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Dissertation submitted as partial fulfillment for requirement of the MSc in Biomedical Engineering

Study on recycling of plastic waste in dialyses department

دراسة عن تدوير النفايات البلاستيكية من أقسام غسيل الكلى

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DEDICATION

"Don't ever give up.
Don't ever give in.
Don't ever stop trying.
Don't ever sell out.
And if you find yourself succumbing to one of the above for a brief moment, pick yourself up, brush yourself off, whisper a prayer, and start where you left off. But never, ever, ever give up."
Richelle E. Goodrich abovementioned words often inspired me throughout my master study, whenever my sense of determination weakened I always recline and derived determination from whom I dedicate to them this dissertation.

I dedicate my dissertation work to my Family, classmates and many friends who have supported me throughout the process. I will always appreciate all they have done.

A special feeling of gratitude to my loving parents, Adam and Malkah whose words of encouragement and push for tenacity ring in my ears. My sisters Rania, Fatima, Reem, Ammar and Ahmed have never left my side and are very special.

I also dedicate this work and give special thanks to my best friend Mohamed Salih Magzoub and my wonderful daughter Haneen for being there for me throughout the entire master program. Both of you have been my best cheerleaders.

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Abbreviations

AMDR	Association of Medical Device Reprocessors
CUBEInC Campus	Clemson University Biomedical Engineering Innovation
CNS	Central Nervous System
EPA	Environmental Protection Agency's
FDA	Food and Drug Administration
FIFO	First In First Out
HIV	Human Immune Virus
ICRC	International Committee of Red Cross
MWTA	Medical Waste Treatment Act
OSHA	Occupational Safety and Health Administration
PEL	Permitted Exposure Level
SSMO	Sudanese Standards and Metrology Organization
UPS	Uninterrupted Power Supply
UV	Ultra Violet
WHO	World Health Organization

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Abstract

The main objective of this study is to find an alternative method for plastic medical waste treatment instead of incineration because plastic burning is harmful for the ecology and public health, beside the economical advantage of plastic recycling.

The study is applied by using the sodium hydroxide 10% concentration for chemical disinfection the plastic medical waste were flooded in sodium hydroxide for six hours, and the expected results had been obtained.

The proposed system for plastic waste disinfection and granulation process was successfully designed in a form of block diagram.

المستخلص

الهدف الرئيسي من البحث هو إيجاد طريقة علمية آمنة لمعالجة النفايات الطبية البلاستيكيه بدلا من الحرق لأن حرق البلاستك له أثار ضاره على البيئة وصحة الإنسان وذلك بغرض إعادة تدوير البلاستك والإستفادة من العائد المادي الناتج من عملية إعادة التصنيع.

لتنفيذ المشروع تم إستخدام محلول هيدروكسيد الصوديوم بتركيز ١٠% بغرض التعقيم الكيميائي. حيث تم غمر للنفايات الطبية البلاستيكية في محلول الصوديوم هيدروكسيد لمدة ٦ ساعات. وقد تم الحصول على النتائج المطلوبة.

وقد تم تصميم مخطط توضيحي لعملية تعقيم النفايات الطبية البلاستيكية وتحبيبها.

Chapter one

Introduction

Medical wastes are wastes generated by health care activities including a broad range of materials, such as needles and syringes to soiled dressings, body parts, diagnostic samples, blood, chemicals, pharmaceuticals, medical devices and radioactive materials.

Poor management of health care waste potentially exposes health care workers, waste handlers, patients and the community at large to infection, toxic effects and injury, as well as polluting the environment. It is essential that all medical waste materials are segregated at the point of generation, appropriately treated and disposed safely [1].

Incineration was the almost exclusive method of treating hazardous medical waste. In 1994, the U.S. Environmental Protection Agency's (EPA) and Related Compounds identified medical waste incineration as the single largest source of dioxin air pollution in the United States of America. In 1997, the EPA promulgated regulations for existing and new incinerators, setting new emission limits (by using filters). In 2000, stricter emission limits for medical waste incinerators were introduced in the European Union. This resulted in the closure of many incinerators and an increase in the number of non- incineration facilities for treating infectious medical waste [2].

Incineration produces both toxic air emissions and toxic ash residue. The air emissions affect the local environment, and in many cases, may affect communities hundreds or thousands of miles away. The ash residue is sent to landfills for disposal, where the pollutants have the potential to leakage into groundwater. In addition to releasing the pollutants contained in the waste stream to the air and into the ash.

1.1 Problem statement:

Incineration produces both toxic air emissions (dioxin, furans) and toxic ash residue. The air emissions affect the local environment, and in many cases, may affect communities hundreds or thousands of miles away. The ash residue is sent to landfills for disposal, where the pollutants have the potential to leach into groundwater.

1.2 Objectives of the study:

The general objective of this study is to find an environment friendly solution for plastic medical waste treatment for recycling purpose. There is another secondary objective economical impact from plastic medical waste recycling.

The plastic used in medical devices is a special type of plastic with high specification and it is imported from outside. One ton of pure plastic costs about 6000$.

In order to maximize the benefits of non-incineration technologies, a strategic framework is presented of which the underlying elements are waste minimization and segregation. By implementing a program that includes segregation, source reduction, recycling, and other pollution prevention techniques, one can reduce the amount of infectious waste that needs to be decontaminated. The framework also entails the implementation of an effective waste collection, transport, and storage system; development of waste management and contingency plans; occupational safety and health considerations; and proper sitting of the non-incineration technology. The medical waste management comprises the following process:

i. Waste minimization.
ii. Waste segregation.
iii. Waste storage.
iv. Waste transportation.
v. Waste treatment.
vi. Waste disposal.

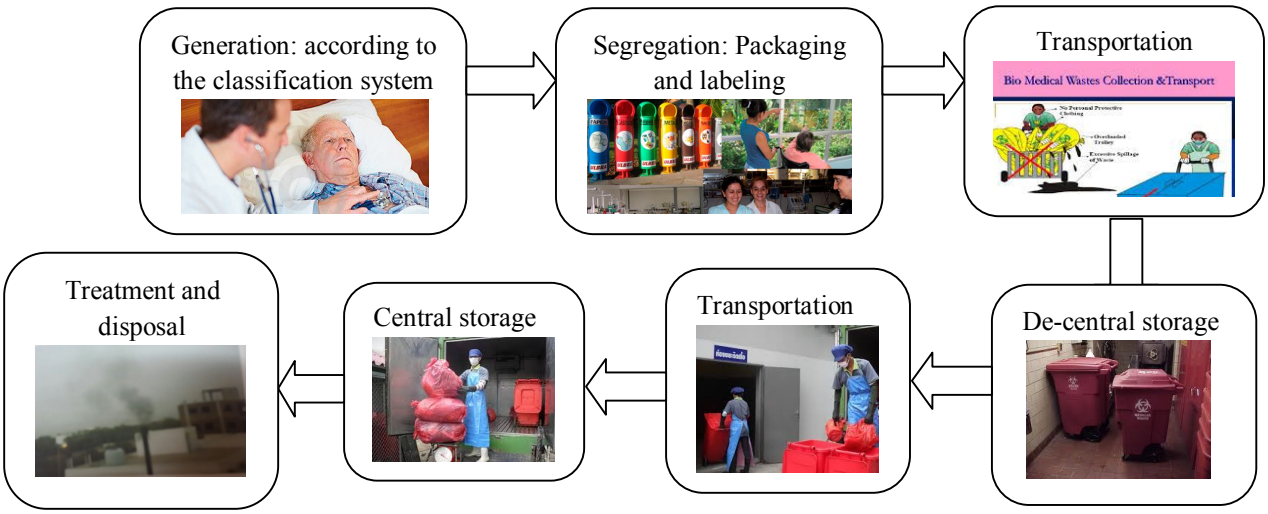

Figure 1.2: Show a strategic framework for medical waste collection, transportation, and storage system.

1.3 Medical waste treatment

The choice of treatment and disposal technique depends on a number of parameters; the quantity and type of waste produced, whether or not there is a waste treatment site near the health care center, the cultural acceptance of treatment methods, the availability of reliable means of transport, whether there is enough space around the health care center, the availability of finance, material and human resources, the availability of regular supply of electricity, whether or not there is a national legislation on the subject, the climate, groundwater level, etc. The method must be selected with the view to minimizing the negative impact on general health and clean environment.

Where there is no appropriate treatment infrastructure in the vicinity, it is the responsibility of the hospital to treat or pre treat their wastes on site. This also has the advantage of avoiding the complications involved in the transport of the hazardous substances.

The following treatment or disposal technique may be used for hazardous medical waste, depending on the circumstances and the type of waste concerned:

1.3.1 Disinfection:

i. Chemical: by adding disinfectants such as chlorine dioxide, sodium hydroxide, peracetic acid, ozone.

ii. Thermal: low temperature (100-180°C) or high temperature (200-1000°C).
iii. Irradiation: UV rays, electron beams.
iv. Biological: Enzymes.

1.3.2 Mechanical processes: shredding.

1.3.3 Encapsulation.

1.3.4 Burial

The appropriate treatment and disposal technique depend on the advantages and disadvantages of all the above techniques [2].

1.4 Hypothesis:

The idea of this research stemmed from recycling management for the huge amount of plastic medical waste coming from haemo-dialysis department. This research was based on chemical treatment for plastic medical waste; by using the Sodium Hydroxide (NaOH) 10% concentration because it will not affect the properties of the plastics polymers and it has the ability to decompose the cells. Sodium hydroxide can be considered as the best solution for the abundance and cheap price if it basses the laboratory tests.

1.5 Thesis layout:

The research contains 5 chapters; chapter one is an introducing chapter addresses briefly the adverse effects of plastic waste incineration on the environment, the alternative treatment options and the main objective of the research. Chapter two addresses the theoretical foundation of the medical waste recycling locally and internationally. Chapter three talk about the methodology of the research. Chapter four addresses the plastic recycling system. And the last chapter addresses the conclusions and recommendation of the research.

Chapter Two

Theoretical Foundation

2.1 Literature review:

Plastic medical waste incinerators emit toxic air pollutants and are a major source of dioxins and furans in the environment. Dioxins and furans are class of chemicals called Organochlorines. They are two classes of chemicals which are made from chlorine, and from hydrogen and oxygen and when they are released they are some of the deadliest toxins known to human. Small quantities of dioxins and furans can enter the body and stay there for a long time and can also pass on from mother to child that means they are inter-generational toxics; dioxins and furans are also hormones remix and long term effect can be cancer. They also have long distance transport capability and so they can spread over boarders. At the global level there is the new Stockholm Convention deals with chemicals like dioxins and furans and there is a section which talks about unintended products of incineration, so there is a global agreement under the treaty and a lot of developing countries are signatory to that treaty to reduce the amount of dioxins and furans to the minimum [3]. They also generate ash that is potentially hazardous. In 1997, the EPA promulgated regulations for new and existing medical waste incinerators. The EPA requirements in effect increase the cost of incineration. Faced with increasing public opposition to incinerators, many health care facilities are searching for ideal alternatives of treatment methods.

Khartoum is highly populated city about 60% of the total country population lives there. More than 5000 health care facility in front of these number we have only one working incinerator located in Omdurman Hospital of Maternity which is located in the center of the city the chimney of the incinerator is about 5 meters height from the ground level (or 2 meters above the first flour) and this incinerator emits a highly toxic gases as measured in the next table. In 2013 at Sudan University of science and technology conducted a research (ed Elias et al. 2013) in medical waste management and disposal by measuring the emitted gases near the incinerator and in the house in front of the hospital. The readings were taken by the Modular Indoor Air Quality reader these

values were compared with the permitted exposure level by OSHA and the following table was drowned:

Table 1.1: values of the measured gases near the incinerator and in house in front of the hospital compared with permitted exposure level (PEL) by OSHA. SSMO= Sudanese Standards and Metrology Organization [3].

Location	**HCl 0.625ppm /PEL OSHA**	**No2 0.625ppm /PEL OSHA**	**SO2 0.625ppm /PEL OSHA**	**NH3 6.25ppm /PEL OSHA**	**TVOCs 625ppm /PEL OSHA**	**Co2 625ppm / PEL**	**H2S 6.25ppm /PEL OSHA**	**CO 6.25ppm /PEL OSHA**	**Dioxin 1,4 0.0000125ppm /PEL OSHA**
	-	**0.03ppm /PEL SSMO**	**0.02ppm /PEL SSMO**	**-**	**-**	**-**	**0.0012ppm /PEL SSMO**	**3.25ppm /PEL SSMO**	**-**
location 1 near incinerator	1.52	0.32	0.0	0.2	2.3112	2368.8	1.44	26.68	0.0356
Location 2 house near the hospital	1.56	0.416	0.28	0.04	1.55	2337.6	0.32	12.24	0.0021

The above table illustrate that there is big variation between the emitted gases and the permitted exposed level specially in Co and HCl.

Although, the emitted toxics is harmful for the environment and the

public health the other main problem more than 90% of the hospitals in Sudan are not segregating the medical waste properly at the point of generation. Thus huge percent of medical waste goes with the municipal waste so it is exposed to the homeless who don't know the risk of medical waste handling [4].

Figure 1.1: Poor medical waste management expose homeless to risk of infection.

The degradation of waste leads to spread of toxics into the water sources whether ground water or surface water beside the soil pollution which affect the food cycle in addition to drinking water contamination thus it represent a hazardous effect on people health.

Last year the Egyptian authorities arrested 43 tons of plastic medical waste in five stores. The plastic wastes are washed and grind then transferred to plastic granules which sold to factories of toys, disposables like dishes and cups, and other plastic products [5].

2.2 History of medical waste recycling:

Despite the accelerating development and investment in recycling industry but the recycling of medical waste have less opportunity. In 1988 when medical wastes washed up on several East Coast beaches, concern over the potential health hazards prompted Congress to enact the Medical Waste Tracking Act (MWTA). Specifically, this act, which amended the

Solid Waste Disposal Act. But it was the starting point for medical waste recycling. Many bodies and associations have been established.

Thus medical devices recycling are a chance for reduction in expenses for the hospital and less waste in the landfill. Hence the idea of formation responsible entity to follow up the cleaning and decontamination process of the equipments before reusing. And formed the Association of Medical Device Reprocesses(AMDR)[6].

In August 2000, the Food and Drug Administration (FDA) established the first reprocessing regulations by issuing a guidance document: "Enforcement Priorities for Single-Use Devices Reprocessed by Third Parties and Hospitals." According to the FDA guidelines, essentially, any business or hospital that reprocesses a medical device would be classified as a manufacturer. However, because many hospitals had neither the resources nor the interest in taking on the manufacturer designation, they turned to third-party companies and the medical device recycling and reprocessing industry was created.

Then Clemson University Biomedical Engineering Innovation Campus (CUBEInC) began offering a Medical Device Recycling and Reprocessing Certificate Program in 2012. Within a yearlong cycle, students from mechanical, electrical, and industrial engineering disciplines learn how to design medical devices that clean with reuse capabilities.

More recently it have been noticed that a obvious increase in the numbers of people with kidney failure and we all know that hemodialysis or peritoneum dialysis is the only solution until finding a matching donor. More over the patients undergoing dialysis from two to three times weekly. And each time the patient need a new disposable dialysis set. Taking the huge amount of the plastic waste coming from the hemodialysis department on a daily base regardless the plastic salt containers which is used in dialysis process and the normal saline bags? These huge quantities of plastic waste each session if treated by incineration it is able to emit toxic gases to pollute the entire city and we know that there is only one working incinerator located in Omdurman Hospital of Birth which is located in the center of the city. Thus the idea of research arises to solve the environment pollution problem then take the financial advantage from the plastic recycling.

There are two types of plastic waste inside the hospital ***nonhazardous*** plastic waste which are free from patient contact and contamination this type about 85% according to an article called "Solid Waste Reduction in U.S hospitals- case studies" published in association with the international federation of hospital engineering; and ***hazardous*** wastes which comes in contact with the patient. This research aim to treat the whole 100% of plastic waste for recycling purpose except small quantities which are contaminated by hebetates or HIV these highly hazardous wastes should be treated by incineration or other safe disposal way because handling will expose the workers to the risk of infection.

The lack of medical waste treatment facilities in Khartoum state or Sudan, at large led to the spread of medical waste disposal with the municipal waste, or keeping it for long periods in open places or under direct sunlight; making it exposed to insects and pets or for weak souls people who are working in irregular recycling of medical waste, and thus the spread of diseases and environmental pollution. The responsible parties of municipal wastes promise to impose sanction on health care facilities that dispose the medical waste with the municipal wastes, but for lack of other options or alternatives to change the situation remained unchanged till last march.

On Thursday 19/March/2015 opened at Khartoum the capital of Sudan, the largest factory in Africa for recycling medical waste at a cost of $ 2 million, and the production capacity is estimated by 20 tons per day, while Khartoum produced about 10 tons of waste per day from 5 thousand unit provides medical and therapeutic services. The factory was built in partnership with the Saudi Gulf Environmental Protection "Sipco environment"[7].

The manufacture which opened lastly in order to protect the environment by providing the latest equipment and devices developed globally for the medical waste treatment and recycling, are responsible to transfer waste from hospitals to the factory, then different types of treatment and dispose of scientifically should be conducted, but the training of workers to sort waste and put it in the right place is responsibility of ministry of health in Khartoum state, and it is important step to guarantee the success of the project outcomes.

Figure 2.1: The thermal treatment unit in medical waste treatment and recycling factory

Chapter Three

The research methodology

3.1 Data collection and sampling

To test current practice against the historical record a personal interview will be conducted to gather primary source data from hospitals, medical consumable factories, and factories currently engaged in the production of plastic granules.

The survey will collect qualitative data on the ability of plastic waste treatment for recycling purpose. A systematic random sample of plastic waste will be drawn from different hospitals for laboratory investigations.

3.2 Data analysis

Comparison for qualitative laboratory investigation for bacteria, fungi, and parasite should be used for data analysis.

3.3 System Design

As the number of hospitals engaged in the defined activity undefined yet thus we will use the block diagram method for system design.

3.4 Research methodology flowchart:

The following flowchart is a formalized graphic representation of the plastic medical waste recycling process, to define the relationship between the problem solving steps. The idea of this study start by the observation of medical waste amounts stored in the roofs of buildings and squars this observations generate questions for the problem analysis, then the hypothesis and prediction should be drwn and the laboratory experiments should be conducted to illustrate the hypothesis and move to system design or go back and develop new hypothesis.

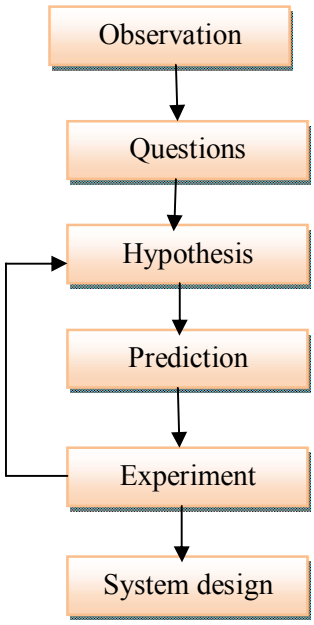

Figure3.1: show a flow chart for the research methodology

3.5 Protocol of laboratory experiment:

This research goes throw different phases of treatment and tests as following:

3.5.1 The sample collection:

The samples are collected from dialysis centers mainly from the dialysis set after the heamo-dialysis treatment process. The samples were taken from five different dialysis centers. After the cleaning phase a part of the used hemo-dialysis sets were cuts from the patients who are screened negatively from HIV, and hepatitis. Because the research did not target the positively screened ones. For the sample collection I used surgical gloves and disposable scalpels were used. Each part of set was taken in separate sealed plate dish.

3.5.2 Preparation of sodium hydroxide 10% concentration(NaOH):

500ml of distilled water was poured into a 1000ml glass beaker. 50g of sodium hydroxide salt was then added to the water.

To calculate the molarities the following equation:

$$Percentage\ concentration(\%) = \frac{weight\ of\ substance\ in\ gramsx100}{volume}$$

The mixture was gently shaken for two minutes. Changes in mixture temperature and transparency during our mixing process

were observed. The translucency and temperature of the new solution returned to normal state after 15 minutes of settling.

3.5.3 Preparation of blood agar media:

100ml of readymade blood agar media autoclaved to dissolve and then poured into a 500ml glass beaker. Small amount of the blood then add to the media. The mixer was gently shaken for two minutes near the flame to avoid the contamination. Changes in mixture color and transparency during the mixing process were observed.

3.5.4 Preparation of chocolate agar media:

100ml of readymade blood agar media autoclaved to dissolve and then poured into a 500ml glass beaker. Small amount of the blood then add to the media. The mixer was gently shaken for two minutes near the flame burner to avoid the contamination. Changes in mixture color and transparency during the mixing process were observed. The mixture was poured in to glass plate dishes. The plate dishes left inside the oven adjusted to 90°C for 20 minutes. Changes in media color from red to brown were observed.

3.5.5 Bacterial culturing:

Bacterial culture is the most important phase in the research because where ever you go bacteria is available and it multiply by division thus it is spread fast. In addition, the medical wastes are a subject for rapid contamination. Bacterial culturing goes throw four test steps two of them before the chemical treatment and two after six hours of chemical treatment. The samples were submerged for 6 hours in sodium hydroxide solution 10% concentration. There are many types of medias for bacterial culture but in the study the blood agar media, and chocolate or heated blood agar media was chosen because it is optimum media for most types of bacteria. In these two media the bacterial growth just need 24 hours inside the lab incubator adjusted to 37°C.

As we mentioned above the research goes throw four steps of bacterial culture as in the following steps:

i. First step is bacteria culturing in blood agar media. This step done before the chemical processing to check if there are bacteria in the samples because samples are collected randomly. The bacterial

culturing start by blood agar media preparation then pour the media in disposable plates till it cover the surface of the culture dish. Each dish takes different label similar to the sample label. Then small part of the plastic tube was drawn and developed in the media according to the label. All the previous steps should be done near the flame to prevent contamination and to remove the air bubbles from the media. Finally the culture dishes were left inside the incubator adjusted to 37°C for 24 hours.

ii. Second step bacteria culturing in chocolate agar media (heating the blood inactivates inhibiters of growths). This step done before the chemical processing to check if there is growth of bacteria in the chocolate agar media. This step started by chocolate agar media preparation. Then small part of the plastic tube sample was drawn and developed in the media according to the label this should be done near the flam. Finally the plate dishes left inside the incubator adjusted to 37°C for 24 hours.

iii. The third step is bacteria culturing in blood agar media after the chemical treatment of the samples. Small glass bottles were disinfected by oven with 100°C for 20 minutes. The sodium hydroxide solution poured in the glass bottles and part of the sample flooded in the solution for six hours. The blood agar media was prepared and poured in the plate dishes, and the samples were developed in the plates, this should be done near the flame. Plates were labeled by adding capital P for the sample label. Then the plates left inside the incubator with37°C for 24 hour.

iv. The last step is culturing of treated samples in chocolate agar media. The treatment and media preparation were noted previously, the plate dishes was labeled and left inside the incubator for 24hour in 37°C.

3.5.6 Parasite microscopic test:

For the parasite test the sample should be fresh and each sample flooded in separate sealed glass bottle filled with small amount of normal saline solution enough to submerge the plastic sample. The samples flooded in normal saline for one hour then centrifuged by 2500rpm for 2 minutes. The concentrated part of the centrifuged solution should be taken to microscopic slides preparation. Two slides from each sample should be prepared and scanned by three

magnification lenses 10, 40, and 100. The 100 magnification lens is an oily lens thus a drop of oil should be dropped on the slide glass cover.

3.5.7 Fungi culturing:

The fungi culturing stage also conducted in two steps as follow:

i. The first step is fungi culturing before the chemical treatment, the Sabouraud dextrose agar media was used for fungi culture because it is the most common one, a small part of each sample have been taken and developed in a glass bottle contain the fungi media the bottles labeled according to the original samples, the bottles should not be tightened or loss it should be in-between to permit the air flow but not contamination, then the samples left inside the incubator adjusted to 37°C for a week approximately because fungi grow slowly unlike bacteria, the fungi growth in this step took 5 days only.

ii. The second step is fungi culturing after six hours of chemical treatment by using sodium hydroxide 10% concentration. After the glass bottles disinfected in the oven, each sample then flooded in different bottle of disinfectant solution then developed in different glass bottles contain the fungi culture media, the glass bottle should not be closed tightly or loosely but intermediate to permit the air flow. And then the samples left inside the incubator with 37°C temperature for 16days.

The bacteria and parasite tests were done at El-Nileen University, faculty of medicine, research center with the help of Dr. Mayada in charge of the lab, Anhar Ismaeel and Gaidaa the lab technicians. The fungi test was done in Stack national lab with the help of Dr. Ayda Hassan in charge of the mycology lab. And the results are obtained successfully.

Chapter four:

Result and discussion:

Infectious disease means a disorders caused by organisms such as bacteria, fungi, virus, or parasite. Many organisms live in and on our bodies. The diseases can be spread, directly or indirectly, from one person to another. This study aim to disinfect the plastic medical waste by using Sodium hydroxide 10% concentration for recycling purposes. Burning plastic is highly harm full for the environment besides the plastic recycling has economical impact on the health care facilities.

The selection of Sodium hydroxide 10 % concentration comes from the following rezones:

The laboratory experiments illustrate the effectiveness of Sodium hydroxide (NaOH) because it can decompose the cells. Sodium hydroxide is already used in medical application such as samples preparation, disinfecting surfaces and for the liquid waste treatment before drainage in the sewage. It is not the only one used but it is the best due to the following rezones:

i. Sodium hydroxide has the ability to disassemble the links between the cells by braking down the collagen bounds and attack each cell separately. Thus it's able to kill the micro organism.
ii. The sodium hydroxide wills not affect the properties of the plastic.
iii. Sodium hydroxide is used as disinfectant in different concentrations 10, 20, 30% but we choose 10% because it is not harmful in case of accidents.
iv. Sodium hydroxide salt is relatively cheap and available.

The laboratory experiments illustrate the effectiveness of sodium hydroxide to kill bacteria, fungi, and parasite but it is effectiveness depends on the time of sample merge thus we choose six hours instead of one or two or three and I recommend more time to be in the safe side because more time will give a chance for the solution to attack all the targeted cells, and will increase the margin of quality.

As mentioned above the main purpose of the research is to disinfect the plastic waste for recycling purpose and the research was conducted in

hemo-dialysis departments because it is one of the departments with high percentage of plastic waste and suffering from lack of income.

The disinfection types are chemical, thermal, irradiation, and biological in this study the chemical treatment was chosen by using sodium hydroxide 10% concentration for it is perfect properties that serve the research from environmental and economical perspectives.

4.1 Bacterial culture results:

As mentioned in the previous chapter the bacteria culturing were done in four phases and took 5 working days. Two phases are culturing of bacteria in blood agar and chocolate agar media before the chemical treatment. These phases took 2 days; the growth of bacteria in all the developed plate dishes was seen. The following images illustrate the results of the first phase.

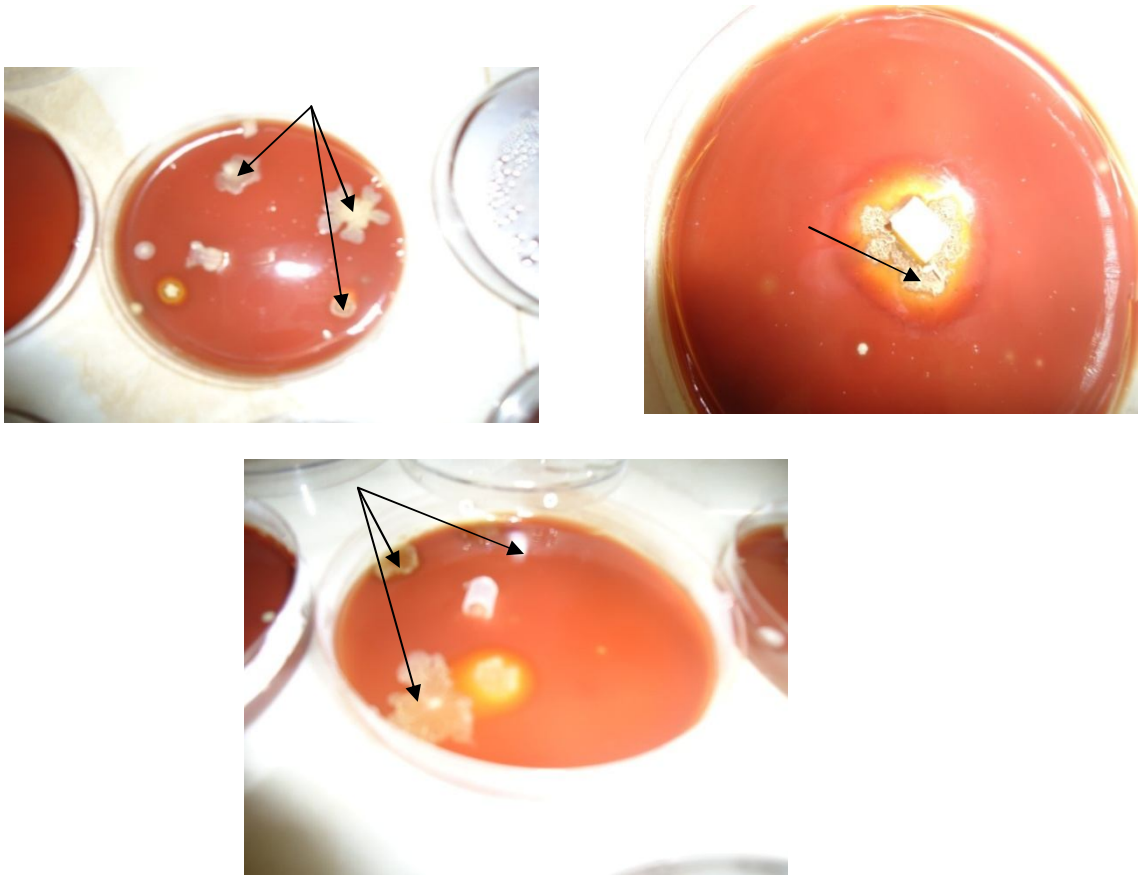

Figure 4.1: The above images illustrate the growth of bacteria in blood agar media after 24h of development in 37°C for different samples.

The following are the results of the chocolate agar media before the chemical treatment:

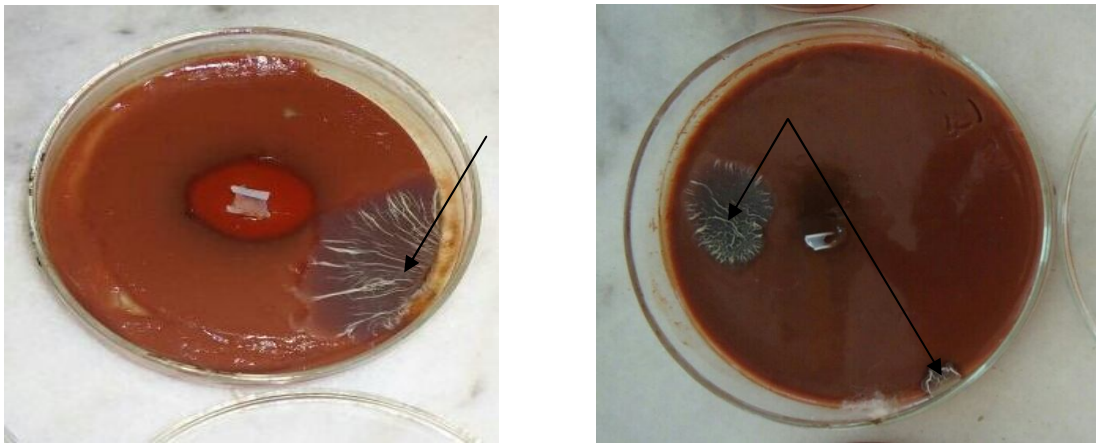

Figure 4.2: The above images illustrate the growth of bacteria in chocolate agar media after 24h of development in 37°C for different samples.

The appearance of bacteria in all the samples of blood agar media culturing and 40% of chocolate agar media refer to the wide spread of bacteria all over the environment and it is fast speed of division as well as the high ability of the blood for contamination.

There are many types bacteria spread in the environment such as Micrococcus, Staphylococcus, Bacillus, and Pseudomonas, but not all are harmful or cause infection some are useful. Pathogenic bacteria that are causing bacterial infection. And the most important pathogenic bacteria type that one's cause tuberculosis and food poisoning. Due to the abundance and fast speed of multiply many disinfectants developed capable of eliminating or reducing the severity of bacterial infection. There are also types of bacteria live in the skin or nose and cause the infection when the immunity is low. Thus the usage of disinfectant is important for bacterial control infection. Sodium hydroxide 10% concentration proved its effectiveness by the laboratory experiments and

the following images illustrate the results of bacterial culturing in blood agar media and chocolate agar media after six hours of chemical treatment by sodium hydroxide 10% concentration.

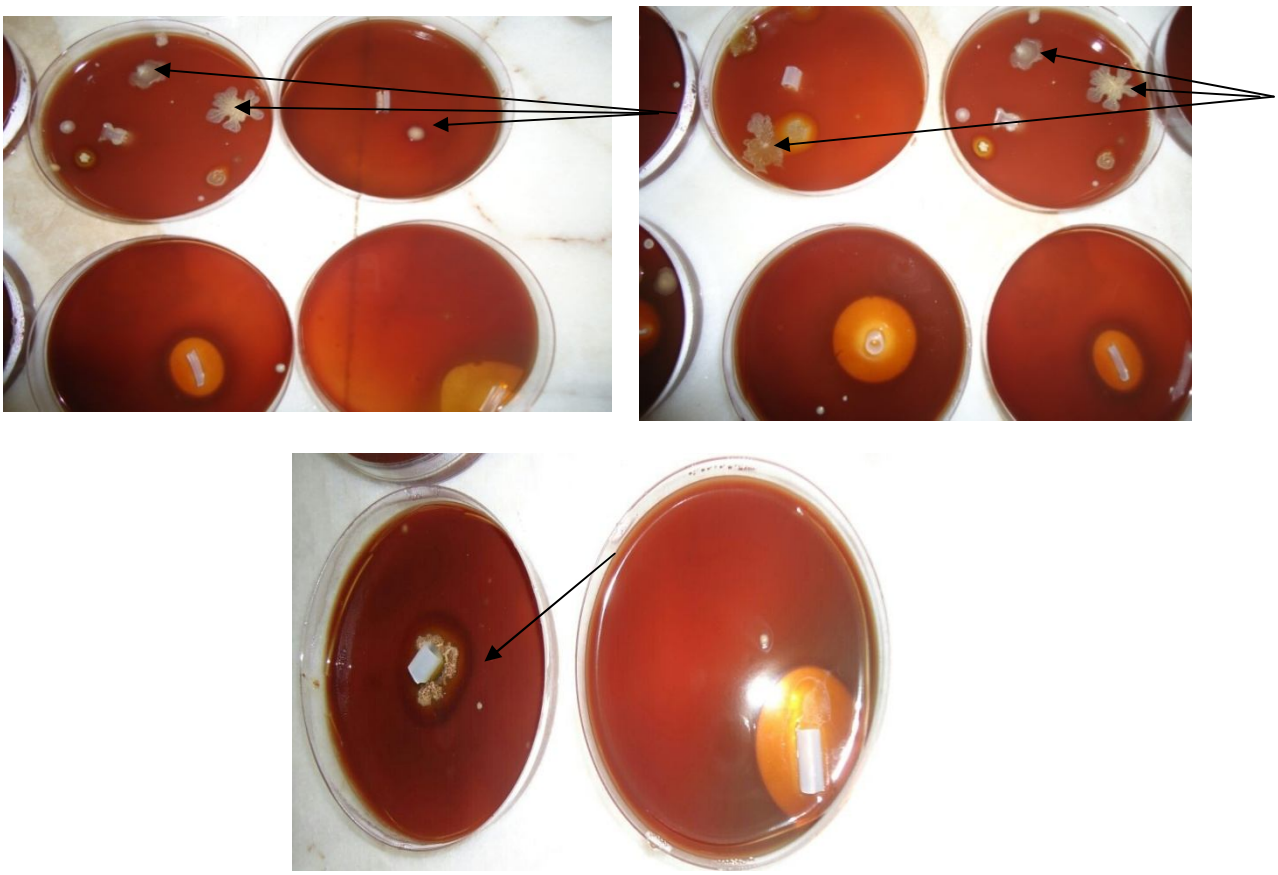

Figure 4.3: The images show the results of bacterial culture in blood agar media after 24hour of incubation in 37°C, the arrows in the images point the growth of bacteria before the chemical treatment but the opposing ones are the culture results after the chemical treatment.

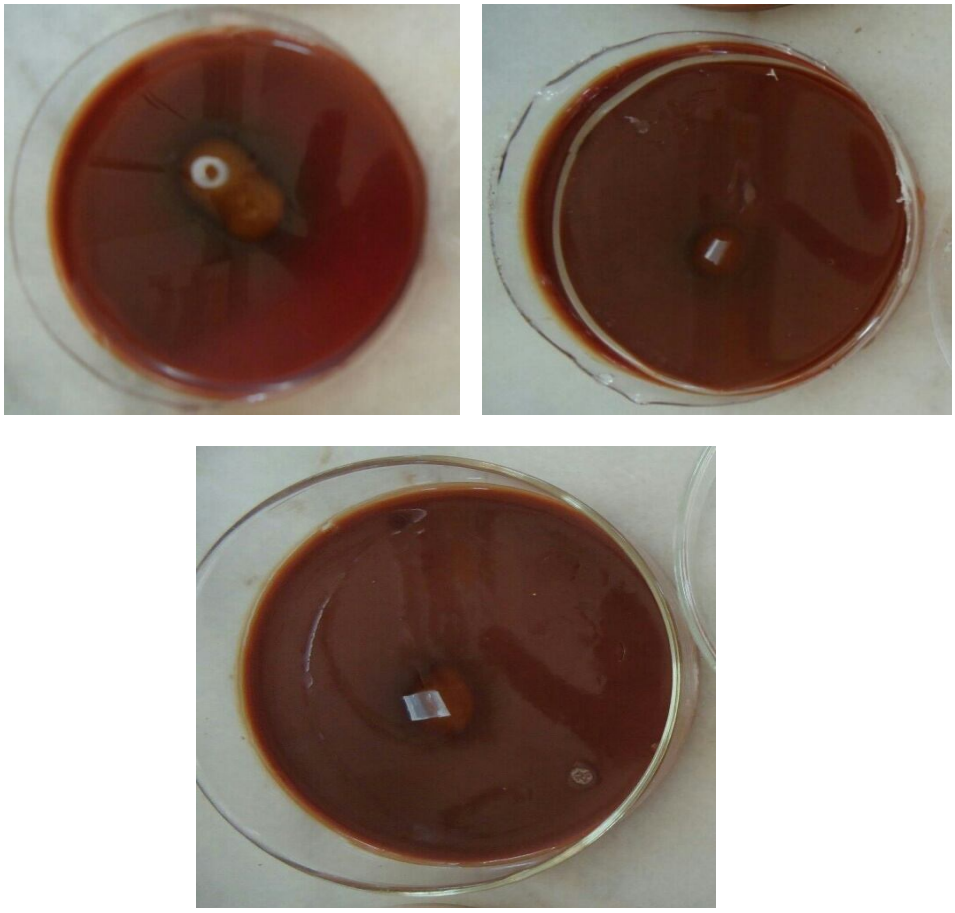

Figure 4.4: The images show the results of bacterial culture in chocolate agar media for the chemically treated samples after 24hour of incubation in 37°C.

4.2 Parasite microscopic test results:

This phase of laboratory experiments took just one day and it's proved that there is no parasite in the samples because the microscopic test with three different magnification lenses (10, 40, 100) illustrates the cells decomposition even before the chemical treatment.

Parasite generally does not pose a significant infection risk because it is life depends on the cell cycle terminals if any terminal misfire the parasite die. For example Trypanosomes blood parasite (multiply in blood, lymph, and CNS) but part of it is cell cycle should be in the Tsetse fly, or the leishmanial blood parasite infect throw the sand fly, even malaria parasite transmitted through Anopheles mosquito

so that if the optimum environment for it is surviving misfire they die. Another reason reduce the risk of blood parasites it feeds on the blood and in case of blood supply disturbance the parasite cells die in a short period. Thus the period when the plastic sets are assembled for disposal is enough to get rid of parasites but it is not our only concern.

4.3 Fungi culture results:

This phase of laboratory experiments were split into two steps it was relatively long it took 19 days for the two steps because the fungi grow slowly. The first step was the culturing of fungi before the chemical treatment, this step took 5 days, after 5 days of fungi culture in 37°C incubator fungal growth appeared in all samples and the following image will illustrate the results:

Figure 4.5: Show the fungi growth in 37°C incubator after 5 days of development.

The second step start from the chemical treatment by sodium hydroxide 10% concentration for six hours and the results do not show any sign of fungi growth within two weeks of incubation in 37°C and the following images illustrate the results:

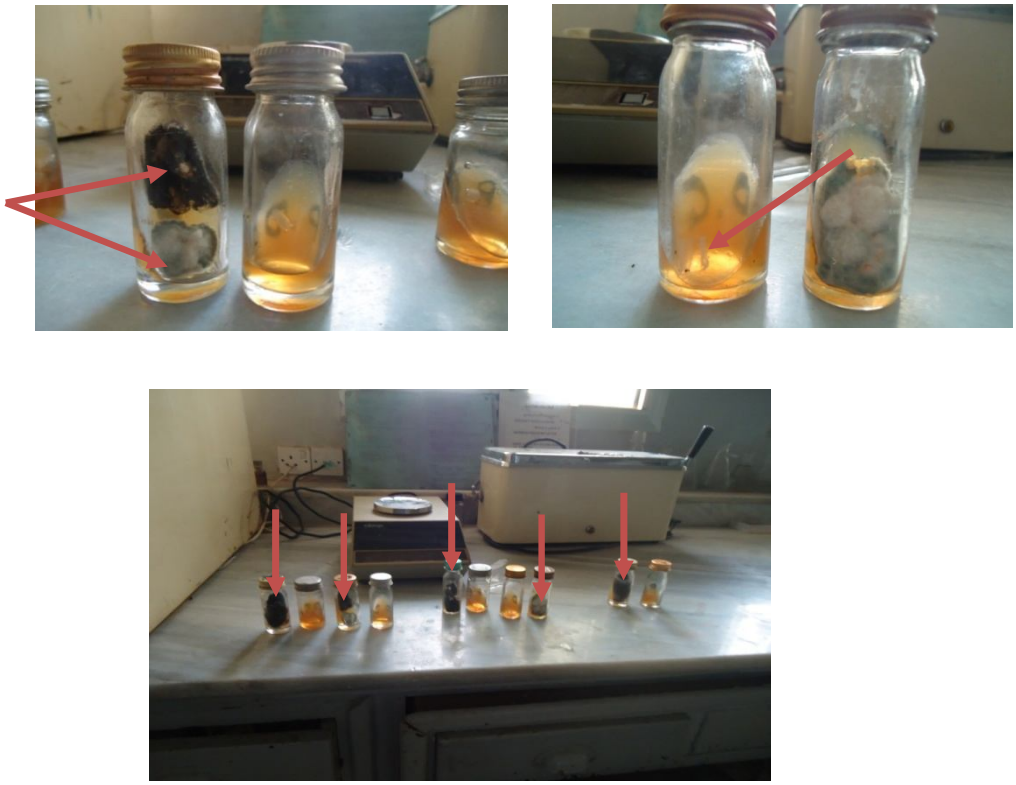

Figure 4.6: Images shows the results of fungi culture pre and post the chemical treatment after 2 weeks of incubation in 37°C. The red arrows point the culture of pre treatment samples and the others are the post treatment samples.

The above images shows a comparisons between results of fungi culturing pre and post the chemical treatment by sodium hydroxide 10% concentration and the fungi growth appear clearly in the samples before the chemical treatment unlike the post-processing samples which did not show signs of fungi growth up to 16 days of development in lab incubator thus sodium hydroxide prove its effectiveness as chemical disinfectant by it is ability to kill the microorganisms if the time of immersing the samples were prolonged enough because as mentioned before it works on the dismantling of cells from each other first and then attacking each cell separately. Although the higher concentration of the sodium hydroxide solution is more efficient, but high concentrations of solution have a detrimental effect on the respiratory system and the skin in the case of accidents.

Generally the sources of infection such as fungi, bacteria, virus, and parasite are available around us everywhere and our immune system, stand stiff to fight various types of infection, but in the case of immune system weakness people become infected. Thus as the saying goes "prevention is better than cure", and to prevent our bodies from the risk of

infection an aggressive decontamination procedures should be conducted specially in health care facilities because it combines the areas of various types of diseases.

The study talk about the different ways of medical wastes disinfection and mainly the chemical disinfection for plastic medical waste by using sodium hydroxide 10% concentration for recycling purpose. The sodium hydroxide prove it is effectiveness by the laboratory experimental results but it is not enough that it is important to discuss the proposed system for the plastic waste disinfection in the next chapter.

Chapter Five

The System Design:

The previous chapter reviews the laboratory results for the plastic waste disinfection by flooding it in sodium hydroxide 10% concentration for six hours and it has proven the effectiveness, but finding the appropriate material not sufficient enough for practical application, this chapter will describe the proposed system design for plastic medical waste disinfection.

Recycling centers are spread worldwide in various kinds and production capacities. Most countries focus on the recycling industry for it is great economic returns because the recycling is a resource-conserving, especially the rare ones. The research is going to re-draw the plastic from the medical waste, because the incineration of plastic medical waste will emit highly toxic gases, which will pollute the whole environment. This research aim to find an environmental friendly solution for plastic medical waste treatment, and then design a center for plastic medical waste recycling according to the available resources.

In the design of plastic medical waste recycling center there are several aspects must be taken in to the account to increase the efficiency such as:

i. The safety of workers in the treatment center in the first place.
ii. The environment friendly treatment method.
iii. The arrangement way of the center departments should serve the purpose and the process flow.
iv. The minimum efficient total cost to serve the purpose and to make a profit.
v. The possibility of future expansion.

The following block diagram Figure (5.1) shows the proposed steps for the plastic waste treatment center. it describe briefly the flow of plastic waste from the moment of arrival to the processing center till it becomes ready for conversion to plastic industries.

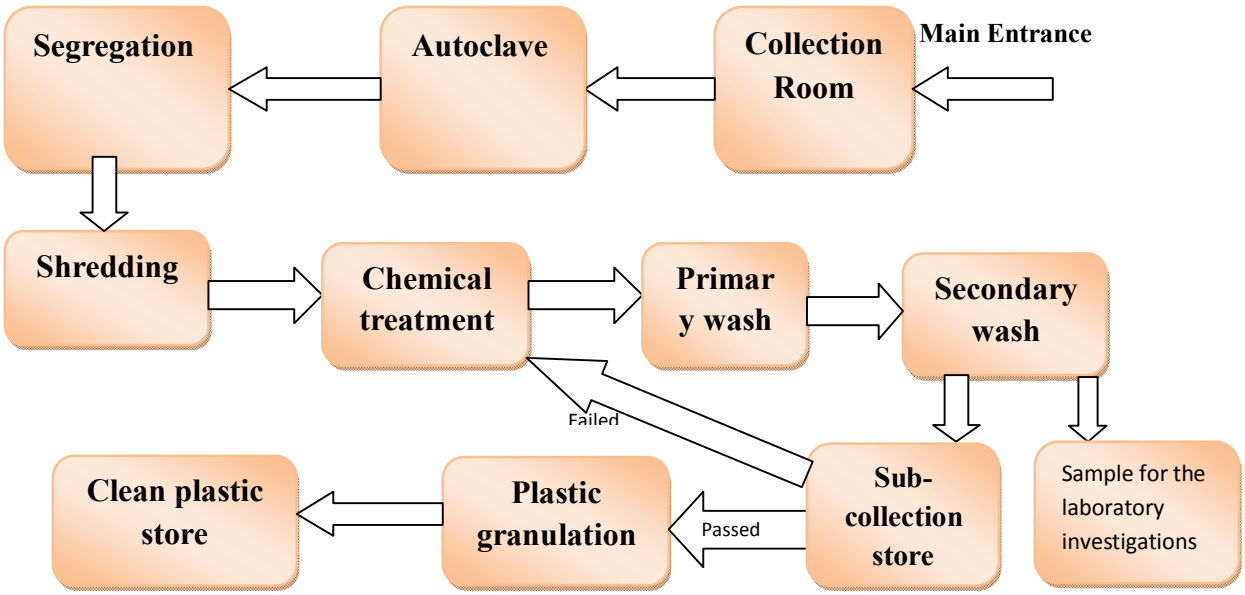

Figure 5.1: Show the main phases of plastic waste disinfection center.

The above block diagram summarize the main phases of the proposed plastic waste treatment center which are designed for the chemical disinfection of plastic medical waste for recycling purpose and the next discussion will show the importance of each phase in the block diagram.

5.1 The collection Room:

Collection room should be near the main entrance, and equipped with a large door with high surface in the entrance to be equivalent to the waste truck door, to facilitate the waste transport from the truck to the collection room. All the surfaces and angles must be blunt to avoid the waste leak. Also the collection room should be prepared with especial type of air conditioner and air filters to avoid the air pollution and contamination control. The waste treatment supposed to be within 48 hour otherwise must provide room with refrigerators because Sudan is hot climate country thus to reduce or control the ratio of pollution in the surrounding environment the waste should be stored in refrigerators until it goes to the autoclave cycle.

5.2 Autoclave:

The plastic waste should be collected in auto-cleavable bags at the point of generation to guarantee the flow of stem inside the bag in the sterilization cycle because the plastic waste bags should not be opened before the end of the autoclave cycle. The waste bags should be transported from the collection room to the auto-cleave

by the primacy of access first in first out (FIFO). For the disinfection of plastic wastes by auto-cleave we chose 100°C and 10-15 bar air pressure, this phase to protect the workers who will work as sorters to the plastic waste according to the type of plastic. The autoclave, segregation, and shredding steps are considered as a preprocessing phase to prepare the plastic for the chemical treatment.

5.3Segregation:

After the auto-cleave cycle the workers open the sealed plastic bags to sort the plastic for type 1, or 2, or 3…ect depending on the chemical composition of the plastic polymers. Each type of plastic should be placed in a separate container.

The worker should wear protective clothing such as: heavy gloves face masks, overalls and protective boots to protect them from infection. Although the wastes are already autoclaved but some of the organisms may be still harmful so it is important to follow the safety procedures and protection tools.

Figure5.3: Show some protective tools for the workers [11].

5.4Shredding:

After the sorting of the plastic types in different containers each type (such as tubes, IV bags, gloves…) should be shredded separately by using plastic shredding machinery. The machine have a rotary cylindrical shaft with sharp cutters as shown in figure (5.4), on both sides of the cylinder there is a narrow lanes when the plastic passes in this lanes it compressed by the cylinder cutters. So the plastic in this phase shredded into small pieces not more than 3mm diameter to facilitate the reuse process and grantee the homogeneity of the plastic granules.

Figure5.4: Show a machine for plastic shredding.

5.6Flooding in sodium hydroxide:

At this stage the plastic should be turned into small parts, then each type of plastic should be flooded in baths of sodium hydroxide solution 10% concentration for six hours minimum in room temberature. The purpose of cutting the plastic before the flooding is to insure the penetration and full contact of the disinfectant solution in all the plastic parts this will increase the disinfection quality and safety margin.

5.7Primary wash:

By using prominent refineries the waste are transferred from the waste treatment bath to the primary wash bath, the primary wash bath filed with clean water to remove the impurities outstanding in the plastic parts.

5.8Secondary wash:

By using prominent refineries the waste are transferred from the primary wash bath to the secondary wash bath, the secondary wash bath filed with clean water to remove the impurities outstanding in the plastic parts.

5.9Laboratory:

It is important to conduct some tests to ensure the disinfection of the plastic waste. In this phase a random sample of treated plastics should go throw different laboratory tests to prove the success of the treatment cycle, and then approve the plastic batch with a special designed signature in the package as ready for recycling to prevent the illegal recycling.

5.10 Sub-collection store:

The sub-collection store to save the plastic after the chemical disinfection process under inspection until it pass the laboratory investigations then it goes to the next granulation step otherwise it will go back to the chemical treatment stage.

5.11 Plastic granulation:

If the treated plastic wastes pass the laboratory tests then the plastic particles placed in the granulation machines to be transferred to plastic granules and then sold for plastic industries.

While the plastic have been already shredded to small parts the granulation process will start from plastic melting phase throw the development of plastic parts in an electrical furnace for plastic melting. Then pour the plastic in the form of medium thickness yarns. Then the plastic yarns should be cooled throw passing it in a long path filled with water. Lastly, after the plastic yarns exit from the water path it goes throw cutters to be transferred to small granules and then packed for sell.

Figure 5.5: show the machine for plastic granulation.

5.11 Store room:

In the store room each type of plastic granules are stored in separate containers then sold to intervention of various plastic industries. The containers in the collection room and store room should take different colors to prevent mixing. There should be vehicles dedicated for the distribution of raw plastic different than vehicles for plastic waste collection to prevent the contamination.

The expected area for the plastic treatment center is $700m^2$ approximately divided to 6 rooms according to the process phases as $50m^2$(5x10x6) for collection room, $50m^2$(5x10x6) for the preprocessing phase which are autoclave and segregation stages, then $100m^2$(10x10x6) for the treatment phase which start by shredding stage and end by the secondary wash and drying stage, then $20m^2$(5x4x6) for laboratory, then the needed area for the granulation room is $200m^2$(20x10x6) with 6m for the roof height, and lastly $50m^2$(5x10x6) for the store room for the sterilized plastic granules. The rest $230m^2$ will be distributed between the related facilities such as: bathrooms, kitchen, cafeteria, barking, and others taking in the account the future expansion.

The above is a design of a plastic treatment center for recycling of a plastic medical waste, with in the available resources. As mentioned in the previous chapter's plastic is one of medical wastes types so this idea can be developed up to an integrated center for treatment and recycling of whole medical wastes.

Chapter Six:
Conclusion and Recommendations

6.1 Conclusion:

Infection disease is a widespread disease that affects millions of people worldwide. Due to the alarming rate of the spread of tuberculosis, hepatitis, and HIV particularly in poor countries, medical professionals are implementing new strategies for the infection control throw proper management of medical waste disposal and recycling processes. In developing countries, such as those in Africa and Southeast Asia, the rate of recycling is relatively low due to the lake of infrastructure for recycling industry. The study was conducted on the heamo-dialysis department due to the high percentage of plastic medical waste generated in that department. And the conclusion from the laboratory investigation found that the chemical treatment by using sodium hydroxide 10% concentration is suitable solution from economical and environmental perspectives.

6.2 Recommendations:

There are, however, some possible recommendations which can tackle the issues; to start with, the waste treatment center must be placed in an easy access area so they can be easily accessible by collections vehicle. Secondly, all the employees who work in these centers must be fully aware by the hazed and how to handle it. Thirdly, after conducting the waste treatment process to insure the laboratory is free from viruses virus tests must be carried out. Fourthly, the regulations of waste treatment must be conducted by Sudanese Standards and Metrology Organization (SSMO). Fifthly, recycling waste management must be introduced as subject in the colleges. Lastly, there should be a link between the ministry of environment in the issue of medical waste disposal and treatment.

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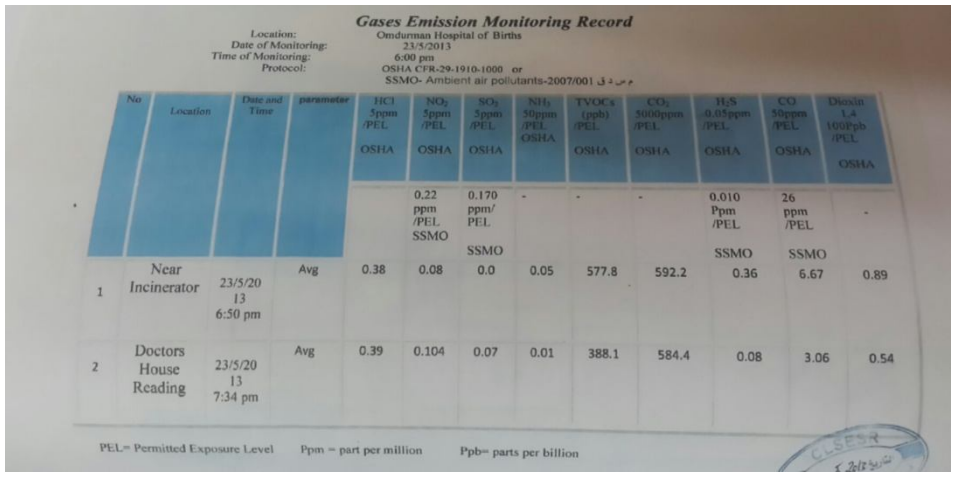
Appendixes

Appendix A:

Figure1: Show the chimney of the medical incinerator located in Omdurman Hospital of Maternity



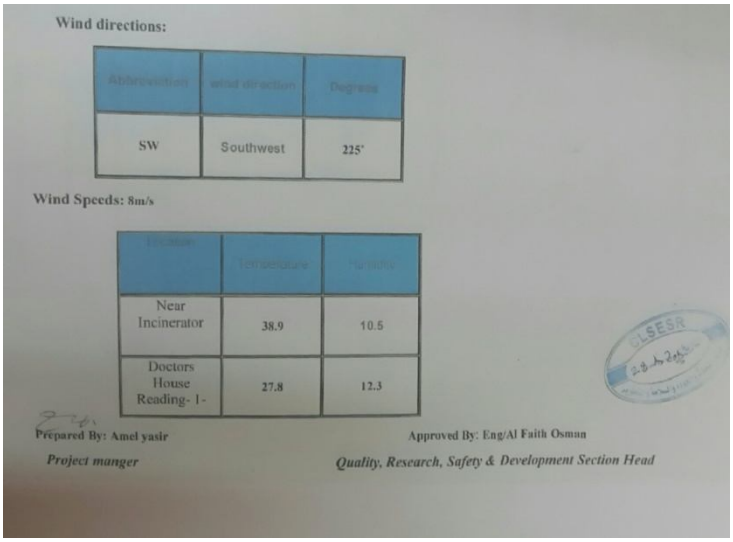
Gases Emission Monitoring Record

Location: Omdurman Hospital of Births
Date of Monitoring: 23/5/2013
Time of Monitoring: 6:00 pm
Protocol: OSHA CFR-29-1910-1000 or SSMO- Ambient air pollutants-2007/001 م ص د ق

No	Location	Date and Time	parameter	HCl 5ppm /PEL OSHA	NO_2 5ppm /PEL OSHA	SO_2 5ppm /PEL OSHA	NH_3 50ppm /PEL OSHA	TVOCs (ppb) /PEL OSHA	CO_2 5000ppm /PEL OSHA	H_2S 0.05ppm /PEL OSHA	CO 50ppm /PEL OSHA	Dioxin 1.4 100Ppb /PEL OSHA
					0.22 ppm /PEL SSMO	0.170 ppm/ PEL SSMO	-	-	-	0.010 Ppm /PEL SSMO	26 ppm /PEL SSMO	-
1	Near Incinerator	23/5/2013 6:50 pm	Avg	0.38	0.08	0.0	0.05	577.8	592.2	0.36	6.67	0.89
2	Doctors House Reading	23/5/2013 7:34 pm	Avg	0.39	0.104	0.07	0.01	388.1	584.4	0.08	3.06	0.54

PEL= Permitted Exposure Level Ppm = part per million Ppb= parts per billion

Figure2: Show the reading certificate of the modular indoor air quality reader



Wind directions:

Abbreviation	wind direction	Degrees
SW	Southwest	225°

Wind Speeds: 8m/s

location	Temperature	Humidity
Near Incinerator	38.9	10.5
Doctors House Reading- 1-	27.8	12.3

Prepared By: Amel yasir
Project manger

Approved By: Eng/Al Faith Osman
Quality, Research, Safety & Development Section Head

Figure3: Show the reading directions

Figure4: Show the device used in the measurement process

Figure5: Show the incubator used in the Fungi culture

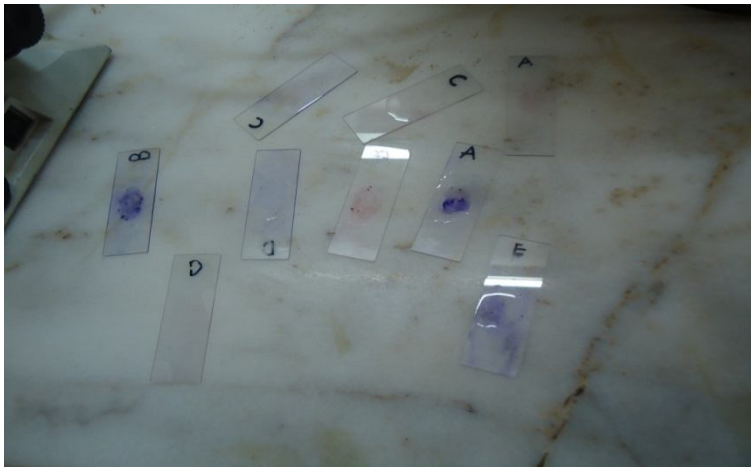


Figure6: Show the slides for Gram stain

Figure 7: Show the Microbiology lab

Figure8: Show the flam device

Figure9: Show the needed kit for slide preparation

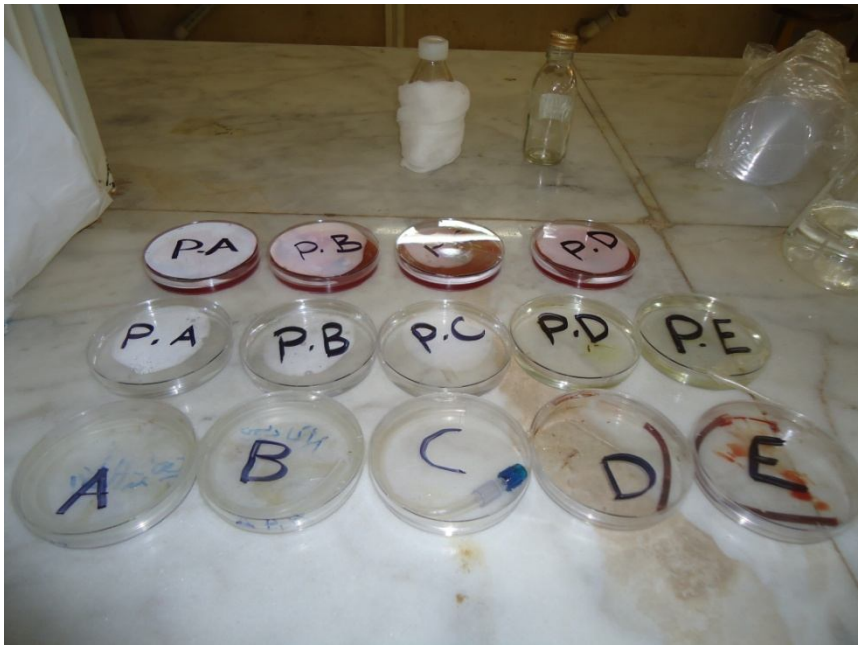


Figure10: Show the platte dishes used in sample collection, culture, and disinfection

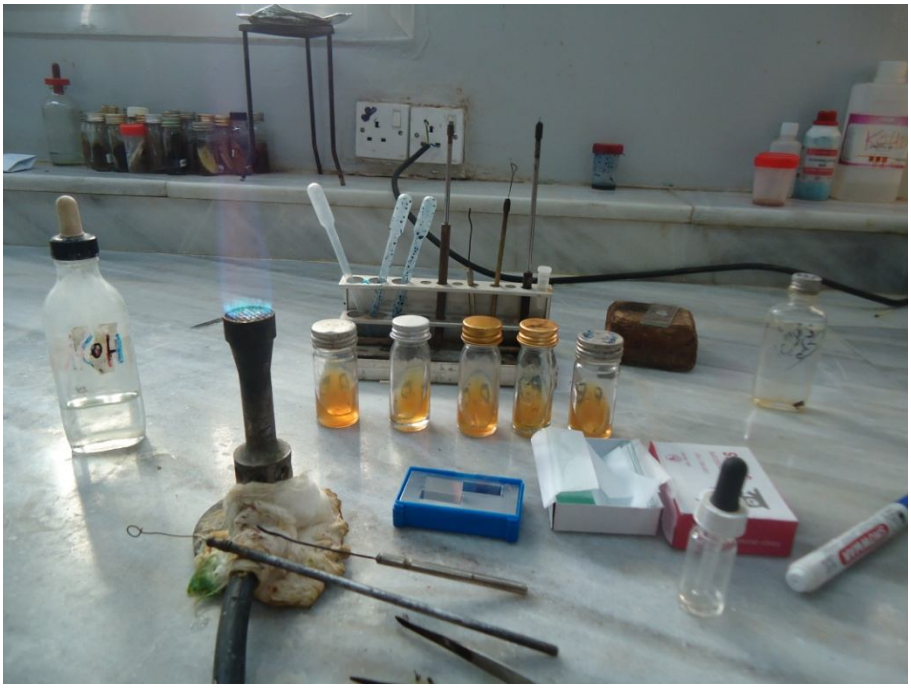


Figure11: Show the needed tools for fungi culture

Appendix B:

بلاغات في مواجهة مرافق
صحية بسبب النفايات الطبية
بالخرطوم

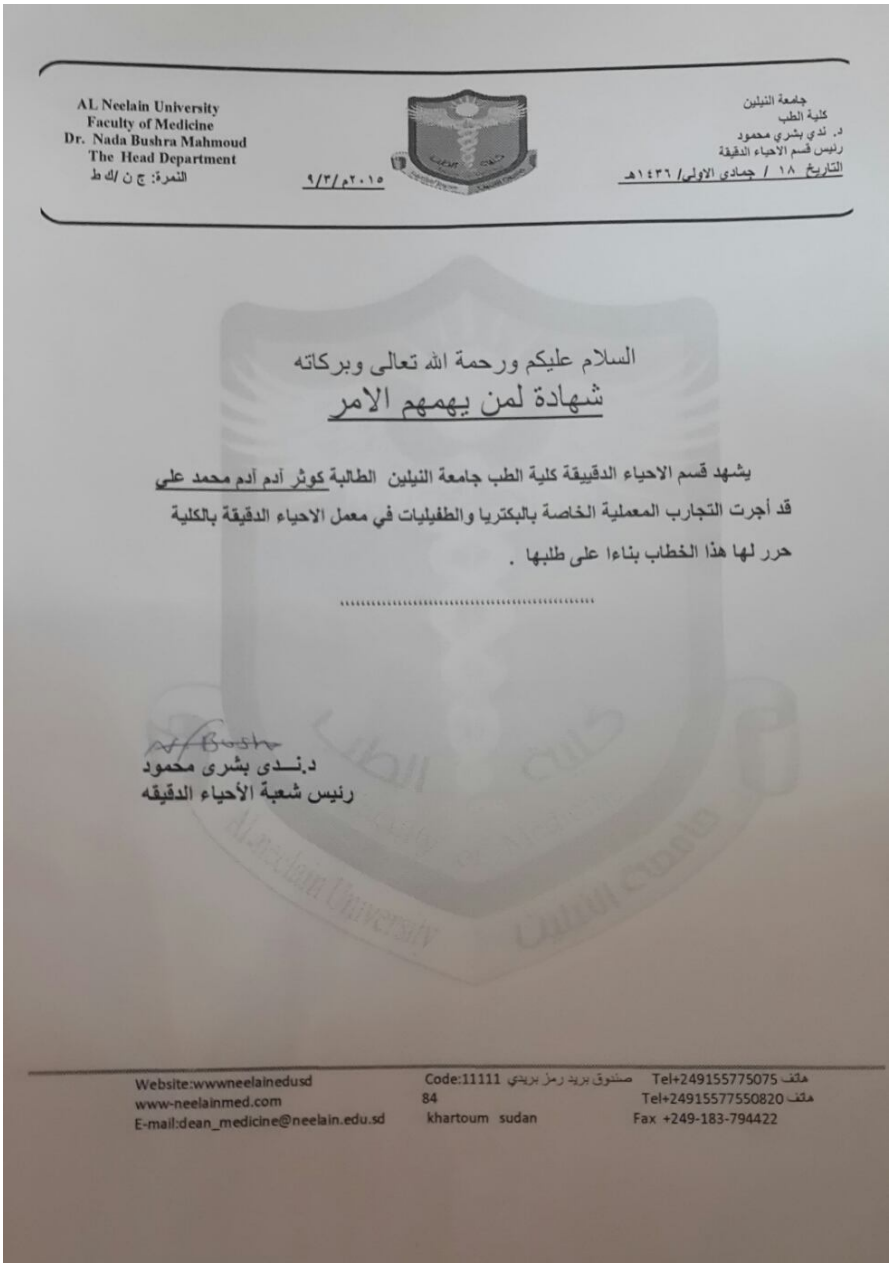
الخرطوم : الأهرام اليوم
أعلن معتمد محلية الخرطوم اللواء عمر نمر عن اتجاه محليته لفتح بلاغات بالنيابة المختصة ضد إي مؤسسة طبية عامة او خاصة تتخلص من نفاياتها الطبية مع النفايات الصلبة الطبيعية بشكل عشوائي وفقا لقانون صحة البيئة والنظافة.

وطالب المعتمد في تصريح لـ(smc) المؤسسات الصحية (المستشفيات والمستوصفات والمراكز الصحية) بمنطقة وسط الخرطوم الالتزام بمعايير الصحة العامة والتخلص من النفايات الطبية بالطريقة الصحيحة وعدم أخراجها مع النفايات الطبيعية والتي تتولي جمعها والتخلص منها هيئة نظافة محلية.

وكشف اللواء نمر بأن الفترة السابقة شهدت تعديات مخلة بالبيئة والصحة العامة درجت عليها بعض المرافق الصحية في التخلص العشوائي من النفايات الطبية، لافتا بانه سيتم فتح بلاغات في المرافق الصحية المخالفة في حالة عدم توفيق أوضاعها حسب القانون.

وأعلن عن خطة نوعية لمعالجة كسورات الصرف الصحي وتسريع العمل في إحلال وإبدال الشبكات القديمة بجانب استكمال العمل في مشروع تاهيل شبكات مياه الشرب بوسط الخرطوم.

Figure1: Show a report assay the medical waste disposal with the municipal wastes



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التاريخ ١٨ / جمادى الاولى/ ١٤٣٦هـ

السلام عليكم ورحمة الله تعالى وبركاته

شهادة لمن يهمهم الامر

يشهد قسم الاحياء الدقيقة كلية الطب جامعة النيلين الطالبة كوثر آدم آدم محمد علي
قد أجرت التجارب المعملية الخاصة بالبكتريا والطفيليات في معمل الاحياء الدقيقة بالكلية
حرر لها هذا الخطاب بناءا على طلبها .

.....

د.نـــدى بشرى محمود
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Figure2: Show the certificate from El-nileen university regarding the laboratory inestigation