



VAASAN AMMATTIKORKEAKOULU
UNIVERSITY OF APPLIED SCIENCES

Teemu Kolsi

INVESTIGATION OF THE FACTORS
ENABLING THE DEVELOPMENT OF
MEDICAL WASTE TREATMENT AND
CHARACTERISTICS IN GHANA

Case: Woima Corporation

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TIIVISTELMÄ

Tekijä	Teemu Kolsi
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Työn tavoitteena on tutkia sairaalajätteen käsittelyn kehittämisen mahdollistavia tekijöitä Ghanassa ja kuinka Woima Corporationin tekniset ratkaisut sopisivat sairaalajätteen hävittämiseen Ghanassa.

Opinnäytetyössä on käytetty laadullisia tutkimusmenetelmiä kirjallisuutta ja haastattelua hyödyntäen. Kirjallisuudesta on kerätty tietoa olemassa olevista sairaalajätteen säädöksistä ja käytännöistä Ghanassa. Haastattelussa kerättiin tietoa sairaalajätteen käsittelyn käytännöistä yhdessä sairaalassa Ghanassa ja yhdessä Suomessa.

Sairaalajäte voi aiheuttaa vakavia terveysriskejä, vahingoittaa luontoa ja sen käsittely vaatii kiireistä huomiota kehitysmaissa. Ghana tarvitsee lainsäädännön pakottamaan terveyslaitoksia kiinnittämään huomiota EPA:n asettamien ohjenuorien noudattamiseen koskien sairaalajätteen oikeanlaisia käsittely- ja hävitystapoja.

Sairaalajätteen oikeanlainen käsittely on tärkeää, johon tämä opinnäytetyö tarjoaa apua jakamalla tietoa kehittyneissä maissa käytetyistä ja todistetusti toimivista tavoista. Tämä työ kasvattaa myös tietoisuutta sairaalajätteen vääränlaisen käsittelyn ja hävittämisen aiheuttamista vaaroista.

Woima Corporationin jätelaitoksen tekniset ratkaisut mahdollistavat myös sairaalajätteen polttamisen ja hajauttamisen ansiosta se auttaisi merkittävästi sairaalajätteen käsittelyä Ghanassa, sekä Suomessa.

ABSTRACT

Author	Teemu Kolsi
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The objective of this study was to investigate the factors enabling the development of medical waste treatment in Ghana and how Woima Corporation's technical solutions are suitable for disposing the medical waste in Ghana.

The research method used in this study is a qualitative literature review and case study. The literature review was used to collect information on existing medical waste regulations and practices in Ghana. The case study was used to explore medical waste regulations and practices in one hospital in Ghana and one in Finland.

Medical waste management needs urgent attention in developing countries, since it can cause severe health risks to the public and the environment. Ghana needs a legislation to force health facilities to focus in strict observation of the guidelines EPA has given according to the handling and management of medical waste.

Proper medical waste management is important, and this study helps to spread information about the methods that are used and proven to work in developed countries. This study also increases people's awareness of the hazards that the improper handling and disposal can cause.

Woima Corporation's technical solutions enable the burning of medical waste and thanks to decentralization it would help to manage the hospital waste in Ghana and Finland.

Keywords	medical waste, management planning, Woima Corporation, waste generation, disposal methods
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1 INTRODUCTION

Waste is a huge problem in the current world. People generate 3.6 million tons of municipal solid waste per day and it is currently more than our planet can sustain. It is forecast to increase to 6.1 million tons by 2025. 2.2 million tons of greenhouse gases are emitted from open landfills or dumps and 5.5 million tons of plastic is added to the oceans annually. /1/

This problem mainly occurs in developing countries where generation and disposal are out of control - affecting public health and causing air pollution. There are three actions that can reduce the waste generation which are reduce, reuse and recycle. These three must be in a good shape to fight against three other forces increasing the amount of waste, which are population growth, economic growth and urbanization. Issues arise when these increasing forces are stronger in countries where waste disposal is on its weakest. As important waste disposal is - so are the methods used. Disposal can be wasteful, unsanitary or both. Incineration is the most common method used in wealthy countries where waste is converted into energy by using environmental technologies. Some countries use sanitary landfills, which contain litter and leakage of methane and contaminated water is prevented. This type of landfill differs from open landfill, which is cheaper and harmful for the environment. Open landfills and uncontrolled incinerations are the norm in developing countries. /1/

Tipping fee is used for each ton of waste received. It is primarily too low in developing countries for effective waste disposal. Increasing the tipping fee could solve a part of these problems, but it is not an option in developing countries where struggling in day-to-day living is real and take priority over the effective waste management. Currently world needs more new affordable sanitary ways to dispose the waste. /1/

1.1 Research problem

Medical waste is waste generated from health care facilities, which includes discarded blood, tissue from surgery or birth, gloves, used bandages, and sharps such as syringes, needles, and blades. Approximately, there are 16 billion injections annually executed

worldwide. In Africa, and specifically Ghana, most of the needles and syringes are sorted and disposed as general waste and not managed properly as medical waste. /2/

Poor management of medical waste can cause health risks directly or indirectly for the public and the environment. /2/

1.2 Research Question

Medical waste collection and disposal are major problems especially in developing countries. Poor handling can cause infections and spread dangerous diseases. The information above leads to the following research questions:

- What are the factors enabling the development and treatment of medical waste in Ghana?
- How medical waste is managed in developed countries like Finland?

Based on the analysis of the above questions the research also explores the possibility of using a Finnish waste to energy technology in Ghana.

1.3 Outline of the Study

Chapter 1 is an introduction including research problem and questions. Chapter 2 describes waste generation and composition in Ghana and definition of medical waste is presented in Chapter 3. Chapter 4 is the management of medical waste describing how it is managed generally and showing different methods. Chapter 5 presents the medical waste in Ghana. What is it in Ghana and how it is managed. Chapter 6 describes research methods used in this study. Chapter 7 gives information about the empirical studies in Finland and Ghana for this study. In Chapter 8 is a discussion on how the medical waste should be managed and disposed and chapter 9 is conclusions.

2 WASTE GENERATION AND COMPOSITION IN GHANA

2.1 Solid Waste Generation

Solid waste management and disposal in urban and rural areas are currently a worldwide problem - especially in developing countries. Factors that have been developing this problem are growing economy, urbanization, rapidly rising population and standards of living. /3/

The solution of managing the waste must be financially durable, possible by current technology, acceptable by social and legal meanings and environmentally friendly. The most common waste disposal methods currently are landfill, composting and incineration. One of the biggest problems is the composition of organic waste, which is increasing rapidly all the time. The most traditional methods to dispose this kind of waste are composting and anaerobic digestion. Anaerobic digestion is a set of processes where micro-organisms break down biodegradable material in the absence of oxygen. Agricultural waste, food waste from households, human and animal wastes together creates the biggest group in organic solid waste. Normally they are used as animal food, disposed to landfill or incinerated. /4/

Poor handling of waste often tells about lack of investments to solid waste management. Mainly because of this, the biggest problems in managing solid waste are located in developing countries, which do not have as good situation economically as in wealthy countries. The next section describes the social, economic and technological factors that may affect waste management in Ghana. /5/

2.2 GDP

The Gross Domestic Product (GDP) measures the value of all products and services produced in certain region and period. Generally, the GDP is announced per capita, when it indicates a value of products and services produced by one person. This gives an overview of how well people living in that certain region are living. It is a good indicator for measuring standards of living. The GDP measures more of economic growth than how well people are living in the country. However, it has been noticed that the GDP can express

how well the economy is doing, but not so much how well the people in that country are living.

The GDP in Ghana (58,997 billion US\$ in 2017):

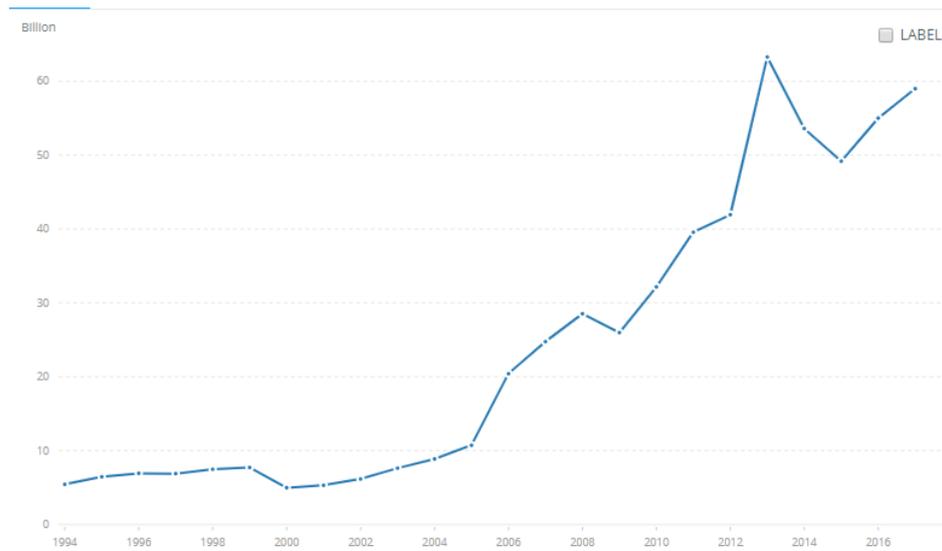


Figure 1. GDP of Ghana. /6/

Figure 1 above describes how Ghana's GDP has developed throughout the years. It has been on its highest in 2013, then followed by a slight bend in 2015 and has been rising after that.

The GDP in Ghana per capita (~2046 US\$ in 2017):

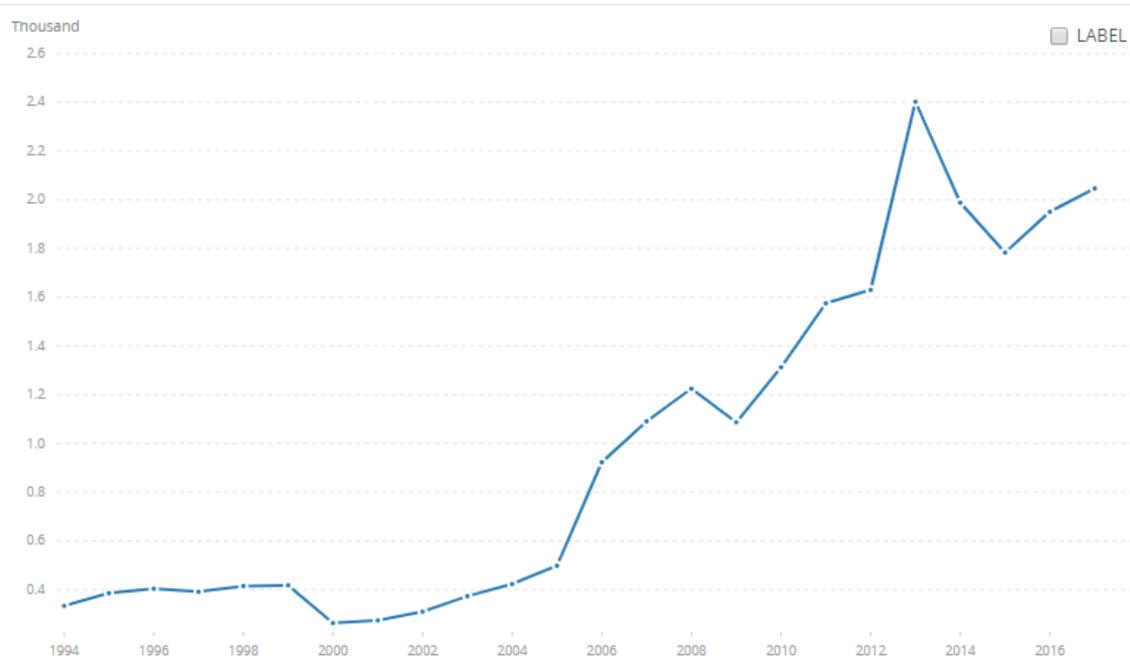


Figure 2. GDP per capita in Ghana /6/

In Figure 2 the GDP is reviewed as per capita.

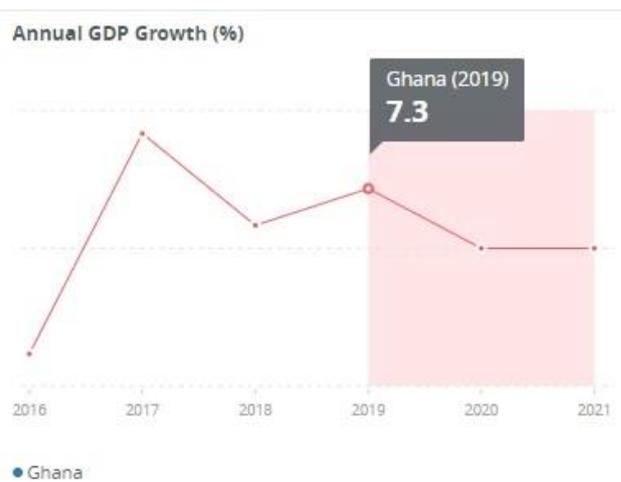


Figure 3. Annual GDP growth (%) /7/

The annual GDP growth rate in 2019 was 7,3%. It is expected to drop a little during the next two years.

2.3 Population

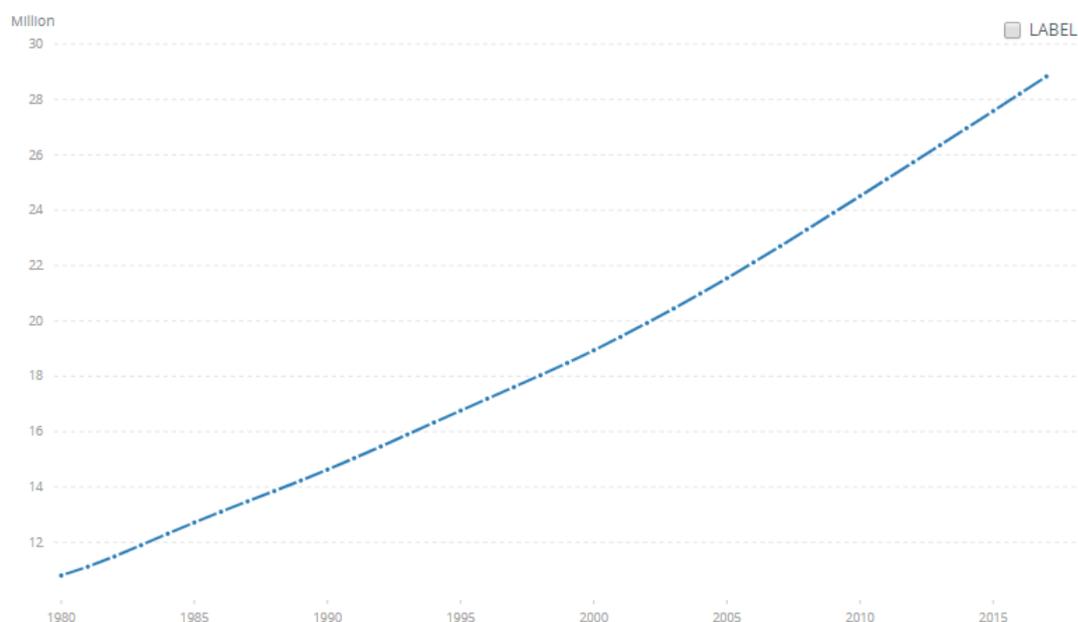


Figure 4. Population of Ghana /7/

The population in Ghana was 28,833,629 million habitants in 2017. It has been growing steadily for all these years.

From these figures, we can see that Ghana's economy, population and overall wellbeing have been growing and keep growing as few bends are not considered.

2.4 Infrastructure

Good road infrastructure is crucial for countries economic growth. Ghana is a good example where the density of paved roads increased by 102% in 1984-1989. The income per capita rose by 11% from 350\$ annually to 390\$. There are about 40 000 kilometres of roads, of which slightly above 11 500 kilometres were paved in 1997. Ghana owned a 953-kilometre railway network in 1997 of tight gauge. Accra, Kumasi, and Takoradi (which are the top mining areas) are connected to the seaports by this railway. The main seaports at Takoradi and Tema are provided also with passenger services from the interior of Ghana by the railway network. /8/

Tano Rivers, Volta and Ankobra together form the main waterways in Ghana providing 1293 kilometres of navigation throughout the year including arterial and feeder waterways. In 1999 there were 12 airports in Ghana of which half had paved runways. /8/

Ghana's telephone system is moderate and has access to the internet. It is relatively trustworthy and is ran by Ghana Telecom. There are around 38 million cellular mobiles in use supported by 3 000 000 main lines. Two biggest operators in Ghana providing fixed line services for the public are Vodafone and Airtel. Nearly 267 000 subscriptions were made by the time of April 2017. /9/

Ghana's most significant infrastructural problem is electric power. The country's electricity need is very dependent of hydro source. Still, it is nearly impossible to produce electricity by full capacity throughout the year, because the amount of water in dams is very low over the dry seasons. /10/

Ghana invests about 1.2 billion dollars on infrastructural development per year. They still need further 1.1 billion dollars in the development of infrastructure. Still it does not mean that there are no deficiencies in the infrastructure in Ghana. A few examples of infrastructural problems in Ghana are traffic jam in sea ports, flight connectivity is dragging compared to others, power supplies are unreliable and road network's physical extension. /11/

2.5 Social Factors

In Ghana people tend to accept a hierarchical order where everybody has their own place in the community. For example, in companies it can be seen in reflecting inherent inequalities, centralization, employees do what they are told to and laudable boss is autocratic. Ghana is a collectivistic society where loyalty is considered very important and offence leads to rejection. Ghanaians work to live, people cherish their value equality, managers pursue consensus and they favour free time and flexibility. /12/

Ghana has a very normative society where people are strict in publishing the absolute truth. They have a normative way of thinking and respect the traditions. /12/

2.6 Waste Generation in Ghana in General

Very little information can be found about generation of waste, composition or effective planning on waste management in Ghana. To get even some data - some households were surveyed to keep track of sorting and separation efficiency, physical composition and waste generation per capita in each region of Ghana. /13/

An outcome from this survey tells interesting results as waste generation was 0,47 kg/person/day, which is almost 13 000 tons of waste per day basing on the current population of about 27 million habitants. Biodegradable waste was 0,318 kg/person/day and non-biodegradable and recyclable materials were 0,096 kg/person/day. Miscellaneous and inert waste was 0,055 kg/person/day. Metropolises generated a higher amount of waste (0.63 kg/person/day) than the municipalities (0,40 kg/person/day). The least waste was generated in the districts (0,20 kg/person/day), mostly because they are less developed. The generation of waste also varied by means of geographical locations. Areas near coasts and forests had a higher rate of generation than the savanna zone in north. /13/

The results are shown also in Tables 1 and 2 below:

Table 1. Amount of waste in Ghana

Type of waste	kg/person/day
Biodegradable waste	0,318
Recyclable waste	0,096
Miscellaneous waste	0,055
Total	0,47

Table 2. Amount of waste in different regions in Ghana

Type of region	kg/person/day
Metropolitan cities	0,63
Municipalities	0,4
Districts	0,2
Total	1,23

Figure 5 below shows the waste structure with the calorific value:

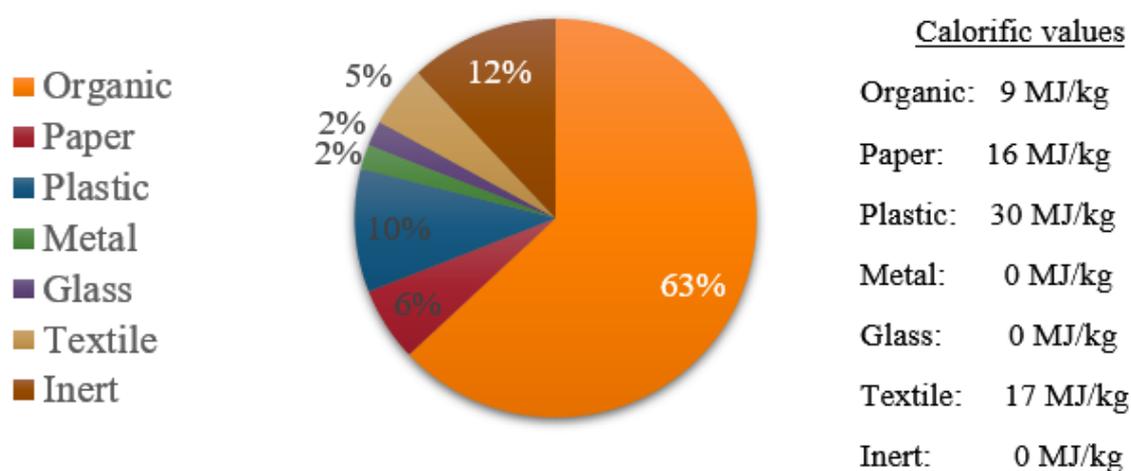


Figure 5. Waste composition and calorific values in Ghana /13/

Table 3 below describes the constituents of each component:

Table 3. Description of constituents of each component used for waste characterization
/14/

Description of constituents of each component used for waste characterization.

Waste component	Description of constituents
Plastic	Plastic bags, poly ethylene, black bags, plastic bottles.
Organic/inert residue	Food particles, humus, wood, plant organics, and inert material
Textile	Fabric, hair, sanitary pads
Paper	Paper scraps, newspaper, cardboard, bags, wrapping paper
Metal	Cans, foils, tins
Glass	Bottles, broken glassware, coloured glass

3 DEFINITION AND CLASSIFICATION OF MEDICAL WASTE

3.1 Definition of Medical Waste

Medical waste is waste generated by health-care facilities. About 75-90% of the waste generated by health-care facilities is defined as general waste and is disposed by standard disposal methods of municipal solid waste. Remaining 10-25% can be defined as hazardous waste. Improper management of hazardous waste can pose serious health risks directly or indirectly for the public. /15/

3.2 Classification of Medical Waste

Medical waste is divided into seven types, which are described next.

3.2.1 Infectious Waste

Infectious waste often contains pathogens such as parasites, viruses, bacteria and fungi. It can cause diseases to persons dealing with this type of waste.

- cultures and stocks of infectious agents from laboratory work
- tissues, and materials or equipment that have been in contact with blood or other body fluids from patients that has infectious diseases
- waste from laboratories of animals that are infected
- all instruments or materials that have been in contact with infected persons or animals.

/15/

3.2.2 Pathological Waste

Pathological waste consists of tissues, organs, body parts, human fetuses and animal carcasses, blood, and body fluids. Within this category, recognizable human or animal body parts are also called anatomical waste. This category should be considered as a subcategory of infectious waste, even though it may also include healthy body parts. /15/

3.2.3 Sharps

Sharps are items that can cause cuts or puncture wounds, including needles, hypodermic needles, scalpel and other blades, knives, and nails. Whether or not they are infected, sharps are usually considered as highly hazardous health-care waste. /15/

3.2.4 Genotoxic Waste

The hazardousness of genotoxic waste is rated high and it may have mutagenic, teratogenic, or carcinogenic properties. It causes serious safety problems inside hospitals and outside after disposal and special attention must be given. Certain cytostatic drugs, vomit, urine, or faeces from patients treated with cytostatic drugs, chemicals, and radioactive materials can be included in genotoxic waste. /2/

Cytotoxic drugs are used mostly in cancer treatments since these drugs can kill certain living cells or stop their growth. Some neoplastic conditions and diseases with immunological bases can be treated with cytotoxic drugs also. They are used commonly in oncology and radiotherapy units, but their use has been increasing throughout the years and can also be used outside the hospital setting. /2/

Genotoxic waste can constitute 1% of the total medical wastes in hospitals specialized in oncology. /15/

3.2.5 Chemical and Pharmaceutical Waste

Chemical and pharmaceutical waste are hazardous as they are toxic, corrosive, flammable, reactive and explosive. Chemical waste from hospitals include solvents used in preparation of laboratory, disinfectants, and heavy metals from health care devices for example mercury. /16/

Pharmaceutical waste includes expired or contaminated drugs and medicines. The category also includes discarded items used in the handling of pharmaceuticals, such as bottles or boxes with residues, gloves, masks, connecting tubing, and drug vials. Expired chemicals and medicines form the most common group of this sort of waste. In small

quantities in biomedical waste they can cause intoxication, burns and injuries when in contact with the skin or eye. /15/

Chemical waste is most commonly flushed into public sewage systems ending up to the ground contaminating ground water and health risk for the public. Plants and animals in nature get their part too. Burning again can cause toxic emissions, such as nitric oxide, particulates, dioxins and heavy metals, such as mercury and cadmium, which can spread into a wide area. Dioxins has been confirmed as a matter of causing cancer and are not biodegradable. Mercury and cadmium can exposure to birth defects. /17/

In 2013 this kind of waste was disposed by burning which can cause another hazard as these pressurized containers can cause a high risk of explosion during the burning. /18/

3.2.6 Radioactive Waste

Radioactive waste is genotoxic and consist of products which are contaminated of radio-nuclides. The current disposal method of radioactive waste in Ghana causes a high risk for the public. /16/

A study by Universal Hospital Group in 2013 on medical waste reveals radioactive waste being managed mostly by burning or adding it to the general waste. Radioactive waste can exposure for headaches, dizziness and intense vomiting leading to death. In many countries such as Ghana, reports on symptoms caused by radioactive waste are often hidden from public, which explains that public or scientific data of effects caused by radioactive waste is not available. /2/

4 MANAGEMENT OF MEDICAL WASTE

Medical waste must be treated properly to avoid exposure to different diseases and minimize health risks to the public and the environment. A good place to start improving health care waste management is sorting. The first step is to use colored bags and containers to sort different types of waste for better handling and selection of proper disposal method.

The WHO noted in their study in 2006 that the lack of medical waste treatment manuals and policy are highly responsible for low awareness of health workers on proper medical waste treatment. This outcome is consistent with other studies also. /19/

The main disposal method worldwide is incineration. Incinerators can include autoclaves, new technological triumph hydroclave treatment, microwave and chemical disinfection. /20/

The choice of treatment and disposal method depends on the type and amount of waste generated, whether there is a disposal site near hospital, the quality and reliability by means of transportation, financial, material and human resources, or national legislation. There is no universal solution to treat medical waste and the method must be selected to minimize health risks to the public and environment. /20/

If an appropriate treatment infrastructure is not available, it is responsibility of health care facilities to treat their wastes properly on-site. This solution has the advantage of avoiding complications involved in transportation done by independent/local collection/transportation company. /20/

Different and most common solutions for disposing the medical waste are incineration, chemical disinfection, autoclaving, shredding, disposal in landfill or waste burial pit, disposal of liquid waste in the sewage, needles destruction or extraction. The extraction of needles can be considered as a part of aiming in reducing the quantity of waste by 3 R's program standing for reduce, reuse, recycle. /20/

4.1 Incineration

Incineration is made in high temperatures as high as above 1000 Celsius degrees. It is one of the few technologies whereupon all sorts of medical waste can be treated properly and reduces significantly the volume and weight of the waste treated. /20/

Advantages and drawbacks of incineration are described in Table 4 below:

Table 4. Advantages and drawbacks of incineration /20/

Incineration	Advantages	Drawbacks
High-temperature incinerator (>1000°C) Rotary kiln (>1200°C)	<ul style="list-style-type: none"> → The waste is completely destroyed. → The waste is not recognizable. → Waste volume and weight are significantly reduced. → Large quantities of waste can be treated. → Toxic emissions are reduced. → Suitable for all types of waste. 	<ul style="list-style-type: none"> → High construction costs (Sfr 25,000 to 100,000 – Sfr 350,000 in the case of rotary kilns). → Relatively high operating and maintenance costs; the more sophisticated the emission control system, the higher the costs. → Requires electricity, highly skilled staff, and fuel. → Produces ash that contains leached metals, dioxins and furans.

4.2 Chemical Disinfection

Chemical disinfection is commonly used in health facilities to kill micro-organisms on medical equipment. In this method, chemicals are added to the waste to dispose pathogens. This treatment method can be used in liquid infectious wastes such as urine, blood, faces or sewage. Solid hospital waste can also be chemically disinfected but must be shredded first. /20/

Advantages and drawbacks of chemical disinfection are described in Table 5 below:

Table 5. Advantages and drawbacks of chemical disinfection /20/

Advantages	Drawbacks
<ul style="list-style-type: none"> → Simple. → Relatively cheap. → Disinfectants are widely available. 	<ul style="list-style-type: none"> → The chemicals used are themselves dangerous substances, which must be handled with caution. → For proper disinfection, the prescribed contact time and concentrations must be complied with. → The waste volume is not reduced. → The wastes have to be shredded /mixed before being treated with chemicals. → The final disposal method must be the same as for untreated medical waste. → The process generates dangerous effluents, which need to be treated. → Mixing chlorine/hypochlorite with organic matter or ammonia creates toxic substances.

4.3 Autoclaving

Autoclaving is a thermal process at low temperatures where the waste is subjected to pressurized saturated steam for a length of time to be disinfected. For example, in a temperature of 102° Celsius and a pressure of 1 bar it takes 60 minutes to get the waste disinfected. Prions causing Creutzfeldt-Jakob's disease included, a cycle of 60 minutes in temperature of 134° Celsius is recommended. /20/

Autoclaving is environmentally friendly method, but in most cases requires electricity, which makes it not suitable for some developing countries. /20/

Advantages and drawbacks of autoclaving are described in Table 6 below:

Table 6. Advantages and drawbacks of autoclaving /20/

Advantages	Drawbacks
<ul style="list-style-type: none"> → Autoclaved waste becomes safe household refuse. → Health facilities are familiar with this processing method. → Ecologically sound technology. → Facilitates the recycling of plastics. → Low operating costs. 	<ul style="list-style-type: none"> → Moderate to high installation costs (Sfr 500 to 100,000). → Requires electricity. → Produces contaminated effluents, which need to undergo special treatment. → In some cases a boiler is needed with emission control. → Unsuitable for chemical or pharmaceutical wastes. → The appearance of the waste does not change. → Shredding is essential in order to avoid re-use. → The weight of the waste does not change. → Unpleasant odours. → Presence of chemicals which can generate toxic fumes. → Slow and time-consuming.

4.4 Shredders

Shredding means cutting the waste into small pieces. Due to the risks for staff during the shredder is running, only disinfected waste should be treated with this method. This treatment method also requires a competent staff who operates and maintains the device. /20/

Advantages and drawbacks of shredders are described in Table 7 below:

Table 7. Advantages and drawbacks of shredders /20/

Advantages	Drawbacks
<ul style="list-style-type: none"> → Makes the waste unrecognizable. → Prevents the re-use of needles and syringes. → Reduces volume. → Facilitates the recycling of plastics. → Enhances the effectiveness of chemical or thermal treatment in closed and integrated systems. 	<ul style="list-style-type: none"> → Requires electricity. → Some facilities are very expensive. → The shredder can be damaged by large pieces of metal. → The waste is not disinfected. → The staff are exposed to air-borne pathogens when untreated waste is shredded. → Requires skilled staff and permanent monitoring.

4.5 Encapsulation

Encapsulation contains a small quantity of hazardous items in a mass of inert material. One advantage and the main purpose of this technology is to prevent the public and environment from having any contacts to the waste. /20/

Containers are sealed, filled with waste, an immobilizing material is added. The process uses either cubic boxes made of high-density polyethylene or metallic drums, which are three-quarters filled with sharps, chemical or pharmaceutical residues, or incinerator ash. The containers or boxes are then filled up with a medium such as plastic foam, bituminous sand, lime, cement mortar, or clay. Once the medium has dried, the containers are sealed and disposed of in a sanitary landfill or waste burial pit. /20/

Advantages and drawbacks of encapsulation are described in Table 8 below:

Table 8. Advantages and drawbacks of encapsulation /20/

Advantages	Drawbacks
<ul style="list-style-type: none"> → Simple, inexpensive and safe. → A solution that can be envisaged for sharps and pharmaceutical wastes. → The risks for scavengers are reduced. 	<ul style="list-style-type: none"> → To be regarded as a temporary solution. → The quantities of waste treated are small. → The weight and volume of the waste is increased.

4.6 Disposal in Landfill or Waste Burial Pit

This technique has been denied in the EU since the new directive in 2016. However, this method can still be considered in developing countries.

There are still certain legislations that must be considered before dumping the waste. For example, the waste must be covered, chemicals cannot be disposed in landfills and leachates must be collected and treated. /20/

Municipal landfill must be inspected before hazardous medical waste can be transported and disposed there. /20/

A waste burial pit can be considered in hospital as an on-site method. To prevent the pollution of groundwater the pit should be lined with low permeability material such as clay, for example. It should also be fenced to keep scavengers away. Medical waste must be buried under a layer of soil after each unloading. Lime can also be added to the waste to add health protection and eliminate odor. After the pit has been filled, it must be sealed. /20/

Advantages and drawbacks of disposal in landfill or waste burial pit are described in Table 9 below:

Table 9. Advantages and drawbacks of disposal in landfill or waste burial pit /20/

	Advantages	Drawbacks
Sanitary landfill, trench method	<ul style="list-style-type: none"> → Simple and inexpensive operating costs. → Can be carried out using an existing municipal waste management system. → Scavengers cannot access the health-care waste if the landfill is well managed. 	<ul style="list-style-type: none"> → The health-care wastes are not treated and remain hazardous. → The landfill must be secure, fenced in, and guarded. → Scavengers and animals need to be controlled. → A high degree of coordination is needed between collectors and landfill operators. → Makes health workers less aware of the need to sort the various types of waste. → Transport to the landfill can be a lengthy and costly operation. → Risk of water pollution.
Separate pit on hospital site	<ul style="list-style-type: none"> → Simple and relatively inexpensive to build and manage. → Dangerous substances are not transported outside the hospital. → Control is facilitated. 	<ul style="list-style-type: none"> → The health-care waste is not treated and remains hazardous. → Risk of water pollution. → Problem of odour. → Vectors (insects, rodents, etc.) need to be controlled. → Space is needed around the hospital.

4.7 Disposal of Liquid Waste in the Sewage

In general, the chemicals and photographic developing liquids should not be disposed into the sewage system or poured down the drain. If there is not an approved firm to recycle this kind of waste, it is allowed to discard the waste in small quantities and under strict limits. Non-hazardous waste such as vitamins, eye drops, and small quantities of blood can be poured down the drain. Before pouring, the infections in liquids must be

inactivated by using chemical disinfection or autoclave. Expired units of blood cannot be poured down the drain since they must be incinerated above 1000° Celsius, autoclaved or buried into the waste burial pit. /20/

5 MEDICAL WASTE IN GHANA

Ghana's management of medical waste needs urgent attention and actions to improve it. Of the waste generated by the health sector 15% is classified as a hazardous waste, which includes biomedical waste. Most part of the waste is handled generously as a normal solid waste. Infectious waste includes waste that contains blood and other fluids secreted by body, samples from culture, and equipment from infectious patients in laboratory and waste from the patients being insulated. /21/

About 15 to 20% of the biomedical waste found in the Greater Accra region has been found infectious waste and sharps which include different sorts of pathogens. /22/

Infections that has been caused by being exposed to the infectious waste are gastro enteric infections, respiratory infections, ocular infection, genital infections, skin infections, meningitis, acquired immunodeficiency syndrome, hemorrhagic fevers, septicaemia, bacteraemia, candidaemia, viral hepatitis A, B and C. /23/

These pathological organs find their way into the human body most commonly through abrasions, wounds, breathing air inside, and nutrition. There are many different dangerous side effects in this kind of wrong handling of hazardous biomedical waste. It can cause all kinds of different infections and diseases. One good example of this indirect impact is when farmers irrigate their corps with the same water from drains that are used to dispose the medical waste. /2/

There was also an actual accident in Accra Military Hospital in 2012 when liquid biomedical waste was let flow into the main gutters for over a year causing health problems for people living near the hospital. /24/

Doctors, nurses, pharmacists, waste handling, waste collection company staff, scavengers, and the public are all in a great danger when exposed to infections and diseases caused by wrong handling of medical waste. Kids playing outside nearby hospital and environment belong also to this risk group. Exposure can be caused by bad smell, toxic emissions, contaminated ground water, vector transmission (rats), and accidental direct contact to the waste by public if not disposed properly. /2/

World Health Organization states the following: *“National legislation is the basis for improving medical waste practices in any country. It establishes legal controls and permits the national agency responsible for the disposal of medical waste, usually the ministry of health, to apply pressure for their implementation. The law should be complemented by a policy document, and by technical guidelines developed for implementation of the law.”* /25/

There is no legislation for managing the medical waste in Ghana. In 2002 Ghana’s Environmental protection agency (EPA) in cooperation with the Ministry of Local Government and Rural Development published a guideline how each health care units should manage their medical waste. /26/

The first phase was to use different coloured bags and containers to classify different types of waste so the handling and disposal by using the right methods would succeed. The colours were as follows: Black for general waste, yellow for infectious waste and brown for hazardous waste. /38/

Table 10 below describes how different types of waste should be managed:

Table 10. Management of different types of waste /2/

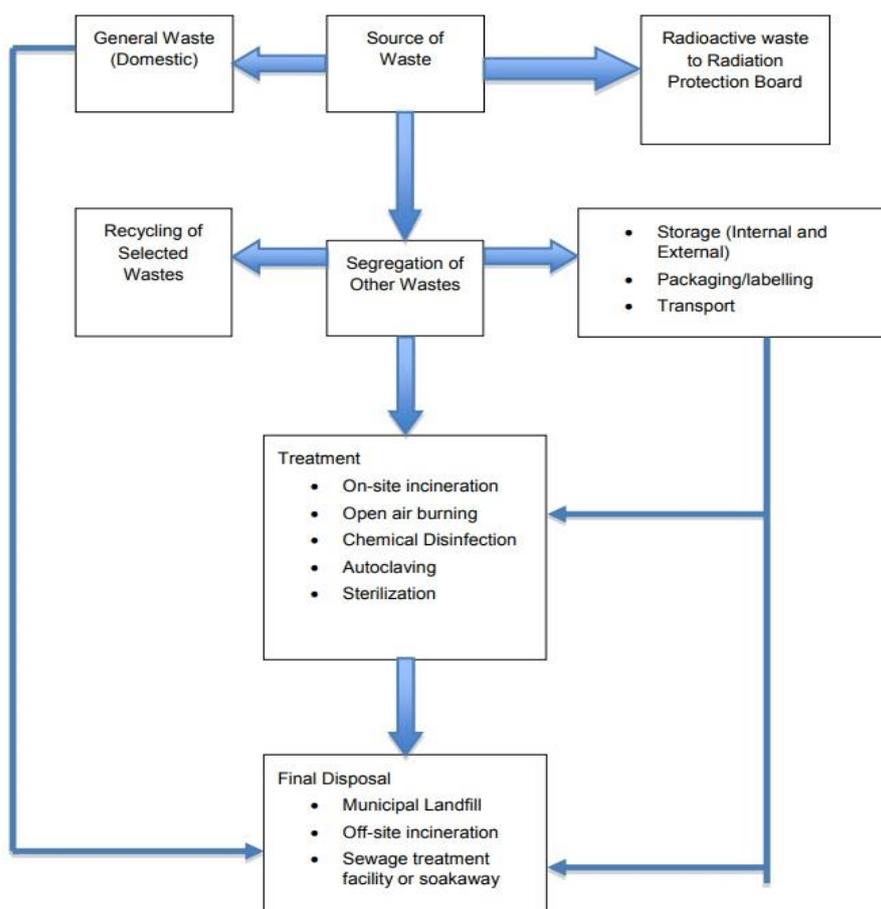


Table 10. Management of different types of waste /2/

Despite these guidelines given by EPA there has not been signs of improved management of medical waste in Ghana. /2/

There is a study done by ESO-Consult in 2014, which focused mainly on how the medical waste was being managed and disposed in Accra, the Korle Bu Teaching Hospital and the Ridge Regional Hospital, which are two of the largest hospitals in Ghana. /2/

In Accra, the Korle Bu Teaching Hospital a blocked sewage system caused flowing of the liquid medical waste to the nearby lagoon and water bodies. Only 20% of the solid

waste was being classified by using different colored bags and containers to segregate the waste even though there were all the equipment and resources to manage this problem.

Despite this small effort, all sorts of waste ended up to the same disposal area where the bags and containers were left open. /2/

Ridge Regional Hospital in the middle of expansion project directed liquid medical waste straight into the municipal communal sewage system. Waste was classified into the different colored bags and containers. /2/

The final designs of the expansion plan include autoclave and shredder which both improve ecological management and disposal of medical waste in this hospital. /2/

Again, despite the effort of the hospital and paying for the waste collecting company all the waste was transported to the same landfill. /2/

There was also another study which studied ways to handle the waste in four hospitals (St. Patrick Hospital, SDA Hospital, Offinso Health Care, Quality Care Clinic) revealing this big problem in management of the waste in Ghana. These four hospitals produced 2626 kilograms of waste of which 420 kilograms was infectious waste. Classification according to the guidelines stated by EPA was randomly done, with few exceptions considered. Waste containers were not covered, and the waste was dumped to the unfenced landfills and holes where they were burned openly. /28/

A case study conducted in 2014 studied the amounts of waste being generated in 120 health care facilities in the Greater Accra Region. Information was collected about waste generation, separation, collection, storage, transportation and disposal by doing site visits, interviews and implementing questionnaires. /32/

The results show that 8221,2 kg of medical waste is generated by 6851 beds per day. It makes 1,2 kg of medical waste per bed per day. It is estimated to increase greatly by time. Compared to other studies Greater Accra Region has a much higher generation rate of medical waste. /32/

Table 11 summaries the management of existing waste in these four hospitals:

Table 11. Existing waste management practices in Offinso Municipality health institutions /28/

Name of health institution	Segregation of waste	Record on quantity of waste	Knowledge Of Hospital Waste Management Policy/Legislation	Labeling On Containers/Colour Code	Training On Waste Handling	Incidence/Reported Case Of Injury/Needle-stick	Handlers of Waste	Type of Containers Used
St. Patrick Hospital	2.2 Kg (0.14%)	No	No	No	No	Yes	Waste handlers and Orderlies	Paper boxes/Polythene bags
SDA Hospital	1.7kg (0.40%)	No	No	No	No	Yes	Orderlies	Paper boxes/Polythene bags
Offinso Health care	1.1 kg (0.33%)	No	No	No		Yes	Any health worker on duty	Paper boxes/Polythene bags
Quality Care Clinic	1.3 kg (1.3%)	No	No	No	No	Yes	Orderly and any health workers on duty	Paper boxes/Polythene bags

Problems with big hospitals revealed by this study tell they are likely to exist in smaller hospitals also. /28/

The Universal Health Group study in 2013 studied different disposal methods instead of burning the waste in over 200 different hospitals. The results are shown in Table 12.

Table 12. Other methods of disposal apart from incineration (% of a sample of 200 randomly sampled health officials) /29/

Sharps	Pathological Waste	Infectious Waste	Radioactive Waste	Chemical Waste
Burying (6%)	Collected by Zoomlion (3%)	Dustbin or litter boxes/ pedal dustbins (3%)	Decontaminated (1%)	Put in septic tanks (2%)
Placing them in separate/ special containers (6%)	Disinfected and concealed for collection company (3%)	Incinerated/ steam sterilized and disposed (4%)	Dark room (1%)	Placed in separate bins (2%)
Broken and buried/ Needles broken off (6%)	Kept in containers with cover and given to patients (3%)	Separated from other waste (5%)	Disposed through the sewage system (1%)	Buried (2%)
Separated into a recycle bin and sent to Korle Bu hospital/ Recycle bin (10%)	Recycle bin (3%)	Disinfected and concealed for collection (5%)	Put in yellow plastic bags (2%)	Bleached (3%)
Safety boxes/ yellow box (10%)	Taken to Korle Bu (4%)	Buried (5%)	Placed in separate rooms (2%)	Connected to the manhole (3%)
	Buried (8%)	Decontaminated (6%)	Putting them in separate containers (2%)	Burnt (7%)
		Flushed into the sewage system (9%)	Added to general waste (2%)	Flushed/Washed away through sewage system (8%)

6 RESEARCH METHODS

The research method used in this study is qualitative, that is a literature review and case study. The case study is a type of scientific research used in obtaining information about culturally specific values, opinions, behaviors and social contexts of particular populations. By determining and defining the research question - complex issues can be understood by a use of this research method. The research design for the study is presented in Figure 6 below:

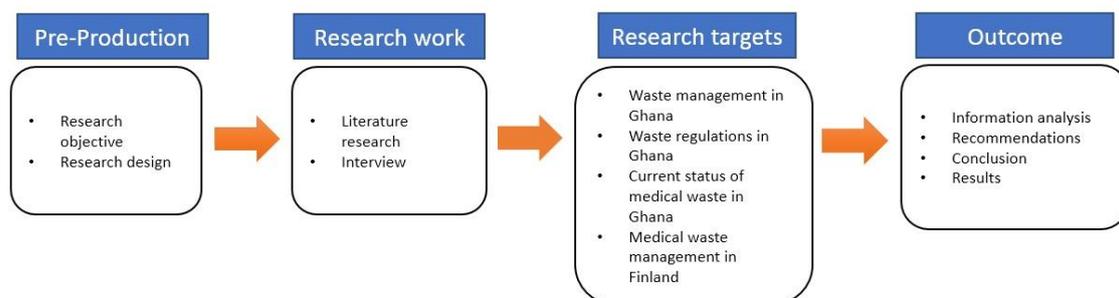


Figure 6. Research design

The pre-production phase deals with the research problem investigating the research problem and how to approach it.

The research work phase contains literature review and interview. Sources in literature review were from scientific studies and other related documents using Google Scholar and ScienceDirect. Literature research was used to collect information about Ghana's medical waste management and its current status. Interviews were used to get actual data from the types and amounts of wastes that are generated in Finnish hospitals. Information about the handling and disposal methods was also received.

In the outcome phase the conclusion, recommendations and results were given based on the information collected from the literature review and interview.

A literature review serves many important purposes, including:

- Establishing the need for the research
- Broadening the horizons of the researcher

- Preventing the researcher from conducting research that already exists

Ensuring the duplication does not occur – the researcher is allowed to find out what has been done in terms of the problem being investigated. This view is being supported by Aitchison. /43/

Bless & Smith share more specific reasons, which include the following:

- To sharpen and deepen the theoretical framework of the research
- To familiarize the researcher with the latest developments in the area of research
- To identify gaps in knowledge, as well as weaknesses in previous studies.
- To discover connections contradictions or other relations between different research results by comparing various investigations.
- To identify variables that must be considered in the research
- To study the definitions used in previous works as well as the characteristics of the populations investigated, with the aim of adopting them for the new research.
- To study the advantages and disadvantages of the research methods used by others, in order to adopt or improve on them in one's own research. /39/

In the literature review, information was collected about:

- waste management in Ghana
- waste regulations in Ghana
- current status of medical waste in Ghana

Type of qualitative method used in this thesis was an interview. Juha Jokinen, Operation Manager in the Päijät-Häme Central Hospital was interviewed about hospital waste management in a Finnish hospital.

6.1 Data Collection Method

The interview was implemented by creating the questions in advance and the results were analyzed by listening the record of the interview. The length of the interview was around

one hour. Good documents presenting the layouts, amount and types of waste being generated in Päijät-Häme Central Hospital were obtained. Interview questions are presented in Appendix 1.

Hospital staff in Ghana were interviewed by a questionnaire sent by email and is presented in Appendix 2.

6.2 Reliability of the Case Study

There was not a chance to visit Ghana and very little information could be found on waste management or generation in Ghana. Based on this the accuracy of the study could have improved by having a concrete view of the current situation and the latest reports. The Lahti case was conducted in Finnish to improve the accuracy of the information collected. The questionnaire sent to Ghana was conducted in English, which is the official language in Ghana.

7 EMPIRICAL STUDY

7.1 Ghana Case

A questionnaire was sent into one hospital in Ghana – Catholic Hospital Battor. Questions can be found in the appendix 2. The questionnaire was answered by hospital administrator. Catholic Hospital Battor is the District Hospital of the North Tongu District in the Volta Region, which capital is Battor-Dugame. Mepe, Osudoku, Ada, Volo, Abutia and Mafi are traditional areas included in Battor border. The hospital is the only one in the Accra Archdiocese region. Still, the hospital is located in the Volta Region and most activities are carried out among all other health facilities in region. /41/



Figure 7. Catholic Hospital Battor, Ghana /42/

Results from the questionnaire are shown below:

1. Is the waste getting burned openly or dumped to the landfill?

- **Answer:** The waste is burned in an incinerator and ashes buried.

2. How much your facility generates medical waste per bed?

- **Answer:** This calculation has never been done.

3. Is there any segregation procedure at the point of generation of waste or before?

- **Answer:** So far no, except that the general waste is separated from hazardous waste, but burnable and unburnable are not being separated.

4. Are there any rules and regulations being followed in the hospital in accordance with the guidelines issued under biomedical waste (management and handling) rules issued by the government and is there any kind of team supervising that these rules are being followed?

- **Answer:** Waste management rules are there, but they are not being followed.

5. What are the various kinds of containers or bags which are used for the different categories of wastes?

- **Answer:** We use mainly aluminum and plastic dustbins with polyethylene linings. The linings are color coded: brown, yellow and black.

From the results can be said that the Ghanaian health facilities use incineration as disposal method, but the technology used and capacity needs improvements.

Woima Corporation's waste plant needs wastes from 200 000 habitants to run efficiently a year-round, so the calculation of how much hospital waste is being generated per bed should be done.

The hazardous waste is being separated from the general waste in Catholic Hospital Bator, but the separation procedure needs also huge improvements as unburnable and burnable waste is not being separated.

The results confirm that the legislation is needed to supervise following of the rules given by EPA. Colored bags are used, and containers are made of aluminum or plastic, lined with polyethylene.

7.2 Finnish Case

The case in Finland was conducted at the Päijät-Häme Central Hospital located in Lahti by interviewing Juha Jokinen, Operation Manager. Detailed information was received about how the waste is managed and how much one hospital generates different sorts of waste annually.

Table 13 below shows the type of waste and amount generated in Päijät-Häme Central Hospital.

Table 13. Types and amounts of waste generated in Päijät-Häme Central Hospital annually

Type of waste	Amount (kg)
Glass	16 900
Misc	261 710
Hazardous	4 410
Laboratoric	8 760
Pharmaceutical	10 370
Construction	49 800
Wood	21 740
Metals	29 680
Angular	23 160
Food	29 430
Energy	285 660
Electronics	9 970
Confidential	66 530
Paper	17 040
Board	85 200
Total	920 360

A total of 23 540 kg of dangerous waste is generated annually. Some of the hazardous waste is even washed to transfer it to general solid waste. The hospital had their own incinerators until 1995 to incinerate the contaminated waste. By that time PHKS generated about one trolley of contaminated waste per day. After the legislation to ban hospital incinerators in 1995 new decrees came into force and since then contaminated waste is

collected in specially designed bags and containers and transported to the landfill or an incineration plant to be burned. No specially designed vehicles are used for the transportation.

Liquid hazardous waste mainly comes from laboratories. The liquid hazardous waste is poured into a specially designed sewage system where the final destination is a 1000 liters tank. After the tank is filled, it is emptied once in a month into a specially designed container and is transported with other wastes. The liquid in tank consists mainly of 40% formalin, 40% ethanol and 20% xylene.

Waste in Finnish hospitals is managed closely as EPA guided in 2002 on how to manage the medical waste in Ghana. There are eight different colored bags for every sort of waste and special containers for hazardous and angular waste.

- Black: Mixed waste
- Green: Paper
- Blue: Confidential waste
- Yellow: Special waste
- White: Glass
- Orange: Energy waste
- Brown: Organic waste
- Red: Hazardous waste

Disposal of hospital waste in Finland and EU changed since the new EU directive in 2016, which bans burying the waste to the landfill. It became a bit of a problem, because Finland has only two waste incineration plants that are able to burn medical waste. They are located in Riihimäki and Vantaa. It caused transportation problems since these two cities are located in south, a long way from many hospitals in Finland. Lot of medical waste for example from Levi is transported to Sundsvall, Sweden where the transportation distance is shorter, and prices are cheaper. A new incinerator plant has been built in Oulu in central Finland, but it does not have the technology to incinerate medical waste.

Medical waste in Finland is divided into seven different classes:

1. Community waste
2. Health care specific waste
3. Penetrating and pungent waste (angular waste)
4. Recognizable biological waste
5. Unrecognizable biological waste
6. Hazardous waste
7. Infectious waste /30/

Compared to Finland, in developing countries, the transportation of the waste can be a huge problem since the infrastructure is not as good as we have for example here in Scandinavia.

8 WOIMA CORPORATION'S TECHNOLOGY

This chapter presents Woima Corporation and its technology.

8.1.1 Introduction

Woima Corporation is a Finnish supplier of waste-to-energy power plants with the aim to mitigate waste-related problems in developing countries. Woima Corporation's mission is to turn waste into wellbeing, which they are doing by delivering best in class circular economy solutions. /40/

Woima offers a turnkey solution that simultaneously significantly reduces waste land-filling and delivers a variety of energy commodities and cuts down waste logistics costs and emissions. /40/

The power plant is scalable and easy to relocate and has an excellent return on investment and a short payback time. The power plant is developed and optimized for wide range of different waste qualities and biomass fuels with excellent energy efficiency. By modular power plant design, higher flexibility can be achieved and unique concept of their own guarantees the full benefits of decentralized power generation and waste logistics. Woima Corporation's small to medium size ecosystems can be spread around the city to optimize the waste transportation routes and to generate the exact energy commodities, electricity, thermal energy, or fuels that are needed locally. /40/

The world is currently struggling in coping with the waste challenges brought by growing economy and population. Woima Corporation's ecosystem can generate clean energy and as an addition to that, it saves environment by eliminating the need of landfills and ensuring that more waste is collected and treated properly. /40/

Most importantly, Woima Corporation's technology meets the highest emission standards of today ensuring cleaner environment. They offer sustainable growth to all stakeholders, such as waste management companies, energy sector, investors and local population alike. /40/

Woima Corporation can provide ecosystem solutions to maximize customer value. This can be done by integrating various circular economy technologies into one solution, such as bio- and landfill gas, waste pre-treatment and incineration, water purification among others. /40/

WoimaCare provides lifecycle support service that makes sure customers have an operations and maintenance under control during the whole lifecycle of the plant. /40/

The power plant fits perfectly in off-grid solutions and can be installed to a very small footprint and has a quick roll-out time. Woima Corporation has experience of various power plants from conventional and biomass projects from more than hundred countries during the last twenty years. /40/

8.1.2 Waste Incineration

The power plant technology is based on grate incineration technology, where the waste moves forward through the combustion phases; drying, pyrolysis and char combustion. Finally, the ash is dropped into a cooling pool. The grate feeds primary air supporting full combustion. The air also cools down the grate prolonging the maintenance gap. The capacity of incineration depends on the composition and the calorific value of the waste fed in. Usually the capacity is 5-7 tons per hour. /34/

After the ash has been cooled down, it is transported to an ash processing system with conveyor belts where residue water is removed and returned to the cooling pond. The ash, what is left of it, is compacted for landfilling, cement production or used in infrastructure construction. /34/



Figure 8. Waste incineration /34/

8.1.3 Heat Radiation and Cooling

Gases from the incineration phase are burned in an adiabatic combustion chamber when the furnace is opened from the middle. The upper combustion chamber helps the ignition and ensures the full combustion of the gases. It is done by directing the secondary and tertiary air to the combustion chamber. After the combustion phase, the gases flow into the cooling channel, where steam and water in the membrane wall piping absorbs the heat of the flue gas. The partially evaporated mix of steam and water is held by the steam drum, where it is recirculated by gravity back into the membrane walls. /34/

The residence time for the flue gas by the EU-standards is 2 seconds in 850° Celsius, which is guaranteed by a lengthy channel. It is required to completely burn out all the highly toxic parts in the flue gas. At the same time, the radiation channel lowers the flue gas temperature to protect the waste heat recovery boiler from corrosion. /34/



Figure 9. Heat radiation and cooling /34/

8.1.4 Waste Heat Recovery

The recovery boiler includes economizer, evaporator, superheater and air preheater, which are a group of piping arrays designed to collect the remaining heat in the flue gas through convection. Its job is to collect the waste heat from the radiation channel. The steam generated in the membrane walls of the radiation channel is then converted into superheated saturated steam for the steam genset by the evaporator and superheater. The water flowing into the steam drum from the water tank is preheated by the economizer. The primary, secondary and tertiary air is preheated by the air preheater for improved efficiency in incineration. /34/

The flue gas includes fly ash, which accumulates on the wall and piping surfaces in the boiler, reducing its heat transfer efficiency over time. To ensure proper functionality of the heat recovery boiler an intensive soot removal process is required. /34/



Figure 10. Waste heat recovery /34/

8.1.5 Air Pollution Control

The control of the air pollution is based on a dry APC-system. Woima Corporation's power plant is equipped with hydrated lime and activated carbon dosing systems and reactor, which are combined with a fabric filtration system. This APC-system guarantees that guidelines by the World Bank and emission standards by the EU are not neglected. There is no sludge to be treated, because both of these systems produce dry ash residue. /34/

Fly and bottom ashes can be used in road construction and cement production. The APC ash contains dangerous heavy metals and toxics and must be transported into landfills or processed in a metal extraction plant. The incineration of waste produces waste where 15% of it is bottom and fly ash and about 3% is more dangerous than APC ash. /34/



Figure 11. Air pollution control /34/

8.1.6 Power Generation

The steam is converted into electricity by a rotating turbine. Depending on the customer's needs, a standard back-pressure of extraction turbine is used. A condensing system then reduces the steam vapor from the used steam back to the water. Efficient operation is ensured by a closed circuit, which maintains the heat produced within the system. The power plant production can be used in the form of steam, thermal power, potable water, electricity, or a combination of these. /34/

An auxiliary diesel generator set is a standard feature of the plant, which can be used in start-up and shut-down of the plant to run the air blowers and conveyor belts. It can also give power for the local operations to reduce drawbacks from blackouts, for example. /34/

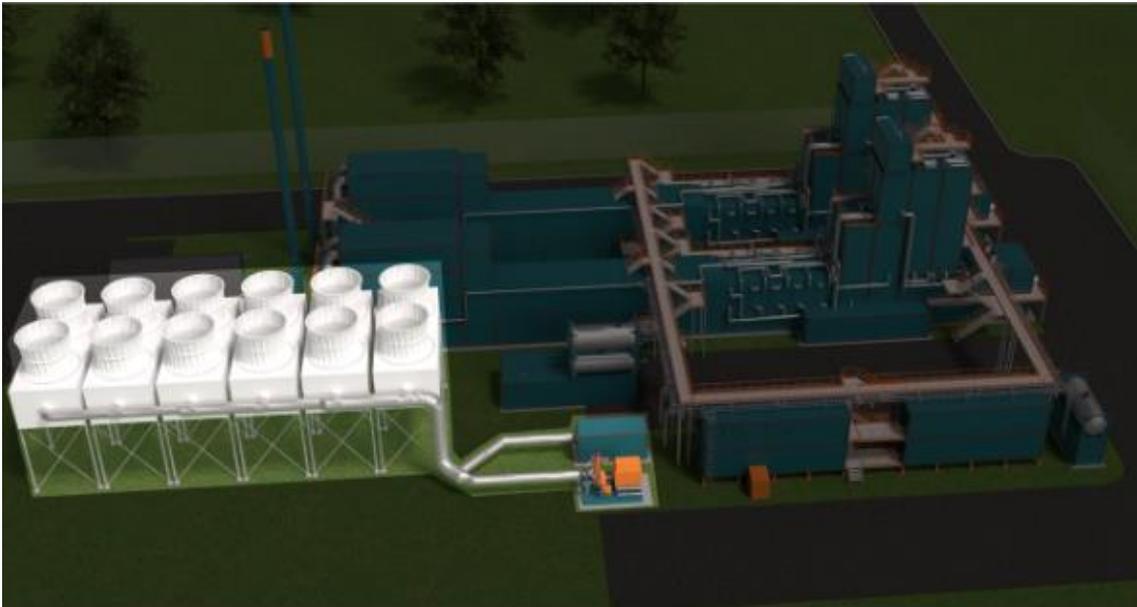


Figure 12. Power generation /34/

8.1.7 Waste Pre-sorting

First, the incoming garbage trucks are weighed before the waste is put into the tipping storage ensuring continuous flow of waste during this operation. /35/

Next, the waste is fed into a shredder where all the big objects are crushed, and bags opened. Waste runs on a conveyor belt where ferrous metals are removed by a magnet onto a screen where biowaste, sand, and all others that are hard to pick by hand are separated. Biowaste can be recycled to the landfill or used in biogas production. /35/

The waste stream from the screen passes through a manual sorting station and is evenly divided on a conveyor belt. The manual sorting phase removes all inert and harmful materials, such as metals, glass and PVC, which are recycled as raw material. The remaining waste continues into a buffer storage, which mainly contains plastics, wood and textiles. The buffer storage ensures a continuous supply of the fuel, which is in this case waste. This buffer is designed to cover the lack of fuel supply during for example the holidays or weekends. /35/

Next, the fuel is fed into the incineration plant. The amount of fuel depends on the calorific value and moisture of the fuel. Exactly the right amount is supplied to the combustion grate, which ensures the maximum extraction of energy and complete combustion of waste. /35/

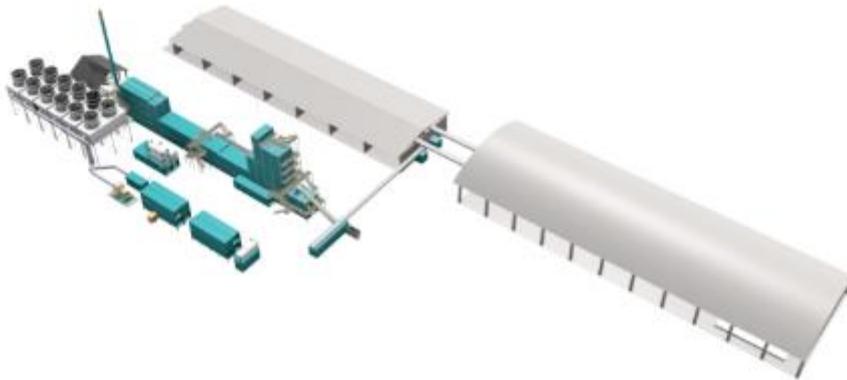
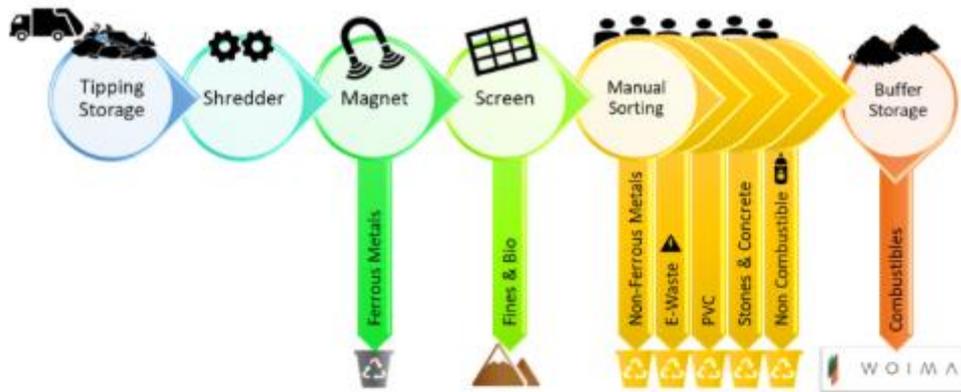


Figure 13. Waste pre-sorting /35/

8.1.8 Woima Ecosystem Solution

Waste recycling or waste-to-fuel/energy solutions and waste pre-sorting are the key factors in the Woima ecosystem. These can vary from biogas production, waste incineration or gasification to pyrolysis. /36/

The Woima ecosystem accepts all kinds of different waste streams, for example solid and liquid, industrial, and animal waste. Every waste stream has their own technical solutions to match the best solutions how to handle each waste. /36/

The waste pre-sorting has an important role in choosing the best solution to follow by removing unwanted particles from the waste and crushing the waste to a suitable size. Energy is produced by incineration or gasification. Traffic fuel that can be used, for example in cooking, heating and electricity production, is generated in anaerobic digestion or pyrolysis. The residual matter produced from incineration can be used in manufacturing industry of cement and bricks, whereas the residual biomass from biogas production can be used as a fertilizer. Finally, the excessing biodegradable matter can be used in compost production. Over 95% of the quantity of the waste can be recycled either as energy or raw material. /36/

Ecosystem components varies depending on the customer's needs and can be easily modified and developed throughout the time to match changing customer's needs. It can also be easily dismantled and relocated. /36/

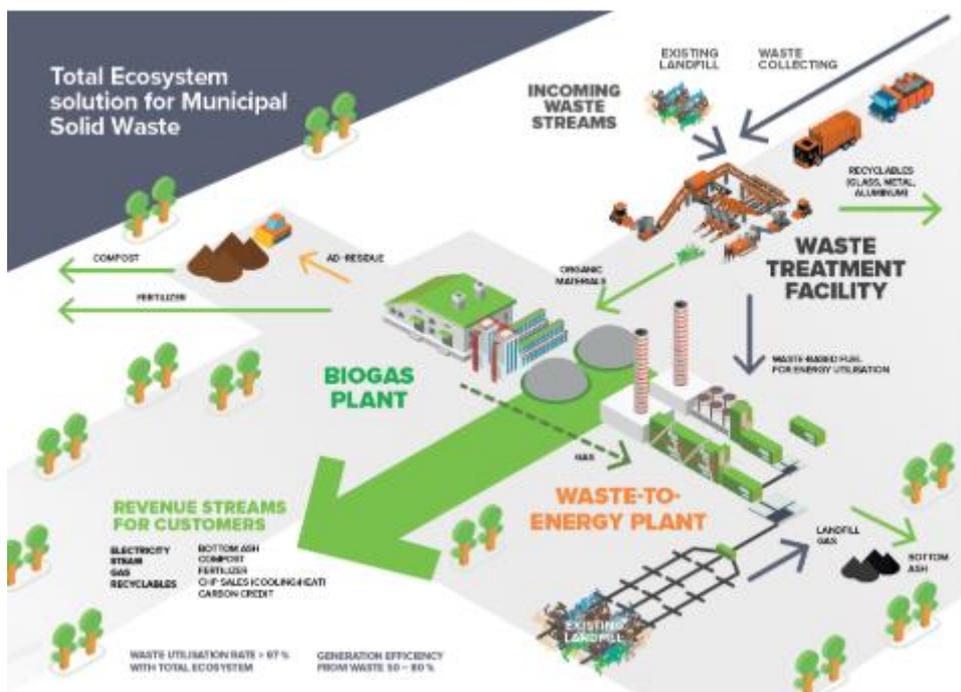


Figure 14. Woima ecosystem solution /36/

8.1.9 Decentralized Waste Management and Power Generation

The following five key cost components are included in all waste to value projects:

1. Waste collection
2. Waste transportation
3. Waste to value solution
4. Waste disposal
5. Energy transmission

The logistic costs of the waste can be reduced by decentralization, which means moving the facilities close to a place where the waste is mostly being produced. This can reduce the logistic costs by 50%, when transportation distances get shorter. The electricity transmission losses can also be reduced by 10% as the end-users are close. In addition, energy produced is more easily available for customers and industries. /37/

These facilities are designed to handle all kinds of different wastes and hospital waste is one of them. Other difficult materials can be handled also, such as animal by products, wastewater sludge, but also tires and others. It can be stated that untreated waste is minimized, which offers significant improvements on air, soil and groundwater emissions, health risks and biodiversity issues. /37/

9 ANALYSIS AND DISCUSSION

Medical waste treatment must improve in developing countries. The current incineration technology lags far behind other countries. Incineration is noted as a best method in the EU to dispose the medical waste, but the latest technology solutions must be employed to maintain high efficiency and amounts of toxic emissions as small as possible.

Using colored bags and containers has been noted to work out well in separating the waste here in Finland, so why not in developing countries also. The containers must be specially designed for different classes of waste, for example angular waste containers cannot be damaged by sharp materials as needles, blades or broken glass.

The safety of workers handling the waste is also important to avoid being exposed to different types of diseases. Proper coats and protective gears, such as masks, gloves and boots must be used depending on the risk of exposure.

As there is a big responsibility in health facilities that generate medical waste to handle and separate it properly, same responsibility lies also with companies that collect and transport the waste into the proper disposal areas.

Acknowledgment must be improved in developing countries by spreading information about the hazards that improper management and disposal methods of medical waste can cause to environment and public and how it is done correctly. The current society underestimates the importance of having a well-managed medical waste handling and disposal system. Many diseases could be avoided, if everybody followed these guidelines published by EPA.

The management of medical waste is the responsibility of each health facility, which produces it. The methods of managing medical waste must be set to meet the current trends and technology. As Ghana currently does not have any legislation regarding the management and disposal of medical waste, the parliament must enact legislation, so health facilities are forced to focus on strict observation of the guidelines EPA has given for the handling and managing of medical waste. Since there is not certain legislation, it has not only lead to aversion from health facilities relating to costs spent in proper handling of

medical waste, but also limited investment from the private sector in improving the current management and infrastructure of medical waste in Ghana. /2/

For example, in United Kingdom it is forbidden to manage and dispose the medical waste, without an issued license. People in contact with medical waste are legally bound to do it in a proper way or transport it to someone who is allowed to do these kinds of actions. /31/

Most of Ghanaian health facilities do not have a powerful waste management system or valid staff enough to manage medical waste. /38/

The biggest hospitals have their own waste incinerator systems, but their capacity is not big enough or they are non-functional. The current burning method also produces toxic emissions and too much greenhouse gases, which are dangerous for the people living near hospitals and for the environment. /2/

Burning as a method of disposing the waste is solid, but its technology must be updated as with current solutions, it has been possible to affect the amounts of toxic emissions produced significantly.

In Ghana the waste is collected by local waste collection companies, which have insufficient know-how to handle and dispose the waste in a proper way, therefore, more local specialty is needed. /32/

Table 14 below gives different options how to handle the waste:

Table 14. Treatment options for Centralized Waste Management Facilities /33/

Waste Category	Treatment options
Infectious waste (e.g. sharps, patient waste, human/animal tissue and cultures/specimens) with the biohazard label	Autoclaving/ Incineration/ Shredding/specialized landfill
Hazardous waste (e.g. expiry drugs, vaccines, chemicals etc). Where only small amounts of chemical wastes are generated, these may be added to the infectious waste.	Advanced Incineration/Chemical treatment/

Currently there is only on-site waste incinerator plants that do not meet the capacity for the waste. Bigger off-site plant investments are needed from private companies with modern technology, which can also incinerate the medical waste. /2/

One option is CHWTSDF (Centralized Health Care Waste Collection, Transportation, Storage, Treatment and Disposal facilities). The CHWTSDF can collect the waste periodically in a certain defined area from health facilities, hospitals and pharmaceutical firms. To regulate this process there must be a revised policy and legislation as mentioned before. The waste should be transported in a vehicle that is designed for this certain purpose – collecting and transporting medical waste. The vehicle must contain different lockers to classify the different colored containers and it must be inspected for leaks at regular intervals. This concept has already been put into practice in many countries and for example the case of India would be good for Ghana to review. /2/

In addition, a campaign is a good idea to raise people's awareness of the risks and hazards that improperly managed and disposed medical waste can cause. /2/

10 CONCLUSIONS

Ghana is a developing country with increasing economy, population and urbanization. Along with these three dimensions also the importance and need of an effective waste management system is increasing. Ghana needs urgent attention on waste management and especially in hospital waste management, which can cause huge health risks for the public and the environment. Legislation is needed to supervise that the guidelines published by EPA are being followed.

Incineration is the main method used for disposal of the medical waste in Finland since burying the waste to the landfills was denied by the EU directive set in 2016. The incineration method needs the latest technology solutions to be an effective disposal method.

In Finland there is also a problem of centralization of the waste plants that can handle the medical waste. Two of these waste plants locate both in south and transportation distances are increasing too much. Some facilities transport their wastes generated to a neighbor country in hope of a smaller transportation distances and costs.

Finnish Woima Corporation offers solutions to help solving this waste problem, not just only in Ghana, but in other developing countries also. Woima Corporation's waste plants can be easily transformed to match changing customer's needs and transported to a different location. This decentralization offers huge benefits as the plants can be located nearby the facilities where the waste is being generated. The quantity of medical waste in Ghana currently might not be enough due to lack of accurate estimation. To meet the basic requirements of Woima Corporation's technology, the medical waste should be combined with municipal waste. This means creating two feeding lines should be incorporated to the Woima Corporation's technology.

There was not a chance to visit Ghana and very little information could be found on waste management/generation in Ghana. Based on this the accuracy of the study could have improved by having a concrete view of the current situation and the latest reports.

Levels of people awareness about health risks and proper management must be increased by spreading information. Incineration is currently the most used method worldwide but

requires latest technology solutions to minimize toxic emissions and maximize the efficiency.

REFERENCES

/1/ Synova web site. Accessed 10.4.2019. <https://synovapower.com/a-global-problem/>

/2/ Biomedical waste management in Ghana. Accessed 20.1.2019. <http://www.imaniafrica.org/wp-content/uploads/2016/05/BIOMEDICAL-WASTE-MANAGEMENT-IN-GHANA.pdf>

/3/ Minghua Z., Xiumin F., Rovetta A., Qichang H., Vicentini F., Bin-kai L., Giusti A., Yi L. 2009. Municipal Solid Waste Management in Pudong New Area, China, Waste Management, Vol 29, October, pp. 1227-1233.

/4/ Abdel-Shafy H.I., & Mansour S.M. 2018. Solid waste issue: Sources, composition, disposal, recycling, and valorization. Egyptian Journal of Petroleum, Vol 27, Issue 4, December, pp. 1275-1290.

/5/ Ó 2018 Egyptian Petroleum Research Institute. Production and hosting by Elsevier B.V.

/6/ World Bank. Ghana GDP. Accessed 15.2.2019. <https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2017&locations=GH&start=1994&view=chart>

/7/ World Bank. Ghana. Accessed 15.2.2019. <https://data.worldbank.org/country/ghana>

/8/ Nations Encyclopedia web site. Accessed 7.2.2019. <https://www.nationsencyclopedia.com/economies/Africa/Ghana-INFRASTRUCTURE-POWER-AND-COMMUNICATIONS.html>

/9/ GhanaWeb, Accessed 7.2.2019. <https://www.ghanaweb.com/GhanaHomePage/communication/#>

/10/ Dramani I., 2012. Providing renewable energy solutions in Ghana: Overview of the business environment regarding some selected renewable energy sources. Bachelor's thesis, Laurea University of Applied Sciences, Finland.

/11/ Foster V., & Pushak N. 2011. Ghana's infrastructure: A continental perspective.

/12/ Hofstede Insights. Accessed 7.2.2019. <https://www.hofstede-insights.com/product/compare-countries/>

/13/ Miezah K., Obiri-Danso K., Kadar Z., Fei-Baffoe B., Mensah M.Y. 2015. Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana, *Waste Management*, Vol. 46, December, pp. 15-27.

/14/ Owusu-Nimo F., Oduro-Kwarteng S., Essandoh H. 2019. Characteristics and Management of Landfill Solid Waste in Kumasi, Ghana, *Scientific African*, Volume 3, March, e00052.

/15/ Definition and Characterization of Health-care Waste. Accessed 23.3.2019. https://www.who.int/water_sanitation_health/medicalwaste/002to019.pdf

/16/ Ibid 16

/17/ World Health Organization 1999. Guidelines for Safe Disposal of Unwanted Pharmaceuticals in and after Emergencies. Accessed 14.2.2019. http://www.who.int/water_sanitation_health/medicalwaste/unwantpharm.pdf

/18/ Myjoyonline 2013. FDA destroys expired TOBINCO pharmaceuticals. Accessed 14.2.2019. <http://www.myjoyonline.com/news/2013/december-26th/fda-destroys-expired-tobinco-pharmaceuticals-products.php>

/19/ Shimuzu K., 2006. Environmental Management: 3R (Reduce, Reuse, Recycle) Sustainable Production and Consumption (SPC) Training Course material, presented at 34th International Training Course on Regional Development in Japan, 18May–28 June, Nagoya: United Nations Centre for Regional Development (UNCRD).

/20/ International Committee of the Red Cross: Medical Waste Management. 2011, November.

/21/ World Health Organization, 2015. Health-care waste. Fact sheet N°253. WHO. Accessed 14.2.2019. <http://www.who.int/mediacentre/factsheets/fs253/en/>

/22/ Universal Hospital Group Limited/SMS. 2013. Biomedical Waste Disposal Study Report. UHGL/SMS. Accra, Ghana.

/23/ World Health Organization. Health impacts of health-care Waste. Accessed 26.3.2019. http://www.who.int/water_sanitation_health/medical-waste/020to030.pdf

/24/ GhanaWeb. 2012. Medical Waste Scandal at 37 Military Hospital. Accessed 18.2.2019. <http://www.ghanaweb.com/GhanaHomePage/NewsArchive/Medical-waste-scandal-at-37-Hospital-228488>

/25/ Safe Management of Wastes from Health-care Activities. 2014. World Health Organization, 2nd Edition. Accessed 28.3.2019. http://apps.who.int/iris/bitstream/10665/85349/1/9789241548564_eng.pdf

/26/ Government of Ghana, Ministry of Local Government and Rural Development, Environmental Protection Agency. 2002. Guidelines for the Management of Health Care and Veterinary Waste in Ghana, Final Draft. Accessed 7.4.2019. <http://gehoa.com.gh/getattachment/2189fbe4-7385-4dd6-adeb-93d4271de0c3/11-healthcare-waste.aspx>

/27/ ESO-Consult. 2014. Study on: Scoping opportunities for commercial waste handling in Ghana – Greater Accra, study performed for Delft Imaging Systems and Universal Health.

/28/ Yawson P. 2014. Assessment of Solid Waste Management in Healthcare Facilities in the Offinso Municipality. Master's Thesis, KNUST IDL, Department of Environmental Science. November.

/29/ Pre-Feasibility Study: Scoping opportunities for commercial waste handling in Ghana – Greater Accra. 2014. ESO-Consult. August.

/30/ Tampere University Hospital. Accessed 26.1.2019. [https://www.tays.fi/fi-FI/Ohjeet/Sairaalahygieniaohjeisto/Valineiden_huolto_ja_sairaalasiivous/Jat-teet_ja_niiden_kasittely\(48473\)](https://www.tays.fi/fi-FI/Ohjeet/Sairaalahygieniaohjeisto/Valineiden_huolto_ja_sairaalasiivous/Jat-teet_ja_niiden_kasittely(48473))

/31/ Department for Environment, Food & Rural Affairs, UK. "Healthcare waste." 2013. 9, April. Accessed 21.4.2019. <https://www.gov.uk/guidance/healthcare-waste>

/32/ Asante O.B., Yanful E., Yaokumah E.B. 2014. Healthcare Waste Management; Its Impact: A Case Study of the Greater Accra Region, Ghana. International Journal of Scientific & Technology Research, Volume 3, Issue 3.

/33/ Author's compilation.

/34/ Woima Corporation web site. Accessed 4.4.2019. <https://www.woimacorporation.com/technical-solution/>

/35/ Woima Corporation web site. Accessed 4.4.2019. <https://www.woimacorporation.com/waste-pre-sorting/>

/36/ Woima Corporation web site. Accessed 4.4.2019. <https://www.woimacorporation.com/waste-to-value/>

/37/ Woima Corporation web site. Accessed 4.4.2019. <https://www.woimacorporation.com/decentralized-waste-to-value/>

/38/ Government of Ghana, Ministry of Local Government and Rural Development, Environmental Protection Agency. 2002. Guidelines for the Management of Health Care and Veterinary Waste in Ghana, Final Draft.

/39/ Bless C., & Higson-Smith C. 2000. Fundamentals of social research methods: an African perspective. 3rd Edition, Juta Education, Lusaka.

/40/ Company presentation, Woima Corporation. Accessed 4.4.2019. <https://www.youtube.com/watch?v=NQighH6SfZc>

/41/ Catholic Hospital Battor web site. Accessed 21.5.2019. <http://www.catholichospitalbattor.org/pages/about.php>

/42/ Catholic Hospital Battor web site. Accessed 21.5.2019. <http://www.catholichospitalbattor.org/index.php#>

/43/ Aitchison J. 1998. Access to books and journal articles by postgraduate students on a coursework Masters programme in Information Studies at the University of Natal. Unpublished MIS thesis. Pietermaritzburg: University of Natal.

APPENDIX 1

Interview questions in Finnish case:

- What is medical waste and how it is disposed?
- How the disposal of medical waste has been developed throughout the years?
- Does Finnish hospitals have any on-site incinerators?
- How the medical waste is segregated?
- Are there any specially designed vehicles for the transportation of medical waste?

APPENDIX 2

Questions in questionnaire sent into two hospitals in Ghana:

- Is the waste getting burned (openly?) or dumped to the landfill?
- How much your facility generates medical waste per bed?
- Is there any segregation procedure at the point of generation of waste or before disposal?
- Are there any rules and regulations being followed in the hospital in accordance with the guidelines issued under biomedical waste (management and handling) rules issued by the government and is there any kind of team supervising that these rules are being followed?
- What are the various kinds of containers or bags which are used for the different categories of wastes?