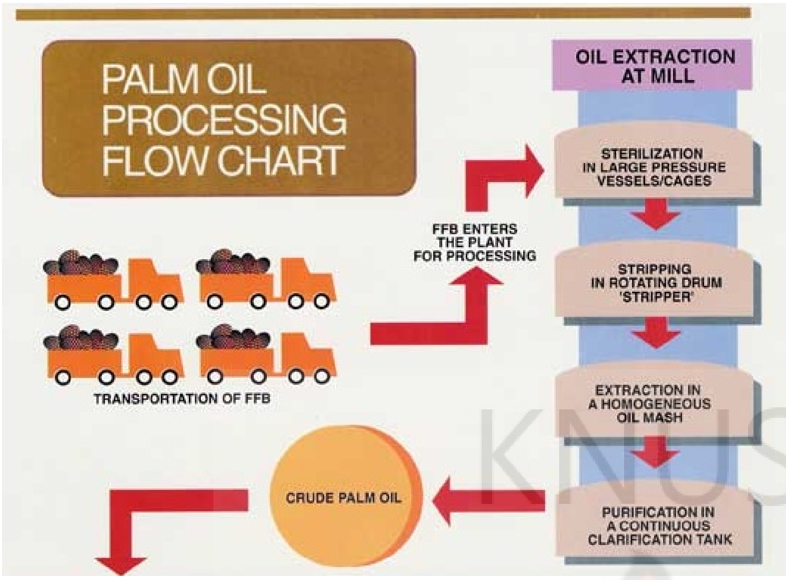

Figure 2.1 Palm oil processing flow chart

(Source: http://www.mpoc.org.my/main_ind_01.asp)

2.1.1 Large-scale automated processing

This refers to industries which have a total processing capacity above five (5) tons per hour where the stages involved are aided by large automated machines. Stages involved in the processing of palm oil are the same as in that of the small-scale industries. The essential features of automated oil palm mills are standard in that they consist of sections or stations for sterilization of bunches, stripping of bunches, digestion or mashing of fruit, extraction of mesocarp oil, clarifying the oil, separation of fibre from the nuts, nut drying, nut grading and cracking, kernel separation and discarding of the shell and kernel drying and bagging.

(Source: http://www.rmrdc.gov.ng/Surveyreport2005/Cocoa.pdf)

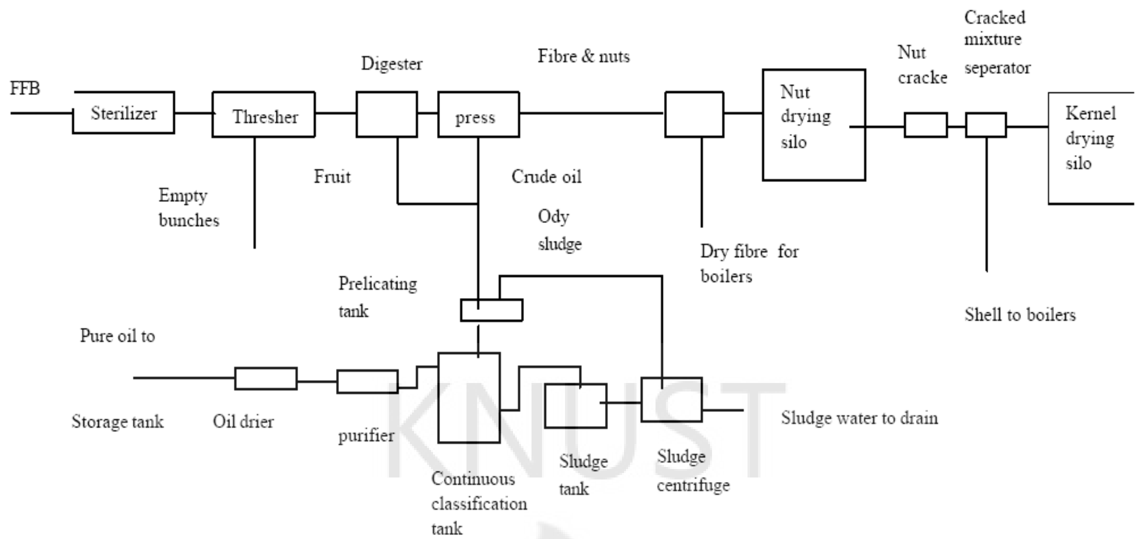

Figure 2.2 Stages of automated milling process

(Source: http://www.rmrdc.gov.ng/Surveyreport2005/Cocoa.pdf)

Sterilization is affected by "pressure cooking" the fresh fruit bunch (FFB) at about 3kg/cm² or 30000Pa pressure and a temperature of around 130ºC for about 1 hour.

(Source: http://www.fao.org/DOCREP/005/Y4355E/y4355e03.htm))

Sterilizers can either be vertical or horizontal. The vertical cages are only suitable for small mills where the cages on rails for horizontal sterilizers cannot be afforded. They are usually of three (3) to five (5) tons capacity but can be constructed to take up to six (6) tons. Horizontal sterilizers are long cylinders placed at ground level into which cages of standard design can be pushed on rails through a door which then closes the whole of one end of the cylinder.

Figure 2.3 Horizontal sterilizers

(Source: http://www.uga.edu/fruit/oilpalm.html)

The capacity of the sterilizer is determined by the length and can hold up to fifteen (15) tons of fresh fruit bunch in six cages. The advantage of horizontal boilers over vertical ones is that it does not require hand emptying and because bunches are sterilized in cages in which they are packed, they are subject to minimum handling and thus less bruising.

Stripping of the fruit from bunches (threshing) – This consists of separating the fruits from bunches by threshing. There are two types of strippers or threshers:

a) The beater arm type. This is smaller and cheaper and is suitable for small mills with a capacity of up to five (5) tons FFB/hr.

b) The rotary drum stripper has a diameter of about six (6) feet and a length of nine (9) to sixteen (16) feet. The longer the drum, the more complete the stripping.

Digestion – The purpose of digestion, as in pounding, is to break up the pulp physically and to liberate the oil from the oil bearing cells; to raise the temperature of the mash to facilitate subsequent pressing (usually to about 90ºC) and to drain away free oil and so reduce the volume to be pressed. Digesters are usually cylindrical vessels enclosed in a steam jacket where the mash is heated to 100ºC. The digester is equipped with rotating knives or beater arms.

(Source: http://www.fao.org/DOCREP/005/Y4355E/y4355e03.htm)

Extraction of crude palm oil **–** The extraction of crude oil from the fruit is effected by pressing. This is usually the rate limiting step and determines the capacity of the mill in terms of FFB milled per hour. There are two basic methods of extracting oils. One is by centrifugal force and the other by squeezing (pressing) the oil and moisture from the digested pulp.

Two types of presses are currently in use:

a) Ram presses – This type includes all those presses in which direct pressure is applied to a mass of fruit by a ram acting within a press cage. The two types currently encountered are the manual and hydraulic presses.

b) Screw presses – Comprising a helical screw turning within a perforated cage. It may be single or double shafted.

(Source: http://www.fao.org/DOCREP/005/Y4355E/y4355e03.htm)

Clarification **-** After the digestion stage the oil contains unacceptable impurities, especially non-oily solids and water, and is known as crude oil. The first stage of the clarification (i.e. the process of separation of oil from water, solid fruit particles and dirt) is affected by natural decantation. The decanted oil is screened and centrifuged to complete the separation. The oil is finally dried in a vacuum dyer and stored.

(Source: http://www.fao.org/DOCREP/005/Y4355E/y4355e03.htm)

2.2 INDUSTRIAL ARCHITECTURE

The industrial revolution of the eighteenth (18$^{th)}$ century introduced the large-scale, organized collection of industrial processes into specific buildings. Larger buildings were required for purpose-made machines in order to take the heavy loads of the machineries used. Industrial or factory aesthetics were created by cast iron, steel and concrete which were the products of the industrial revolution. The introduction of lighter cladding materials allowed the design of large clear-span sheds which can be adapted to a variety of uses.

Industrial buildings just like any other architectural building require considerations in

1. site selection and planning
2. construction of buildings
3. services
4. landscaping

2.2.1 Site selection and planning

The siting of industrial buildings is governed by four major factors which are

a. raw material source
b. market
c. work force
d. transportation mode

Raw material source as much as possible must be of close proximity to processing sites and must be linked with good transport ways in the form of road or rail way. The amount of raw materials suggests the capacity of the industry for sustainability which will also determine the size of the area to be developed in terms of its physical structure or its architecture. Amount of raw materials also determines the sizes of the machines to be used and the amount of energy consumption of the industry. Market centres and the size of the markets will determine how frequent finished goods will be dispatched and hence a depiction of the mode of storage of finished products and the size of the storage facilities.

The habitations of the work force of the industry must also be at a considerable distance to the production site to ensure an effective and continuous running of the industry. Proper transport ways must also link places of habitation of workers to ensure punctuality and regularity to achieve efficiency within the working hours of the industry.

Site selection for a palm oil processing industry must have considerations of the physical characteristics of the site such as topography, climate, geology and vegetation. Climatic conditions of the site must not be harsh in terms of excessive rainfall and solar radiation. It must be that which will facilitate the growth or survival of raw materials so that a nursery for the cultivation of palm seedlings can be sited on production sites where necessary. The topography of the site must also be one which will pose ease in vehicular manoeuvring, reduce amount of surface run-off and erosion. On sloping sites it is advisable to cut and fill to create a uniform land form for the manoeuvring of vehicles, especially, trucks. The geology which determines the type of soil and its bearing capacity must not be water-logged but rather one which can receive the heavy loads of the machineries to be used.

Selected sites for industries must have an Environmental Impact Assessment (EIA) with consideration given to;

a. noise from machinery and vehicles

b. vibrations of machineries
c. fume and dust pollution
d. effluent discharge
e. hazard of possible explosion

Appropriately, industrial sites must be located on the outskirts of towns to be prevent possible pollution of the industries to surrounding residences. The planning of selected site for factories and industries must pay attention to expansion potential. The total coverage of the industry must not exceed seventy five (75) percent hence allowing an expansion potential of twenty five (25) to forty (40) percent of the site under consideration. Layout of site must also bear in mind economics so as to reduce operational cost, adaptability, expansion possibility and economic efficiency.

The flow of work of the industrial process plays an immense role in site planning. Site must be planned such that the basic process of "raw material delivery- processing- store" will be easily facilitated without unnecessary meanderings. A linear flow of work must be aimed at with reduced walking distances. The production process as much as possible must be orientated north-south.

Parking areas form an integral part of factory designs. These are basically parking spaces for trucks for delivery of raw materials and dispatch of finished goods as well as buses for the transportation of work force and vehicles for other staff members and visitors or customers. Parking spaces provided for customers and visitors are dependent on the size of market for the finished goods and how often the goods are dispatched off site. In all, traffic flow must be well organized to reduce vehicular-pedestrian conflict zones. If possible, different accesses must be provided for vehicles and pedestrians.

2.2.2 Construction of buildings

The construction of factory buildings must be such that each component of the building helps to distribute evenly the loads of the heavy machines unto the ground without damage of parts of the building.

2.2.2.1 Foundation

The most appropriate foundation type used for light weight industrial buildings is the raft foundation type. This consists of a continuous reinforced concrete slab under the building in order to carry all the downward loads and distribute them evenly over a large enough area to avoid over stressing of the soil.

2.2.2.2 Flooring

The flooring of food processing industries must be durable to transmit the superimposed load directly to the supporting ground. The required floor finish must have a high wearing resistance and provide a safe, non-slip and easy-to-clean surface. Floor areas where heavy machines are to be sited can be made of in-situ terrazzo floor finish whereas area liable to spillage of oil may be finished with porcelain tiles for easy cleaning.

2.2.2.3 Roofing

Industrial buildings need a clear floor area without interruption by columns and therefore they usually have longer spans. Spanning them requires trusses of whichever material appropriate.

Steel is however often preferred due to its light weight and flexibility with design. It is chosen over other materials because of its ease of erection in cases of expansion possibilities. The roof systems of industrial buildings vary from simple steel trusses to space frames based on their clear span. These structures are usually mounted on vertical steel members which are I-sections in most cases.

Roofing materials used for factory designs come in all forms of corrugated aluminium and Perspex blocks in the tropics as a means of receiving sky light into production halls.

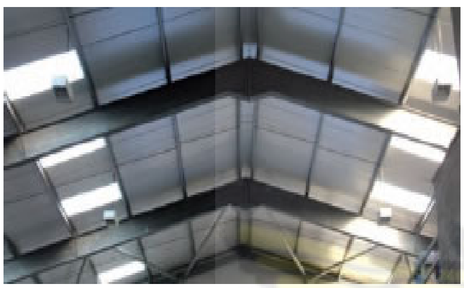

Figure 2.4 Roofing system Figure 2.5 Sky lighting

(Source: http://www.jamessmithfencing.co.uk/content_sub.asp?page=61)

Due to the large span with column centres at five (5) metres or above, steel purlin members are used with bolts onto roofing sheets.

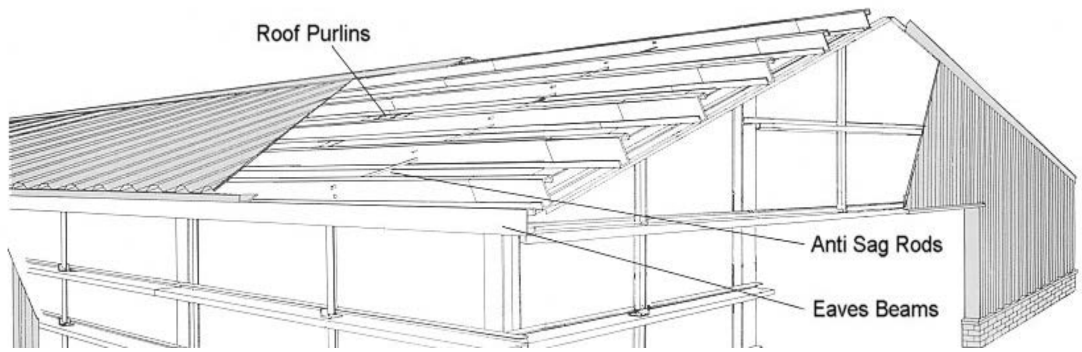

Figure 2.6 Roof purlins

(Source: http://www.cladrite-ics.co.uk/)

Figure 2.7 Roofing members

(Source: http//www.metsec.com)

2.2.2.4 Cladding

Covering industrial buildings usually require the use of light materials such as metal sheets. In the tropics particular attention is given to the choice of cladding material in terms of the conductance of the material so as to control the rate of solar heat gain into the industrial building. Corrugated iron or aluminium sheets are used in Ghana due to their availability and conductance.

The fixing of claddings to the main frame of steel sections needs the introduction of cleats to receive claddings by bolting.

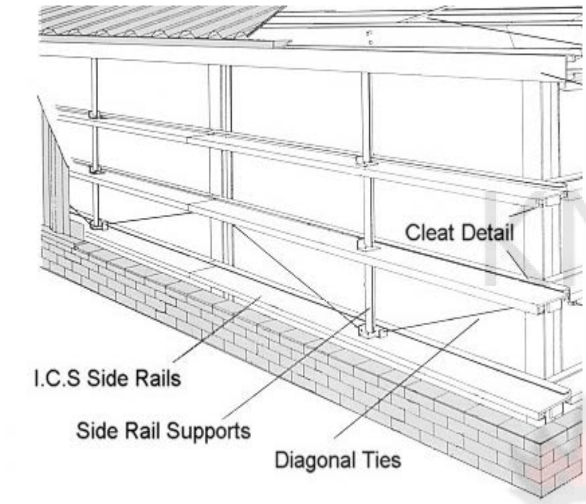

Figure 2.8 Cladding details

(Source: http://www.cladrite-ics.co.uk/)

2.2.3 Services

2.2.3.1 Electricity

The amount of energy consumption is dependent on the machineries used in the industry. The total consumption of the machines determines whether the energy supply (hydro-electric energy) from transformers will be stepped up or down. Using public energy supply often lowers the voltage of electricity for the community. For this reason most industries do generate their own electric energy. Palm oil mills in most cases have boiler houses for the generation of energy. This is fueled by shells and fibres that are end products of the milling process. The fuels are burnt in a furnace and used to boil water treated with caustic soda. There is the production of steam which is used to drive turbines to generate energy. The resultant energy is conveyed by underground cables to prevent all problems associated with overhead cables.

The process in the boiler house is shown in the diagram below

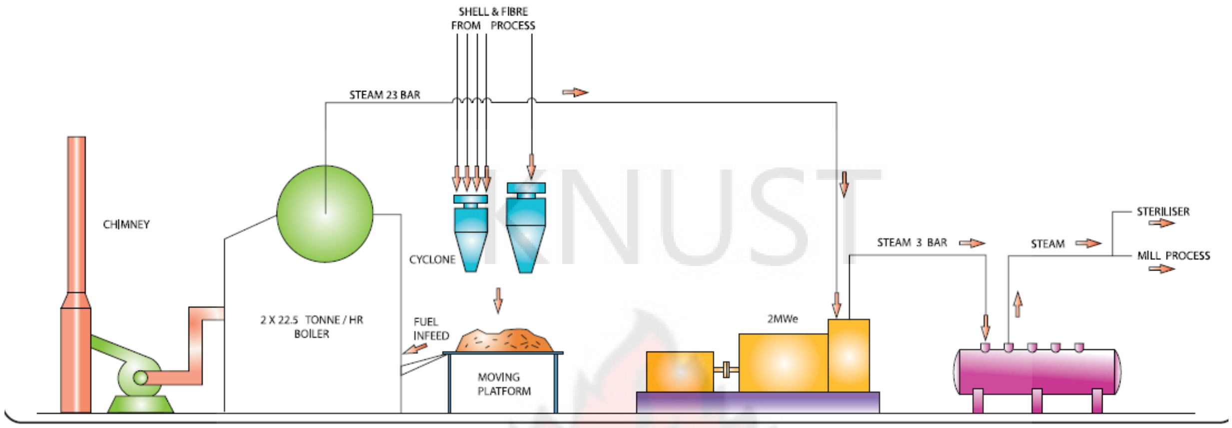

Figure 2.9 Process diagram of the boiler house

(Source: http://www.cogen3.net/doc/fsdp_infosheet/GuthrieInfoSheet.pdf)

Averagely, the total energy consumption of all electric machines used in the production process is 14.46 kWh/ton FFB.

(Source: http://library.wur.nl/file/wurpubs/LUWPUBRD_00333582_A502_001.pdf)

The boiler produces high pressure and temperature steam, which expands in a back pressure steam turbine and produces enough electric power for the internal needs of the mill. The exhaust steam from the turbine goes to an accumulator which distributes the steam to various processes in the mill. The power plant in the crude palm oil mill incorporates water tube boiler with a steaming capacity of twenty (20) to thirty (30) tons of steam per hour. Fibre is used as fuel for generation of power in factory and used to supply the domestic needs (3.3% of total electricity consumption).

2.2.3.2 Water consumption

Crude palm oil mill uses a lot of water in the production process. Supplied water is treated by clarification and filtration. Alum and polymer are used as coagulant and flocculent in the clarifiers. More than sixty percent (60 %) of water used is for cooling system in turbine generator, the rest of forty percent (40 %) is for steam boiler. Steam from boiler is first applied to turbine generator for electricity, and then supplied to sterilization, digestion, kernel dryer tank, hot water tank, and clarification tank and oil storage tank. Cooling water is also reused in the production process.

Water supply is required for the following process:

1. Boiler make-up water
   - During power generation, steam from boiler is supplied to turbine generator.
   - During sterilization, live steam from boiler is applied to autoclave in order to facilitate the stripping of fruits
   - During digestion to facilitate homogenization.
   - Heating purpose, to control temperature in the oil settling tank, hot water tank, oil storage tank and the kernel dryer tank,
2. Cooling water for the turbine is used to generate electricity from burning fibre.
3. During extraction, hot water is used to remove oil from fibre.
4. During the removal of large particle from oil in decanter, hot water is used to clean the surface of the vibrating screen.
5. During oil recovery from sludge, as dilution water for sludge to adjust the concentration of sludge before going to the separator.
6. Miscellaneous usage such as seal water pump and factory and machine cleaning.

(Source: http://library.wur.nl/file/wurpubs/LUWPUBRD_00333582_A502_001.pdf)

Table 2.1 The breakdown of water consumed in the various production stages

Process stream	**Amount of water consumed (m^3/ton of ffb)**
Boiler make-up water	***0.4***
digester	0.15
sterilizer	0.02
Screw press	0.08
Vibrating screen	0.005
separator	0.1
Factory cleaning	0.08
Domestic purposes	0.68
others	0.23

(Source: http://library.wur.nl/file/wurpubs/LUWPUBRD_00333582_A502_001.pdf)

2.3.3.3 Waste management

The major waste includes empty fruit bunches, fibre and effluent (sludge). The fibre is used for firing the boiler. Some quantity of the Empty Fruit Bunch (EFB) is used for mulching in the plantations. A considerable quantity of the EFB is wasted due to lack of appropriate plan for its utilization.

Large- and medium-scale mills produce copious volumes of liquid waste from the sterilizer, clarifying centrifuges and hydro-cyclones. This effluent must be treated before discharge to avoid serious environmental pollution. Liquid waste treatment involves a series of fermentation in large ponds until the effluent quality is suitable for discharge. In some of the mills the treated effluent is used on the farm as manure and source of water for irrigation.

To manage the amount of oil entrained in the effluent, while at the same time improving the efficiency of oil recovery, the large mills use de-watering and decanting centrifuges at various locations in the process line.

Traditional processors operate so close to nature that they simply return liquids to the surrounding bushes. The discharged quantities are so small that the ground easily absorbs the waste matter and the operators have not yet seen their activities as injurious to their surroundings. However, in the more organized intermediate technology mills, sludge from the clarifying tanks is carried in buckets or rudimentary gutters to sludge pits dug in the nearby bushes. When the sludge pit begins to give off a bad odour the pit is filled in and another one dug for the purpose. Charcoal from the cooking fires is dumped into the pits to absorb some of the odour. Sometimes the oil in the sludge pit is recovered and mixed with fibre to make a fire-starting cake called ‘flint’. The mills sell effluent from the sludge to fish farmers but the quantity produced is more than the demand for the sludge.

2.2.3.4 Fuel demand

Fuel used in the production process consists of 0.12 litres diesel oil/ ton FFB. Diesel oil is used for diesel generator for start-up boiler.

2.2.4 Landscaping

Landscaping is very relevant in the industrial design. In the industry landscape helps to;

i. Beautify the entire industrial site
ii. Suggest the uses of the different outdoor spaces
iii. Rejuvenate the workforce of the industrial "spirit".

Elements of industrial landscape range from hard landscaping elements, soft elements and signage among others. Different materials must also be used for paths with different purposes. Hard elements in the form of pavers used must bear in mind the live loads of all vehicles used in the industry. For paths accessed by loading trucks, concrete pavement blocks must be used since they have a high bearing capacity. Walkways for workforce can be paved by any material chosen by the designer once it helps to integrate the whole design. Soft landscape elements for industrial purposes must be made of plants that are resistant to dust, soot and other pollutants of the industry. Due to the poor maintenance practice of Ghanaians, it is advised that plants used must be drought resistant and maintenance-free. Examples of such plants include *Cassia floribunda*, *Ipomea Abore, Nerium oleander*.

2.3 EFFICIENCY IN PRODUCTION

Production can be basically defined as the conversion of inputs into outputs. It is an economic process that uses resources to create a good or services that is suitable for exchange. Production is a process, and as such occurs through time and space. Because it is a flow concept, production is measured as a rate of output per period of time.

Efficiency is the quality of productivity. It is a measure of production with minimum time and no wastage of resources.

In any production process, the efficiency is influenced by its inputs and resources which are;

a. Raw materials

b. Production process and machinery

c. Labour/ work-force.

2.4 INDUSTRIAL ARCHITECTURE AND EFFICIENCY IN PRODUCTION

2.4.1 Raw materials

The site selected for the industrial purpose must be of close proximity to the source of raw material and be linked with good transportation system as stated in Chapter 2. Once the raw materials are conveyed to the site, the architecture of the industry must protect the fresh fruits bunch from deteriorating. The supply loading bay, where fresh fruits are received on site, must be protected from rain and other vagaries of the weather. This is because exposure to the weather softens the fruit which makes the exocarp soft, making it susceptible to attack by lipolytic enzymes, especially at the base when the fruit becomes detached from the bunch. The enzymatic attack results in an increase in the Free Fatty Acids (FFA) of the oil through hydrolysis. Research has shown that if the fruit is bruised, the FFA in the damaged part of the fruit increases rapidly to 60 percent in an hour. (Source: http://www.cepatoolkit.org/html/resources/89/897FE218-90F0-4030-B7A3-3A87869C3C88/Sustainable%20Palm%20Oil.pdf)

Protection of fruits from excessive heat means the loading bay must not be fully cladded. Where cladding is required, materials should be insulating enough for no heat transfer. Spaces must be left for ventilation as this helps to reduce the amount of fatty acids that will be produced in the crude palm oil.

Flooring materials for raw material loading bay are to bear in mind the loading of the supply trucks. For this purpose, concrete paving blocks are preferred because they have a high bearing capacity for the live load of such vehicles.

The roof level of the bay must also consider the anthropometrics of the loading trucks. A double volume which has a clear height of not less than five metres (5m) is usually used.

Appropriate industrial architecture helps to protect the fresh fruit bunch from decay so that all received raw materials are used as inputs for the production process.

2.4.2 Production process and machinery

Architecture plays an important role in the production process. It is the duty of architecture to ensure that the production process chain is not broken. The design of the production block that houses the production process must be such that it will facilitate all activities in the various stages of the production.

a. reception

The supply loading bay forms the first point of the production process. It must be sited close to the main production hall and yet not far from the main entry of the industrial site.

b. sterilization

The mode of conveyance of fresh fruits bunch from reception to sterilization is by cages which are pushed on rails. It is easier to push these cages on a straight rail than a turning rail. Due to this, sterilization points should be in straight line with the loading bay to avoid all problems that will be created by the turning of these cages.

The sterilization process is affected by pressure cooking of 30,000 Pa and temperature of 130ºC. As such, the point of sterilization must be protected against excessive heat gain. Ventilation is a major concern therefore less cladding must be used if there is the need to. During sterilization, there is the production of waste water. Proper drains are constructed to safely discharge these waste out of the industrial site. Steam pipes from the boiler house are used to convey steam for the sterilization process. Industrial architecture ensures that proper ducting are constructed to convey these pipes so that they do not interrupt the working space of the production hall

c. stripping

At stripping, sterilized fruits are conveyed in cages to the thresher by cranes. These cranes are suspended at roof level and operated for the work-force. The design of roof members is very salient at this stage. The various members used must allow the fixing of the crane. Steel members are generally used to cater for this construction.

Plate 2.1 The gantry cranes of the Juabeng Oil Mills

(Source: author's field survey)

Due to the weight of the thresher used in the production process, the foundation and the flooring material for the stripping stage are chosen to help distribute the live load evenly to the ground.

d. Digestion, oil extraction and clarification

There is lots of spillage of crude palm oil on the floors and walls of the production hall at theses stage of the production process. To keep the floor off accidents and to aid easy cleaning of stains, the texture of the flooring material must be considered. Therefore, surfaces of floor materials must not be too rough so that less time is used in the cleaning of the spillage. The various machines are powered by electricity conveyed by pipes and cables. Provision of ducts must be made to carry these cables so as to avoid obstructing the production hall which increase the risk of accidents.

e. the boiler house

The boiler house generates all the energy needed to run the industry through a furnace hence the generation of massive heat. A proper understanding of materials is necessary to choose an appropriate material that is heat insulating. There is the generation of waste water in the process of energy production in the boiler house. Drains must be provided to dispose the waste water from the boiler house. Services in terms of ducting must also be provided to convey the generated energy and steam to the various stages of the production process.

2.4.3 Labour service/ work-force

No matter how automated an industry is, the conversion of inputs to outputs requires labour force. As major determinants of efficiency and productivity, much attention should be given to work-force in the design of industries to reduce operator fatigue and maximize productivity. The selection of industrial site should be such that there is the ease of the transportation of the work force to and form the industrial site.

Attention must be given to design ergonomics. These are design factors, as for the workplace, intended to maximize productivity by minimizing operator fatigue and discomfort.

In the production hall, a straight line of production must be achieved with no allowance for turning, meandering and interruption. Path ways in the production hall must be straight and direct through a central aisle. Underground cables and ducting are usually advisable to avoid obstructing the workspace which increases the risk of accidents. Industrial floors must be easily cleanable and prevent accidents due to fall.

Thermal comfort of the workers is also relevant and the selection of cladding materials must meet the need of heat insulation and allow adequate ventilation.

There is the need for a facility that ensures the welfare of the work force. This facility must consist of changing facilities, a canteen and a health care centre serving as a first aid in cases of accidents.

Changing facilities are to be made of toilets, showers and locker rooms. This facility must be oriented east-west to make efficient use of the antiseptic effect of the sun. It must be at close proximity to the staff entrance to the site because it acts as the first point of call where workers switch from their attire to the working gear and vice versa.

Health care must be strategically positioned so that it is close to the changing facility and the production hall. To the production hall, the health care must have an uninterrupted path so that workers can be immediately rushed in during cases of accidents. Industrial health care must have restricted number of beds in the rest room to deter workers from sleeping during working hours.

The presence of a canteen on site reduces the amount of time wasted by workers during break as compared to situations where workers have to look for their meals off the site. The accumulated saved time can then be used for other purposes of the production process. The canteen must be as open as possible for ventilation but should also address issues of solar ingress and protection from rain. The spatial organization of the canteen must also prevent human traffic to reduce the amount of time spent.

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CHAPTER THREE: RESEARCH METHODOLOGY

3.0 INTRODUCTION

For this research to be successful and authentic, the author needed to obtain facts to facilitate genuine documentation, analysis, discussions and recommendations. Primary and secondary sources of data were used in this research.

3.1 PRIMARY SOURCES OF DATA

3.1.1 Case studies

The Twifo Praso Oil Mill and the Ghana Oil Palm Development Company (GOPDC) were initially considered for study. After a reconnaissance, survey it was found out that these two industries were too large in scale of tonnage of processing to be considered for this research. With a background of the general process of palm oil production obtained from internet research, the Juabeng Oil Mills was studied to see how the general process has been detailed to suit this region. A calculation of the capacity of the industry in terms of tonnage of raw materials to be processed was obtained from the Production Technician. This formed a basis of determining the capacity of the intended design of this research.

Another case study of the Adansi Oil Mills was conducted to find out how industrial architecture in terms of site location, site planning and components of building had been put to play. It also served as a case to examine efficiency in the production of palm oil.

3.1.2 Interviews

At the Juabeng Oil Mill, the Technical Manager, the Assistant Technician and the Laboratory Technician were interviewed. Information on the proper handling of raw materials that will avoid wastage and maximize efficiency was spelt out by the Technical Manager. The Laboratory Technician provided information on some of the causes of the impurities and reduced amount of finished goods against the expected.

Twenty three (23) junior staff members of the production hall of the Juabeng Oil Mill were interviewed. This represents a percentage of forty eight (48) out of forty nine (49) workers.
At the Adansi Oil Mill, the production manager was interviewed to obtain information on some of the determinants of efficiency in the production of the crude palm oil. Five (5) out of the ten (10) junior staff members, representing 50%, were interviewed. The interview of the junior staff members was to find out how labour affects efficiency in the production of palm oil.

3.1.3 Measured drawings

A measured drawing of the production hall of the Juabeng Oil Mill was conducted to aid the analysis of relationship between floor areas and the machinery used. Measured drawings of the various machines used in the palm oil processing were also conducted to determine the floor spaces occupied by the machines. This was a necessary basis for deriving an accommodation schedule.

3.1.4 Site analysis

A thorough site analysis and inventory was made to identify the strength and weakness of the site intended for the design through a SWOT analysis. Two sites were considered in Agona of the Afigya-Sekyere District of the Ashanti Region. These sites were analyzed on issues necessary for site selection of an industry which included nearness to raw materials, access to site and impacts on the environment among others.

The amount of raw materials to be obtained on the site allocated for the design was also searched into since this would determine the capacity of the intended industry.

3.1.5 Photography

Photographs were taken to enable the author describe accurately the situation found during case study and site analysis.

3.2 SECONDARY SOURCES OF DATA

3.2.1 Internet

Series of internet research formed major source of literature review. This was the initial method used as a means of familiarizing with the methods and process involved in palm oil processing. It was a means of defining industrial architecture, its evolution and its components. The definition of efficiency and its determinants were also obtained from the internet

3.2.2 Books

Books and journals with publications on oil palm from the Juabeng Oil Mill and the Adansi Oil Mill were of great help in writing the literature review. These had information on standard codes for the designing of palm oil mill as stated by Stork-Amsterdam. Other books such as Architects Data and Metric Hand Book provided useful information such as the general brief of an industrial design, basic parameters for selecting industrial sites, minimum spatial requirements for machines and circulation.

3.3 ANALYSIS OF DATA

A localized production process was drawn and juxta-posed with the general process obtained from the internet. The measured drawings conducted were used as a basis for spatial requirements of the various production spaces. Sizes of machines with allowance for circulation were used to derive an accommodation schedule.

Data collected from the various interviews were used to derive a workable brief that would ensure the welfare of the work-force which would in turn ensure maximum efficiency.

Through site analysis, it was found out that one of the sites was more appropriate for the industrial design. Even though both would have been suitable, one site would have posed danger to its environment since it was located in the habitable area of the town. This would have been most appropriate if easy access by workforce was the primary concern. The amount of raw materials to be obtained for the selected size was researched into. With this obtained, the capacity of the industry was calculated for using the technique obtained from the Juabeng Oil Mill.

Data collected from the Adansi Oil Mills form a guiding principle to ensure a straight line of the production process so as to prevent all problems created by bends and meander and to maximize output from workers. From the responses of the junior staff who were interviewed, it was found out that the mill was understaffed. These data formed a basis to estimate and determine the number of workers to be employed in the intended design. It was also pointed out that no infrastructure was in place to ensure the welfare of workers. This formed a basis for providing a welfare block in the intended design.

3.4 LIMITATIONS

The cases of Twifo Praso Oil Mill or the Ghana Oil Palm Development Company (GOPDC), Kade were intended to be studied in addition to the Juabeng oil Mill. These two industries had a lot of bureaucracies which made it impossible for me to reach the General Manager so as to send a petition for these cases to be studied.

Two foreign case studies, namely the Jugra Oil Mill in Selangor, Malaysia and the Asian Oil Mill in Krabi, Thailand were also considered. However, information pertaining to the subject matter of this research was not available on the internet.

At the local case study area, since the visits were made during hours of production, not enough workers were interviewed. Some of the workers available were not willing to be interviewed because they thought they would be publicized.

CHAPTER FOUR: RESEARCH FINDINGS

4.1 CASE STUDY 2: JUABENG OIL MILLS

The Juabeng Oil Mills is located at Juabeng in the Ejisu- Juabeng district of the Ashanti region. It is a both primary and secondary processing industry where red crude palm oil and refined cooking oil are processed. The mill is located at a five (5) minutes drive away from the town centre where it is sited opposite the Government Health Centre of the Juabeng District.

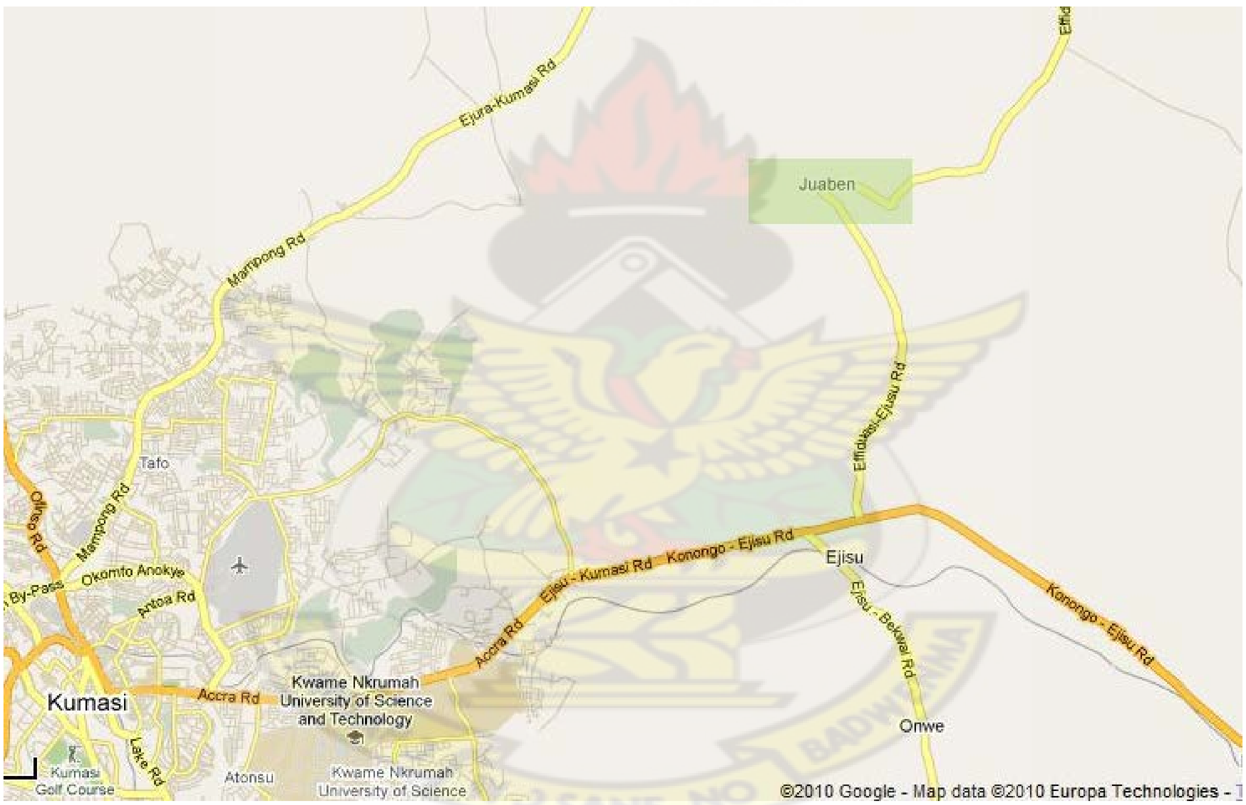


Figure 4.1 Location map of Juabeng

(Source: http://maps.google.com/)

Juabeng Oil Mills has three sources of raw materials which are from

1. Private farm holders
2. Out-growers farm
3. Nucleus estate of the company

In all 5530 hectares of farm land annually is responsible for the sustenance of the factory. The distribution is as follows:

- Private farm holders - 2323 hectares
- Out-growers farms - 1659 hectares
- Nucleus estates - 1548 hectares

4.1.1 Objective(s)

The objectives for this case study are

1. To know how the site has been planned to enhance the act of processing.
2. To examine how the flow chart of processing has been translated in the design of spaces to facilitate activities.
3. To assess how the mill design affected choices of materials and building components of the production block such as
   - Foundation
   - Flooring
   - Framing and structure
   - Roofing
   - Cladding

4. To examine how services (electricity, water supply, waste management) have been integrated into the design.
5. To analyze the amount of oil produced in relation to amount of raw materials supplied and its market analysis.
6. To study the organizational structure of the administrative body of the Juabeng Oil Mills.

4.1.2 Capacity determination

- The total area (hectares) of raw material supply is 5530 hectares as stated previously.
- Juabeng has a performance yield of 12.5 tons/hectare/year.

Therefore the amount of raw materials obtained in a year is

5530hectares x 12.5tons/hectares/year = 69125 tons/year

$$\text{Monthly yield} = \frac{69125}{12\text{months}} = 5760.4 \text{ tons/month}$$

- In a month the mill operates on 20 working days,

$$\text{Daily amount of fresh fruits} = \frac{5760.4 \text{ tons/month}}{20 \text{ days}} = 288.02 \text{ tons/day}$$

- The Juabeng oil mill operates a 24-hour processing with three (3) shifts.

Therefore the amount of fresh fruits that can be processed is

$$\frac{288.02 \text{ tons/day}}{24\text{hours}} = 12.00 \text{ tons/hour}$$

- The mill has a work-force of 276 for 24-hour processing running three (3) shifts

Therefore each shift has

- 8 working hours
- 92 workers

4.1.3 Site planning

The site of the industry has been planned with facilities like the Administration building, Warehouses, Security Post in addition to the main facility, Production block.

The first point of call onto the site is the Security Post where visitors, staff and production trucks are inspected before they are allowed in and out of the industry. For this reason, pilfering and theft cases by staff are minimized.

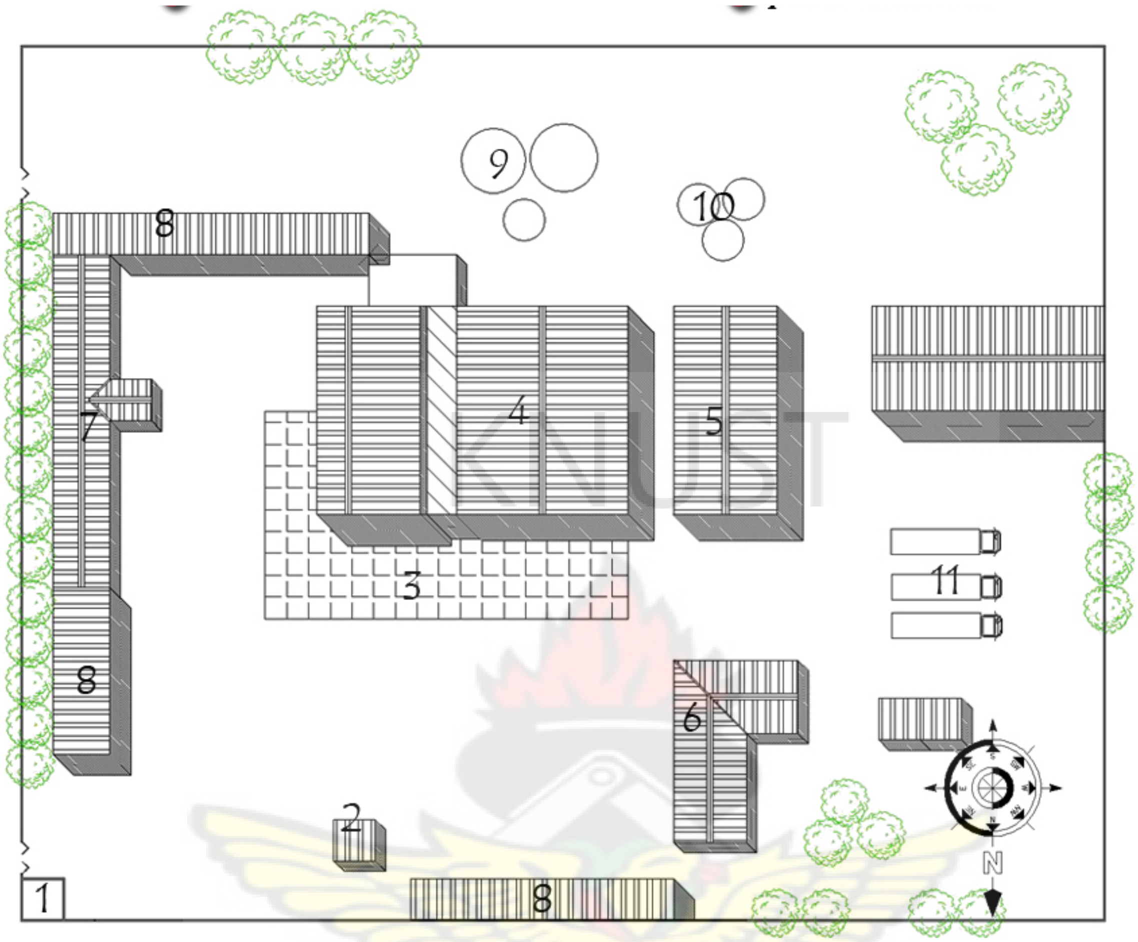


Figure 4.2 Site layout of Juabeng Oil Mills

(Source: author's field survey)

Legend

1. Security
2. Weigh bridge
3. Supply loading bay
4. Production block
5. Boiler house
6. Technical department
7. Administration

8. Warehouse

9. Crude oil tank

10. Kernel oil tank

11. Maintenance unit

To the immediate south of the security post is a long structure which is used as warehouse for shea butter seeds since Juabeng Oil Mills processes shea-butter. The weigh booth is located north-west of the warehouse. This has a digitally sensitive scale which records the gross weight of fresh fruit bunches which are received onto the site for processing.

To the north-west of the weigh bridge is situated another warehouse and on its south-west is a block which made up of the Technical and Out-growers Department.

The south of this building is situated the production block with its supply loading bay. The Administration block is located on the east of the Production Block and behind that are plantings demarcating the boundaries of the industrial site.

4.1.4 Facilitation of activities

4.1.4.1 The process

Stages involved in the production of palm oil and kernel oil at Juabeng Oil Mills are shown in the diagrams below;

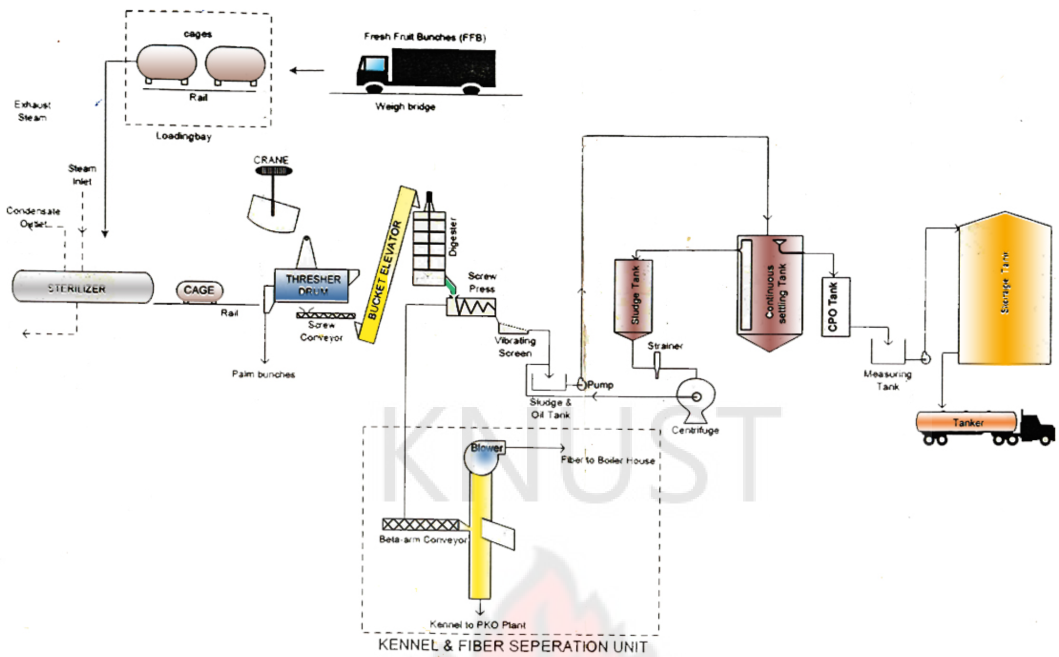


Figure 4.3 Process diagram of crude palm oil production (Juabeng Oil Mills)

(Source: Juabeng Oil Mills)

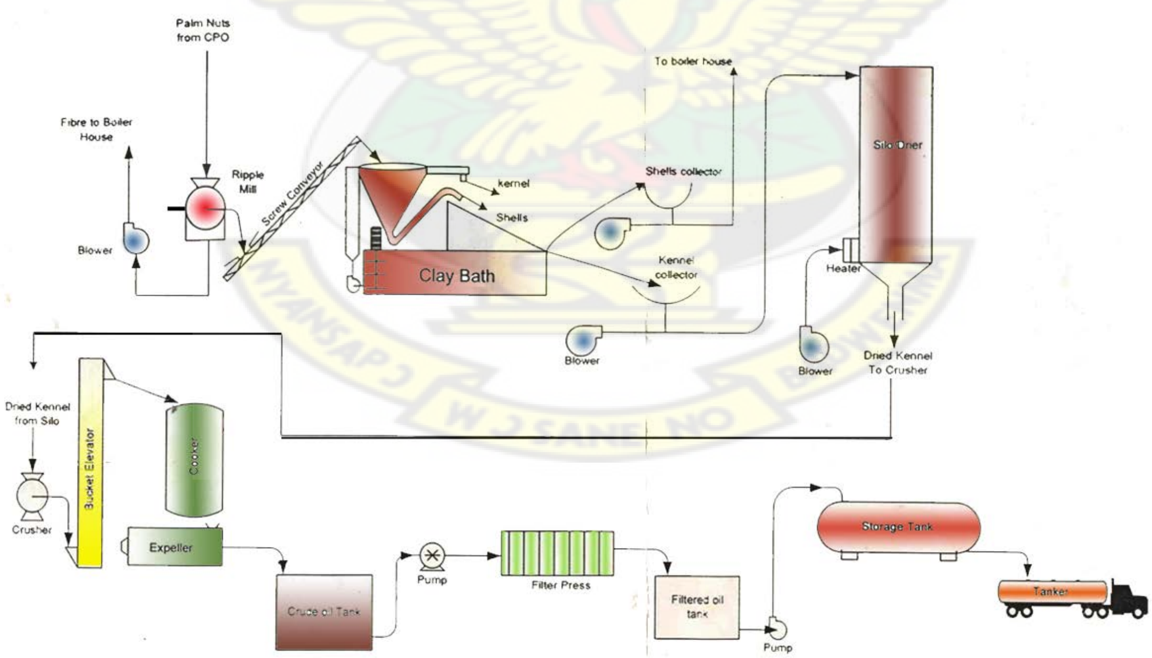


Figure 4.4 Process diagram of kernel oil production (Juabeng Oil Mills)

(Source: Juabeng Oil Mills)

4.1.5 Utilization of resources of the Production Block (Juabeng Oil Mill)

4.1.5.1 Foundation

The production block is raised on a raft foundation 900mm above the ground to uniformly distribute loading of machines to the ground.

4.1.5.2 Flooring

The ground floor of the block is raised on a concrete floor slab 900mm above the ground. Flooring of the ground floor was finished in terrazzo which is resistant to wear and durable to receive all the loadings.

Plate 4.1 Concrete floor slab of the production block (Juabeng Oil Mills) (Source: author's field survey)

Plate 4.2 Terrazzo floor finish of the production block (Juabeng Oil Mills) (Source: author's field survey)

There are three floor levels for the Production Block. The floors of the upper levels are made of a network of I-section steel members. This is because some of the heavy machines like the digester is located on the upper levels. Therefore the steel network of I-sections helps carry the load of the machines without damage to part or the entire building.

Plate 4.3 Structure of the upper floor of the production block(Juabeng Oil Mills)
(Source: author's field survey)

Plate 4.4 Machine on an upper floor of the production block (Juabeng Oil Mills)
(Source: author's field survey)

The upper floors are linked to lower ones by stairs which are also constructed in steel. These staircases are inclined at an angle of 45º to the ground.

Plate 4.5 Stairs linking floors of the production block (Juabeng Oil Mills)
(Source: author's field survey)

Plate 4.6 Angle of inclination of stairs of the production block (Juabeng Oil Mills)
(Source: author's field survey)

Upper floors were finished in a non-slip flooring material known as norament.

Plate 4.7 Norament floor finish of the production block (Juabeng Oil Mills)

(Source: author's field survey)

4.1.5.3 Framing and structure

The structure of the factory design is made up of steel structural components. A span of eighteen (18) metres was made possible by steel trusses mounted on I-section columns at five (5m) centres.

Plate 4.8 Network of trusses of the production block (Juabeng Oil Mills)

(Source: author's field survey)

4.1.5.4 Roofing

The roofing system consists of steel purlins over steel trusses. The roofing material used is corrugated aluminium sheets. An overhang of 600mm has been provided to cater for shading and draining of rain water into provided gully ways on the east and west of the buildings. There are no fascias on the eaves of the roof. The roof ends of the north and south are folded over the cladding of the structure for protection against rain.

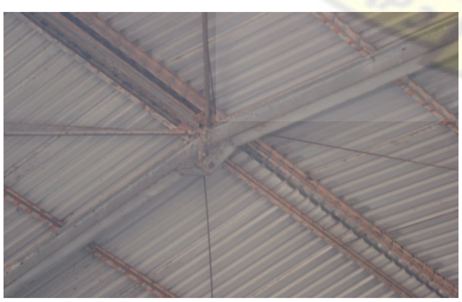


Plate 4.9 Steel roofing members of the production block (Juabeng Oil Mills)

(Source: author's field survey)

Plate 4.10 Roof over hang on the west of the production block (Juabeng Oil Mills)

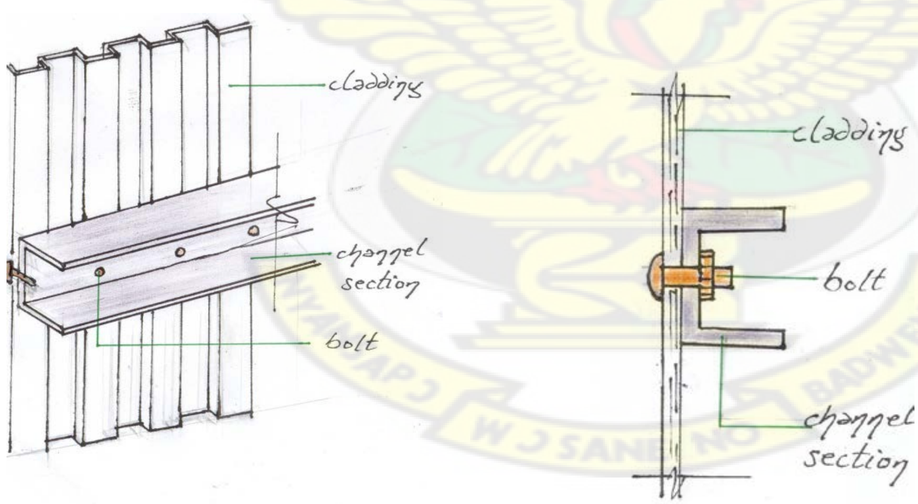
(Source: author's field survey)

4.1.5.5 Cladding

Cladding of the structure is made in corrugated aluminium sheets. This was made possible by bolting channel cleats into the main frame, I-sections, to receive cladding which is also attached to the channel cleats by bolts.

Plate 4.11 Corrugated aluminium cladding of the production block (Juabeng Oil Mills)

(Source: author's field survey)



3 dimensional view section

Figure 4.5 Detail of cladding fixing (Juabeng Oil Mills)

(Source: Author's field survey)

Merits

1. Security-tight entry serves as a means of controlling theft cases.
2. Plantings used as a demarcation the site is an attempt to control noise pollution to surrounding facilities.
3. The use of appropriate construction materials has lead to the survival of the structure from time of erection to date.

Demerits

1. Buildings have been spread on site leaving a little space for future expansion.
2. No demarcated circulation routes for vehicles and pedestrians hence the creation of vehicular-pedestrian conflict zones.
3. The absence of proper landscaping elements leaves site bare and building as pockets without linkages.
4. Absence of a well designed welfare block with changing facilities.

4.1.6 Services

4.1.6.1 Electricity

The presence of a boiler house is responsible for the generation of electric energy to power all machines and other buildings on the site. The boiler house is fuelled by fibres and shells which are end products of the oil production process. Juabeng Oil Mill has both the fire-tube boiler and the water-tube boiler. Fuel for the boiler house is deposited into a furnace which boils water treated with caustic soda.

Plate 4.12 The furnace (Juabeng Oil Mills) Plate 4.13 The boiler (Juabeng Oil Mills)

(Source: author's field survey) (Source: author's field survey)

There is the generation of 15-20 bar steam which is used to drive turbines to produce electric energy of magnitude 175-200 kWh for consumption by machines. Some of the generated steam is conveyed by over head pipes to sterilizer tanks to sterilize fresh fruit bunches.

Plate 4.14 Steam turbines (Juabeng Oil Mills) Plate 4.15 Pipes conveying steam to sterilizers (Juabeng Oil Mills)

(Source: author's field survey) (Source: author's field survey)

Generated electricity is carried by underground cables to the production hall providing a clear working hall.

4.1.6.2 Water consumption and supply

Water consumed by Juabeng Oil Mills is for domestic and industrial purposes. Domestically, water is used in the cleaning of the entire industry and the flushing of cisterns of various sanitary wares. Industrially, water is used in the various stages of the production line. The table below indicates the amount of water used in the mill.

Table 4.1 Amount of water used in the Juabeng Oil Mills

Production stream	**Amount of water (m^3/ffb/h)**	**Amount of water (m^3) for 12tons/h**
Digester	0.15	1.8
Sterilizer	0.02	0.24
Screw press	0.08	0.96
Vibrating screen	0.005	0.06
separator	0.1	1.2
Factory cleaning	0.08	0.96
Domestic purposes	0.68	8.16
Others	0.23	2.76

(Source: Juabeng Oil Mills)

4.1.6.3 Waste management

a. Empty bunches

Empty bunches which are generated after the threshing of fresh fruit bunches are collected and burnt on site and are used as fertilizers for the nursery and nucleus estate.

b. Shells and fibres

Shells and fibres which acts as fuels for the generation of power are collected and conveyed manually to the boiler house.

c. Sludge

Sludge from the process is channelled by drains 300 mm wide into main drain ways which are then linked to the central sewage system of the Juabeng township.

Plate 4.16   Primary drain ways (Juabeng Oil Mills)

(Source: author’s field survey)

4.1.6.4   Smoke and fire protection

Provision for smoke ventilation is made possible by leaving some facades of the building unclothed. Fire extinguishers have been provided at vantage points of the site as first aids in times of fire out-break.

4.1.7   Administrative organization

The hierarchy of the administration of the Juabeng Oil Mills is shown in the figure below

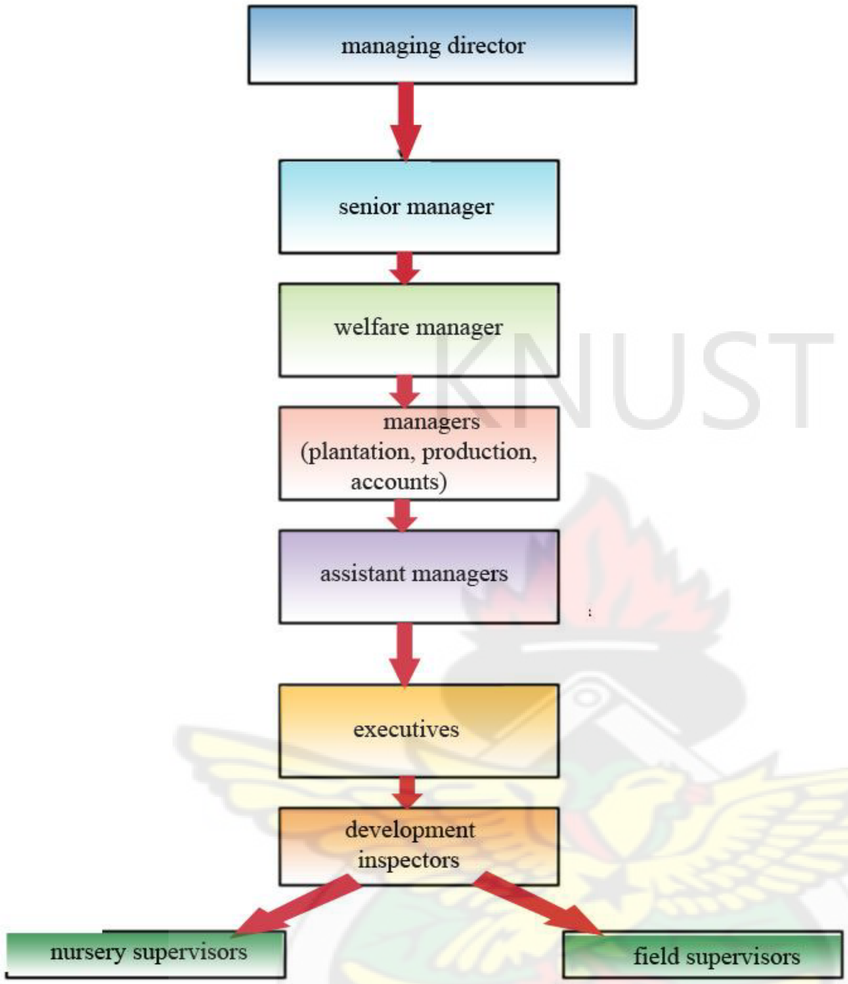


Figure 4.6 Organizational structure of the administration of Juabeng Oil Mills

(Source: author's field survey)

4.2 CASE STUDY 2: ADANSI OIL MILLS LIMITED

The Adansi Oil Mills Limited is located at Dompoase in the Adansi district of the Ashanti region. It is a primary processing industry where crude palm oil is produced. The plant has a processing capacity of 3 tons/hr and its raw materials are from private farms and a nucleus estate of the company.

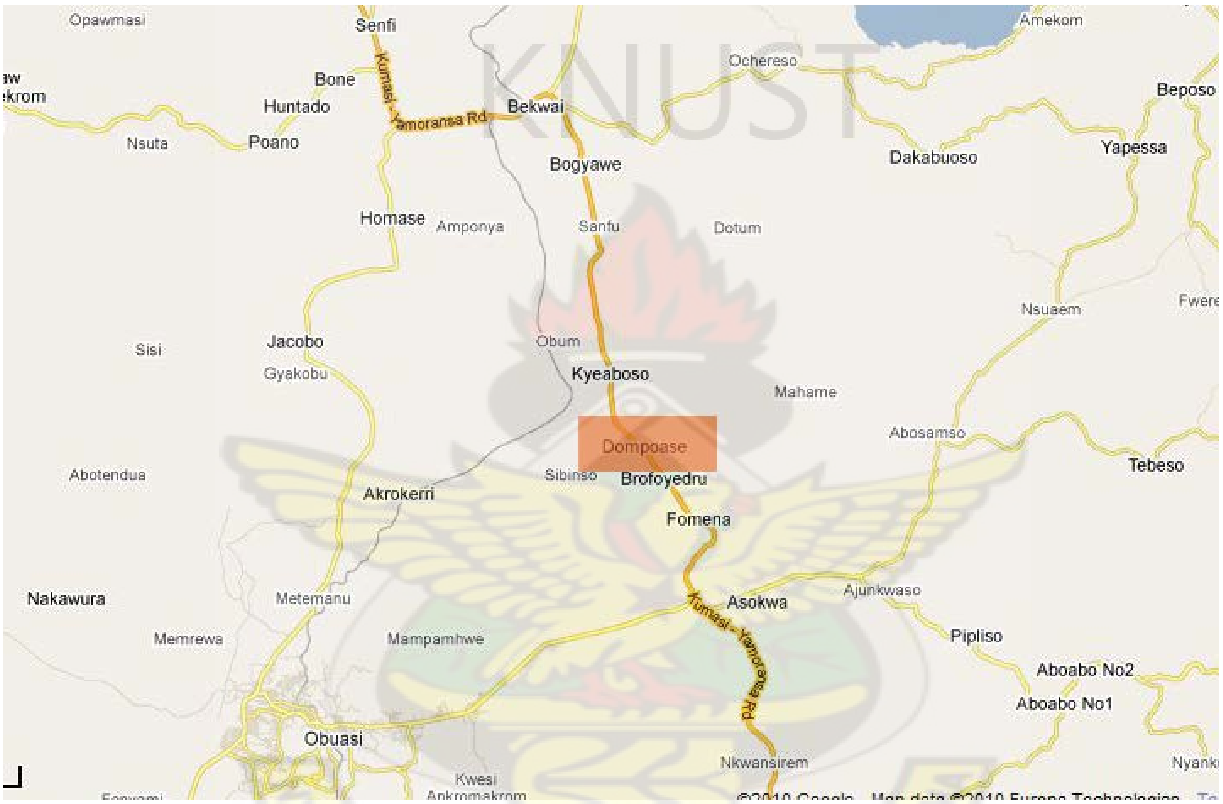


Figure 4.7   Location map of Dompoase

(Source: http://maps.google.com/)

4.2.1   Objective(s)

The objectives for this case study are

1. To analyze the role played by the following elements on the plant
    - Site location
    - Site planning
    - Construction of the industrial building
    - Services
    - Landscaping
2. To assess how efficiency has been achieved in the production process
3. To know how the welfare of the workers has been catered for in the industrial design.

4.2.2 Site location

The Adansi Oil Mills Limited is located in the woods, far away from the habitable areas of the town. This was an attempt to prevent all the pollution it poses to its surroundings. The industrial site is quite a distance from its nucleus estate but it is linked with a good transport way hence, raw materials are easily transported to the site. The topography of the site is fairly flat and this enables easy vehicular manoeuvring and reduces surface run-off and erosion.

4.2.3 Site planning

The industrial site consists of a security post, weight bridge, administration and production hall as shown in the figure.

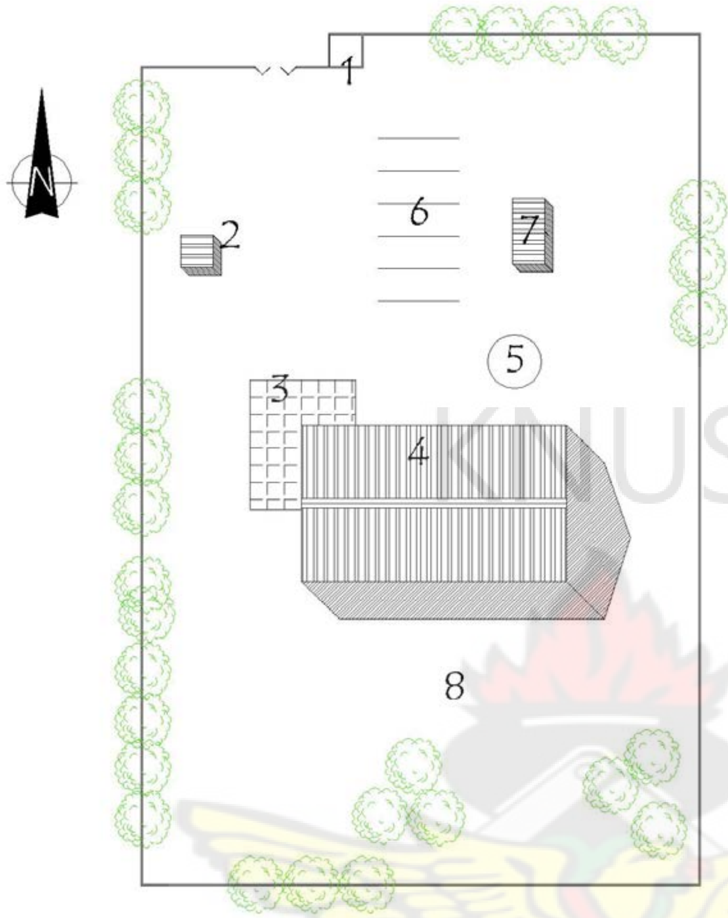


Figure 4.8 Site layout of the Adansi Oil Mills

(Source: author’s field survey)

Legend

1. Security Post
2. Weigh bridge
3. Supply loading platform
4. Production hall
5. Crude palm oil storage tank
6. Dispatching parking/ maintenance unit
7. Administration
8. Kernel drying point

There is only one access to the industrial site which has a security post for both purposes of security and addressing theft cases. Undefined parking spaces have been provided for delivery and dispatch trucks. Little provision has been made for visitors and customers parking space because of the market size of its finished goods. Finished goods are marketed to the Twifo Praso Oil Mills and hence the most common customer vehicles are the dispatch trucks. For this reason, the crude oil storage tank is located in front of the production hall so as to be in close proximity with the dispatch parking area.

Plate 4.17   Crude palm oil tank sited in front of the production hall (Adansi Oil Mills)

(Source: author’s field survey)

Even though the site is oriented East-West a conscious effort had been made to orient the production hall North-South to allow for north lighting and other benefits of this orientation.

4.2.4   Construction of the industrial building

The foundation of the production hall is lifted on a raft foundation to uniformly distribute the loads of all the machines to the ground. The flooring of the production hall is made of concrete screed for load bearing but it is not easily cleanable and has therefore been covered with layers of oil and dirt.

Plate 4.18 Monolithic concrete screed

(Adansi Oil Mills)

(Source: author's field survey)

Plate 4.19 Floor covered with oil and dirt

(Adansi Oil Mills)

(Source: author's field survey)

Upper floors of the production hall are made of a network of steel I-sections to bear the load of the digester and other machines located on these floors. The various floors were linked with steel stairs inclined at a steep angle to reduce spaces that would been occupied by this form of circulation.

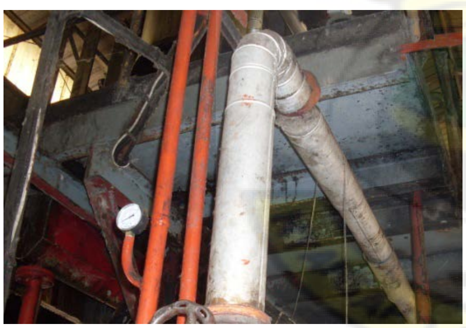


Plate 4.20 Network of I-sections

(Adansi Oil Mills)

(Source: author's field survey)

Plate 4.21 Steel stair in the production hall (Adansi Oil Mills)

(Source: author's field survey)

Framing of the production hall is made up of steel components where steel portal frames with steel purlins have been used to achieve a span of 20 metres.

Plate 4.22 Vertical member of portal frame (Adansi Oil Mills)

(Source: author's field survey)

Plate 4.23 Horizontal member of portal frame (Adansi Oil Mills)

(Source: author's field survey)

Cladding was done in corrugated galvanised steel to resist corrosion and protection against vagaries of the weather

Plate 4.24 Corrugated galvanized steel cladding (Adansi Oil Mills)

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Source: author's field survey

4.2.5 Services

The main source of energy that is used to power the machines is hydro-electric energy produced by the Volta River Authority. There is also a stand-by generator with a capactiy of 104 kW as an alternative in cases of power outage. There is a boiler house that generates steam used for the sterilization of fresh fruits used in the process. Water supply for the industry is a dug bore hole which pumps underground water to a reservoir to be used for all purposes.

Generated waste in the form of empty bunches after threshing is burnt on site aand used as fertilizers for the nucleus estate. Shells and fibres generated are used as fuel for the boiler furnace. Sludge generated are further filtered to collect oil and then discharged from the site. Smoke ventilation is made possible by the opening of the peripherals of the ground level of the production hall and the structure of the roof.

Plate 4.25   Roof form allowing for smoke ventilation (Adansi Oil Mills)

(Source: author’s field survey)

4.2.6   Landscaping

Little attempt had been made for landscaping in the form of both hard and soft landscaping elements. Prevention of surface run-off and erosion was made by grasses grown on the industrial site

Plate 4.26   Grass reducing erosion on industrial site (Adansi Oil Mills)

(Source: author's field survey)

4.2.7   Efficiency in production

The production process of the Adansi Oil Mills is shown in the figure below;

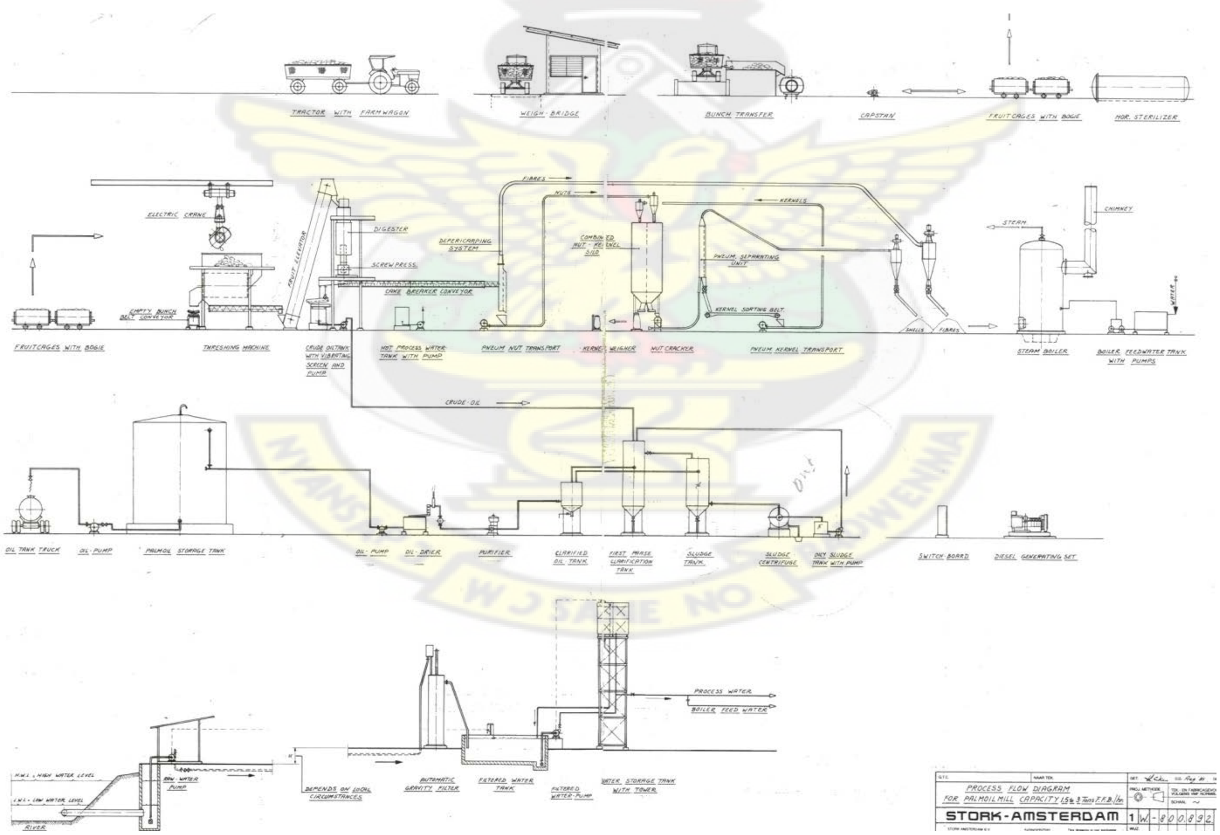

Figure 4.9   The production process of Adansi Oil Mills

(Source: Adansi Oil Mills)

Kernel obtained from the milling process are washed manually, dried and sold to individuals for the production of kernel oil.

An efficient palm oil mill which process *Tenera* species of the palm fruit has a crude palm oil (CPO) yielding rate of 20-22% of the amount of fresh fruit bunch processed. (Source: http://www.hort.purdue.edu/newcrop/duke_energy/elaeis_guineensis.html)

The Adansi Oil Mills processes 3 tons/hr of fresh fruits bunch and runs for 9 hours in a day. With a mean yielding rate of 21%, the amount of crude palm oil to be produced in a day would be

$$\frac{21}{100} \times 3 \text{ tons/hr} \times 9 \text{ hours} = 5.67 \text{ tons of crude palm oil (CPO)}$$

However, the amount of actual amount of crude palm oil produced in a day, as stated by the production manager, is **4 tons.**

There is a loss of 1.67 tons of oil daily and this can be attributed to the following;

1. Improper handling of raw materials on the industrial site
2. Conditions in the production hall
3. The size of labour/ work-force
4. The welfare of the labour/ work-force

4.2.7.1 Handling of raw materials on site

On the industrial site of Adansi Oil Mills, fresh fruit bunches from the various farms are poured from the supply trucks unto an open floor known as the loading platform. These fruits are exposed to the vagaries of the weather which soften the exocarp. Even though the softened fruits would have been easier to sterilize, they are attacked by lipolytic enzymes and the enzymatic attack results in the increase of fatty acids thereby reducing the amount of palm oil produced. The size of the loading platform was comparatively small as compared to the amount of fresh fruit bunches received. As a result, some of the fruits were loaded on the floor, causing bruises which damage the fruit. The bruised fruits have a higher free fatty acids and this also reduces the amount of crude palm oil that was produced.

Plate 4.27 The loading platform

(Adansi Oil Mills)

(Source: author’s field survey)

Plate 4.28 Bruised and mouldy fruits

(Adansi Oil Mills)

(Source: author’s field survey)

4.2.7.2 Conditions in the production hall

Fruits loading platform were manually loaded into the sterilization cages. These were then transported to the horizontal sterilizers by a cage rail of almost 30 metres in length. The layout of the production hall of the Adansi Oil Mills is shown in the figure;

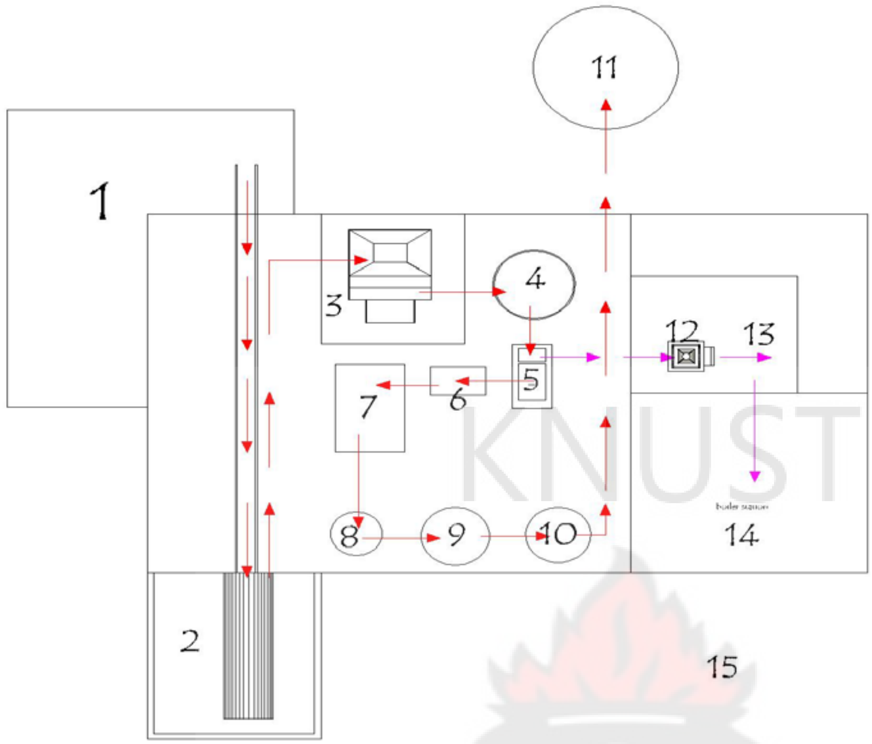

Figure 4.10 The production line of Adansi Oil Mills

(Source: author's filed survey)

Legend

Production line of palm oil

Production line of kernel and shells

1. Loading platform
2. Sterilizing station
3. Thresher
4. Digester
5. Screw press
6. Vibrating screen
7. Sludge and oil tank
8. Sludge tank
9. Continuous settling tank
10. C.P.O tank
11. C.P.O storage tank
12. Ripple mill
13. Nut and shell separation
14. Boiler station
15. Nuts drying area

From the diagram, it is seen that the sequence of the production line is not linear. With bends and meanders, there is the increase in risk of accidents. The production hall was also interrupted with various pipes and electrical cables, interfering with the circulation spaces.

Plate 4.29 Pipes interfering circulation paths (Adansi Oil Mills)

Source: author's field survey

4.2.7.3   The size of labour

The Adansi Oil Mills has a work-force of 15 workers made up of four (4) senior staff and eleven (11) junior staffs. The eleven junior staff are;

- 1 security man
- 3 loading bay workers
- 1 worker in the sterilization station
- 1 worker at the Crude Palm Oil tank
- 1 worker at the kernel separation station
- 1 worker at the clay bath
- 1 worker at the kernel drying area
- 2workers at the boiler station

The resulting situation of the under-staffed industry was that, the workers had to do multi tasks. An example was that, as the fresh fruits had completed the sterilization stage, the 3workers of the loading bay had to stop work and assist in the conveying of these fruits from the horizontal sterilizers and transport them to the thresher. Since the production line was not a linear, there were often meanders and turning, reducing the energy of these already multi tasked workers which in turn reduced their inputs and thereby reducing efficiency.

4.2.7.4 The welfare of the labour

The Adansi Oil Mill had not put much effort to ensure the welfare of its workers in that, changing rooms, washing area and a canteen were non-existent. There was however a washroom for both male and female workers.

Because the industrial site was located far off the habitable area of the town, workers had to walk long distances in search for food during lunch. The statutory break period of one hour (1hr) was not enough for these workers. This meant that resuming work after break was always delayed, reducing the number of effective hours for inputs. Since workers always had to multi task, they often grew tired before the actual closing time.

4.3 CONCLUSION ON CASE STUDIES

From the two case studies, it will be necessary to

1. Select a site which is away from the habitable area of the vicinity so as to reduce pollution to its surrounding.
2. Select a site whose topography is fairly flat to enable vehicular manoeuvring and reduce surface run-off.

3. Reduce the number of accesses to the industrial site to reduce theft cases.
4. Orientate industrial building North-South to made advantage of north lighting and appropriate air flow.
5. Give the industrial site an expansion potential for future growth.
6. Prevent pedestrian-vehicular conflicts by providing defined circulation paths for vehicles and pedestrians.
7. Use appropriate landscaping elements to unite the various buildings on the industrial site to create a single entity.
8. Provide a roofed supply loading bay to prevent fresh fruit bunches from the vagaries of the weather and bruises which will in turn prevent enzyme attack on oil palm fruit.
9. Reduce bends and meanders in the line of production to reduce risks of accidents in the production hall.
10. Provide a welfare block that will contain a canteen, health care centre and changing facilities to ensure the welfare of workers so that maximum input can be assured.
11. Provide the industry with appropriate staff to reduce over-tasking of workers and reduce operator fatigue.

4.4 SITE INVENTORY AND ANALYSIS

4.4.1 Site selection and location

The selection of site for this project was governed by a number of criteria as discussed in Chapter Two. Two sites were obtained in Agona, a town in the Afigya-Sekyere district of the Ashanti region of Ghana because:

i. The Presidential Special Initiative, (PSI), on oil palm had plans of increasing the production of oil palm cultivation in a yet to be determined location in the Ashanti region. It had ordered the Oil Palm Research Institute to supply some amount of oil palm seedlings annually to the region.
ii. Community needs of Agona at the district level suggested an increment in its industrial sector to reduce the high unemployment status of its populace.
iii. There are large palm plantations in Agona, Jamasi and other towns of the district which were only processed by small-scaled traditional industries. As a result, a huge amount of fresh fruits are destroyed due to lack of processing. These fruits, in the short term, can serve as raw materials for the palm oil processing industry to be designed.
iv. The geology of Agona facilitates the cultivation of oil palm hence the long term issue of nucleus estate development can be achieved by the industry.

Figure 4.11 Site location (Agona)

(Source: http://maps.google.com/)

The selection of one of the sites under consideration was governed by parameters namely

1. proximity to source of raw materials
2. road accessibility to site
3. proximity to work-force
4. topography of site to aid vehicle manoeuvring
5. expansion potential
6. access to public amenities
7. geology of soil to support nursery development
8. availability of good source of water
9. environmental impact on surroundings

4.4.1.1 Site option 1

This site is located at the outskirts of the town. The site has an area of 33,000 m² with a seasonal water body dividing it into halves. It is within a reasonable proximity to raw material source and is located off the Mampong- Kumasi road hence a good road access. Due to its location, cost of transportation of potential work-force from the Agona township will be high. The north, south and west boundaries are vegetations of the tropical rain forest. On its east is one residential facility.

Figure 4.12 Site option 1

(Source: Afigya-Sekyere District Assembly)

4.4.1.2 Site option 2

Option 2 is located within the habitation of the potential work-force therefore an assurance of punctuality and regularity of workers to the industry. However, this poses a larger threat to its surrounding residential facilities. Measures of waste and pollution control must be extensively done to minimize negative environmental impacts to its surroundings. Site option 2 has an area of 19,275m² and poses some difficulties with vehicular manoeuvring due to its topography. The east and immediate south of the site is bounded by vegetation of the forest. The absence of a water body may pose a problem if nursery development becomes an integration of the factory design.

Figure 4.13 Site option 2

(Source: Afigya-Sekyere District Assembly)

The table below shows a comparative analysis between the two sites

Table 4.2   Comparison between the two site options

Parameters	**Option 1**	**Option 2**
Proximity to source of raw materials	yes	yes
Road accessibility to site	yes	yes
Proximity to work-force	no	yes
Topography for vehicle manoeuvring	yes	no
Expansion potential	yes	yes
Access to public amenities	yes	yes
Cost of minimizing environmental impact	low	high
Availability of good source of water	yes	no
Geology to support nursery development	yes	yes

From the comparison between the two sites, option 1 was considered advantageous over option 2. These parameters form the justification for the selection of site option 1.

4.4.2 Site context

The selected site, option 1, is orientated north-south with its immediate east bounded by the Mampong-Kumasi road. Its north, south and west are bounded by forest lands which can be acquired for the nucleus estate in the long term action plan.

Plate 4.30 Surrounding vegetation

(Source: author's field survey)

Plate 4.31 Surrounding vegetation

(Source: author's field survey)

The only residential facility is found on the east, across the road. There is also the presence of an electricity transformer suggesting the availability of hydro-electric power supply.

Plate 4.32 Surrounding residence

(Source: author's field survey)

Plate 4.33 Electricity transformer on site

(Source: author's field survey)

4.4.3 Physical characteristics

a. Climate

The climate of the site is equatorial, having a double rainfall maxima regime with the major seasons occurring between the month of March and July. It has 110-120 rainy days annually with a mean annual rainfall of 855 mm-1500 mm. low temperature ranges from 17-19 ºC and on the high sides is a range of 32-33 ºC giving a mean monthly temperature of 27 ºC.

b. Geology

The site falls within the Voltaian formation which is formed by the deposition of sediments over a long period of time. Its main soil typology is that of the Kumasi-Offin compound.

c. Vegetation

Its vegetation is made up of trees of the rain forest, shrubs and grasses.

d. Topography

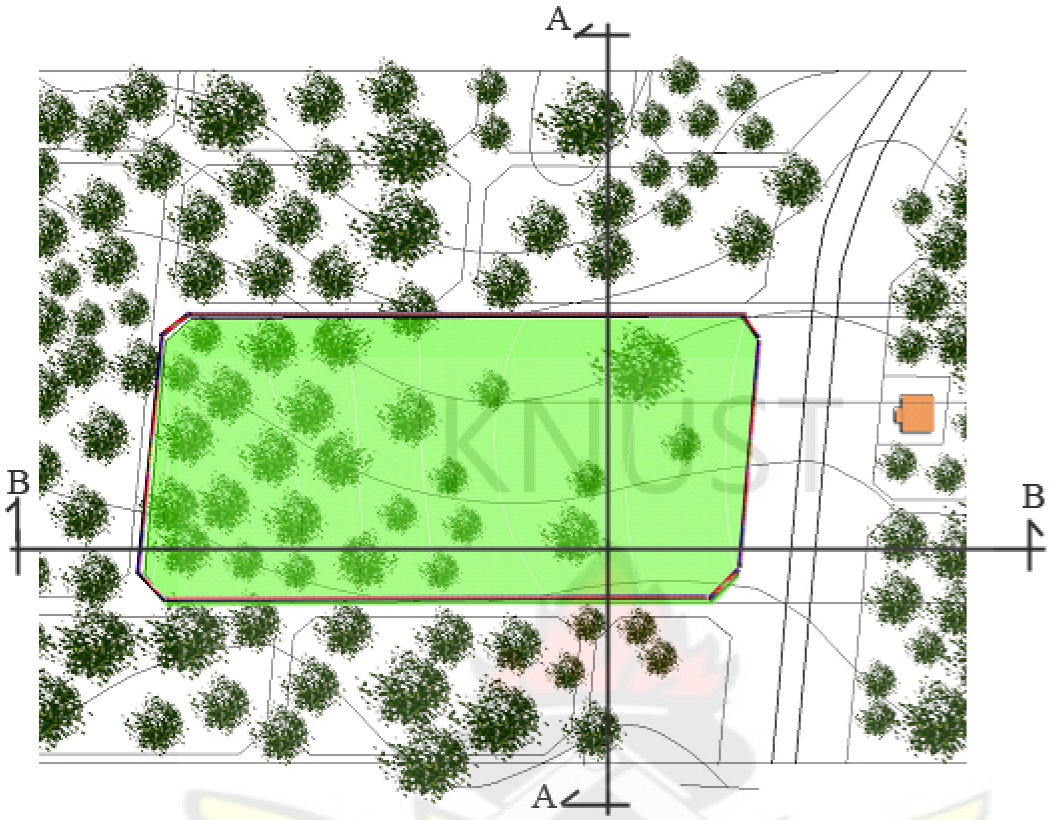

Figure 4.14   The selected site (site option 1)

(Source: Afigya-Sekyere District Assembly)

A section through the site shows the following

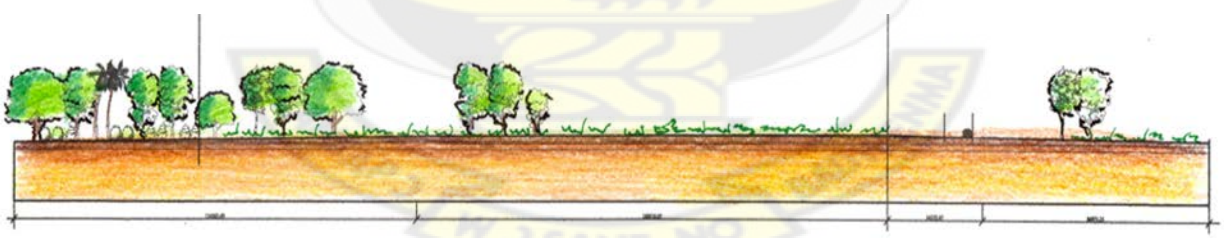

Figure 4.15 Section AA’ through the site

(Source: author’s field survey)

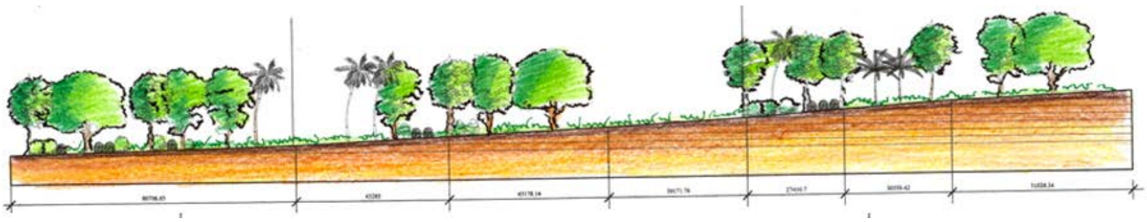

Figure 4.16 Section BB’ through the site

(Source: author’s field survey)

4.4.4 Site analysis

The SWOT analysis was used where various conditions of the site fell under the headings strength, weakness, opportunity and threats.

<u>Strength(s)</u>

- The longest side of the site faces the north hence a north-south orientation.
- Presence of proposed access roads bounding both the north and south of the site
- Presence of seasonal water body
- Located by the road means high visibility

<u>Weakness</u>

- Slope of land may create some difficulty in vehicular manoeuvring
- Site is liable to surface run-off and erosion
- Seasonal water body may flood site during maximum rainfall period.

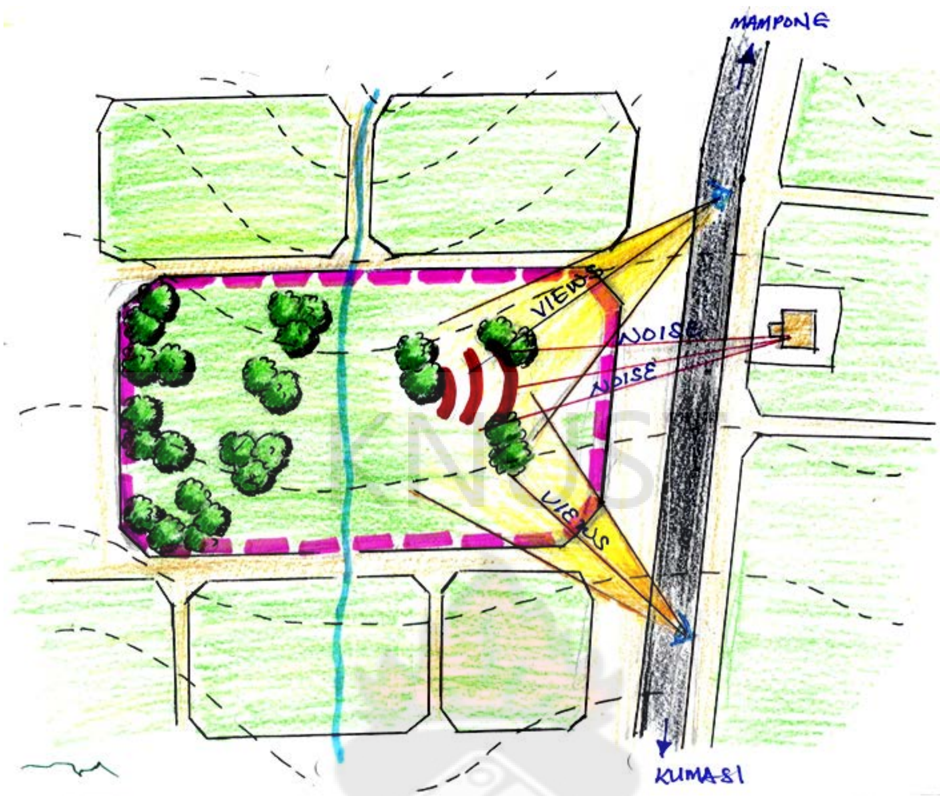

Figure 4.17 SWOT analysis

(Source: author's field survey)

Opportunities

- Located off the road suggest easy transportation of raw materials to site and finished goods off site.
- Presence of transformers indicates the ease of tapping energy onto site.

Threats

- Adjacent residential facility might be polluted with waste and noise.

Possibilities

Some possibilities that arose from the conditions of the site are

- As much as possible buildings and the production line should be orientated north - south.

- Tree planting must be integrated into the design to reduce the amount of noise polluting the adjacent residence.
- Site can be terraced as an attempt to reduce the effect of erosion
- Path of the seasonal water body can be channelled for treatment and storage.
- Supplementary energy in the form of hydro-electric power can be tapped from the near by transformer.

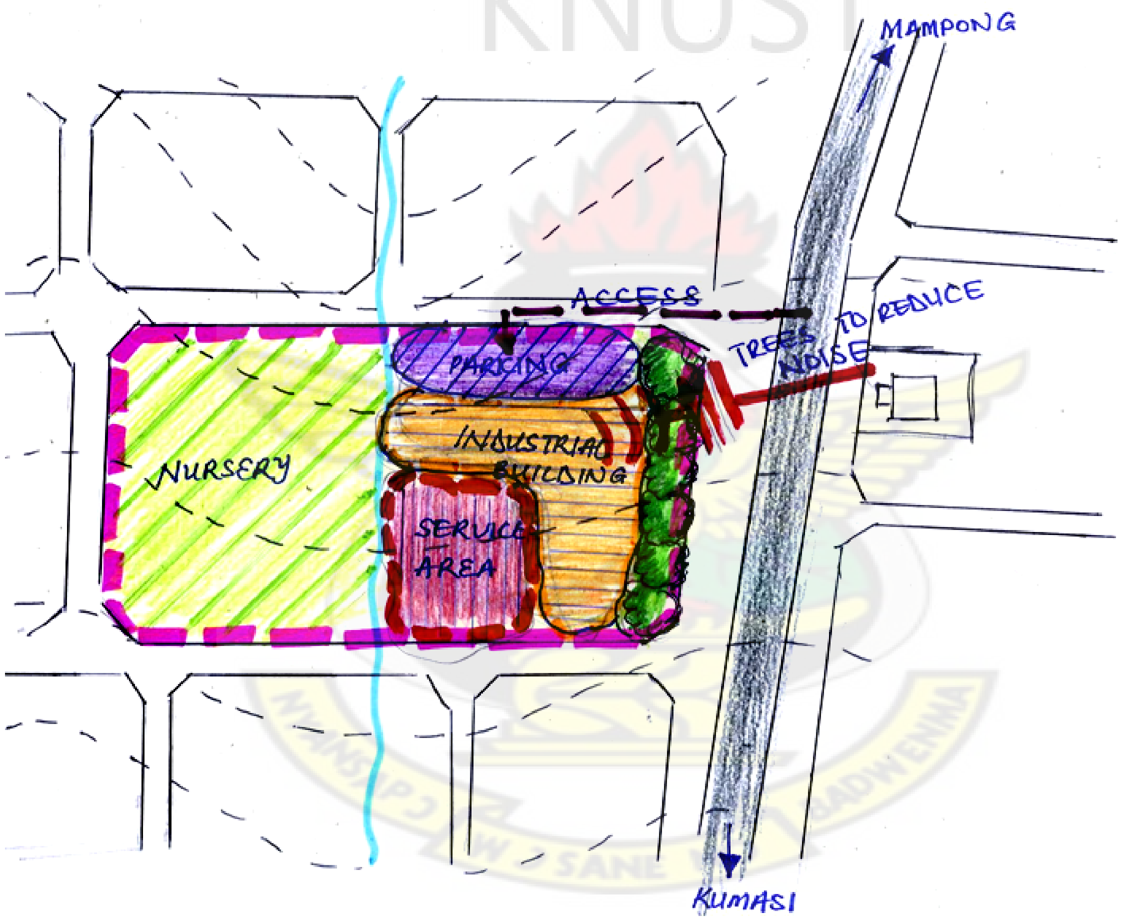

Figure 4.18 Possibilities of the site

(Source: author's field survey)

4.5 DESIGN PHILOSOPHY

It is typical of the Ghanaian society to pilfer raw materials or finished goods from processing sites to their homes. With this notion in mind a philosophy that would help eradicate this act is very necessary, hence the design philosophy "self-sufficiency and security, an approach to efficiency in production".

Self-sufficiency as defined by the oxford advanced learner dictionary is "the ability to do or produce all that you need without the help of others" pp1069.

Security in the context of the design philosophy is defined as ensuring safety and precaution against attack or loss of property.

Efficiency in production is the measure of the ability to manufacture products effectively without wasted energy and efforts.

4.6 CONCEPTS

In attaining self-sufficiency there will be the provision of all the necessary facilities that will enable the industry to exist on its own in terms of raw material supply, energy supply and health care.

The concepts for achieving efficiency are;

1. Minimizing entrances to the site to reduce routes for cases of thefts.
2. Providing security check points at vantage points
3. Avoiding unnecessary meandering to reduce the risks of accidents on site.
4. Eliminating vehicular-pedestrian conflict zones

Based on the philosophy and concepts the derived brief in addition to the industry includes;

1. a nursery, to produce raw materials on site

2. a boiler house, to generate energy for the entire facility
3. a health care facility, as a first aid point in cases of accidents on site
4. a canteen, to reduce time spent at break hours for efficiency in production
5. changing rooms
6. an administration block
7. staff parking
8. customer and visitors parking

4.7 CAPACITY DETERMINATION

4.7.1 Raw material analysis

The size of the industry will depend on the processing capacity which is also determined by the amount of raw materials to be processed.

In Agona, Jamasi and Wiamoase

- The total cultivatable land is 53,250 hectares
- Palm cultivation is 4% of the total cultivatable land,

» palm cultivation = $\frac{4}{100}$ x 53,250 hectares = 2106 hectares

The Presidential Special Initiative (PSI) suggest processing of 80% of cultivated plantations

Therefore, $\frac{80}{100}$ x 2106 hectares = 1684.8 hectares

A cultivation of 1684.8hectares at a yielding rate of 12.5 tons/hectare/year has fruit of

1684.8 hectares x 12.5 tons/hectare/year = 21,060 tons/year

Annual amount of fresh fruit = 21,060 tons/year

Monthly amount = $\frac{21,060}{12 \text{ months}}$ = 1755 tons/month

With 20working days per month, daily amount of fresh fruits =

$\frac{1755 \text{ tons/month}}{20 \text{ days}}$ = 87.75 tons/day

Daily working hours of 9, (8am-5pm)

An hourly amount = $\frac{87.75\text{tons/day}}{9 \text{ hours}}$ = 9.32 tons/hour

Therefore, the capacity of the industry is 9 tons/hour

4.7.2 Amount of finished goods

A 9 ton/hour industry at

- Crude Palm Oil (C.P.O) yielding rate of 22% has palm oil amount of

  $\frac{22}{100}$ x 9 tons/hour = 1.98 tons

- Kernel oil yielding rate of 5% kernel oil amount of

  $\frac{5}{100}$ x 9 tons/hour = 0.45 tons/hour

4.7.3 Waste generation

4.7.3.1 Solid waste

The table below shows the distribution and amount of solid waste to be generated in the proposed design.

Table 4.3 The distribution of solid waste to be generated in the proposed palm oil mill, Agona

type of solid waste	**percentage/ton ffb**	**amount for 9tons/hr (kg)**
empty fruit bunches	23%	2.07
fibre	12%	1.08
shell	7%	0.63
decanter cake	4.2%	0.378
ash	4.8%	0.432

4.7.3.2 Air emission

Table 4.4 estimated amount of air emissions in the proposed industry

type of emission	**amount in gNm²/ton ffb**	**amount for 9tons/hr Nm²**
particulate	0.00664	0.0598
SO2	0.00121	0.0109
NO2	0.0188	0.17

4.7.3.3 Waste water

Waste water generation rate per fresh fruit bunch is = 0.5 m^3/ffb

Therefore, 9tons/hour = 0.53 m3 x 9 tons/hr = 4.77 m/hr

Waste water generated daily = 4.77 m3/hr x 9 hrs = 42.93 m^3

4.7.4 Energy production and consumption

The amount of energy needed to power the entire facility is dependent on the capacity of the machines and the amount of raw materials to be processed.

Averagely, the total energy consumption of all electric machines used in the production process is 14.46 kWh/ton of Fresh Fruit Bunch (FFB).

Therefore a capacity of 9 tons/hour will have a total consumption of

9 x 14.46 kWh = 130.14 kWh

A ton of FFB/hour is able to produce shells and fibres to generate electricity of magnitude 16.67kW/h

- 9 tons/hour will therefore generate

  9 x 16.67 kW/h = 150 kW/h

An excess energy of 150 kW/h - 130.14 kW/h = 19.86k W/h will be resulted.

This will be used up by the administration and lighting of the entire facility.

4.7.5 Water consumption

Table 4.5 Amount of water to be consumed in the proposed industry

Production stream	**Amount of water (m^3/ffb/h)**	**Amount of water (m^3) for 9tons/h**
Digester	0.15	1.35
Sterilizer	0.02	0.18
Screw press	0.08	0.72
Vibrating screen	0.005	0.045
separator	0.1	0.9
Factory cleaning	0.08	0.72

Domestic purposes	0.68	6.2
Others	0.23	2.07

Total……………………………………………………………………..12.105 m³

4.7.6 Workforce

With a capacity of 12 tons/hour, Juabeng has a work-force of 92 workers

A capacity of 9tons/hr will have $\frac{9}{12} \times 92 = 69$ workers

At an expansion potential of 30% workforce will be

1.3 x 69 = 94, approximately, 100 workers

4.8 CONCEPTUAL SITE PLANNING

4.8.1 Option 1

This planning has security as its priority, therefore, it has a single access to the site. Facilities provided in addition to the factory are an administration block, boiler house, health care building, changing rooms, canteen and parking. The first point of call onto the site is the security post where both vehicles and pedestrians are checked. The factory was positioned away from the road as a measure to reduce noise pollution from the site to the surrounding residence.

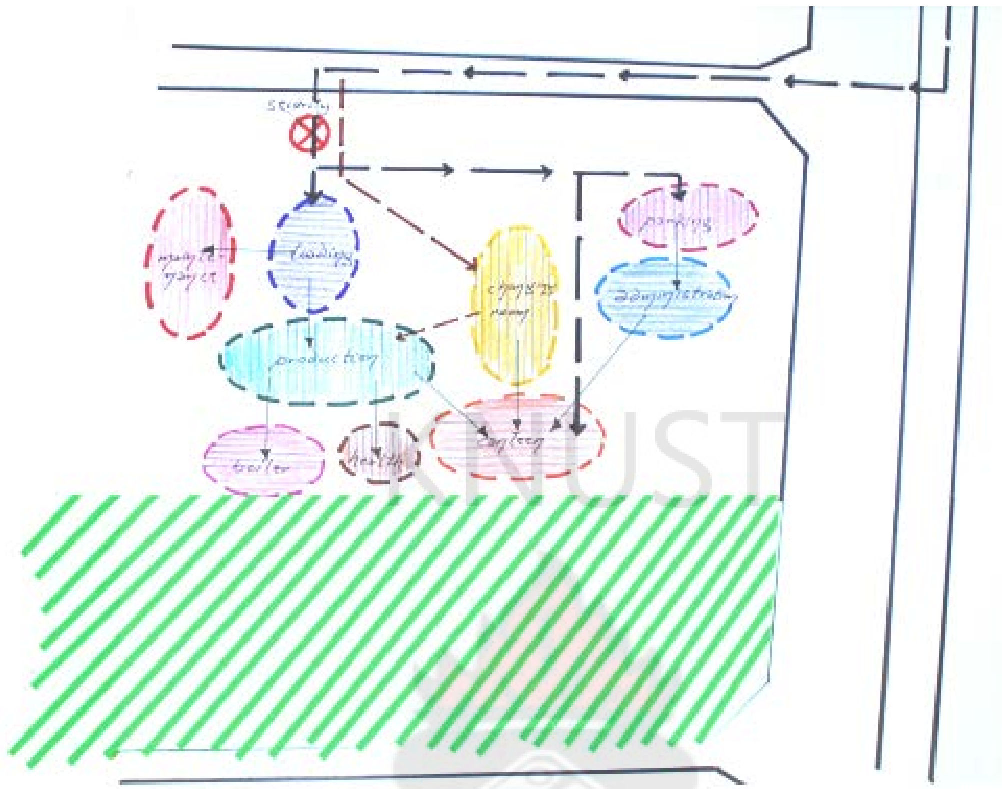

Figure 4.19 Conceptual site planning Option 1

(Source: author’s field survey)

Merits

1. One access to site enhances security.
2. Health care is close to the factory
3. Factory positioned away from road reduces noise to surrounding residence.

Demerits

1. Health care is far from administration
2. In cases of emergency access from health care to a hospital will be problematic.
3. Vehicular-pedestrian conflict can be created at the entrance due to the single access to the site.

4.8.2 Option 2

The second option of the conceptual site planning has two accesses with security posts as a means of preventing potential vehicular-pedestrian conflict that might be created in option 1. The first access to the site from the Kumasi-Mampong road is to be used by small vehicles and staff members. The second access is solely for the production line specifically, trucks for supplying raw materials and dispatching finished goods. Different loading bays have also been provided for supply and dispatch of goods.

Option 2 combines the changing facility, health care and canteen to form a unit referred to as the welfare block. The maintenance unit of the facility is located at the nursery allowing enough space for vehicle manoeuvring.

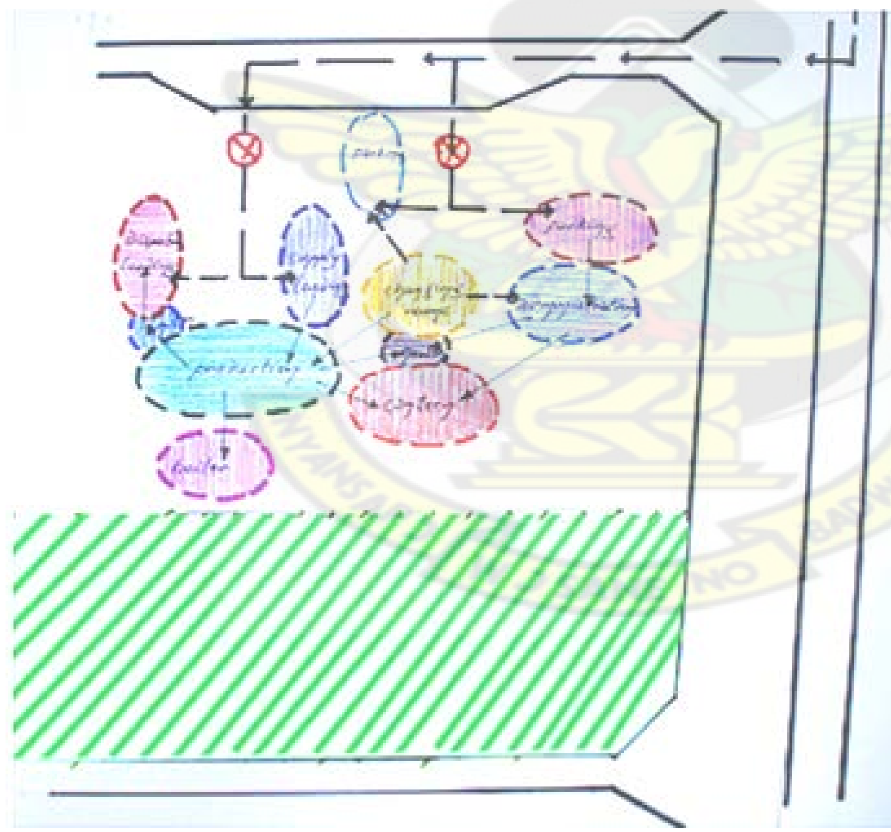

Figure 4.20 Conceptual site planning Option 2

(Source: author's field survey)

Merits

1. Different loading bay for supply and dispatch reduces traffic
2. Health care is equidistant to factory and administration
3. Separate parking for junior and senior staff
4. Different accesses for production and staff

Option 2 was chosen because it addresses the issue of security and eliminates possible vehicular-pedestrian conflict and conflict between trucks and small vehicles.

CHAPTER FIVE: RECOMMENDATIONS AND CONCLUSION

5.1 RECOMMENDATION

The recommendations for this study are design innovations that emerged in the intended design. These addressed issues concerning;

1. Site layout and planning
2. Construction and materials
3. Efficiency in production hall
4. Landscaping
5. Services

5.1.1 Site layout and planning

Achieving efficiency in production through architecture must also consider a design philosophy of self-sufficiency and security.

Two accesses were created into the industrial site. One access was provided solely for the production vehicles while the other is for visitors and staff members. These entrances are security-tight, provided with security posts.

On the industrial site, visitors' car park was secluded from all other parking areas. It is recommendable that it is located at the frontage of the site and visible from the security check point.

The parking space for junior staff of the industry was located on a lay-by created outside the site in order for them to enter via a security check point onto the industrial site. Once on the site, the first building to be accessed by the junior staff is the welfare block which now contains the changing facility, health care and the canteen. The production block was then placed in a distance not more than 100m from the welfare block.

Parking space for the senior staff members was also separated from that of the junior staff and the visitors. In this study, it was located behind the Administration block with an access to the health care and canteen of the welfare block. (See Appendix I)

In the Administration block located at the frontage of the plant, all offices that would be frequently used by customers and visitors were located on the ground floor.

These include general office and offices of the Accountant, Welfare Manager, Human Resource Manager and that of the field and Nursery Managers. Offices of the Managing Director and the Senior Manager are located on the first floor. (See Appendix II)

In the changing facility, niches for sitting and resting had been provided in addition to the lockers, bath and toilet facilities. A nurse's station, dispensary and rest room with minimum bed (three in this study) was provided in the health care centre. In the canteen also, eating areas for junior staff were secluded from that of the senior staff for security reasons during riots. (See Appendix III)

The orientation of the production process must be north-south to allow for north lighting into the Production Hall. The Production Hall must have offices for the Production Manager, the Quality Control Officer and the Quality Control Laboratory. The Quality Control Laboratory is juxtaposed to the crude palm oil measuring tank and cooking and purification stage of the kernel oil extraction to facilitate ease in testing before the oils are conveyed to the storage tanks.

The cyclone which receives nuts and shells into the boiler house for power generation must also be well positioned to the shell collection point of the production hall. (See Appendix IV)

5.1.2 Construction and materials

Steel trusses and reinforced concrete are basically the mode of construction used in industries. Galvanized iron sheets can be used as cladding materials because it is resistant to corrosion, cracking and is very durable.

5.1.3 Efficiency in production

To avoid the manual loading of fresh fruit bunch into sterilization cages, the cage store was located beneath the supply loading bay (in a basement that is naturally ventilated). See Appendix V. The loading bay has shutters which are either closed or opened by the pressing of buttons. When the button is pressed for opening, fruits from the supply loading bay are dropped into cages in the cage store. This is to avoid mishandling of fruits which cause bruises that increase the free fatty acids content which in turn reduces the amount of palm oil to be generated.

Once loaded, the cages are then pulled by a horizontal pulley via cage rails into the sterilizers. This is to avoid the manual transportation of cages by workers since the loaded cages are heavy and require a lot of energy to be pushed.

By the nature of the sites topography, the sterilization station is also located in a basement. Sterilized fruits are transported to the thresher by cranes with gantry second floor.

In the Production Hall, an unobstructed circulation aisle was intended to reduce the risk of accidents and all problems caused by obstructions. This was achieved by grouping the various stages in a linear sequence. See Appendix VI

The office of the Production Manager is located within the Production Hall. This is made so that the said manager may be constantly at work for supervision with ease without walking from other blocks on site such as the Administration. Once the production manager is in close proximity, lackadaisical and negative attitudes towards work would be drastically reduced by junior staffs, hence maximum inputs will be assured thereby increasing efficiency.

Shells and fibres collection point is located parallel to the cyclone of the boiler house which is linked by a conveyor for transportation. Fuel for the boiler house will not then be conveyed manually, hence saving energy of labour to be used in other ways to increase efficiency.

The Quality Control Laboratory and the office of the Quality Control Technician are also located within the Production Hall. This has been made possible to avoid further settling of impurities on the crude palm oil specimen and other likely problems that would have been caused during the transportation of the specimen if the laboratory was located elsewhere.

Certified crude palm oil and kernel oil can then be pumped into storage tanks located next to the control laboratory and also close to the dispatch loading bay.

To make use of the sludge that is generated from the oil production, an aerobic digester tank has been introduced. This tank recycles sludge to form water which can then be reused in the boiler house to generate steam to be used in sterilization and other stages in the oil production.

5.1.4 Landscaping

Greenery in the form of grass and shading trees must be employed throughout the site. The frontage of the site can be adorned with *Restonia regia*, date palm. Trees such as *Nerium oleander, Cassia floribunda* and *Ipomea abore* must be used because they are dust resistant, maintenance free and shade-giving. (See Appendix VII)

5.1.5 Services

a. Electricity

Generated energy must be conveyed by underground cables to various blocks. Conduit wiring should be employed in all facilities but the production block. Due to the use of short walls and iron cladding trunking will be used. (See Appendix VIII)

b. Water supply

On sites where the water table is considerably high, a bore hole should be dug to supply water for the milling process. Potable water for drinking must be obtained by tapping from the mains as provided by the government. (See Appendix IX)

c. Waste management

Empty bunches which are generated after the threshing of fresh fruit bunches should be collected and burnt on site and are used as fertilizers for the nursery and nucleus estate. Shells and fibres of tonnage 0.99 ton/hour and 0.628 ton/hour respectively should be collected and conveyed to the boiler house which acts as fuels for the generation of power. Sludge from the process must be channelled by drains into an anaerobic digester tank that recycles the waste water to be reused in the boiler house to generate steam. The generated steam is used for sterilization and others. (See Appendix X). The digester tank is shown in the diagram below:

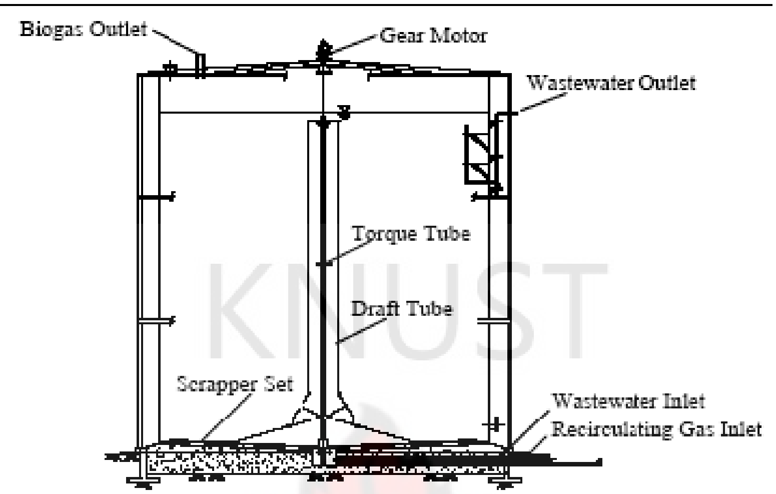

Figure 5.1 Anaerobic digester

(Source: http://mpob.gov.my/oilpalm_env/mill_waste1.html)

d. Smoke ventilation and fire protection

Fire hydrants must be positioned on site at 50 metres radius to cater for fire outbreaks. As much as possible some peripherals of the production hall must be left open to aid in smoke ventilation and allow north lighting.

5.2 CONCLUSION

Efficiency in production of palm oil does not only consist of the effective workability of the various machines involved in the process but to a great deal the architecture of the whole industry. By designing and implementation of proper site planning, there is the creation of a continuous production process without breaks in the entire site. This industry is one which has the welfare of its work force in mind. It has depicted the well being of its staff by the creation of a safe working environment which has minimized risks of accidents through adequate spatial configuration in the production hall. This ensures effective flow of work which is void obstructions and unnecessary bends and meanders. It has also reduced operator fatigue of work force by putting measures in place that will reduce the amount of energy needed to get work done. To make sure that all harvested fruits that are received on site are used in the production process, consideration was given to the architecture of the loading bay to prevent deteriorating of fruits. This ensures maximum inputs of raw materials which results in increased output of finished goods. This industry also processes its waste to generate energy and water for reuse in the milling process among others and makes policies that will reduce pollution to its surrounding environment.

In simple terms, every aspect of the architecture of the industry has been given the necessary consideration to maximize output thereby increasing efficiency. Efficiency in the production of palm oil in an industry therefore lies in the hand of the architect through appropriate design and implementation.

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