UNIVERSITI PUTRA MALAYSIA

APPLICATION OF MICROWAVES IN HEALTH CARE SOLID WASTE DISINFECTION

ALI BASIM MAHDI

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By

ALI BASIM MAHDI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, In Fulfilment of the Requirements for the Degree of Master of Science

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DEDICATION

To my lord and close friend.....

To my ever-encouraging mother, father and aunt

To my altruistic and beloved wife (Zahraa)

To my lovely siblings (Mohammad, Zahraa and hassan)

To my heart.... lovely son (Shubbar)

To my wife's family (Alhajia, Ali, and Ahmad)

To my friends

To every striving person who is constantly improving aspects of life…

To those who are compassionate towards achieving perfection…

To the consistent pursuers of knowledge aiming for positive change..

A special contribution to my home country Iraq and to Malaysia;

With lots of gratitud

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

APPLICATION OF MICROWAVES IN HEALTH CARE SOLID WASTE DISINFECTION

By

ALI BASIM MAHDI

April 2014

Chairman: Assoc. Prof. Chandima Gomes, PhD

Faculty: Engineering

This thesis intensively investigates the management of solid health care waste (HCW) and technologies available for collection at the generation point, segregation, transportation, storage and disposal. Many national and international environmental and health agencies have revealed their concerns towards these wastes as they may cause serious infectious diseases such as hepatitis, tuberculosis and HIV / AIDS. In addition, it would appear that most of the health care facilities and hospitals do not have adequate management and disposal technology systems which consequently leads to health and environmental problems of hygiene and sanitation in and out of hospital.

Accordingly, the focus point of this thesis is to enhance the performance of the HCW management system, to achieve a high level of cleanliness and to protect humans and the environment from infection generated from HCW. This point arises from the need for appropriate management of that contains disease causing agents. Effective HCW

management and disposal can be performed only by considering various components of the waste management system which are comprehensively investigated in this research.

This study was conducted in two leading government hospitals in Kuala Lumpur, Malaysia, namely Serdang Hospital and Ampang Hospital. The study was initiated by site visits to the two general hospitals in order to investigate the HCW management components, the amount of the waste, the required cost, and the handling and transportation stages. Then, the disposal technology used to destroy the waste was examined and compared with various treatment technologies as the treatment and disposal of HCW are complementary stages to protect the environment.

The results of site visits provided a wealth of data and were very useful to obtain real and practical findings in order to make a decision using information that is as accurate as possible. Based on the results obtained, the HCW management systems in these hospitals, the data collected on the amount of generated waste, and the required cost for managing the systems have been covered and estimated. Due to the bed occupancy rates which are influenced by the geographical location of the hospitals, the figures are higher in Serdang than in the Ampang hospital, and the monthly averages of the HCW generated and the associated management cost are higher for Serdang than for Ampang hospital.

The current study then proceeds to propose microwave technology to be used as a disinfection technology in addition to assistance by shredding the artificial HCW before applying microwave radiation. To evaluate the efficacy of microwave disinfection technique, artificial HCW was inoculated with the most common disease causing

bacteria in HCW, namely, *Staphylococcus aureus* (*S. aureus*) and *Escherichia coli* O157:H7(*E. coli*O157:H7). The assessment of the ability of microwave radiation to kill the selected bacteria was conducted by counting the bacterial cells before and after treatment with respect to the microwave radiation power and the time duration of the process.

The most striking observation to emerge from the bioengineering work is that the bacteria reduced from five million cells per 500 gram of artificial HCW to non-viable bacteria after just 2.5 minutes of treatment with 700 W of microwave power for both species of bacteria. The findings show the influencing factor for killing the investigated bacteria is the microwave radiation; not temperature as bacteria are killed at the best range of temperature for growth.

With this completed, the best solution has been selected to provide the highest confidence in the on-site HCW treatment in order to eliminate cross contamination, and by opting for microwave treatment technology to disinfect HCW on-site and at the point it is generated. By employing the conditions determined in this current study (700 W radiation and 2.5 minutes) which leads to complete bacterial reduction, if implemented, then the scientific result presented in this work can be used as a foundation study to build up an on-site HCW treatment machine by using microwave radiation as the disinfecting technology.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

APLIKASI GELOMBANG MIKRO UNTUK PEMBASMIAN SISA PEPEJAL BUANGAN PENJAGAAN KESIHATAN

Oleh

ALI BASIM MAHDI

April 2014

Chairman: Assoc. Prof. Chandima Gomes, PhD

Fakulti :Kejuruteraan

Tesis ini menyelidik secara intensif pengurusan bahan buangan pepejal penjagaan kesihatan (HCW) dan teknologi sedia ada untuk pengumpulan pada peringkat penjanaan, pengasingan, pengangkutan, penyimpanan dan pelupusan. Banyak agensi alam sekitar dan kesihatan di peringkat tempatan mahupun antarabangsa yang menyuarakan kebimbangan terhadap sisa-sisa tersebut kerana mereka mampu menyebabkan jangkitan penyakit seperti hepatitis, tibi dan HIV/AIDS. Tambahan pula, kebanyakan hospital dan fasiliti kesihatan tidak mempunyai sistem teknologi pengurusan dan pelupusan yang mencukupi dan ini akan menyebabkan masalah kesihatan dan alam sekitar dari segi kebersihan dan sanitasi dalam dan luar hospital.

Sewajarnya, fokus tesis ini adalah untuk memperbaiki prestasi sistem pengurusan HCW bagi mencapai tahap kebersihan yang tinggi dan untuk melindungi manusia dan alam sekitar daripada ancaman penyakit berjangkit yang disebabkan oleh HCW.Fokus ini terbentuk kerana wujudnya keperluan untuk sistem pengurusan yang mampu menyekat agen-agen penyakit berjangkit. Pengurusan dan pelupusan HCW secara efektif hanya

boleh dilakukan dengan mempertimbangkan pelbagai komponen sistem pengurusan bahan buangan yang akan disiasat secara menyeluruh dalam penyelidikan ini.

Penyelidikan ini telah dijalankan di antara dua hospital kerajaan terulung di kawasan Kuala Lumpur iaitu Hospital Serdang dan Hospital Ampang. Penyelidikan ini dimulakan dengan lawatan ke hospital-hospital tersebut untuk mengkaji komponen-komponen pengurusan HCW, jumlah bahan buangan, kos yang diperlukan dan peringkat pengendalian serta pengangkutan. Kemudian, teknologi pelupusan yang digunakan untuk membasmi sisa-sisa buangan tersebut telah diperiksa dan dibandingkan dengan pelbagai teknologi rawatan kerana rawatan dan pelupusan HCW adalah dua peringkat yang saling melengkapi untuk perlindungan alam sekitar.

Banyak data telah diperoleh hasil daripada lawatan-lawatan tersebut.Data tersebut adalah amat berguna ketika membuat keputusan untuk mengguna maklumat yang setepat mungkin. Daripada data yang diperoleh juga, maklumat-maklumat berkenaan sistem pengurusan HCW di hospital-hospital tersebut, jumlah bahan buangan yang dihasilkan, dan kos yang diperlukan untuk pengurusan sistem-sistem tersebut telah dianalisis dan dianggarkan. Disebabkan kadar penghunian yang dipengaruhi faktor lokasi hospital, purata bulanan jumlah penghasilan HCW dan kos berkaitan dengan pengurusan adalah lebih tinggi di Hospital Serdang berbanding dengan Hospital Ampang.

Peringkat seterusnya kajian ini ialah untuk mencadangkan teknologi gelombang mikro yang akan digunakan sebagai teknologi pembasmian serta pencarikan HCW tiruan sebelum disinarkan dengan gelombang mikro. Demi menilai keberkesanan teknik

pembasmian gelombang mikro, HCW tiruan akan disuntik dengan bakteria-bakteria umum yang mampu menyebabkan penyakit berjangkit seperti HCW *Staphylococcus aureus*(*S. aureus*) dan *Escherichia coli* O157:H7 (*E. coli* O157:H7). Penilaian keupayaan sinaran gelombang mikro dalam pembasmian bakteria terpilih telah dilakukan dengan mengira bilangan sel bakteria sebelum dan selepas teknik rawatan tersebut berkenaan dengan kuasa dan tempoh proses sinaran gelombang mikro.

Penemuan yang paling menarik daripada kajian biokejuruteraan ini ialah bakteria sebanyak 5 juta sel per 500 gram daripada HCW tiruan telah berjaya dibasmi selepas rawatan selama 2.5 minit pada kuasa 700 W bagi kedua-dua spesies bakteria tersebut. Hasil kajian tersebut menunjukkan bahawa faktor utama yang mempengaruhi keberkesanan pembasmian bakteria yang diselidik ialah sinaran gelombang mikro dan bukannya suhu.

Dengan tercapainya matlamat tersebut, kaedah penyelesaian yang terbaik telah dipilih untuk memberikan keyakinan tertinggi terhadap rawatan HCW secara *in situ* bagi menghapuskan pencemaran silang dan dengan memilih teknologi rawatan gelombang mikro untuk membasmi HCW secara *in situ* dan di lokasi penjanaan HCW. Akhir sekali, dengan mempertimbangkan syarat-syarat yang ditemukan hasil penyelidikan ini yang akan membawa kepada pembasmian bakteria secara menyeluruh, jika dilaksanakan, maka hasil kajian saintifik yang telah dibentangkan ini boleh digunakan sebagai asas kajian untuk membina mesin rawatan HCW *in situ* dengan menggunakan sinaran gelombang mikro sebagai teknologi pembasmian

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I certify that a Thesis Examination Committee has met on (date of viva voce) to conduct the final examination of ALI BASIM MAHDIon his thesis entitled "APPLICATION OF MICROWAVES IN HEALTH CARE SOLID WASTE DISINFECTION**"**in accordance withthe Universities and University Colleges Act 1971 and the Constitution of theUniversiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committeerecommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Nasri bin Sulaiman, PhD
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Maryam bt.Mohd. Isa, PhD
Senior lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

RoslinaMohdSidek, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Zulkurnain Abdul-Malek, PhD
Associate Professor
Institute of High Voltage and High Current (IVAT)
UniversitiTeknologi Malaysia
Malaysia
(External Examiner)

NORITAH OMAR, PhD
Associate Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 19 MAY 2014

This thesis was submitted to the Senate of Universiti Putra Malaysia and has beenaccepted as fulfillment of the requirement for the degree of Master of Science. Themembers of the Supervisory Committee were as follows:

Chandima Gomes, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

MohdZainalAbidin b. Ab. Kadir, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Fatimah Abu Bakar.2, PhD
Professor
Faculty of pFood Science and Technology
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUA, PhD
Professor and Dean
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Universiti Putra Malaysia

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Signature:

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Signature:

Name of

Member of

Supervisory

Committee:

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LIST OF ABBREVIATIONS

ANOVA	One-Way Analysis of Variance
CWMS	Clinical Waste Management System
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency
(G+)	Gram-Positive
(G-)	Gram-Negative
HCW	Health Care Waste
HIV / AIDS	Human Immunodeficiency Virus Infection / Acquired Immunodeficiency Syndrome
HSC	Health and Safety Commission
MSA	Mannitol Salt Agar
PHSS	Privatized Hospital Support Service
S. aureus	*Staphylococcus aureus*
SEM	Scanning Electronic Microscope
SPSS	Statistical Package for the Social Sciences
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Introduction

One of the most significant environmental issues under discussion is waste. In general, governments focus on improving environmental protection and the use of natural resources in a way that is compatible with the environment and also the economic and social factors.

The world mainstream is focussed on disposables in almost all aspect of life in addition to new trends in recycling, although this is still small at this point in time. This could possibly be due to the fast pace of life, technology, hectic schedules and a shortage of time, especially for a developing country such as Malaysia which has witnessed many essential changes over the last fifty years. These significant improvements have allowed the people to grow in affluence and have resulted in greater centres of population concentration. However, at the same time more waste is generated. Malaysia has experienced phenomenal economic developments whereby it has undergone massive changes from an agricultural to a manufacturing-based economy.

The whole world is facing the waste management issue regardless of whether a given country is developed or developing. Therefore, this issue really needs combined efforts by national, international, governmental and non-governmental agencies in finding viable solutions.

Numerous published research studies emphasize how waste is problematic especially over the past 30 years (Lee and Huffman, 1991, Lee and Huffman, 1996, Lee and Huffman, 1996, WHO, 2007, Ferreira and Teixeira, 2010, Tudor et al., 2010, Hossain et al., 2011, Patwary et al., 2011, Anabela, 2012, Karmperis et al., 2012, Komilis et al., 2012, Omar, 2012). This problem obviously started in developed countries such as the U.S. and U.K. in the 80s where massive amounts of waste were thrown near beaches when the waste caused many illnesses (William et al., 1992, Dutzik and Group, 2010, Chen et al., 2013, Kuepouo, 2013, Moreira and Gunther, 2013).

The Malaysian government has established firm measures to address rules and regulations related to environmental protection by the Environmental Act 1974. The main objectives of the Environmental Act 1974 are to prevent and reduce pollution as much as possible, to protect the Malaysian environment and then protect the Malaysian people. At the same time this act has ensured a parallel development with the industrial aspect as well.

Waste can be defined as useless, harmful and/or unwanted materials that arise from any activity, whereas, waste that comes from health care activities needs a greater and special management approach in handling. Any waste containing human or animal body parts infectious agents, sharp edges, pharmaceutical, radioactive or chemical materials that arise from health facilities, are all considered as a health care waste (HCW). In hospitals or health care centres two main streams of waste are generated. With regard to the content of these wastes, if these contain viable microorganisms then these are referred to as infectious, otherwise they are called non-infectious wastes. Furthermore, there are several classifications depending, for example, on state, i.e. solid-state, liquid-

state or gases-state wastes. There is also classification based on the location where wastes are generated, for example pharmaceutical waste which is generated from pharmaceutical units etc. However, HCW needs to be handled carefully and also must not be considered as general waste. Many organizations and agencies have established regulations and rules to deal with this hazardous waste. In order to achieve a high level of hygiene in a health care environment, these organizations and agencies concerned have divided the management procedure into several steps. These steps enable good supervision and applicable implementation. The management steps start from where the HCW is generated, through segregation, transportation, storage, external transportation, and finally to disposal.

Although drastic improvements have been made in the health care field, numerous fatalities have occurred and furthermore many natural resources have been affected by HCW due to the content of these wastes from microbes, germs, pathogens, viruses, bacteria to disease causing agents. An example of a major cause of patient morbidity and mortality is antibiotic resistant organisms(Tudor et al., 2010). Moreover, a study has proven that more than five million people die each year as a result of diseases that arise from incorrect handling of waste and the majority of these are children (Akter, 2000).

Despite their long clinical success, infections arising from health care units have increased in number due to problems in safeguarding and properly disposing of infectious waste. Infection control is one of the most critical issues in hospital environments due to its controlling and limiting the spread of microorganisms. Health care waste is considered as an infectious carrier, so it requires an optimum management style to minimize the spread of infection. In order to clarify how crucial the matter is,

around 35 million patients annually are admitted to hospitals in the United States of which at least 2.5 million of those patients will acquire at least one type of health care-associated infection (Al-Rawajfah et al., 2012). A considerable amount of literature has been published regarding bacteria for reasons such as their omnipresence, their use for experimental work and their ease of handling compared to other microorganisms. *Staphylococcus aureus* (*S. aureus*) as a Gram-positive (G+) and *Escherichia coli* (*E. coli* O157:H7) as a Gram-negative (G-) are the most common bacteria not just in HCW but also in different locations such as hospital toilets and food waste and where they cause many illnesses in humans (Chen et al., 2012, Threedeach et al., 2012).

The amount of HCW has increased incrementally over the years and HCW management needs much more attention to achieve acceptable hygiene levels that protects humans and the environment. From the economic point of view, the segregation stage in waste management is essential because it keeps other or general waste from mixing with HCW and thus reduces the amount of infectious waste that has to be dealt with. From the technical and engineering standpoint, the treatment technology has not improved by leaps and bounds as in other disciplines. Incinerators are still the most popular technology used across the whole world (Chen et al., 2013). There is no doubt however of how many problems arise from this treatment method whether to humans or to the environment as a result of the smoke and ash (Li et al., 2012, Nzihou et al., 2012, Rajor et al., 2012). By-products are generated from incomplete combustion containing Polycyclic Aromatic Hydrocarbons and this has been verified as containing high carcinogenicity, high teratogenicity, mutagenicity and genotoxicity (Chen et al., 2013).

This work is conducted to explain the necessity of perfecting HCW management by establishing a new management style for HCW and providing a baseline to modify the treatment technology by using microwave radiation.

1.2 Health Care Waste Background

Safety is at the heart of understanding the health care environment. Hence, one environmental issue declared as hazardous waste is in the form of Solid HCW. Issues of improving HCW management are receiving increased attention across the whole world since hospitals and healthcare centres generate tons of solid HCW each year and due to the mounting evidence of the disastrous impact of such waste on both humans as well as the environment.

Recent developments in the field of health care have heightened the need for improved HCW management. The issue did not receive sufficient and particular focus of attention until 1980 when two events occurred. The first was when syringes washed up on a New Jersey beach and second in New York harbour when a huge amount of HCW was dumped in an unlawful manner. In UK, a similar event occurred on a British beach which was proposed as the reason for an outbreak of hepatitis B among people using the recreational waters (Dutzik and Group, 2010, Bernard, 2012). Some references indicate that since the development of disposable medical products in the early 1960s, the problem of HCW has arisen in hospitals as well as health care units(Bernard, 2012). Before that, reusable products included items such as bandages, syringes, and surgical blades; they were sterilized or disinfected prior to reuse. Thus the amount of HCW products was not as much as today. In 2000, the World Health Organization(WHO)

estimated that morbidity rates of 21 million hepatitis B virus (HBV) infections, two million hepatitis C virus (HCV) infections, and at least 260 000 HIV infections were because of improper solid HCW management by the reuse of contaminated syringes. WHO reported another result regarding 22 developing countries in 2002 that the proportion of health care facilities that do not use proper waste disposal methods ranges from 18 % to 64% (WHO, 2011). In addition, many environmental and natural resources issues have arisen from improper HCW management.

Most publications discuss the amount of HCW generated per bed per day. This is essential to create a database to plan for an effective management style, but the real situation on the ground needs practical measurements. Examples of such bear borne essential measurements are studying the waste management to discover weak stages of implementing the management strategy, studying staff attitudes to waste management to remove staff obstacles, examining the waste treatment methods to define less polluting techniques, and reviewing finances to determine the economic limits. Hence this study is undertaken basically to design a treatment technology to improve HCW management.

1.3 Problem Statement

In order to provide an excellent level of HCW management at minimal required cost with less cross contamination and to be more environmental friendly and applicable across different scales, HCW management needs to be re-examined and re-evaluated with respect to safety, efficacy, and accuracy. Moreover, the time needed for handling the waste should be reduced.

Addressing various challenges and opening new issues such as the rising amount of HCW generated, improper management, and ineffective practices of HCW exposes health workers, the public and also the environment to health and safety hazards. In addition, the current HCW system is very costly and the current incinerator treatment technology is perceived as a source of pollution for the surrounding area.

Health care waste is considered to be the most harmful type of hazardous waste because of its infectious characteristic. It is necessary to search for ways to improve the HCW management system in order to eliminate or at least minimize the harm done by HCW to humans and the environment.

1.4 Goals and objectives

This thesis aims to enhance the performances of the HCW management system in hospitals, which leads to protecting people whether medical staff, patients or visitors, and also to preserve natural resources and the environment on the other hand. Hence, the objectives of this research can be stated as below:

1. To identify the weak points of HCW management systems, methods of handling, and the amount of HCW generated daily.

2. To isolate and identify the microorganisms that exist in HCW which are generated in hospital Serdang and Hospital Ampang.
3. To apply microwave radiation directly at the post stage of waste generation.

1.5 Scope of Research

The research was conducted to improve different scales of HCW management by proposing an on-site solid HCW treatment machine. Therefore, it involves with comprehensive research for solid HCW management. In other words, it is a study of solid HCW from the generation point 'cradle' to the final resting point 'grave' and it gives special attention to microwave treatment technology. So that, improve HCW management in primary, secondary, general, and/or specialist health care facility leads to decrease the HCW dangers of infection agents present in HCW by using microwave treatment technology.

1.6 Significance of Research and the Knowledge Gap

Discussion of HCW requires objective measurements to address the massive amount of such waste which poses a serious problem. Previous studies cover either the HCW management elements and styles, or HCW management technologies (WHO, 2007, Kuepouo, 2013). Although, HCW management consists of treatment elements in steps, it is always discussed only briefly. Regarding HCW management, there is no clear correlation between the amounts of HCW generated and bed occupancy rates in the health care facilities used for the research. On the other hand, the majority of researchers have deeply studied incineration as a common treatment technology. Nevertheless incineration technology remains highly controversial. If the opportunity is not taken up to use smart technologies such as microwave applied in the field of waste treatment, not just for HCW treatment, the problem remains unsolved. This research investigates the

ability to utilize an on-site HCW treatment machine to increase worker safety, lessen public health risks and lower the inherent costs.

1.7 Organization of Thesis

This thesis addresses practical problems in HCW management and suggests the use of applying microwave radiation on-site for HCW treatment and at the point it is generated. A methodical study of a HCW management system will be introduced.

Chapter 1 presents an introduction and a brief review of the HCW hazards and potential risks to people and the environment. It also includes the problem statement, the objectives of this study, scope of research, the significance of the research and the knowledge gap.

Chapter 2 discusses the related technical background. It begins with hazard waste, HCW, general information and parameters about hospitals, and a definition of solid HCW. Health care waste categories are reviewed. The basic concept of HCW management, starting from the generation stage to the stage of disposal is discussed. In comparison with other issues, treatment technologies involved are also mentioned in this chapter. The microbiological field is discussed with general information about nosocomial infection “hospital-acquired infection”, bacterial classification and staining. Microwave technology used as a treatment utility and related works are the last section discussed it this chapter. In addition, the motivation for utilizing microwave radiation as a smart HCW treatment technology is presented.

Chapter 3 defines the materials used and proposed methods. The underlying idea of reducing the risks that come from solid heath care waste is introduced. The methods employed are divided into two mainstream categories based on the workspaces. Site visits to obtain reliable data is the first method used. Secondly, other methods are conducted in different laboratories and named as bioengineering work. They can be described as an assessment of the ability of microwave radiation to destroy bacteria with different powers and time durations, and as a technique to maximize the temperature elevation of exposed disposal items to microwave radiation with various soaking materials.

Chapter 4 focuses on the results obtained and presents in three sets of findings. The first set is the results from site visits to two hospitals, streams of HCW management, amounts of HCW generated in each one, and other observations. The second set discusses the effect of microwave radiation on two types of bacteria in HCW with respect to power and time. Finally, this set reports the heating effect of microwave radiation on disposable materials, based on various soaking mediums.

Chapter 5 provides conclusions and summarizes the thesis, followed by a discussion of the main contributions of the proposed work. Also, it presents several directions and recommendations for future work to complete and optimize the proposal.

1.8 Summary

This chapter states that HCW is an important issue and at the same time it still really needs more attention. This chapter provides a brief introduction to HCW and related

issues with the management and treatment, objectives and knowledge gap, and finally the organization of the thesis is given to facilitate the understanding of the readers.

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