بسم الله الرحمن الرحيم

Republic of Sudan

Ministry of Higher Education and Scientific Research

Shendi University

Faculty of Graduate Studies

Assessment of Healthcare solid waste management in shendi locality hospitals –River Nile state –Sudan

A Thesis Submitted for the Requirements of the PhD Degree in Public health (Environmental health)

Submitted By:

Elkhitma Ahmed Elemam Ahmed

BSc. University of Khartoum, MSc. University of Khartoum

Supervisor:

Dr. Abdallah Ahmed Adam Belal.

Associate professor in public health (Environmental health)

BSc. University of Khartoum, **MSc.** University of Khartoum
PhD. (Shendi University)

Co- Supervisor:

Dr. Hawa balla Elfaki Mohmmad

Assistant professor in Public health (Epidemiology)

BSc. Shendi university , Msc. Alzaim Alazhari University,
PhD. (Shendi University)

October 2024

Dedication

This thesis is dedicated to

my father and mother,

my husband

to all my family,

and

my friends

Also, I dedicated this thesis to my colleagues.

Special thanks are extended to Dr. Monzer Alzepir Saleh.

Acknowledgements

Thanks to Allah in the First and the Last. I express my sincere and deep appreciation to ***Dr. Abdallah Ahmed Adam Belal*** *for his kind and constructive guidance during this research, his professional observations and discussion, and his friendly attitude, which encouraged me to achieve this study. Special thanks to the Department of Environmental Health, College of Public Health, Shendi University.*

Abstract

Background: healthcare solid waste requires special treatment given its impact on the environment and humanity. The management of activities related to its segregation, storage, transport, and destruction is an important point in the sustainable development of mankind, especially in the current context of the pandemic. This Descriptive cross-sectional hospital-based study aimed to assess the medical waste management at Shandi locality hospitals.

Methods: A total of ten hospitals were selected and the data was collected by questionnaires from hospital's manpower's and measured the waste by scale. Data was analyzed by SPSSv22 program and Excel. **Results**; The study found 33.25 kg/day as the average rate of waste generation in hospitals, and indicate significant fluctuations in daily waste production. The highest rate was recorded at Elmaknemir Hospital with 84 kg/day.

The study found varying levels of awareness among healthcare workers about different types of waste. Only 33.6% of respondents confirmed the existence of segregation practices, highlighting a significant training gap. A significant portion of hospitals lacks essential waste management infrastructure, such as incinerators and autoclave, leading to improper waste disposal practices. There is a significant disparity in the use of protective equipment among healthcare workers, with only 89.1% using gloves and 76.4% using masks, while apron usage remains low at 30%. Only 56% of hospitals have a dedicated budget for waste disposal, which impacts the immunization rates among healthcare workers. **Recommendations**: the study recommended ministry of health and hospitals directors that proper budgeting is crucial for effective waste management and immunization practices. The study underscores the necessity of developing a comprehensive waste management program for Shendi locality hospitals. This includes improving sorting protocols, upgrading storage facilities, ensuring safe transportation, and providing ongoing training for healthcare staff. Implementing effective treatment technologies and adhering to regulatory standards are essential for safe and sustainable medical waste management.

مستخلص البحث

الخلفية: تتطلب نفايات الرعاية الصحية الصلبة معاملة خاصة نظرًا لتأثيرها على الصحة العامة وعلى البيئة. تعد إدارة النفايات الطبية الصلبة والتى تتعلق بفرزها، جمعها، تخزينها، نقلها والتخلص منها نقطة مهمة في التنمية المستدامة للبشرية. تهدف هذه الدراسة الوصفية المقطعية إلى تقييم إدارة النفايات الطبية الصلبة في مستشفيات محلية شندي.

طريقة الدراسة: تم تغطية عشرة مستشفيات وتم جمع البيانات من خلال استبيانات من الكوادر الطبية وعمال النظافة وقياس النفايات حسب الحجم. تم تحليل البيانات من خلال نموذج التحليل الاحصائي SPSS22 و Excel

النتائج؛ وجد أن متوسط معدل انتاج النفايات في المستشفيات يبلغ 25.33 كجم / يوم، ويسلط الضوء على التقلبات الكبيرة في إنتاج النفايات اليومية. تم تسجيل أعلى معدل في مستشفى إلمك نمر بـ 84 كجم / يوم. مما يشير إلى الحاجة إلى تدابير شاملة لإدارة النفايات. وجدت الدراسة مستويات متفاوتة من الوعي بين العاملين في مجال الرعاية الصحية حول أنواع النفايات. أكد 6.33 ٪ فقط من المستجيبين وجود ممارسات الفصل، مما يسلط الضوء على فجوة تدريب كبيرة .يفتقر جزء كبير من المستشفيات إلى البنية التحتية الأساسية لإدارة النفايات، مثل محارق النفايات والأوتوكليف، مما يؤدي إلى ممارسات التخلص غير السليم من النفايات. هناك تباين كبير في استخدام معدات الحماية بين العاملين في مجال الرعاية الصحية، حيث يستخدم 1.89٪فقط القفازات و 4.76٪ يستخدمون الأقنعة، بينما يظل استخدام الملابس الواقية(المرايل) منخفضا عند 30٪

56 ٪ فقط من المستشفيات لديها ميزانية مخصصة للتخلص من النفايات، مما يؤثر على معدلات بعض الخدمات كتوفير التطعيم للعاملين في مجال الرعاية الصحية

التوصيات: أوصت الدراسة وزارة الصحة وادارة المستشفيات بأن وضع الميزانية المناسبة أمر بالغ الأهمية لإدارة النفايات وتطعيم العاملين. وتؤكد الدراسة على ضرورة وضع برنامج شامل لإدارة النفايات في مستشفيات محلية شندي ويتضمن ذلك تحسين فرز النفايات، وترقية مرافق التخزين، وضمان النقل الآمن، وتوفير التدريب المستمر لموظفي الرعاية الصحية. كما إن تنفيذ تقنيات المعالجة الفعالة والالتزام بالمعايير التنظيمية أمر ضروري لإدارة النفايات الطبية بشكل آمن ومستدام.

List of Abbreviations

Abbreviation	Meaning
CAT	Axial Computerized Tomography
HCW	Health Care Waste
HCWM	Healthcare Waste Management
HBV	Hepatitis B Virus
HIV	Human Immunodeficiency Virus
ICRC	International Committee of The Red Cros
KG	Kilogram
MRI	Magnetic Resonance Imaging
MWM	Medical Waste Management
MSW	Municipal Solid Waste
PPE	Personal Protective Equipment
PET	Positron Emission Tomography
PPC	Puncture Proof Container
SPECT	Single Photon Emission Computed Tomography
WHO	World Health Organization

List of contents

List of Tables

List of Figure

Chapter one

- Introduction
- Justification
- Objectives

1-Introduction:

Infectious and non-infectious medical waste is two different types of municipal solid waste (MSW), which is a specific sort of garbage. (1) Because there are ineffective methods for managing those wastes, the resultant medical waste from healthcare settings in many nations has given rise to a number of challenges (2) Medical waste may contain potential pathological organisms. (3) Which, if not handled appropriately, might put healthcare workers and the public in danger (4). Medical solid waste has been mixed with non-clinical trash in developing nations, which is increasingly posing inescapable health dangers (5). Concerns about the Hepatitis B virus (HBV) and HIV exposure in the 1980s and 1990s led to an increase in worries about potential hazards from medical waste (6). Due to its numerous effects as a hazard to the health of patients, medical personnel, and others outside the medical profession, garbage produced by hospitals and clinics has therefore become a focus (7). Additionally, healthcare professionals are not well-versed on the dangers posed by medical waste. (8). Studies have shown personnel dealing with medical waste are by the biological, physical, and chemical hazards such as needle sticks, cuts, falls, strains, sprains, burns, and eye and back injuries. Several injuries such as hand-cut due to handling broken glass occurred due to exposure to medical wastes inside and outside hospital premises (9). The World Health Organization (WHO) confirms the risks associated with infectious waste and sharps that nurses are exposed to during healthcare delivery (3). Other personnel is also exposed to such risks during the transportation of medical wastes. (10)Additionally, the features of the chemical material, such as its toxicity and flammability, are linked to problems caused by chemical and pharmaceutical wastes. These wastes are produced when they are undesirable or have expired, and they can be poisonous if ingested,

inhaled, or absorbed via the skin (10). Similar health hazards are associated with incineration, which is the ultimate step in the disposal of hazardous waste [11]. Medical waste incinerators allegedly release a significant quantity of poisonous gases, including Dioxin thatis harmful to human health [12]. Management of both healthcare and home-generated HCW in Sudan is inefficient, as all wastes are mixed together and disposed of improperly, especially used needles. The study attributes this to many reasons, including a lack of waste segregation at the source, lack of policies, failure of planning, inadequate training, lack of awareness of the hazardous nature of such kinds of waste, weak infrastructure, and a lack of suitable treatment technologies. The estimated average generated rate of HCW ranged from 0.38 to 0.87 kg/bed/day in 2009 and 2012, respectively. Such ineffective healthcare waste management HCWM, especially used needles, can put public health as well as the environment at risk, particularly waste workers, thus urgent action needs to be taken by all involved parties and at all levels.(13)

1-2 Research Problem:

Large urban hospitals can generate more than two million tons of waste each year. Yet many hospitals in developing countries dump all waste streams together, from reception area trash to operating-room waste, and burn them together in incinerators. Over the years the world has learned that incineration is a leading source of air pollutants that threatens human and the environment.

What's more, some urban and many rural hospitals and clinics in the developing world simply discard their medical waste with regular trash 4and risk the spread of diseases among scavenger populations. Discarded needles and syringes may result in the spread of blood-borne pathogens such as HIV and hepatitis. Others burn their waste in open dumps or in

small incinerators without pollution control, exposing communities. Downwind to toxic by-products such as dioxins and mercury, and generating potentially hazardous ash.As health programs expand, the problem of medical waste treatment and disposal in rural areas becomes critical. And so people have to work together to minimize the amount and toxicity of all waste generated by the health- care sector, to ensure the proper management and segregation of medical waste, and to eliminate the improper practices of incineration by promoting and implementing alternatives. In order for the medical ethic to 'first do no harm' institutions charged with safeguarding public health, together with the healthcare industry havea responsibility to manage waste in ways that protect the public and the environment.

1-3 Hypothesis

The study is carried out to test the following hypothesizes:

- There is the improper and scientific methods and techniques to deal with healthcare solid waste.

- Unavailability of equipment, type of machinery, and qualified staff to deal with healthcare solid waste disposal.

-There is Lack of suitable plans and policies for proper management of healthcare solid waste.

1-4Justification

Healthcare solid waste requires special treatment given its impact on the environment and on humanity. The management of activities related to its storage, transport, and destruction is an important point in the sustainable development of mankind, especially in the current context of the pandemic. Medical waste is a continuous increase in quantity and involves many effects in various activity fields. (14)Medical care is vital for our life, health, and well-being. But the waste generated from medical activities can be hazardous, toxic, and even lethal because of its high potential for disease transmission. The hazardous and toxic parts of waste from healthcare establishments comprise infectious, medical, and radioactive material, as well as sharps,which constitute grave risks to mankind and the environment if these are not properly treated/disposed ofand are allowed to be mixed with other municipal waste.(15)

In Sudan practical information on this aspect is inadequate and research on the public health implications of poor management of medical waste is few and limited in scope. Findings drawn from Literature, particularly in third-world countries highlight financial problems, lack of awareness of risks involved in MWM, lack of appropriate legislation, and lack of specialized MWM staff.

1-5Objectives:

1-5-1 General objective:

To assess healthcare solid Waste Management in Hospitals of Shendi locality.

1-5-2 Specific objectives:

1- To identify the components, classification, and generation rates of healthcare solid waste in hospitals.
2- To measure the health risk among staff whose deal with healthcare solid waste
3- To know the method of final disposal of healthcare solid waste in hospitals.
4- To develop and suggest a comprehensive program for healthcare solid waste management in hospitals.

Chapter two

literature review

2- Literature review

2-1 Definition of medical waste:

healthcare solid waste is "any solid waste that is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biological. (15). It is estimated by the World Health Organization (WHO) that 20 percent of these medical wastes can be classified as hazardous materials that may be infectious, toxic, or radioactive.(16) However, there is no globally agreed-upon definition of medical waste, which poses a challenge from a comparative standpoint, as changing definitions make a meaningful comparison between countries, or even between regions within countries, quite difficult. Further, the absence of a standard definition of medical waste has led to a lack of standardization of medical waste streams and disposal receptacles. (17) Generally, there are four terms used when discussing medical waste, and all are often used interchangeably, with no universally accepted definition for each term.(18) These are hospital waste, medical waste, regulated medical waste, and infectious medical waste. In order to provide clarity and consistency throughout this review, the term medical waste will be used to refer to all waste that is generated at any healthcare or healthcare-related facility, which is consistent with the definition of medical waste given by the United States Environmental Protection Agency. The term infectious medical waste will refer to the subset of waste generated at healthcare facilities that are unsuitable for disposal in a municipal solid waste system due to pathogenic concerns. (19)

2-2 medical waste generation rate:

Medical waste generation rate is not a homogeneous indicator without considering the differences in the hospital's scale, type, specialization, technical level, and quality, and efficiency, people cannot simply use the generation rate to compare performance between hospitals. A way to adjust the indicator before the comparison is needed.(20)Medical waste-generation assessment is an important first step in the continuing improvement of hospital medical waste management. The results could be used to establish a baseline for planning, budgeting, cost-controlling, and optimizing waste-management systems. The process of medical waste-generation assessment also provides an opportunity to compare with other hospitals, share experiences, improve current practices, and determine the potential for waste minimization.(21)The Generation of healthcare waste is different not only from country to country but also within the country. 9 Figure 2.2 shows the generation rates of medical waste in different countries. Waste generation depends on numerous factors such as established waste management methods, type of healthcare establishment, hospital specialization, the proportion of reusable or disposable medical devices employed in healthcare, occupancy rate and proportion of patients treated on daily basis, and the degree of regulation enforcement at national and local levels, definitions of medical waste, training of medical waste management and medical waste treatment and disposal policy type. (23)

2.3 Nature of clinical waste

Defines clinical waste very broadly, as being any solid or liquid that is used in the diagnosis, treatment, or immunization of human beings or animals in research pertaining thereto, or in the production or testing of biological matter. This definition includes a number of waste materials such as blood-soaked bandages, culture dishes and other glassware,

discarded surgical gloves and instruments, discarded needles and lancets, cultures and stock, and removable body organs. Clinical waste is a type of waste that is commonly generated in medical facilities.(22)

2-4 Medical waste classification

2-4-1 Common waste in Healthcare facilities:

There exist certain types of waste that are considered too hazardous to be recycled and reused without pretreatment. Infectious healthcare waste is one such kind of waste. According to World Health Organization (WHO), around 75% to 90% of the waste generated across healthcare facilities can be considered nonhazardous; it is the remaining 10–25% that cannot be ignored. (24)

2-4-2 High infectious medical waste

Basically, medical waste can be divided into harmful and harmless. A special kind of harmful waste is infectious and highly infectious waste which is considered a human health hazard due to "it contains different kinds of pathogens or organisms that are potential for infection or disease if it is not properly disposed of". The subjective WHO's definition of 'infectious waste' as the potential to be infectious leads to the different interpretations developed by individual countries depending on national circumstances, policies, and regulations.(25)

Infectious and highly infectious waste represents any type of dangerous waste that due to its pathogenic nature and presents of microorganisms poses risk to human health, such as cultures and materials from laboratories that contain infectious agents; equipment, materials, and supplies that were in contact with blood, blood derivate, bodily liquids; excretions from clinically affirmed infectious patients including surgical operations and autopsies; waste from pathology and infectious patients' isolation departments; waste from dialysis, IV therapy and other similar procedures, including all disposable supplies and materials; contaminated

waste that was in contact with infectious patients; highly infectious waste from medical laboratories. According to the explanation given by the World Health Organization the difference between infectious and highly infectious waste is seen in the fact that highly infectious waste has "cultures and stocks of highly infectious agents, waste from autopsies, animal bodies, and other waste items that have been inoculated, infected, or in contact with such agents". Infectious waste "contains potentially harmful micro-organisms which can infect hospital patients, healthcare workers, and the general public. Other potential infectious risks may include the spread of drug-resistant micro-organisms from healthcare establishments into the environment. (26)

2-4-3 Sharps medical waste

By definition, medical "sharps" include DM-related products, such as needles, syringes, lancets, insulin pens, infusion sets, and connecting needles and sets. These sharps represent a form of medical waste that, unless properly discarded, could put an unsuspecting bystander at risk for direct contact with biological materials via a needle stick injury. (27) Sharps are defined as any medical utensil that can puncture human or animal skin. Sharps are used frequently in healthcare settings, especially for vaccination, drawing blood, and inserting an IV. They have their own containers specially made for them for disposal. Examples include Needles Syringes Scalpels Lancets Auto injector Regardless of whether these wastes are contaminated or not, they should be collected in an impenetrable safety box. (28)

The containers for collecting these wastes should have a sound lid and the materials used for the manufacture of these containers should be rigid and impermeable that in addition to keeping sharp objects, they should keep any remnants of the fluids inside the syringes. The methods for the

management of these wastes include; liquid disinfection by chlorine 0.5%, autoclave/shredding, encapsulation, incineration, and eventually disposal in protected sharps barrels or pits. (30)

2-4-4 Pathological medical waste

Medical wastes constitute a larger portion of infectious wastes, which are potentially dangerous since they may contain pathogenic agents. The production of these wastes will continue to be an ongoing phenomenon as long as there are human activities. (29)These wastes should be collected and kept inside resistant bags in washable and disinfected tanks with a special sign of infectious wastes. The best method for infectious waste disposal is disinfection at the point of generation including the use of an autoclave and controlled proper disposal or the use of an incinerator.(31)

2-4-5 Chemical and pharmaceutical wastes

According to the Basel Convention, many common drugs used in the treatment of patients referring to clinics are not considered hazardous drugs and they can be treated as household wastes and get disposed of accordingly. This group of wastes is found in trace amounts in medical clinics. In radiology clinics, trace amounts of chemical wastes are generated which are recycled for silver recovery. The waste of radiology clinics involves chemicals in the processing of radiographic film. These solutions contain silver and the chemical wastes generated in radiology clinics which were recycled in the clinics studied in this research. The radioactive wastes of these clinics are also managed under the supervision of the Atomic Energy Organization of Iran. Therefore, the amount of chemical and pharmaceutical waste in medical clinics was negligible, and many of the commonly used drugs used to treat patients referred to the clinics were not considered hazardous drugs, and this group of medicines was co-disposed with household wastes.(32)

2-4-6 Radioactive waste

Across the globe, the use of radioactive substances for medical treatment, by hospitals has resulted in the generation of toxic wastes on a large scale. Disposal of these wastes is being entrusted to waste disposal vendors. Environmental concerns, pressures, restrictions, and high labor costs, compel these vendors to dump these wastes in third-world countries, where enforcement and awareness are substantially low. Unrestricted access to these waste dumps is an open invitation to terror organizations to extract toxic substances and fabricate crude dirty bombs to threaten public safety and cause low-level contamination of sensitive installations. It is therefore imperative to create an international organization to monitor, regulate, and supervise the safe disposal of toxic radioactive wastes.(33)

Hospitals across the world use radioactive substances for purposes ranging from diagnosis to treatment. Hospitals have therefore become a major source of nuclear waste in the developed and developing world. Most hospital radioactive wastes are generated in the hospitals' departments of nuclear medicine. These wastes are in liquid, solid, and gaseous states.(34)

Disposal of these wastes is proving to be a vexatious problem, and many in developed countries connive with unscrupulous waste vendors to either dump wastes into oceans or in developing countries. These sites of unguarded, toxic, radioactive wastes can be accessed easily by terror organizations to fabricate crude radioactive dispersal devices. For example, Chechen rebels have attempted twice to detonate crude dirty bombs which were manufactured from "orphaned" sources obtained from unguarded nuclear waste sites, but timely intervention by the authorities averted major tragedies.(33)Medical treatment involves the use of both nuclear medicine and radiology. In nuclear medicine, radioisotopes are

introduced into the body internally, whereas, in radiology, x-rays penetrate the body from the outside .(35) X-rays, Magnetic Resonance Imaging (MRI) Scanners, Computerized Axial Tomography (CAT) Scanners, and Ultrasound all use nuclear science to examine different parts of the body and diagnose conditions. Nuclear imaging procedures include Positron Emission Tomography (PET), Single Photon Emission Computed Tomography (SPECT), and cardiovascular imaging. All these procedures involve the administration of radioisotopes which enable the detection of the radiation they emit. The administration is by injection, inhalation, or by mouth. For example, a gamma camera captures an image from isotopes in the body that emit gamma radiation. Then computers enhance the image, thereby revealing the presence of tumors. (36) This process is different from a diagnostic x-ray, where external radiation is passed through the body to form an image [3]. Nuclear medicine also enables imaging of the whole body; examples include whole-body PET scans, CT scans, Gallium scans, Iridium white blood cell scans, and octreotidescans. (37)

2-5 Sources of the medical waste

It is well known, that hospitals, clinics, nursing homes, laboratories, veterinary clinics, and many more establishments have to dispose of waste materials that have been generated in the process of medical care and treatment.Also biomedical waste is a broader term applied to waste generated during the diagnosis, treatment, or immunization of human beings or animals or in research activities pertaining thereto or in the production or testing of biological. (38)With the proliferation of blood-borne diseases, more attention is being focused on the issue of infectious medical waste and its disposal, health care institutions must be aware of the potential risk in handling infectious waste, and adhere to the highest standards of disposal and transport. Education of the staff, patients, and

community about the management of infectious waste is crucial in the healthcare area. With increasing awareness in the general population regarding hazards of hospital waste, public interest, litigate were was filed against erring officials. Some landmark decisions to streamline line hospital waste management have been made in the recent past. (39)

2-6 Medical waste management technologies

Africa is the second most populous continent, and its population has the fastest growth rate. Some African countries are still plagued by poverty, poor sanitary conditions, and limited resources, such as clean drinking water, food supply, electricity, and effective waste management systems. Underfunded healthcare systems, poor training, and lack of awareness of policies and legislations on handling medical waste have led to increased improper handling of waste within hospitals, healthcare facilities, and transportation and storage of medical waste. Some countries, including Ethiopia, Botswana, Nigeria, and Algeria, do not have national guidelines in place to adhere to the correct disposal of such wastage. Incineration is often the favored disposal method due to the rapid diminishment of up to 90% of waste, as well as the production of heat for boilers or for energy production. This type of method – if not applying the right technologies – potentially creates hazardous risks of its own, such as harmful emissions and residuals. (40)

A waste management system consists of appropriate segregation and disposal, with the inclusion of transportation, storage and training facilities for workers. An effective waste management system is often administered by local authorities, with a confined capacity for planning, restricted resources, operational monitoring, and contract management. These limiting factors make sustainable waste management a difficult proposition. (41)The aspect of sustainability and sustainable waste management in this review is the reduction of medical waste that is

released into the environment by reducing the volume of waste produced.(42)Various waste disposal methods are used across the continent, with incineration being the favored method due to the quick diminishment of up to 90% of waste, and utilization of its heat for boilers and energy production.(43)

2-6-1 Medical waste segregation

Medical waste management is a major concern for healthcare facilities. One important element is the segregation of infectious waste from domestic, non-infectious waste. (44)The amount of medical waste generated depends on various factors, including the size of the healthcare facility, number of beds, occupancy rate, segregation procedures, and types of services provided.(45)Waste segregation must be established as a key determinant in implementing an effective waste management system in any healthcare facility. The success of waste segregation in healthcare institutions is highly dependent on good hospital management, organizational policies, efficient budget planning for waste management, and operational running costsin Nigeria including poor or lack of segregation of medical waste at the point of generation, a deficient or non-existent recommended medical waste color–coding or labeling system, inadequate personal protective equipment (PPE) for waste handlers, inadequate medical waste management information for health workers and waste handlers, and the incessant dumping of medical waste into municipal dumpsites.(46) The medical waste management process comprises interrelated key stages starting from segregation, collection, storage, transportation, and treatment and ending up with its final disposal. Appraisal of medical waste handlers` knowledge and their skill in proper waste management could be a fruitful exercise to quantify and minimize occupational associated risks. (47)

2-6-1-1 Types of Waste Containers and Bags

Red Bag - Syringes (without needles), soiled gloves, catheters, IV tubes, etc. should be all disposed of in a red-colored bag, which will later be incinerated. Yellow Bag - All dressings, bandages, and cotton swabs with body fluids, blood bags, human anatomical waste, and body parts are to be discarded in yellow bags. Cardboard box with blue marking - Glass vials, ampules, and other glass are to be discarded in a cardboard box with a blue marking/ sticker. White Puncture Proof Container (PPC) - Needles, sharps, and blades are disposed of in a white translucent puncture-proof container Chemotherapy Sharps Container - Cytotoxic and Geotaxis Waste includes chemotherapy needles, syringes, iv catheter, sutures, broken glasses & scalpels Black Bags - These are to be used for non-biomedical waste. In a hospital setup, this includes stationary, vegetable and fruit peels, leftovers, packaging including that medicines, disposable caps, disposable masks, disposable shoe-covers, disposable teacups, cartons, sweeping dust, kitchen waste, etc.(51)

2-6-2 Medical waste collection

Medical waste should be collected in containers that are leak-proof and sufficiently strong to prevent breakage during handling, storage, and transportation. (48)There are approximately 15 million people engaged in waste collection worldwide.1 In low- and middle-income countries, recyclable collectors represent 1% of the urban workforce.(49)Waste collection is linked to adverse health effects, including injuries (e.g. cuts), hearing loss, musculoskeletal disorders, respiratory diseases (e.g. bronchitis, pneumonia, allergies), skin diseases (e.g. dermatitis, sunburn), communicable diseases (e.g. HIV/AIDS, sexually transmitted infections, hepatitis B and C), waterborne diseases (e.g. dengue, leptospirosis, diarrhea), and psychological disorders (e.g. depression, stress, anxiety). (50)

The proper medical waste collection entails the following conditions: A. Organizing the methods of collecting medical waste bags and containers and transporting them to the temporary collection point daily. B. To ensure safety and avoid danger, a unified classification system must be followed for marking and coding waste containers, in accordance with Annex 1. C. Providing male and female workers with personal protective clothing and tools necessary for the process of collecting medical waste (bags and boxes for medical waste) in addition to the materials used for cleaning and sterilization. D. Waste of communicable diseases departments, medical laboratories, and the like must be sterilized from the source before being transported to the collection point. (51)

2-6-3 Storage of medical waste

Medical waste storage at healthcare centers and the transportation of these potentially harmful materials to treatment centers are two mutually affected risky tasks. The former entails the occupational risk related to the storage and handling of hazardous medical waste while the latter includes the public risk associated with hazardous materials transportation.. The medical waste collection business involves servicing customers, depending on the customer demand and environmental regulations. Environmental rules mandate daily treatment of infectious medical waste if it is kept at room temperature and weekly treatment if it is kept at a temperature less than 5 ◦C. (52)

Medical wastes requiring storage should be kept in labeled, leak-proof, puncture-resistant containers under conditions that minimize or prevent foul odors. The storage area should be well-ventilated and inaccessible to pests. (53)These labels are warnings to employees and the public about the type of waste in the container. Your local jurisdiction may have rules about warning labels that must be affixed to storage containers. Even if

there are no legal requirements, best practices call for warnings that indicate the nature of the hazard. (54)

Storage rooms should have locks and be away from the public and most building occupants. Ideally they should be indoors, but any outdoor storage should be fenced to keep away animals and humans.

State regulations often dictate the maximum amount of time that medical waste can be stored prior to treatment. For example, in the state of New York, storage of regulated medical waste is limited to seven days. Medical waste must be stored separately from municipal solid waste. All reusable storage containers must be disinfected after they have been emptied unless they employ a disposable liner that is removed from the waste.

Workplace safety rules apply to medical facilities, and waste managers must worry about employee safety. (55)The International Committee of the Red Cross (ICRC) Recommends storage time for infectious waste does not exceed 72 hours in winter and 48 hours in summer in temperature climate zones. In hot climates, the recommended limits are 48 hours in the cooler season and 24 hours in the warmer season. If refrigerated storage is available, hold times can go up to a week, per the ICRC, if the temperature is between 3 °C and 8 °C.(56)

The ICRC recommends criteria for storage areas. While these does not have the force of law, they are good guidelines and should help you with regulators:

- ✓ The area should be closed, and access must be restricted to authorized persons only.
- ✓ The waste storage area must be separate from the food storage area and should be covered and sheltered from the sun.
- ✓ Flooring must be waterproof with good drainage.
- ✓ Must be easy to clean.

- ✓ Must be protected from rodents, birds, and other animals. Must allow easy access for on-site and off-site means of transport.
- ✓ Should well-lightened.
- ✓ Should be big enough to sort waste if possible and to allow the physical separation of different categories of waste. Ideally, it should have some physical barriers to prevent the mixing of wastes of different categories.
- ✓ Should be close to any on-site treatment.
- ✓ Compartmented (so that the various types of waste can be sorted).
- ✓ Should have eye-washes and other PPE.
- ✓ Should be near wash basins.
- ✓ The entrance must be marked with a sign to discourage people from entering unless they need to be there and a warning of hazards. (57)

2-6-4 Transportation of medical waste

Medical waste transportation refers to the haulage and handling of waste from inside healthcare facilities to treatment sites, which can either exist on-site at a hospital or be a central off-site facility. A second transportation phase typically occurs when the treated waste residual, typically ash from an incinerator or waste sterilized through autoclaving or microwaving, is moved to a landfill for final disposal.(biomedical.(60)It is common practice for healthcare facilities to have their infectious waste stream transported by a third-party firm, contracted to take the waste from the healthcare facility to an appropriate waste depo.(61)wastes are typically taken from the facility that generates them to a transfer station or a treatment, storage, and disposal facility (TSDF) rather than straight to a landfill. The TSDF may have its own landfill or it might transfer the waste elsewhere for ultimate disposal (or

for more treatment).(58)The hospitals have the responsibility for providing on-site transport of medical waste, while off-site transport to the final disposal site is handled by disposal companies. These companies are also in charge of the final disposal of medical waste in Nanjing. Medical waste is transported through pre-established routes, which include specific corridors and elevators on each floor, and are strictly used to transport waste from the intermediate storerooms to the final storerooms in the basement of the hospital. (59)

2-6-5 Medical waste Treatment methods

Safe disposal of infectious medical wastes is a problem of considerable scope, with the WHO stating that "at present, there are practically no environmentally friendly, low-cost options for safe disposal of infectious wastes" (61)In the United States, studies have found that 49e60% of medical waste is incinerated, 20e37% is autoclaved, and 4e5% is treated by other technologies.(62)However, concerns over air pollution have raised questions about the suitability of incineration as a treatment method. Further, the medical waste contains a significantly higher plastic content than typical municipal solid waste, and as a, result the combustion of medical waste leads to the formation of polychloridibenzo-dioxinsioxins (dioxins) and polychlorinated dibenzofurans (furans), both highly toxic substances (63). This has led to an increased focus on alternative treatment methods such as autoclaving and microwaving to kill any pathogens present.

2-6-5-1 Medical waste incineration:

Incineration is the process of destructing waste by burning it at elevated temperatures in furnaces. The process removes hazardous materials, reduces the mass and volume of the waste, and converts it into ash which is harmless. Incineration is suitable for wastes that are 60% combustible. Incineration is suitable for pathological and infectious waste or sharp

wastes. Incinerators exist in several different types; each type has a specific function. A mobile incinerator called a “drug terminator” is used for the disposal of pharmaceuticals. A diesel-fired medical waste incinerator called “MediBurn” treats pathological and infectious waste in small medical facilities, and laboratories.(64)The advantage of incineration process is that the volume of the waste that will remain for disposal will be reduced by 50 - 400 times. (65)Incineration has a significant advantage of decreasing the volume of the wastes; however its disadvantages include high costs, smoke generation and pollution risks. Incinerators used in hospitals produce more furans and dioxins than incinerators used in municipality. This higher concentration of furans and dioxins are due to a) frequent startups and shutdowns b) less stringent emission controls c) poor combustion control (e.g., waste mixing and oxygen controls), and d) differences in the waste feed composition as compared with municipal solid waste. (66)Incinerators are usually built with a chimney to reduce the smoke and its effect on pollution. Moreover, incinerators are usually located at least 100 m away from the medical center in order to reduce the effect of smoke. A pit belowthe incinerator is usually available in order to collect the ashes. Incineration is one of the most efficient methods of disinfecting medical waste. (65)

2-6-5-2 A new Technology of Medical Waste Treatment

New technology for the management of hazardous medical waste that transfers regulated medical waste into municipal solid waste is recently introduced. This method involves shredding and grinding the infectious medical waste bags via sharp cutting blades that are installed within the vessels. The blades rotate around 1750 revolutions per minute and the volume of the shredded waste is reduced by 80%. The steps included in the process are loading, shredding, heating, sterilization, cooling, draining, vacuuming, and unloading. The whole process is enclosed in a

compact system and there is no intermediate handling of the waste within the process. Due to the compact size, this system can easily be used for on-site treatment of waste and installed in hospitals. This will reduce the transportation costs of medical waste. In terms of environmental aspects, it is a clean and chemical-free technology and does not have any hazardous emissions or radiation (67) this method is economical and environmentally friendly and is reliable in terms of ease of use and maintenance. This technology is currently practiced in the middle-eastern countries such as Iraq, Jordan, Kuwait, Lebanon, Syria, and UAE. (68)

The machine converts the medical waste into disposable municipal waste using shredders that shred the waste into smaller particles which are then wetted with disinfectant spray and immersed in a disinfection solution. The wet waste is then dried using a hot off-gas in a drying chamber. Considering the number of clinics and hospitals inmiddle-east, this method will be very successful if utilized, as it can treat the medical waste on-site which helps in better management of waste. (66)

2-6-5-2-1 Incinerator emissions

2-6-5-2-1-1 Dioxin and furan emissions

One of the major issues associated with the incineration of infectious waste from healthcare facilities is the formation of dioxins, furans, and similar compounds during the combustion process. (68)Dioxins are organic compounds with two benzene rings connected by two oxygen atoms and contain four to eight chlorines substituted for hydrogen atoms on the benzene rings (69)Dioxins are extremely persistent toxins, with an estimated half-life in humans of 7e11 years, and result primarily from human activity. They are known to be highly carcinogenic and cause reproductive harm in humans (70). Furans are structurally similar to dioxins, but with only one oxygen atom between the two benzene rings,

and have similarly toxic properties. Hereafter in this paper, the term dioxin is used to refer to dioxin, furan, and similar compounds. (69)

2-6-5-2-1-2 Mercury emissions

Incineration of waste, both medical and municipal, is estimated to represent 13 percent of anthropogenic mercury emissions in North America, making it second only to coal combustion (at 55 percent) as an emissions source. Further, at least 3 percent of global anthropogenic mercury emissions come from waste incineration. (71) Atmospheric mercury emissions pose a significant health and environmental risk, as airborne mercury can readily enter the body through the lungs where it accumulates in fatty tissue. This is concerning, as elevated mercury levels in the body have been shown to damage the nervous, excretory, and reproductive systems (72)

2-6-5-2-1-3Emissions control

The two leading methods for dioxin emission control from incineration facilities are fabric filter bag houses and dry scrubbers in combination with electrostatic precipitators. However, the use of fabric filters is generally accepted to be a more effective method of dioxin controll (73). Further, incinerator operating conditions play an important role in dioxin emission levels, with dioxin formation greatly increasing when combustion is incomplete due to lack of oxygen or when combustion occurs at temperatures below 800 C. Flue gas temperatures in the range of 250 Ce450 C must also be avoided (74). By operating incineration facilities at optimal conditions the dioxin emissions associated with medical waste incineration can be greatly reduced.The control of mercury emissions commonly involves injecting powdered activated carbon into the flue gas stream, onto which the gas-phase mercury adsorbs. The particles of carbon onto which the gaseous mercury has been adsorbed

can then be removed using such particulate matter control technologies as fabric filters or electrostatic precipitators (73).

2-6-5-2-1-3Autoclave waste treatment

Considering the high costs and environmental impacts of medical waste disposal through incineration, many researchers and firms are devoted to developing alternate treatment methods for infectious medical waste. The leading alternative to waste incineration is autoclaving, a process whereby infectious waste is treated with the addition of dry heat or steam to raise the temperature of infectious waste to levels sufficient to kill microbial contamination, with these systems generally operating at temperatures between 121 and 163 C (63). After treatment, the autoclaved waste can be taken to a municipal solid waste (MSW) landfill site and disposed of in the same manner as non-infectious waste (75). Autoclave treatment of infectious medical waste is considered environmentally advantageous when compared with incineration, as it does not release poisonous dioxin and mercury emissions into the atmosphere (63). However, there are drawbacks to the use of autoclaving as an infectious waste treatment method. Because autoclave treatment merely heats the waste to a sufficient temperature to kill pathogens, the waste does not change in appearance after autoclave treatment, giving the appearance that untreated infectious waste is being disposed of in landfill sites (75). As a result, autoclaved waste is often re-treated via incineration before final disposal due to the reluctance of many communities to allow non-incinerated infectious waste into their landfills, making the autoclave treatment redundant (76). This double treatment of infectious medical waste unnecessarily increases the cost of disposal and creates needless environmental impacts due to the use of energy in the autoclaving process. Another argument against autoclaving infectious waste is that it does not significantly reduce the volume of waste to be landfilled,

whereas incineration leaves only 20 to 30 percent of the original waste volume behind as ash, greatly reducing the amount of space the waste occupies in a landfill (78).Drawbacks of autoclave infectious medical waste treatment must be considered alongside the drawbacks of medical waste incineration. The macro-scale benefit of waste volume reduction in the incineration treatment method may be dubious, as medical waste represents a very small fraction of the total volume of waste generated per year compared to other types of waste sent to landfill (79). A variation of autoclave treatment is microwave treatment, which involves a process similar to the autoclave process outlined above but instead uses microwaves to add heat (80). However, one major difference between microwaving and autoclaving waste is that with microwaves, metal cannot be present in the waste, as microwaves impacting on metal can cause large, potentially dangerous sparks. Further, some question the ability of the microwave process to sufficiently reduce the pathogen content of infectious medical waste (63)

2.7- Previous studies

2.7.1- Study about Assessment of composition and generation rate of healthcare wastes in selected public and private hospitals of Ethiopia. Researchers investigated the generation rate and composition of healthcare wastes in six public and three private hospitals. they conducted healthcare waste composition and characterization measurements for seven consecutive days in the selected hospitals following the protocol described by the World Health Organization (WHO). The results revealed that the total generation rate of healthcare wastes of hospitals ranged from 0.25 to 2.77 kg/bed/day with a median value of 1.67 kg/bed/day for inpatients to 0.21–0.65 in kg/patient/day with a median value of

0.31 kg/patient/day for outpatients. The waste generation rate in private hospitals (median 3.9 kg/bed/day) was significantly greater (Kruskal–Wallis test, $P < 0.05$) than in government hospitals (median 1.5 kg/bed/day). The median values of percent hazardous waste estimated for private and government hospitals were 63.4% and 52.2%, respectively.(80)

2.7.2- Study about Analysis of the measured medical waste generation rate in Tanzanian district hospitals using statistical methods. the study carryout at Amana and Ligula hospitals. In this study, Researcher found The rate of medical waste generation is high; about 2,250 kg/day in Amana and 2,500 kg/day in Ligula hospital. The waste generation rate per patient per day is also high about 1.8 (Amana) and 2.0 (Ligula) kg/patient. day. The daily medical waste generation rate is not constant, and fluctuates randomly. About 6 to 10% of waste generated is left uncollected. Eight medical waste categories were measured and compared: general waste, pathological waste, radioactive waste, chemical waste, infectious waste, sharps waste, pharmaceutical waste, and pressurized containers. The results indicated general waste to have high generation rate while others waste types such as chemical and radioactive wastes have low generation rates. Due to differences in generation rates, the data was normalized in order to compare statistical parameters used to assess medical waste generation rates. The statistical parameters used include: range, skewness, kurtosis, probability density functions and histograms. The study revealed that management of medical waste is still facing critical problems and requires skilled health workers, appropriate technologies and suitable equipment for collection, storage and transportation.(82)

2.7.3- Study about Evaluation of medical solid waste management in some hospitals in Najaf city/Iraq. This study aimed to develop models to predict the rate of medical waste production in hospitals in Hilla city, Iraq. In this study the researcher used Predictive models and long-term data on the composition and rate of solid medical waste generation and developed a longitudinal study design. Also a standardized questionnaire and weighted scale were used to measure solid medical waste generated from the five public hospitals. In addition Statistics were used to create models predicting the amount of waste generated at each hospital. These models demonstrated a significant correlation between inpatient and outpatient numbers and waste generation. Different hospitals treat different numbers of inpatients and outpatients. Different models have been created based on various types of hospitals. (83)

2.7.4- Study about Practice and enforcement of national Hospital Waste Management 2005 rules in Pakistan. the study aimed to assessed the adherence to hospital west management 2005 rules by tertiary care teaching hospitals of Peshawar District with respect to hospital waste management personnel, policy and practices. The methods of this study was Pretested structured questionnaires based on WHO recommendations were used to survey all teaching hospitals of Peshawar District from January to March 2015. Data were also collected on HWM infrastructure and processes from randomly selected medical, surgical, paediatric, and obstetrics/gynaecology unit in each hospital. Besides descriptive statistics, public and private hospitals were compared using Fisher's exact and Wilcoxon rank-sum tests. Study Results indicates the Most surveyed hospitals lacked formal HWM plans (70%), written procedures (80%), related job descriptions (80%) or records (90%).

Many hospitals neither had trained HWM supervisors (56%) nor did they organize formal HWM trainings for new staff (40%). None of the hospitals followed waste segregation and colour coding. When compared to national HWM 2005 rules, multiple gaps in appropriate transportation, storage and disposal were found with no statistically significant difference between public and private hospitals. (84)

2.7.5- Study about Hospital waste management—awareness and practices: a study of three states in India. The study was conducted in Andhra Pradesh, Maharashtra and Uttar Pradesh in India. Hospitals/nursing homes and private medical practitioners in urban as well as rural areas and those from the private as well as the government sector were covered. Information on (a) awareness of bio-medical waste management rules, (b) training undertaken and (c) practices with respect to segregation, use of colour coding, sharps management, access to common waste management facilities and disposal was collected. Awareness of Bio-medical Waste Management Rules was better among hospital staff in comparison with private medical practitioners and awareness was marginally higher among those in urban areas in comparison with those in rural areas. Training gained momentum only after the dead-line for compliance was over. Segregation and use of colour codes revealed gaps, which need correction. About 70% of the healthcare facilities used a needle cutter/destroyer for sharps management. Access to Common Waste Management facilities was low at about 35%. Dumping biomedical waste on the roads outside the hospital is still prevalent and access to Common Waste facilities is still limited. Surveillance, monitoring and penal machinery was found to be deficient and these require

strengthening to improve compliance with the Bio-medical Waste Management Rules and to safeguard the health of employees, patients and communities. (85)

2.7.6- Study about Knowledge, attitudes and vaccination coverage of healthcare workers regarding occupational vaccinations. The study aimed to evaluate knowledge regarding occupational vaccinations, HBV, Varicella and influenza vaccinations rates and attitudes towards influenza vaccine among health care workers. The study conducted as a cross-sectional survey in (Medicine and Pediatrics) of a 1182-bed teaching hospital in Paris, France. A standardized, anonymous, self-administered questionnaire was used. Results of this study as: of 580 HCWs, 395 (68%) completed the questionnaire. Knowledge about the occupational vaccinations of HCWs was low. HBV (69%), tuberculosis (54%) and influenza (52%) were the most cited vaccinations. Pediatrics staff was more aware of influenza and pertussis immunizations ($p < .05$). HBV vaccination rate was 93%, among whom 65% were aware of their immune status. Influenza vaccination rate for 2006–2007 was 30% overall, ranging from 50% among physicians to 20% among paramedical staff ($p < .05$). Physicians based their refusal on doubts about vaccine efficacy, although paramedics feared side effects. Influenza vaccination was associated with knowledge of vaccine recommendations [OR = 1.75, 95% CI: 1.13–2.57] and contact with patients [OR = 3.05, 95% CI: 1.50–5.91]. (88)

2.7.7- Study about Assessment of Hospital Waste Management Practices in Public and Private Healthcare establishments of Rahim Yar Khan. This study aimed to assess the hospital waste management practices in private and public-sector healthcare establishments at district Rahim Yar Khan. The study was cross-

sectional conducted in conveniently selected 34 healthcare establishments (HCEs) of district Rahim Yar Khan, from 1 st January to 30 th March 2018. Healthcare establishments included wards of a tertiary care hospital, basic health units, private clinics and hospitals of the district. Variables included were number of beds, color coding, hospital waste segregation at source, appropriate transportation vehicle, storage site and vehicles. SPSS version 21 was used for data entry and analysis. The study results indicate that Twenty-six (76.5%) of the healthcare establishments have waste segregation at source and 1 (2.9%) of HCE have no proper color coding and 21 (61.8%) of the HCEs have workers wearing protective gears and fifteen (44.1%) have appropriate vehicle for waste transport. Waste disposal was incineration in nineteen (55.89%) of HCEs. Eleven (57.9%) of the public sector HCEs were following segregation.(p= 0.00) In private sector method of disposal of waste was mostly land disposal 7 (46.7%) while in public sector HCEs, was mostly incineration in 14 (73.7%%).(p= 0.00) and out of total 34 HCEs, training about handling and waste management were given in only one (6.6%) of Private Hospitals. (86)

2.7.8- Study about Knowledge, attitude and practice of staff on segregation of hospital waste: a case study of a tertiary private hospital in Kenya. This study set to find out the knowledge, attitude and practice of hospital staff in segregation of hospital waste. Specifically, the study sought to analyse how healthcare waste is segregated, what organizational factors affect the practice, knowledge on proper management of biomedical waste and the attitude of workers towards the practice. A sample size of 105 respondents was included in the study from a population of 442

members of staff. Stratified random sampling technique was used. A structured questionnaire was administered to the sample. The Statistical Package for the Social Sciences was used for the purpose of data analysis. Data was analyzed using descriptive statistical techniques. Inferences were drawn using chi-square test of significance. Results revealed that waste segregation was done across all the departments at the hospital except the accounts department. Syringes and needles made up most of the waste segregated from the various departments at the hospital. With the exception of surgical blades and needles which were disposed in yellow sharps containers, all the other healthcare wastes were disposed in any of the bins. Clear instructions and guidelines influenced the practice of waste segregation among staff at the hospital. The study recommended that training on health care waste management should be done on a regular basis. Adequate quantity of the right colour of waste disposal bags should be provided. Policies and guidelines should be introduced in order to guide and direct staff on what the institution expects of them. A waste segregation plan should be introduced. (87)

2.7.9- Study about Effectiveness of a training program about bio-medical waste management on the knowledge and practices of health-care professionals at a tertiary care teaching institute of North India. The study aimed to evaluate the existing knowledge regarding (BMW) management rules among selected health-care professionals and to evaluate the impact of training program on bio medical waste (BMW) management on the knowledge and practices of health-care professionals. The training program on BMW management rules was conducted in April 2018. A total of 250 participants were trained. A structured validated questionnaire

was used. The data were analyzed, and the mean score of pre- and post-test was compared by the paired-t test. Majority of the participants were female (83%) aged 20–30 years (56%). The majority of the participants were married (74%) and were from urban areas (74%). The mean pretest and posttest score were 14.00 and 19.94 respectively ($P < 0.000$). (92)

2.7.10- Study about Disposal of medical waste: a legal perspective: forum-medicine and the law. researcher indicate that The Constitution of the Republic of South Africa provides that everyone has the right to an environment that is not harmful to their health and well-being. The illegal dumping of hazardous waste poses a danger to the environment when pollutants migrate into water sources and ultimately cause widespread infection or toxicity, endangering the health of humans who might become exposed to infection and toxins. To give effect to the Constitution, the safe disposal of hazardous waste is governed by legislation in South Africa. Reports of the illegal disposal of waste suggest a general lack of awareness and training in regard to the safe disposal of medical waste. (96)

2.7.11- Study about knowledge, attitudes and practices of nurses towards healthcare waste management in port Sudan city, Sudan, 2019-2020- aimed to assess the nurses knowledge, attitude and practice towards health care waste management in port Sudan city ,Sudan 2019- 2020. The study findings pointed to upgrading nurse's knowledge, attitude and practice related to segregation, collection, storage, color coding system and treatment of health care waste. The Study has suggested that the knowledge, attitude practice of nurses towards safety measures (immunization, wearing protective cloth , periodic examination , hand hygiene), need awareness raising through training.(97)

Chapter three

Methodology

Chapter Three

3. Materials and Methods

3.1 Study Design:

An observational descriptive cross-sectional study was conducted in hospitals of shendi locality to assess the Healthcare solid waste management at the hospitals during the period of March 2021 to July 2024

3.2 Study area:

Shendi locality is one of the localities of the River Nile State. It is bounded by Khartoum state to the south, Elddamer locality to the north, River Nile to the west and kassala state to the east. It consists of five administrative units (Kaposhia, North rural, Shendi city, South rural and Hagar alasaal). The main crops are cash crops such as white beans, onions, wheat and sorghum, goats and camels are practiced both by the few nomadic 'Rashaida' and the settled farmers. Culturally the population of Shendi is a mixture of the various cultures that occur in Sudan though the Northern tribes, particularly El-Gaalien, are predominant. The total population of Shendi ‘locality’ is estimated at about 245000. Growth Rate: 2.3%, Male 48.7%, Female % 51.3%. The average family size is 6members, 78% of the population depends upon subsistence agriculture while the rest are traders, teachers, and handcraft workers, including spinners, weavers, and other artisans. About 60% of the population is rated as 'poor'. The literacy rate is high in the towns and villages in the locality. Basic Education consists of (112) primary schools. Secondary Education consists of (17) secondary schools. Shendi University was established in the early 1990s and includes (14) faculties in the shendi locality.

Many governmental and private health services were established, to provide health care to the community. There are (10) hospitals, (38) health centers, (17) basic health units, and other health programs in the locality, (maternal and child health (MCH) and expanded program of immunization (EPI)). Moreover, environmental Health and Sanitary activities are carried out by the Environmental Health staff. The major constraints facing the health facilities in the locality are the small number of qualified staff, lack of training courses**,** and the shortage of types of equipmen**, (**81**)**

3.3 Study population:

A total of ten(10) Hospitals, and health care workers in hospitals

3.3.1 Inclusion Criteria; physicians, nurse, lab technicians, cleaning workers, Health Officers,the total of the study population 671 persons

Table (3-1) Distribution of study population in the study area according to hospitals:

NO	Hospital	Doctors	nursing	lab technician	Phermciti lca	6-cleaner worker	Health officer
1.	Elmaknemir	84	160	45	8	40	1
2.	Shendi education hospitals	24	36	21	6	27	2
3.	Hagar alasaal	2	17	1	2	8	0
4.	Kaposhia	2	8	7	2	10	1
5.	Tumer herapy center	5	13	7	3	17	0
6.	Alhowsh	4	14	6	1	6	1
7.	Albasaber	2	5	2	1	6	
8.	Military	2	71	7	2	9	2
9.	Almisaktab	2	8	2	1	19	1
10.	Alshagalwa	5	16	4	1	8	1
11.	Total population	132	348	102	27	150	9

3.3.3 Exclusion criteria: All persons were absent or refuse to respond or, during the field survey.

3.4 Sampling and sample size:

Total coverage sample was followed to select the (10) hospitals and 253 persons (110 health staff+ 143 clean workers) from 768 persons of health care workers in the Shendy locality hospitals.

Sample size was calculated by the equation. $$n = \frac{N}{1+Ne^2}$$

Source; Survey Sparrow. (2024, July 15). Sample size calculator with Slovin's formula for more effective surveys. Retrieved October 21, 2024, from https://surveysparrow.com/blog

Where the; n= Sample size, N= study population, e= merging error (0.05)

$$n = \frac{768}{1+768(0.05)^2} = 256,$$ *there are (3) samples was missed, so 253 samples was entered to analysis in this study.*

The distribution of the sample size on the criteria of the study population was calculated by this equation $$\frac{\text{Size of the strata}}{\text{total population(N)}} \times \text{Sample size(n)}$$

Table(3-2) Sample size details and strata for each hospitals in Shendi locality:

NO	Hospital	Doctors	Nursing	lab technician	cleaner worker	Health officer
1.	Elmaknemer	28	53	15	13	1
2.	Shendi	8	12	7	9	2
3.	Hagar alasaal	1	6	0	3	0
4.	Kaposhia	1	3	2	3	1
5.	Tumer Therapy center	2	4	2	6	0
6.	Alhowsh	1	5	2	2	1
7.	Albasaber	1	2	1	2	
8.	Military	1	24	2	3	2
9.	Almisaktab	1	3	1	6	1
10.	Alshagalwa	2	5	1	3	1
11.	Total population	44	53	34	50	9

3.4.1 Sample technique:

The study population were divided in stratified cluster, and then the sampling technique were used to select the health care workers that participant in the study bymultistage type of random samplestechnique

3.5 Data collection tools: multiple tools were used for this study including; (structure questionnaire, check list, interview with hospitals managers, reviewing records and measurements for waste weight.

Data was collect by using:

Questionnaire design: pretested Structural Questionnaire was used designed to collect data from (physicians, nurse, lab technicians, cleaning worker, and medical assistant, Health Officers, Medical Receptionist). Including multiple variables related with study objectives such as: demographic variables (age, gender, education level and position); training information, **health staff and clean workers** practices regarding to medical waste management, knowledge regarding medical waste types and risk related

Interview: designed to discusses with 10 hospitals managers about hospitals sections and number of staff, duration of work addition to hospitals planning to healthcare solid waste management.

Reviewing record: record reviewed to know information related with staff and works as screening test and immunization status.

Measurements: this tool was used to weight of the solid waste generated from hospitals. Was applied as flowing;

Waste category	Quantities of Waste Produced Per day			
	Day 1	**Day2**	**Day 3**	**Average**

- ✓ The quantities of waste were weighed by using a portable crane scale.
- ✓ Colored plastic bags were distributed to supervisors and waste workers to collect and segregate waste in each hospital.
- ✓ In some hospitals the waste is collected in two or three shifts, the accumulated quantities of all shifts per day were measured.
- ✓ To assess methods of waste segregation, collection, storage, handling, transport and disposal 3-5 days were spent in each hospital to closely watch the waste stream management practices, interviews with management staff, supervisors, workers and also localities responsible personnel to assess the transport and final disposal methods of waste.
- ✓ Photos of different steps were taken.
- ✓ Personnel information was provided from personnel department of each hospital.

3.6 Data analysis: the experimented data, questionnaire and interviews were analyzed using statistical Excel and Statistical Package for the Social Sciences (SPSS) software. The SPSS^{v22} was used to provide statistical analysis of data. Data to be analyzed were entered in a format where cases (each question in the survey) are represented by rows and variables (the different replies to one question of a survey) are represented by columns. Then the data were manipulated and changed to percentage scale. Descriptive analysis was made to some questions and then the descriptive parameters (maximum, minimum, standard deviation) were found. multi of statistics needed in this study as:

- ❖ **Frequencies tables**; to show data include percentages and frequencies
- ❖ **Cross tabulations;** to know the relationship between two or more variables
- ❖ **Chi squire;** to know significance between variables at P- value 0f 0.05 or less as significant value.

Sampling and Analysis

3.7. WHO guidelines for healthcare solid west classification

The waste characterization in the study was carried out according to WHO guidelines (WHO 1999, WHO 2001) and adopted the WHO classification of medical wastes:

- ✓ General waste.
- ✓ Pathological waste.
- ✓ Radioactive waste.
- ✓ Chemical waste.
- ✓ Infectious waste.
- ✓ Sharps waste
- ✓ Pharmaceutical waste
- ✓ Pressurized waste

Sampling procedures represented a core activity under this study where all of the wastes generated in 10 Hospitals were segregated and weighed during a period of five months, The environmental health experts as well as quality control administration, managers of waste collection, storage, and transportation recorded the amount of medical waste on the data form. The wastes from hospitals were collected from storage areas, and the quantity and compositions were determined at each hospital. Parallel to the interviews, the physical waste compositions in hospitals were determined. Masks and large forceps were used to segregate waste into several types. During segregation, each type of medical waste was discarded into bags. General and medical wastes from outpatient and inpatient services were collected separately. The weighing and analysis of wastes performed in the particular site. The medical wastes were previously stored in various components such as serum, syringes, needles, etc. The weight of each component of medical waste was recorded on special data forms. Following these procedures, the wastes were transported to a special site for storage and final disposal. This waste "composition study" was part of continuing efforts to measure and understand the waste generated in hospitals. The raw survey data was compiled and managed so as to enable the estimation of waste generation quantities and management practices. For weighing the generated solid waste in each hospital the following table was used:

Hospital name	Quantities of Waste Produced Per day			
	Day 1	Day2	Day 3	Average

3.8 Ethical approval:

The study was firstly approved by ethical committee of the Faculty of Graduate Studies (Institute Research Board) at Shendi University. Permission was also taken from the directors of health facilities to be studied. Names and personal data were completely secured.Also an individual informed consent was taken from all participants before filling of questionnaires.

Chapter four

Results

Chapter Four

Results

Table (1): Demographic Information of the Technicians at the Hospitals in Shendi locality, River Nile State , 2023 (n=110)

Variables	Category	Frequency	Percent
Gender	Male	37	33.6
	Female	73	66.4
Education	Basic	2	1.8
	Secondary	5	4.5
	Graduate	69	62.7
	postgraduates	34	30.9
Age	18-25yrs	31	28.2
	26-35yrs	45	40.9
	36-45yrs	29	26.4
	46-55yrs	4	3.6
	Above 55 Years	1	.9
Occupational	Doctor/dentist	42	38.2
	Medical assistant	2	1.8
	Nursing	42	38.2
	lab technician	20	18.2
	Medical receptionist	1	.9
	health Officer	3	2.7
Total		110	100%

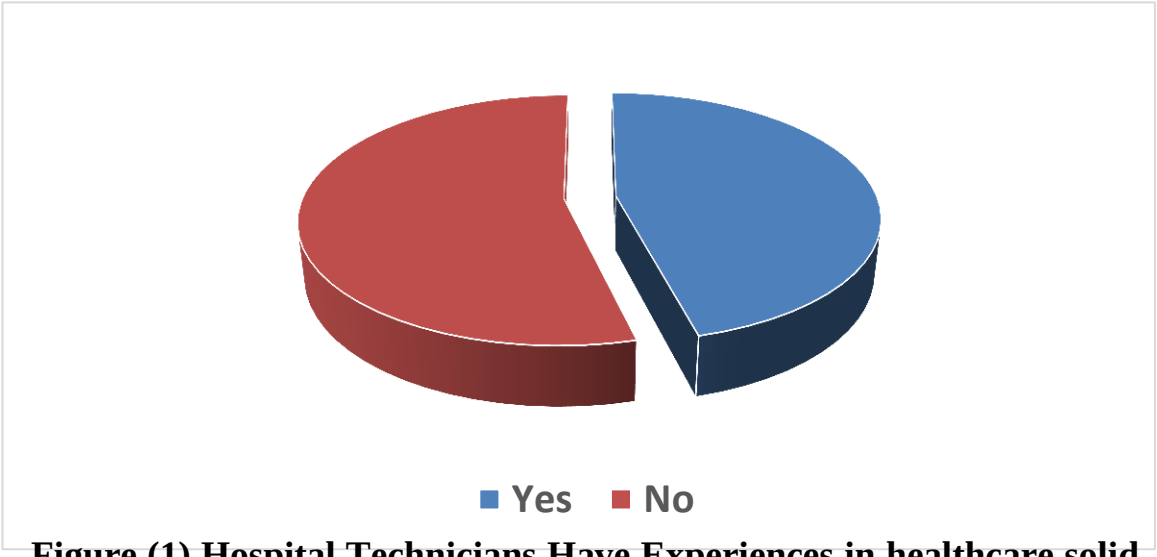


Figure (1) Hospital Technicians Have Experiences in healthcare solid Waste Management in Shendi Locality 2023 (n=110)

Table (2): healthcare solid Waste Management Training Program Delivered in Hospitals Shendi locality, River Nile State , 2023 (n=110)

Variables	Category	Frequency	Percent
Technicians Receive Specialized Training	Yes	52	47.3
	No	58	52.7
The Existence of a regular Training Program	Yes	43	39.1
	No	67	60.9
Regular Training Program	Yes	40	36.4
	No	70	63.6
Total		110	100%

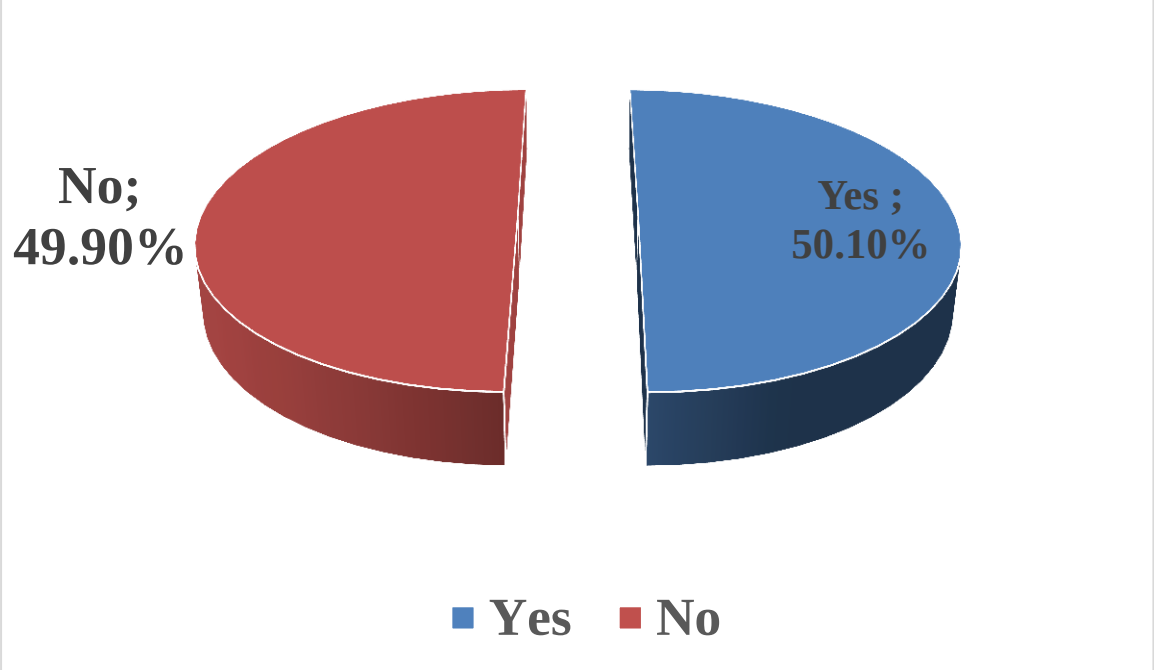


Figure (2): A designated Employee for the Disposal of healthcare solid waste at Hospitals in Shendi locality, River Nile State , 2023 (n=110)

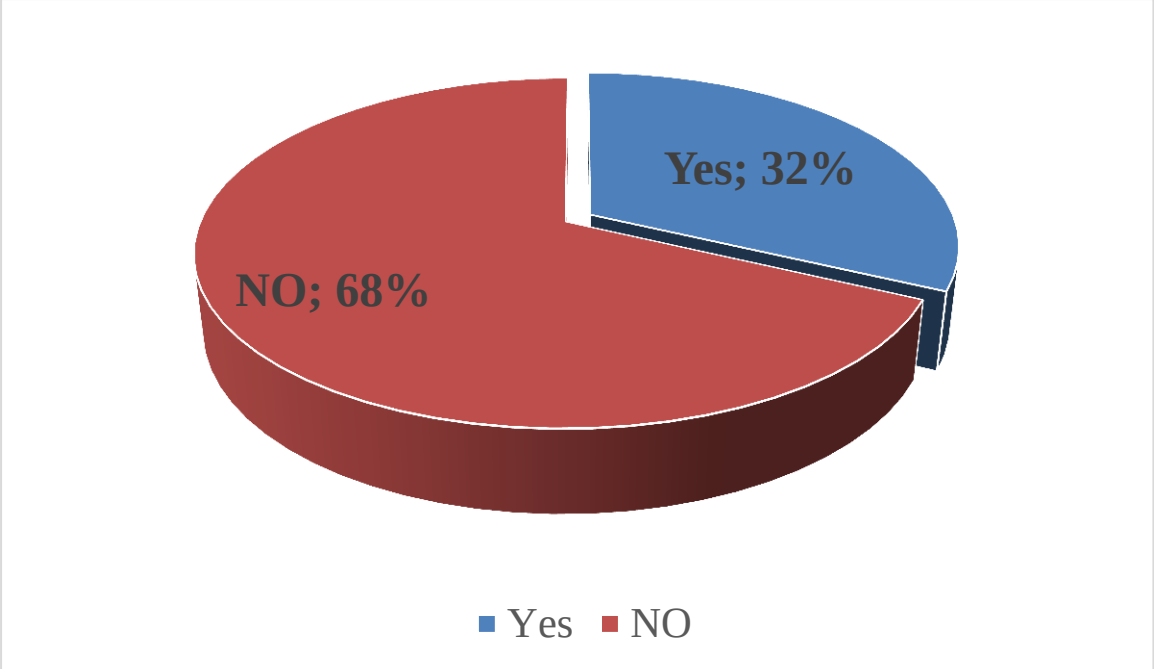


Figure (3): Hospitals have Keep Record Volumes of different waste in Shendi locality, River Nile State , 2023 (n=110).

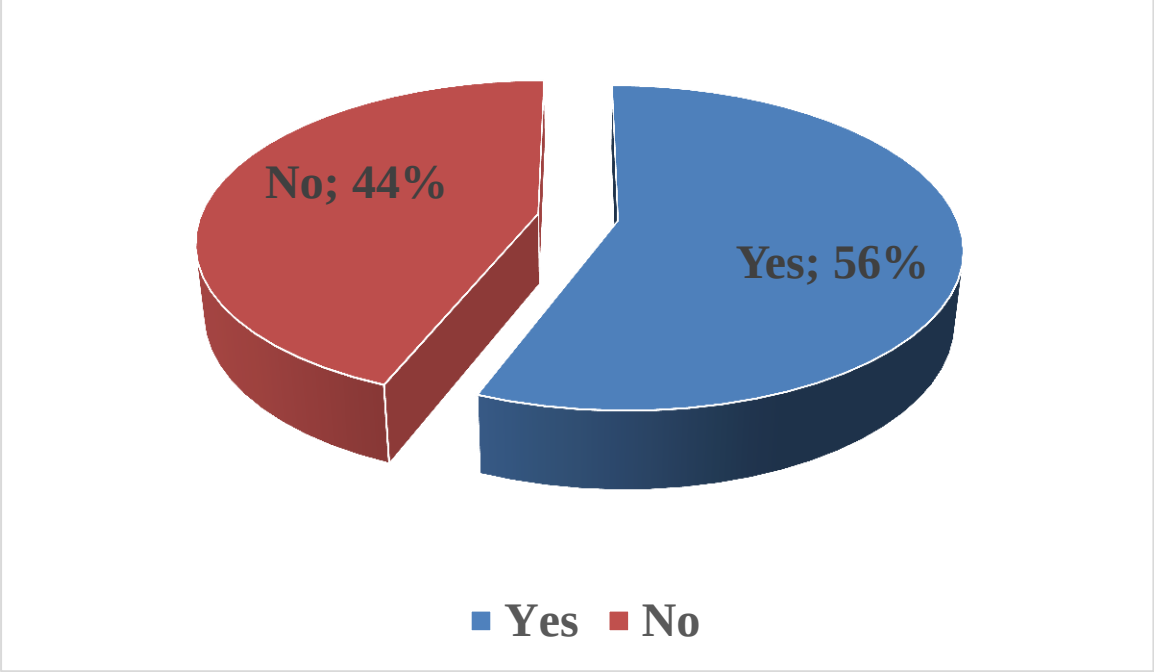


Figure (4): Hospitals Havean Adequate Budget for Waste Disposal in Shendi locality, River Nile State , 2023 (n=110)

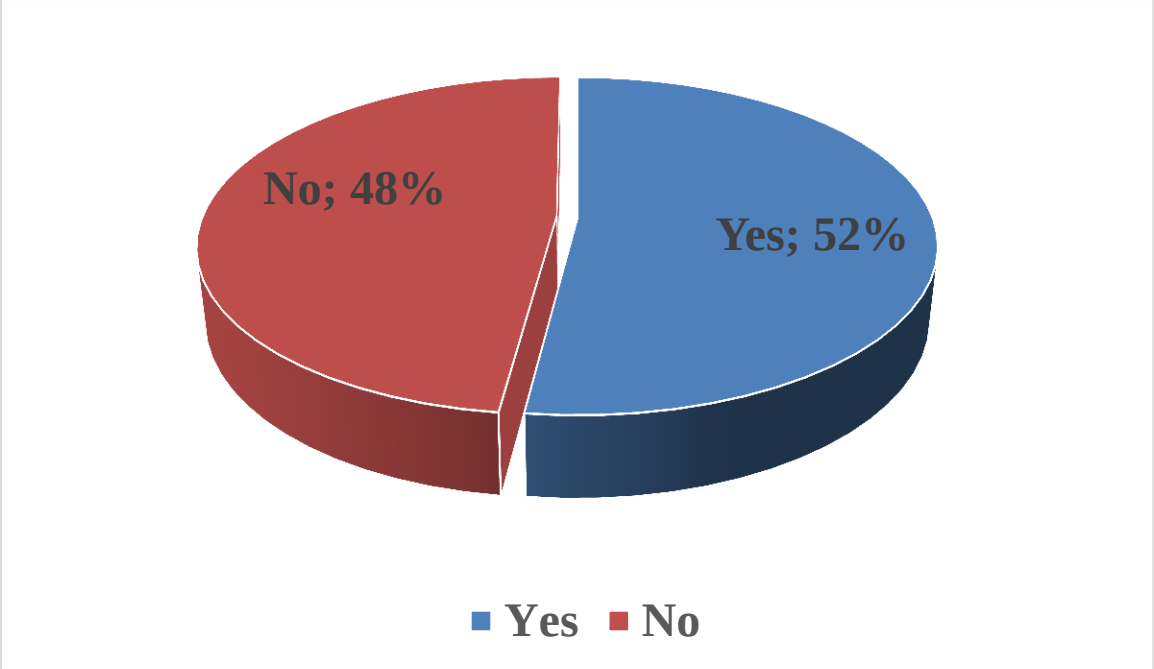


Figure (5): Immunization Status of Technicians at Hospitals in Shendi locality, River Nile State , 2023 (n=110)

Table (3): Technicians' Competence to Using PPE at Hospitals in Shendi locality, River Nile State , 2023 (n=110)

Variables	Category	Frequency	Percent
Gloves	Yes	98	89.1
	No	12	10.9
Mask	Yes	84	76.4
	No	26	23.6
Apron	Yes	33	30.0
	No	77	70.0
Protective Shoes	Yes	35	31.8
	No	75	68.2
Shades	Yes	17	15.5
	No	93	84.5
Total		110	100%

Table (4): knowledge of Technicians about the type of healthcare Solid Waste Generation in Hospitals in Shendi locality, River Nile State, 2023 (n=110).

Variables	Category	Frequency	Percent
General Waste	Yes	78	70.9
	No	32	29.1
Pathological Waste	Yes	52	47.3
	No	58	52.7
Radioactive waste	Yes	22	20.0
	No	88	80.0
Chemical Waste	Yes	54	49.1
	No	56	50.9
Infectious Waste	Yes	66	60.0
	No	44	40.0
Sharp Waste	Yes	77	70.0
	No	33	30.0
Pharmaceutical Waste	Yes	44	40.0
	No	66	60.0
Pressurized Material	Yes	25	22.7
	No	85	77.3
Total		110	100%

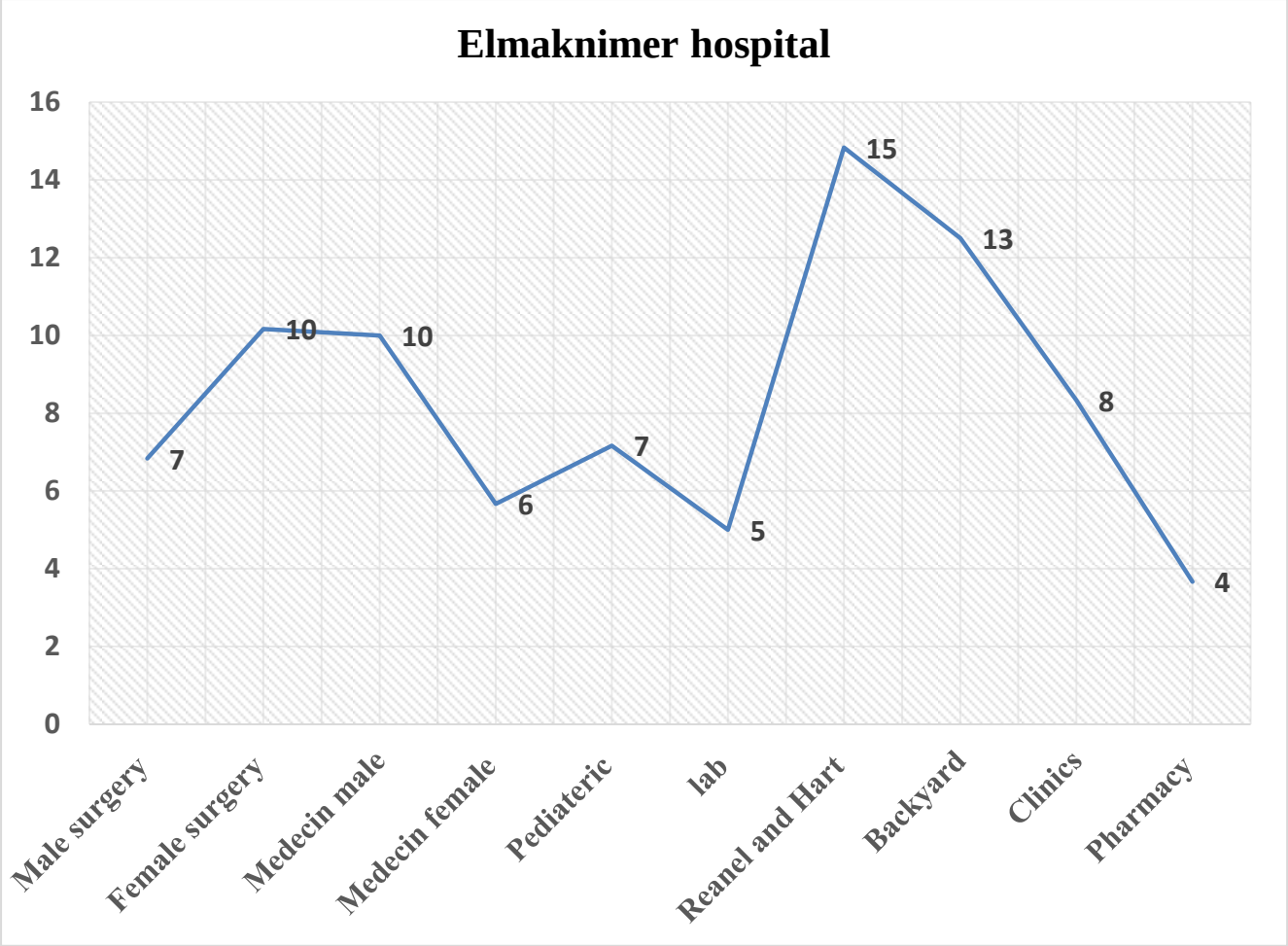


Figure (6): Average amount of healthcare solid waste generated at an Elmaknimer hospital in Shendi locality, River Nile State , 2023 by department (Kg\day)

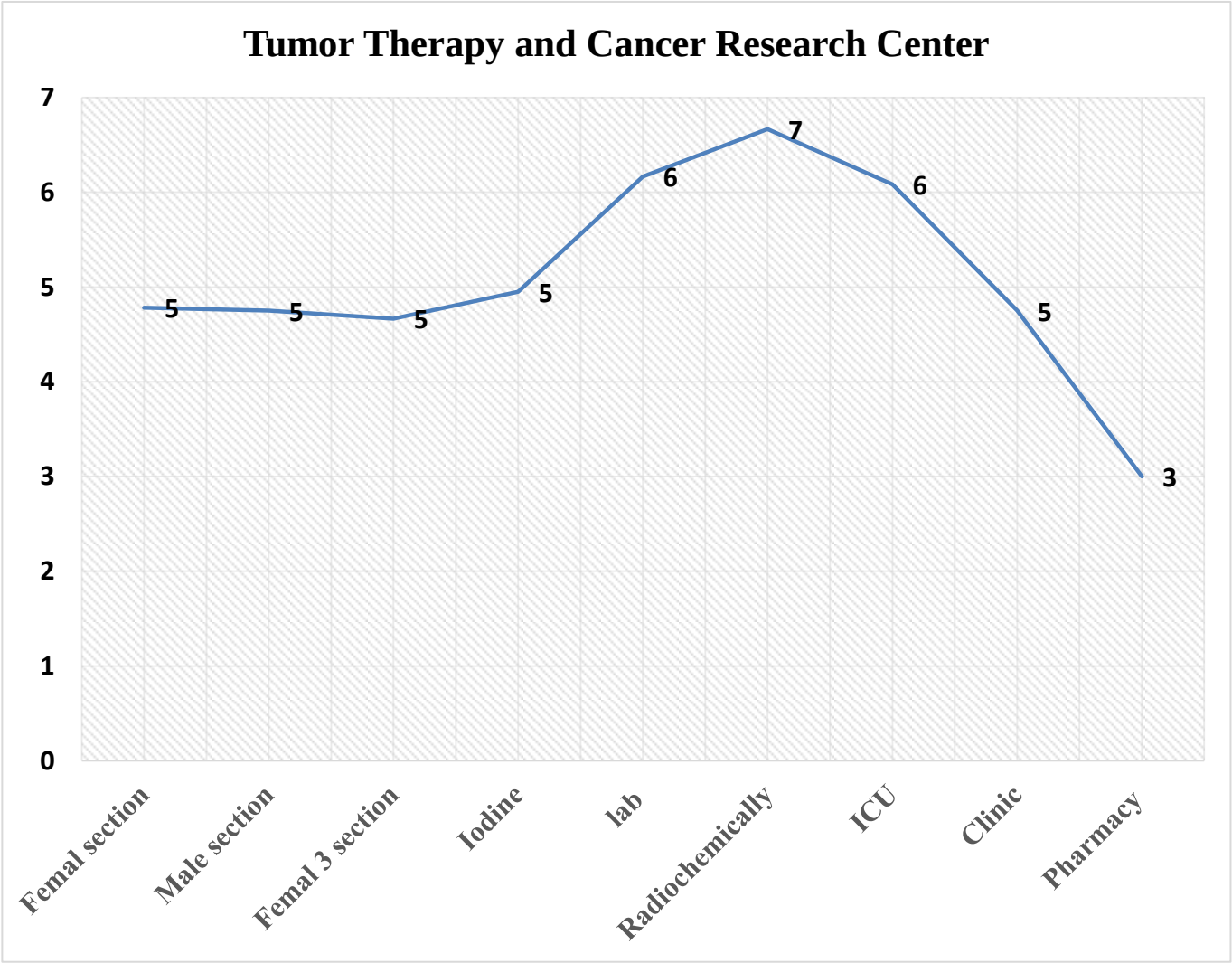


Figure (7): Average amount of healthcare solid waste generated at a Tumor Therapy and Cancer Research Centerin Shendi locality, River Nile State , 2023 by department (Kg\day)

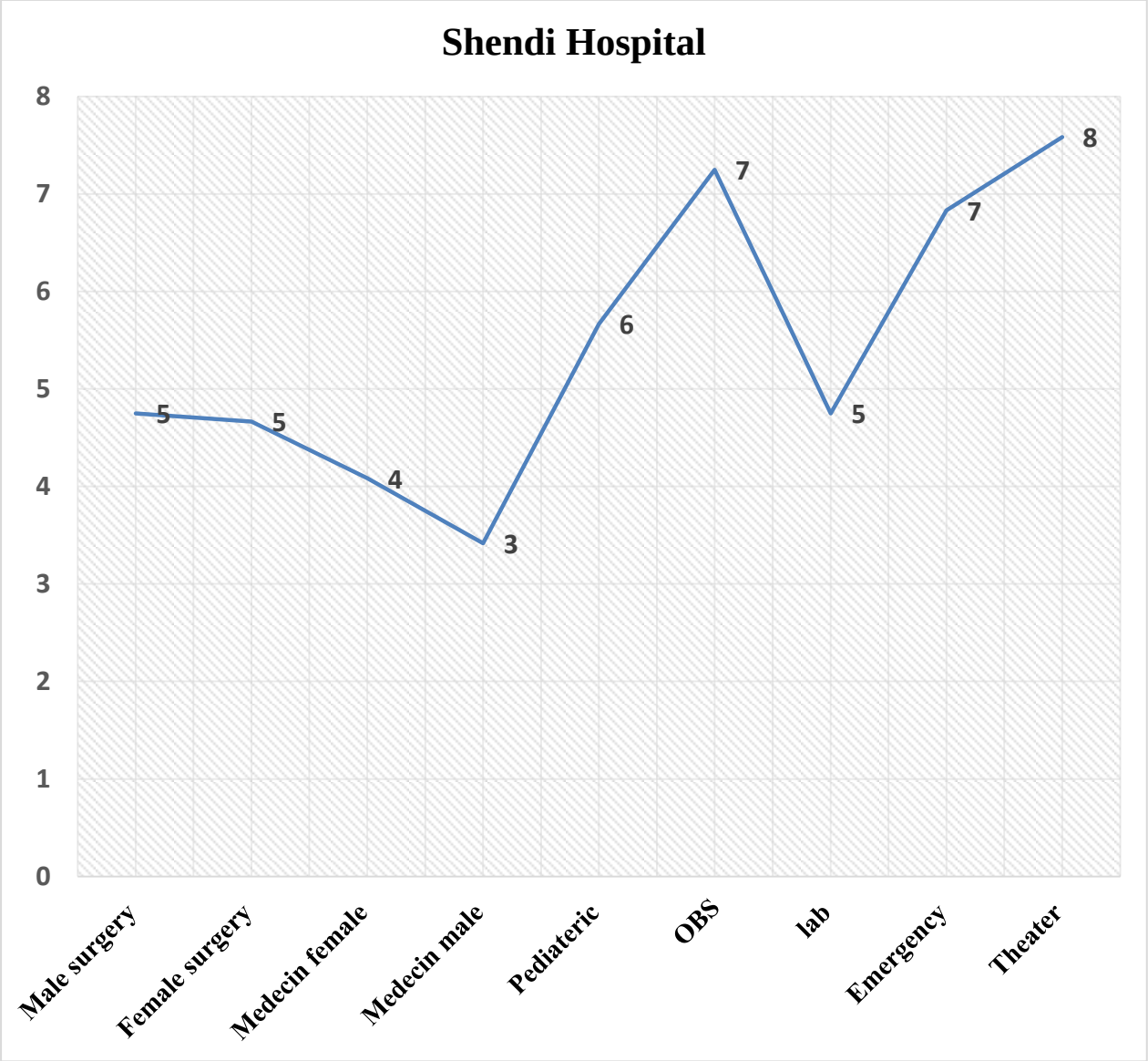


Figure (8): Average amount of healthcare solid waste generated at a Shendi Hospital in Shendi locality, River Nile State , 2023 Locality by department (Kg\day)

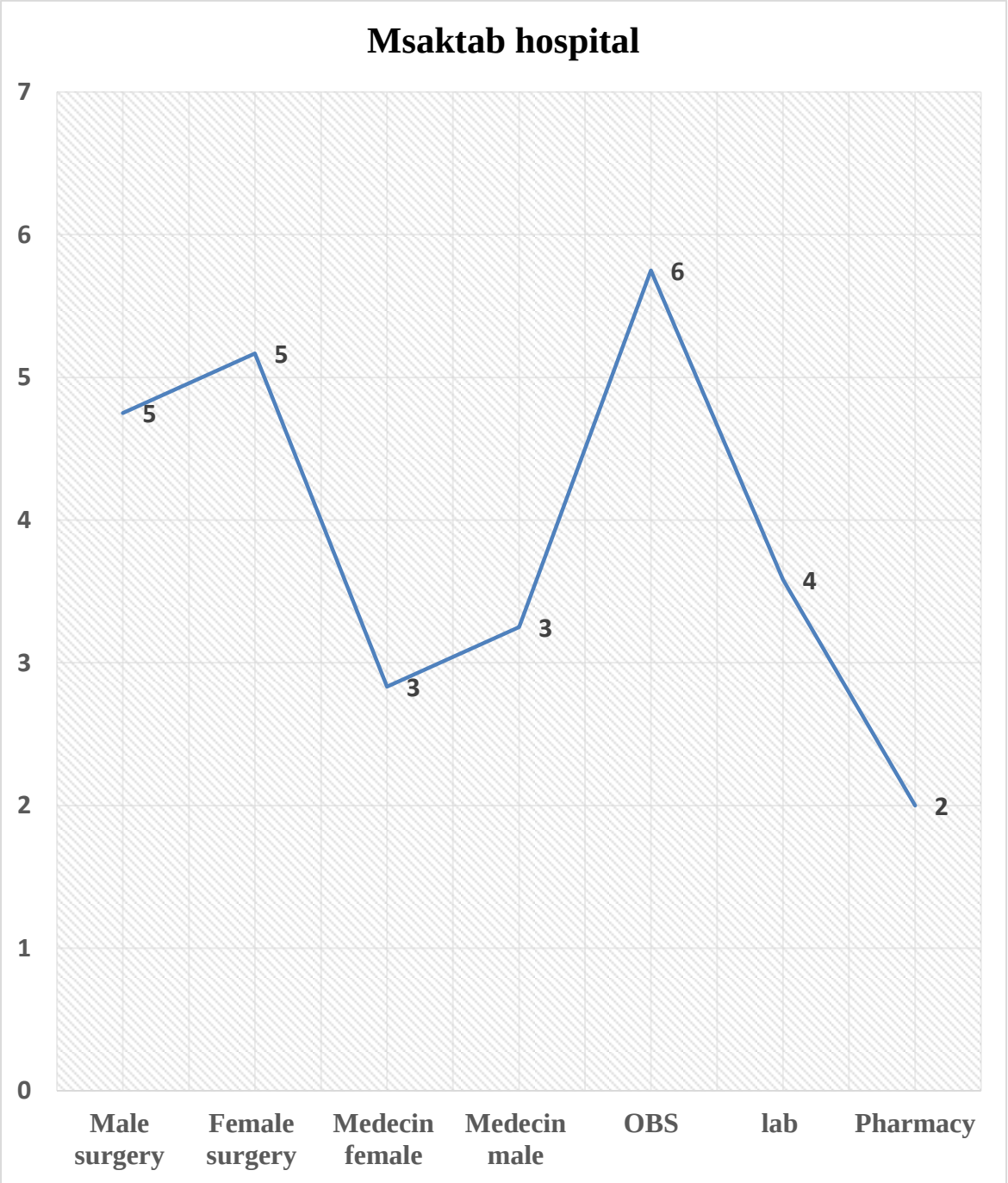


Figure (9): Average amount of healthcare solid waste generated at alMsaktab Hospital in Shendi locality, River Nile State , 2023 by department (Kg\day)

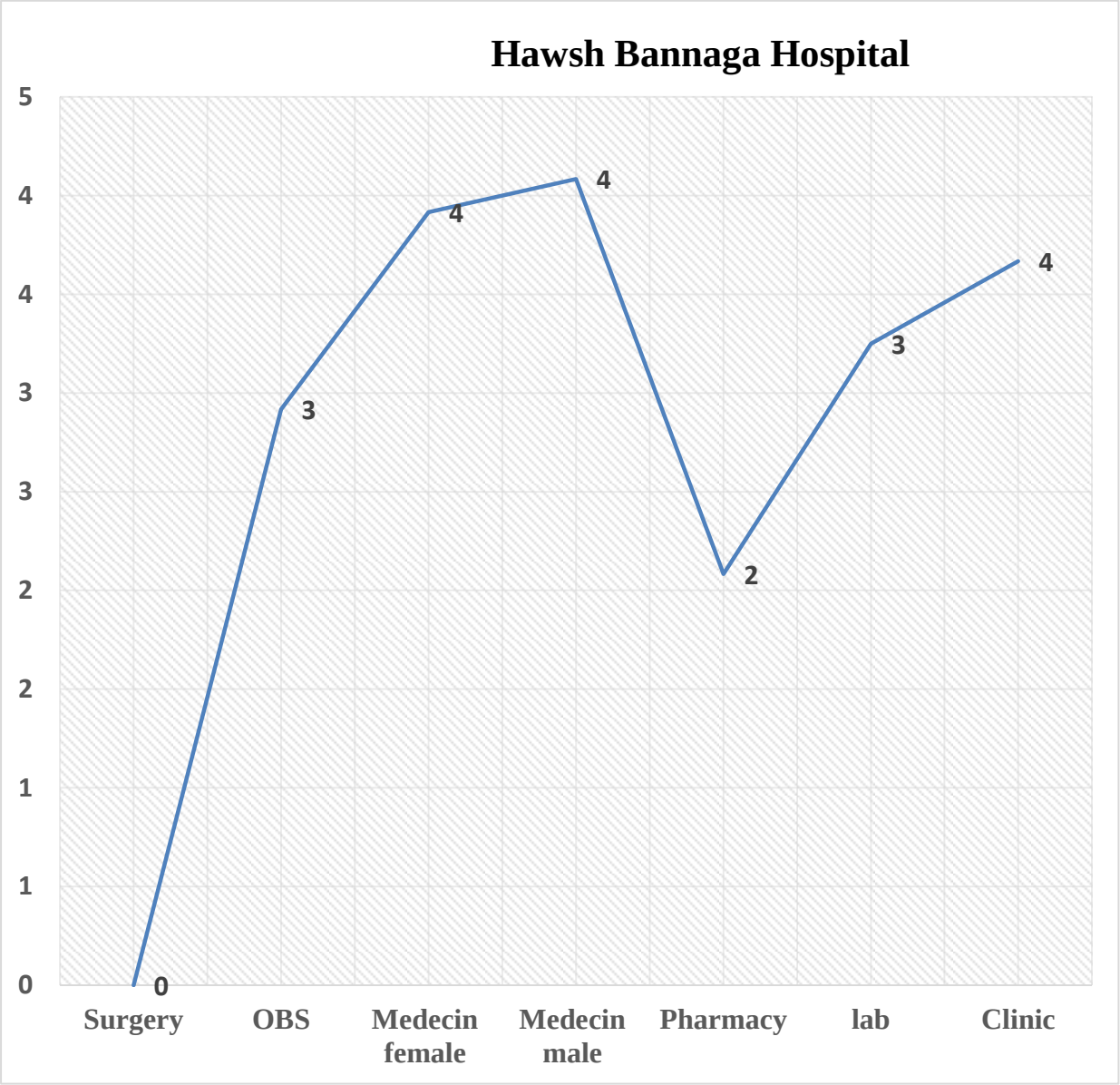


Figure (10): Average amount of healthcare solid waste generated at anAlhooshHospital in Shendi locality, River Nile State , 2023 by department (Kg\day)

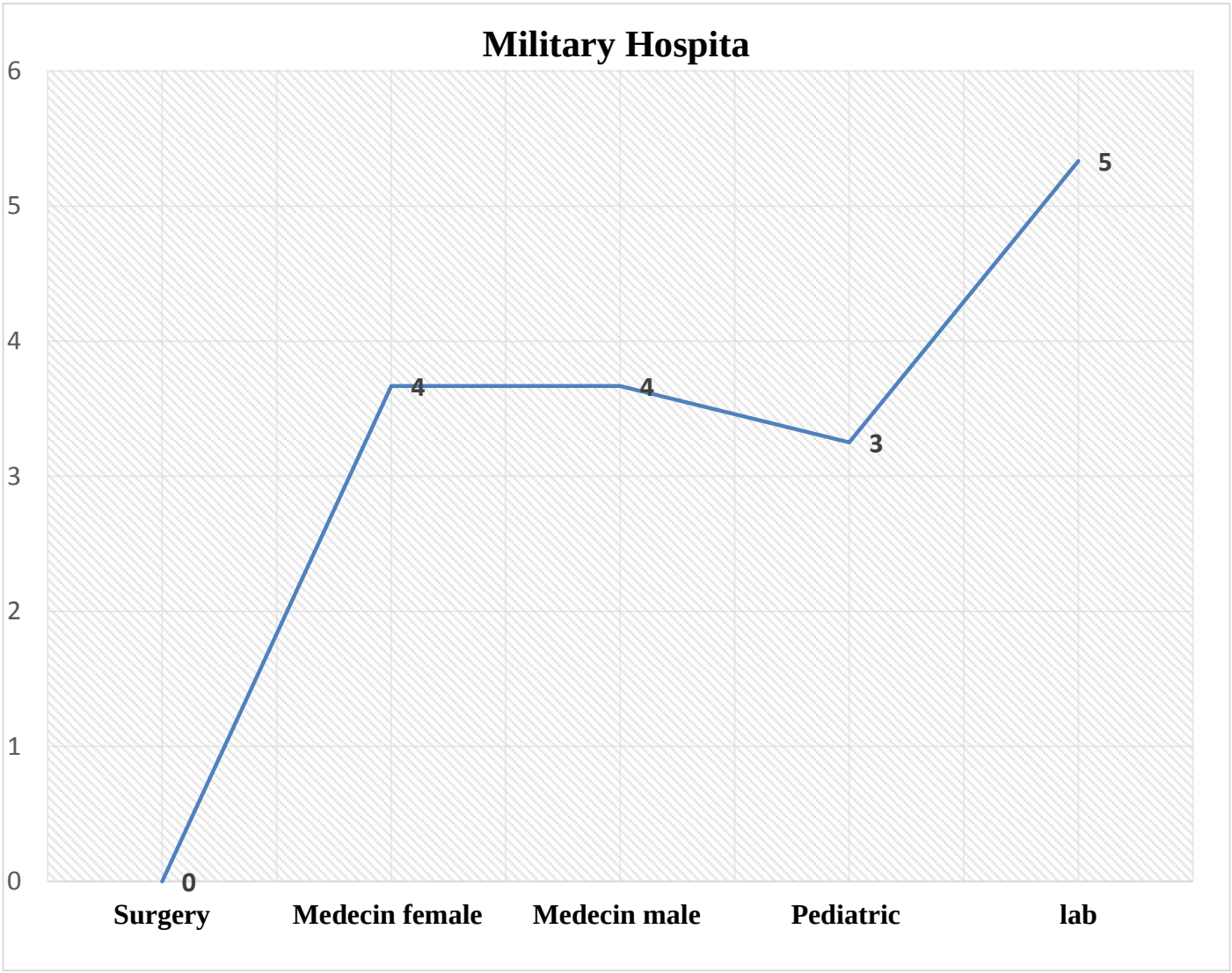


Figure (11): Average amount of solid waste generated at a Military Hospital in Shendi locality, River Nile State , 2023 by department (Kg\day)

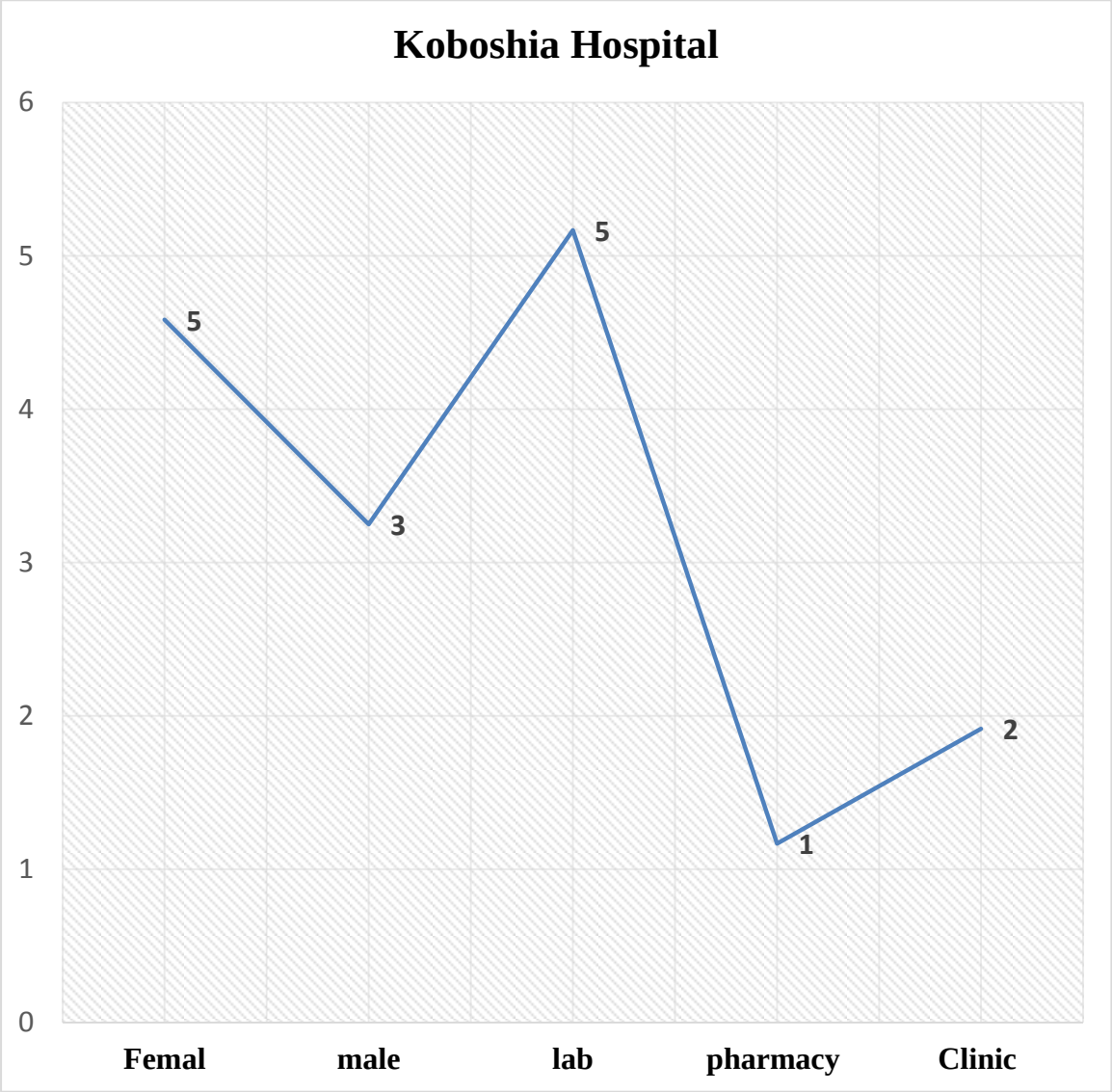


Figure (12): Average amount of healthcare solid waste generated at a Koboshia Hospital in Shendi locality, River Nile State , 2023 by department (Kg\day)

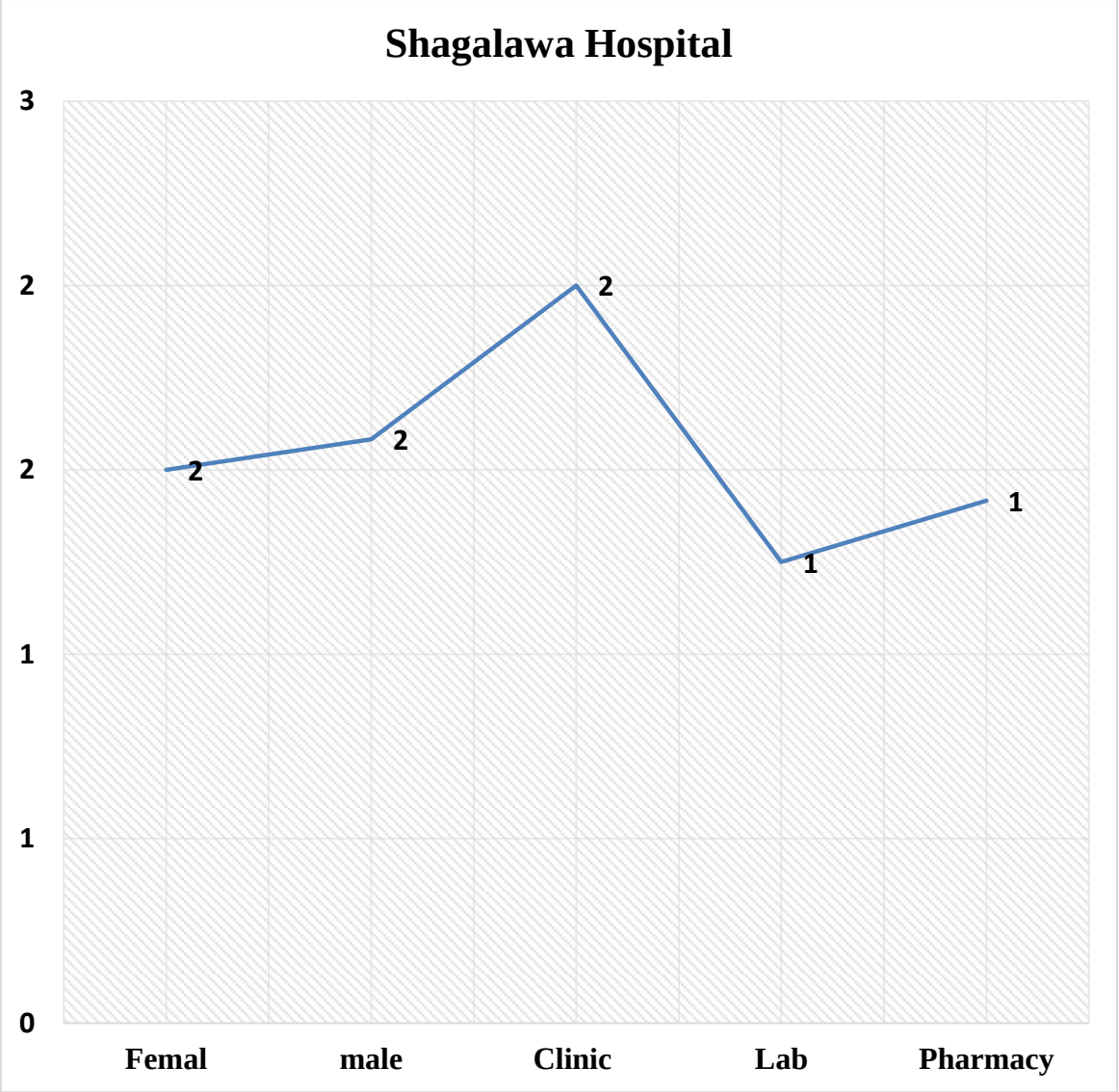


Figure (13): Average amount of healthcare solid waste generated at a Shagalawa Hospital in Shendi locality, River Nile State , 2023 by department (Kg\day)

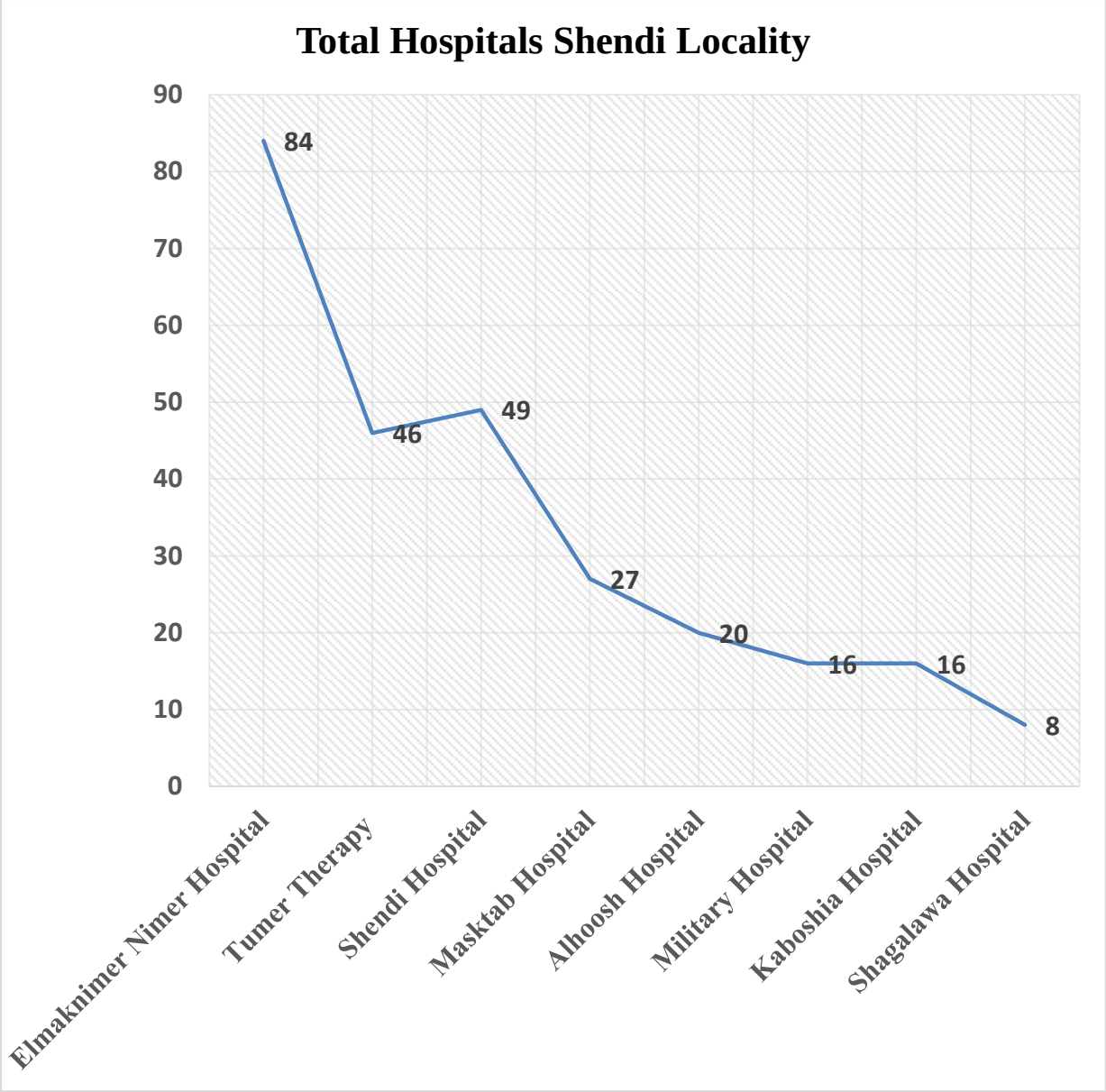


Figure (14): Average amount of healthcare solid waste generated at Hospitals in Shendi locality, River Nile State , 2023 by department (Kg\day)

Table (5): knowledge of Technicians about the Segregation of healthcare solid Waste Generation According to Type in Hospitals in Shendi locality, River Nile State , 2023 (n=110).

Variables	Category	Frequency	Percent
General separated	Yes	83	75.5
	No	27	24.5
Syringes separated	yes	76	69.1
	No	34	30.9
Infectious separated	Yes	73	66.4
	No	37	33.6
Pathological separated	Yes	51	46.4
	No	59	53.6
Hazardous infection	Yes	35	31.8
	No	75	68.2
Chemical waste separated	Yes	35	31.8
	No	75	68.2
Pharmaceutical waste separated	Yes	37	33.6
	No	73	66.4
Total		110	100%

Table (6): Segregating, and labeled healthcare solid Waste Generatedin Hospitals in Shendi locality, River Nile State , 2023 (n=110).

Variables	Category	Frequency	Percent
Color code generation	Yes	39	35.5
	No	71	64.5
Waste storage site	Inside the health unit	60	54.5
	Outside the health unit	50	45.5
Existence Segregation	Yes	37	33.6
	No	23	20.9
	Don't know	49	44.5
Responsibility of Segregation	Medical Staff	22	20.0
	Cleaning worker	36	32.7
	Do not know	45	40.9
	Not applicable	6	5.5
Place of Segregation	At the point of generation	18	16.4
	After the Collection	22	20.0
	At the Waste Storage place	18	16.4
	Not applicable	3	2.7
	Don't know	49	44.5
Total		110	100%

Table (7): Transportation, and Storage of healthcare solid Waste Generated in Hospitals in Shendi locality, River Nile State , 2023 (n=110).

Variables	Category	Frequency	Percent
Transportation method to the Storage point	Yes	69	62.7
	No	41	37.3
Accessibility of Temporary Storage Area	Accessible	52	47.3
	Not Accessible	58	52.7
Labeled Container at the Storage Point	Yes	41	37.3
	No	69	62.7
Special Sign to show the place of storage	Yes	25	22.7
	No	55	50.0
	Don't Know	30	27.3
Storage area sufficient inside the hospital	Yes	32	29.1
	No	47	42.7
	Don't Know	31	28.2
Duration of Storage Time	1 to 2 Days	28	25.5
	3 to 5 days	17	15.5
	7 days	13	11.8
	Not available	4	3.6
	Don't Know	48	43.6
Storage Point Protected Well	Yes	32	29.1
	No	38	34.5
	Not Know	39	35.5
	5.00	1	.9
Total		110	100%

Table (8):Disposable Methods of healthcare solid Waste Generated in Hospitals in Shendi locality, River Nile State , 2023 (n=110).

Variables	Category	Frequency	Percent
methods of Sharps disposal	Safety box	85	77.3
	Ordinary waste bags	25	22.7
Medical waste disposal method at the hospital	private infectious waste management company	16	14.5
	Takes to our hospital incinerator	17	15.5
	Take to incinerator out sit	13	11.8
	Take to the general waste bin	63	57.3
	5.00	1	.9
Availability of incinerator in hospital	Present (Functional	36	32.7
	Not present	73	66.4
	4.00	1	.9
Frequency of medical waste disposal	Daily	71	64.5
	times per week	9	8.2
	Twice weekly	5	4.5
	Once weekly	16	14.5
	Monthly	9	8.2
Total		110	100%

Table (9): Demographic Information of the Cleaners at the Hospitals in Shendi locality, River Nile State , 2023 2023 (n=143).

Variables	Category	Frequency	Percent
Age	(18-25) Year	5	3.5
	(25-35) Year	33	23.1
	(35-45) Year	50	35.0
	more than 45	55	38.5
Gender	Male	24	16.8
	Female	119	83.2
Education Level	Khalwa	55	38.5
	Basic School	61	42.7
	Secondary	26	18.2
	Graduated	1	.7
Total		110	100%

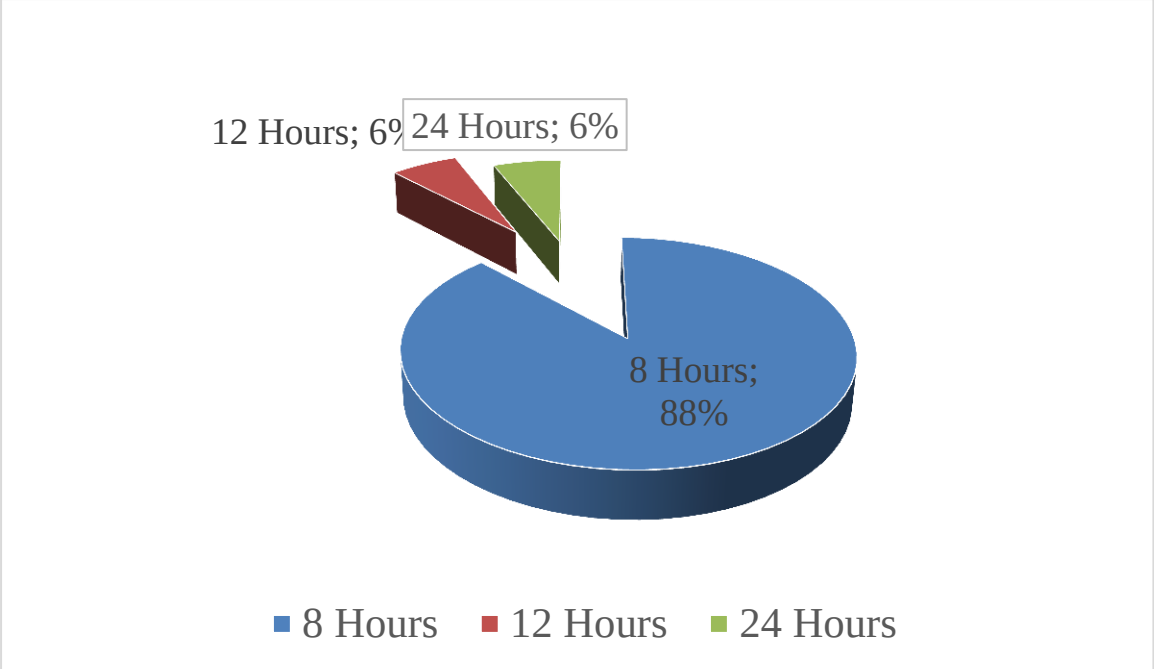


Figure (15): Duration of the work Shift of the Cleaners at the Hospitals in Shendi locality, River Nile State , 2023 (n=143).

Table (10): Training Program for the Cleaners at the Hospitals in Shendi locality, River Nile State , 2023 (n=143).

Variables	Category	Frequency	Percent
Trained worker	Yes	106	74.1
	No	37	25.9
Training Place (n=106)	In Hospital	99	93
	Out of Hospital	7	7
Duration of Training Program (n=106)	One Day	75	71
	More than Day	31	29
Training of recently cleaner recruitment	Yes	79	55.2
	No	37	25.9
	Don't Know	27	18.9
Total		110	100%

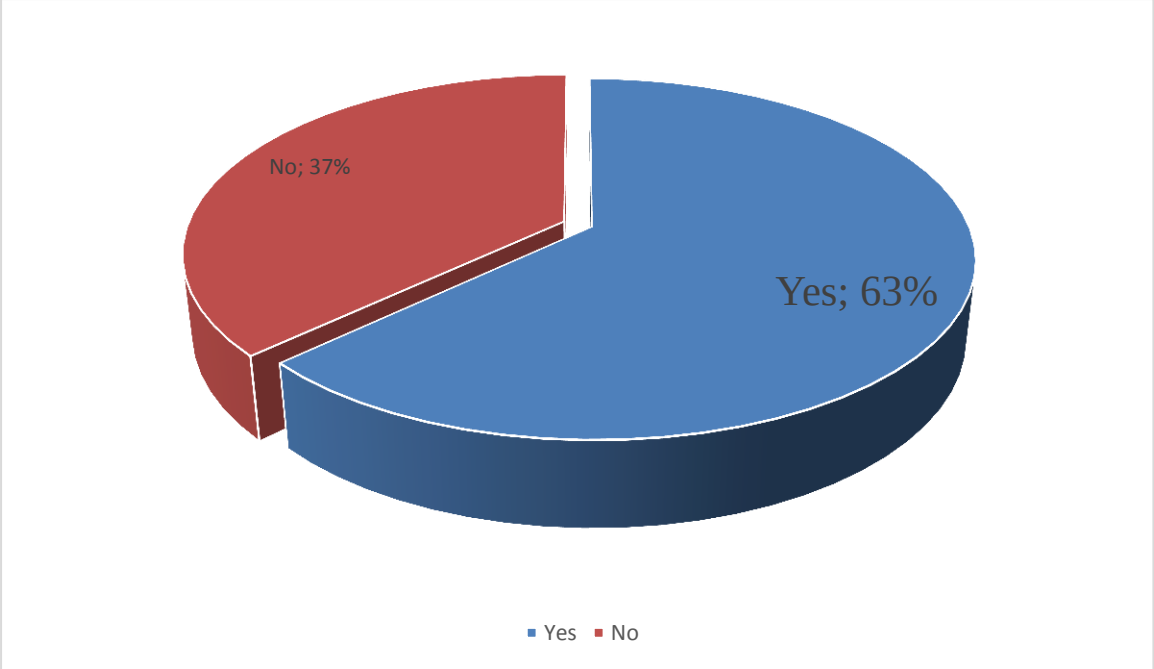


Figure (16) Cleaner Segregate healthcare solid Waste from General Waste at the Hospitals in Shendi locality, River Nile State , 2023 (n=143).

Table (11): Risks to which cleaning workers are exposed at the Hospitals in Shendi locality, River Nile State , 2023 (n=143).

Variables	Category	Frequency	Percent
Rupture and damage of containers	Yes	79	55.2
	No	37	25.9
	Don't Know	27	18.9
Overfilled the Containers	Yes	30	21.0
	No	85	59.4
	Sometime	28	19.6
Easy To load and Transport	Yes	94	65.7
	No	10	7.0
	Sometime	39	27.3
Carefully Tie the bags	Yes	129	90.2
	No	11	7.7
	Sometime	3	2.1
Use the PPE	Yes	82	57.3
	No	58	40.6
	Sometime	3	2.1
Disposal of Face Mask	Together Medical waste	19	13.3
	together medical and general waste	85	59.4
	together general waste	39	27.3
Use Hand to Compact Bags of waste	Yes	65	45.5
	No	78	53.8
Needle stick	Yes	52	36.4
	No	91	63.6
Injury by Other Objects	Yes	52	36.4
	No	91	63.6
Total		110	100%

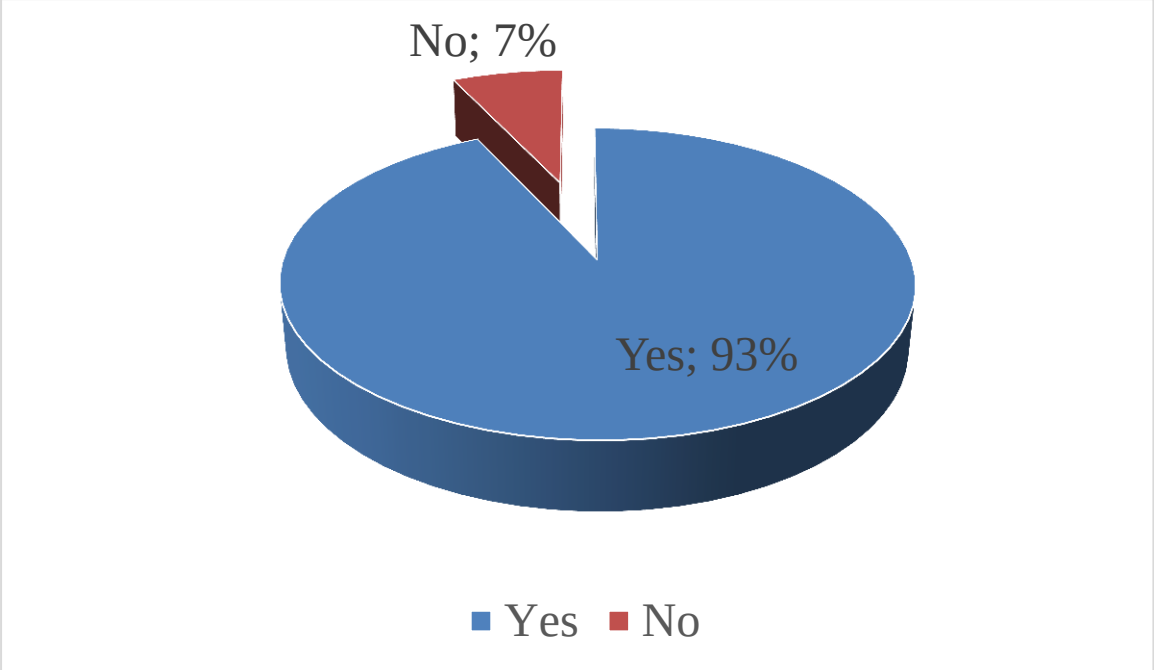


Figure (17):Supervision and follow-up of cleaning workers at the Hospitals in Shendi locality, River Nile State , 2023 (n=143).

Table (12): Pre-employment procedures forcleaning workers at the Hospitals in Shendi locality, River Nile State , 2023 (n=143).

Variables	Category	Frequency	Percent
Prescreening	Yes	59	41.3
	No	84	58.7
Periodic Screening	Yes	49	34.3
	No	94	65.7
Vaccination	Yes	114	79.7
	No	29	20.3
Total		110	100%

Table (13) Correlation Between Experience in healthcare solid waste Management, and Occupation of the Technicians at Hospitals in Shendi locality, River Nile State , 2023

Experience	Occupation				
	Doctor/dentist	Medical assistant	nursing	lab technician	Medical receptionist
Yes	19	1	17	10	0
No	23	1	25	10	1
Total	42	2	42	20	1
P value = 0.411				X2= 5.03	

Table (14) Correlation Between Experience in healthcare solid Waste Management, and Training program for Technicians at Hospitals in Shendi locality, River Nile State , 2023

Experience	training program		Total
	Yes	No	
Yes	33	17	50
No	10	50	60
Total	43	67	110
P value = 0.000		X2= 27.877	

Table (15) Correlation betweenGender t, and wear the protected apron at Hospitals in Shendi locality, River Nile State , 2023

Gender	Apron		Total
	Yes	No	
Male	20	17	37
Female	13	60	73
Total	33	77	110
P value = 0.000		X2= 15.514	

Table (16) Correlation Between Experience in healthcare solid Waste Management, and Immunization Status for Technicians at Hospitals in Shendi locality, River Nile State , 2023

Experience	Immunization		Total
	vaccinated	Not vaccinated	
Yes	32	18	50
No	25	35	60
Total	57	53	110
P value = 0.016		X2= 5.448	

Table (17) Correlation Between Used of Gloves, and Occupation of the Technicians at Hospitals in Shendi locality, River Nile State , 2023

Occupation	Gloves		Total
	Yes	No	
Doctor/dentist	37	5	42
Medical assistant	1	1	2
nursing	39	3	42
lab technician	19	1	20
Medical receptionist	1	0	1
health Officer	1	2	3
Total	98	12	110
P value = 0.014		X2= 14.238	

Table (18) Correlation Between Immunization Status, and Occupation of the Technicians at Hospitals in Shendi locality, River Nile State , 2023

Occupation	Immunization		Total
	vaccinated	Not vaccinated	
Doctor/dentist	23	19	42
Medical assistant	0	2	2
nursing	23	19	42
lab technician	11	9	20
Medical receptionist	0	1	1
health Officer	0	3	3
Total	57	53	110
P value = 0.234		X2= 6.825	

Table (19) Correlation Between Experience in healthcare solid Waste Management, and Ragular Training program for Technicians at Hospitals in Shendi locality, River Nile State , 2023

Experience	Regular training program		Total
	Yes	No	
Yes	24	26	50
No	16	44	60
Total	40	70	110
P value = 0.017		X2= 5.364	

Table (20) Correlation Between Budget and Immunization Status of the Technicians at Hospitals in Shendi locality, River Nile State , 2023

Budget	Immunization		Total
	vaccinated	Not vaccinated	
Yes	40	22	62
No	17	31	48
Total	57	53	110
P value = 0.002		X2= 9.176	

Table (21):Correlation Between Flow up and Monitoring of Cleaners, and Use of Hand to Compact Waste Bags at Hospitals in Shendi locality, River Nile State , 2023

Flow Up	Use hand for compact bags of waste			Total
	Yes	No	3.00	
Yes	57	75	1	133
No	8	2	0	10
Total	65	77	1	143
P value = 0.075			X2= 5.185	

Table (22):Correlation Between Needle stick, and Use of Hand to Compact Waste Bags at Hospitals in Shendi locality, River Nile State , 2023

Use of Hand to Compact	Needle stick		Total
	Yes	No	
Yes	34	31	65
No	18	60	78
Total	52	91	143
P value = 0.001			X2= 13.324

Table (23):Correlation Between Needle Stik, and Use of Hand to Compact Waste Bags at Hospitals in Shendi locality, River Nile State , 2023

Use of Hand to Compact	Injury by other Objects		Total
	Yes	No	
Yes	33	32	65
No	19	59	78
Total	52	91	143
P value = 0.004			X2= 10.946

Table (24):Correlation Between Pertaining for Cleaners, and Use of Personal Protection Equipment at Hospitals in Shendi locality, River Nile State , 2023

Pertaining	P.P.E			Total
	Yes	No	Sometime	
Yes	63	40	3	106
No	19	18	0	37
Total	82	58	3	143
P value = 0.339			X2= 2.165	

Table (25):CorrelationBetweenPertaining to Cleaners, and Mask Disposal Methods at Hospitals in Shendi locality, River Nile State , 2023

Pertaining	Mask disposal			Total
	Together Medical waste	together medical and general waste	together general waste	
Yes	14	64	28	106
No	5	21	11	37
Total	19	85	39	143
P value = 0.917			X2= 0.173	

Table (26):Correlation Waste Container Damage, and Needle Stick at Hospitals in Shendi locality, River Nile State , 2023

Container Damage	Needle stik		Total
	Yes	No	
Yes	30	39	69
No	22	52	74
Total	52	91	143
P value = 0.026		X2= 7.303	

Table (27):Correlation Between Flow up and Monitoring of Cleaners, and Use of P.P.E at Hospitals in Shendi locality, River Nile State , 2023

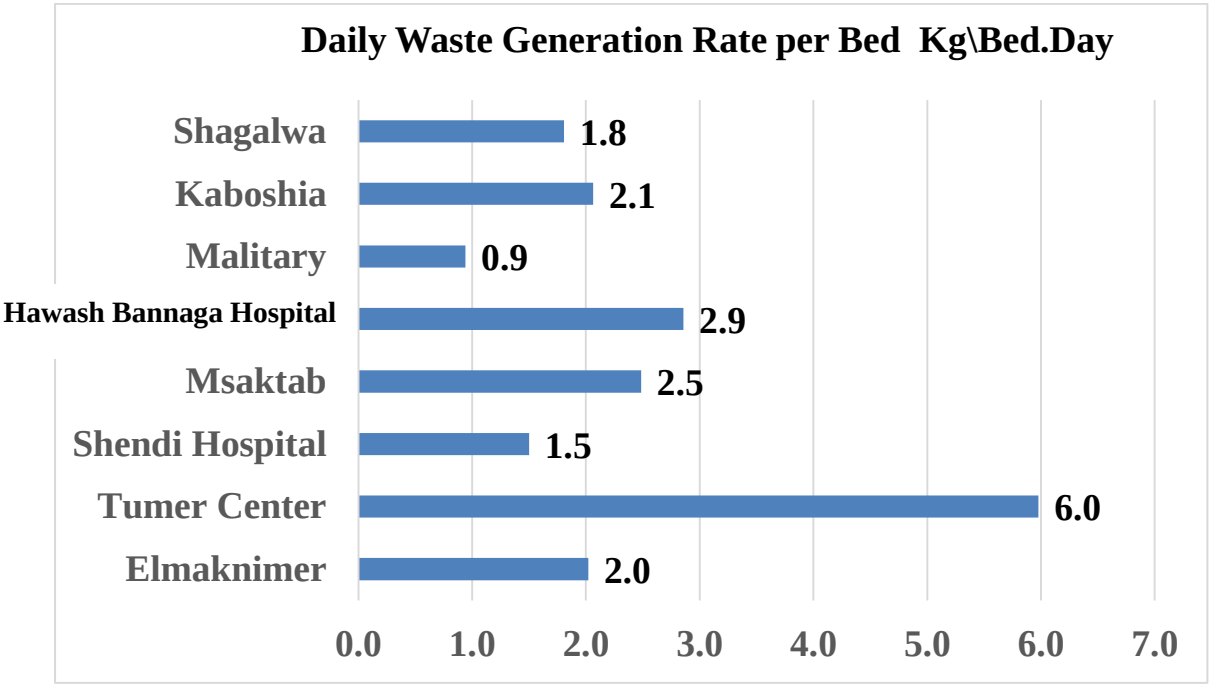
Flow up and Monitoring	PPE			Total
	Yes	No	Sometime	
Yes	79	53	1	133
No	3	5	2	10
Total	82	58	3	143
P value = 0.000			X2= 18.063	

Table (28):Correlation Between Flow up and Monitoring of Cleaners, and Container overfilled at Hospitals in Shendi locality, River Nile State , 2023

Flow up and Monitoring	Overfilling			Total
	Yes	No	Sometime	
Yes	25	82	26	133
No	5	3	2	10
Total	30	85	28	143
P value = 0.053			X2= 5.885	

Table(29):Shows Daily Waste Generation Rate per Bed Kg\Bed.Day

Hospital Name	Waste generation	Beds	Waste\bed
Elmaknimer	505	250	2.0
Tumer Center	275	46	6.0
Shendi Hospital	294	196	1.5
Msaktab	164	66	2.5
Hawsh Bannaga Hospital	120	42	2.9
Malitary	96	102	0.9
Kaboshia	97	47	2.1
Shagalwa	47	26	1.8
Total	1598	775	2.1



Figure(18): Shows Daily Waste Generation Rate per Bed Kg\Bed.Day

Chapter five

- Discussion
- Conclusion
- Recommendation

5.1 Discussion

In this study the healthcare solid waste generation rates at Shendi locality hospitals were measured and analyzed. The current study found that daily healthcare solid waste generation rate is not constant, and fluctuates randomly.

The average generation rate of healthcare solid waste in Shendi locality hospitals (33.25kg/day), therefore it requires comprehensive measures to control and mitigate the risks. Eighty-four kilograms per day generated from Elmiknemir hospital represent the highest generation rate was observed. Generation of medical waste. Healthcare solid waste generation rates vary significantly across hospitals and countries. In Ethiopia, rates ranged from 0.25 to 2.77 kg/bed/day for inpatients, with private hospitals generating more waste than public ones (80). Tanzanian district hospitals reported higher rates of 1.8-2.0 kg/patient/day (82). Iraqi hospitals in Najaf City showed rates ranging from 1.074 to 3.844 kg/capita/day (83). These studies highlight the need for improved waste management systems, particularly in less developed areas. Waste generation by many factors such as hospital type, patient numbers, and healthcare practices. Proper segregation, collection, and disposal of medical waste remain critical challenges, requiring financial support, administrative monitoring, and increased awareness among healthcare workers.

The study revealed (70.9%) of the study population aware of general waste category, indicating a broad understanding of waste types that do not fall under specialized categories. This awareness is crucial as general waste management is a fundamental aspect of overall waste management practices. Proper handling and disposal of general waste are essential to maintain cleanliness and prevent environmental contamination.

Awareness of pathological waste is relatively balanced, with 47.3% of participants acknowledging this type of waste and 52.7% not recognizing it. Pathological waste, which includes human tissues and body fluids, requires specialized handling to prevent disease transmission and environmental contamination. The nearly even split suggests a need for increased education and training to enhance understanding of this critical waste type. A substantial majority (80.0%) of the study population does not recognize radioactive waste, which could be due to its less common presence in many healthcare settings compared to other waste types. Radioactive waste, generated from medical treatments and diagnostic procedures, requires stringent management to ensure safety and regulatory compliance. The low level of awareness highlights the need for targeted education in environments where radioactive materials are used or stored. (70.0%) of the participants recognize sharp waste, which includes needles, blades, and other objects that can cause puncture wounds or cuts. The high level of awareness is encouraging as proper disposal of sharp waste is essential to prevent injuries and the spread of infections. The findings highlight varied levels of awareness among the study population regarding different types of solid waste. While there is a good understanding of general, infectious, and sharp waste, there is a notable gap in knowledge concerning pathological, radioactive, chemical, pharmaceutical, and pressurized waste. Addressing these gaps through targeted education and training programs is essential for improving overall waste management practices and ensuring the safety of both individuals and the environment.

The study revealed a significant majority (64.5%) of hospitals do not use color coding for waste generation, which is concerning. Color coding is a fundamental practice for the segregation of waste types, facilitating safer

handling and disposal. The low adherence to this practice indicates a need for increased policy enforcement to standardize waste management practices. Studies across multiple countries reveal significant gaps in hospital waste management practices. In Pakistan, a majority of hospitals lacked formal waste management plans, trained supervisors, and proper segregation procedures (84). Similarly, in India, awareness of biomedical waste management rules was limited, particularly among private practitioners and in rural areas (85). A study Rahim Yar Khan in Pakistan, found that while 76.5% of healthcare establishments practiced waste segregation at source, only 61.8% provided protective gear for workers (86). Sorting medical waste by color plays an important role in avoiding its risks; Black bags are used for general waste, red is used for containers (bags) that contain hazardous waste, and yellow with a radiation mark is used for radioactive waste. It can also be used for chemical, infectious, and medical laboratory waste with a distinctive sign for each of them, and using a safety box for sharp waste such as needles. The Study revealed that it is necessary to adhere to these classifications to improve it management system. On the other hand, workers and related individuals are exposed to many health risks. These include wounds, acupuncture, and infection. Even if its percentage is low, it represents a major problem due to the sensitivity of the tasks. If they do not commit to following preventive measures such as protective clothing and vaccinations they will become exposed to hazards. The distribution of waste storage sites is fairly balanced, with slightly more hospitals storing waste inside the health unit (54.5%) than outside (45.5%). Storing waste inside the health unit can be problematic if not managed properly, as it can increase the risk of infection and contamination within the healthcare facility. (33.6%)of the respondents confirm the existence of segregation practices, while 20.9% report no segregation. 44.5% are unaware of

whether segregation is practiced. This lack of awareness underscores a significant gap in training and communication regarding waste management protocols among hospital staff, 32.7% of the participants answered the responsibility for segregation falls predominantly on cleaning workers, with medical staff taking responsibility in only 20% of cases. (40.9%) of responders do not know who is responsible for segregation, indicating a lack of clear role definition and accountability in waste management processes. The studies consistently highlight gaps in knowledge and practices regarding biomedical waste management among hospital staff. While doctors generally demonstrate better awareness of waste management rules, nurses and laboratory staff often show superior knowledge of color coding and waste segregation (87), (16.4%)of the participants' mentioned waste is segregated at the point of generation which is the recommended practice for effective waste management. Segregation after collection or at the storage place can lead to increased handling risks. (44.5%) of respondents do not know where segregation occurs. Further emphasizes the need structured protocols. (89.1%) of the study population reported using gloves. This is a positive finding as gloves are fundamental in preventing the transmission of pathogens through direct contact. (76.4%) of respondents use masks, which are crucial for protecting against airborne pathogens. However, (23.6%) do not use masks, indicating a significant varied gap in protective measures that need to be addressed to ensure the safety of healthcare workers and patients, 30% of the respondents use aprons. The low usage rate (70% not using aprons) suggests a need for better enforcement of apron use, particularly in high-risk areas. (56%) of the hospitals have a dedicated budget for medical waste disposal. This positive indicator suggests that over half of the hospitals recognize the importance of allocating financial resources for proper waste management practices. The immunization

status of healthcare workers in this study reveals that slightly more than half of the healthcare workers (52%). Healthcare workers are at a higher risk of exposure to infectious diseases due to their close and frequent contact with patients. Immunization is crucial to protect healthcare workers and their patients from vaccine-preventable diseases.The studyhas shown that healthcare worker immunization can significantly reduce the transmission of infectious diseases within healthcare settings, leading to improved patient outcomes and reduced healthcare costs. Immunization rates vary across different vaccines. Studies have found that hepatitis B vaccination coverage among HCWs ranges from 59.4% to 93%. However, influenza vaccination rates are lower, with one study reporting only 30% coverage (88). Reasons for non-immunization include lack of motivation, high vaccine costs, and concerns about side effects. Risk perception varies among HCWs, with less than half of potentially susceptible individuals feeling at risk for certain diseases. To improve vaccination rates, researchers suggest implementing educational campaigns, providing free vaccines, and making immunization mandatory for HCWs (89). This indicates that 48% of the population is susceptible to infection. The risks to which workers are exposed may not stop only with them but have the possibility of being transmitted to society. (54%) of the study population reported positive experiences with healthcare solid waste management. This distribution suggests that while some aspects of healthcare solid waste management are functioning well, healthcare worker training requires improvement. Effective training on healthcare solid waste management protocols can lead to positive experiences among healthcare workers. The availability of proper disposal facilities and equipment, such as sharps containers and waste segregation systems, can enhance compliance and satisfaction with

healthcare solid waste management practices findings highlight the need for ongoing training programs.

The study Illustrates (76.4%) of participant mentioned sharps objects are disposed of in safety boxes, which is the recommended practice for reducing needle stick injuries and the risk of infection transmission. Safety boxes are puncture-resistant containers specifically designed for the safe disposal of needles and other sharp objects. Healthcare waste handlers face significant risks of needle stick and sharps injuries, which can lead to serious infections. Studies have shown high rates of such injuries among waste handlers, with one study reporting 71.1% experiencing injuries in 6 months. Proper disposal of sharps in puncture-resistant safety boxes is crucial, with one study noting 97.5% compliance (90). (57.3%) study population mention healthcare solid waste is disposed of in general waste bins, which is highly inappropriate and poses a serious public health risk. 32.7% of hospitals have functional incinerators, indicating a significant deficiency in essential waste management infrastructure. Incinerators are crucial for the safe disposal of infectious and hazardous medical waste, ensuring that it is rendered non-infectious before final disposal. The absence of incinerators needs policies for investment in waste management facilities to comply with health and safety regulations and protect public health. (64.5%) of study participant mentions daily disposal of medical waste, is optimal as it reduces the risk of waste accumulation, which can lead to contamination, unpleasant odors, and attraction of pests. The gap indicates lapses in effective waste management practices, which can compromise hygiene and safety standards within healthcare facilities. The study reveals several critical issues in the management of healthcare solid waste in hospitals. The lack of adequate infrastructure, such as autoclaves, incinerators, and the

infrequent disposal of healthcare solid waste are concerning and highlight the need for improvements in waste management policies and practices. Enhancing investing in proper waste disposal facilities are essential steps to address these challenges and ensure safe and effective medical waste management in hospitals. 15.5% of participants statedwaste burned in incinerator on hospital property, 11.8% at other facilities, and 14.5% disposal by organizations that expertise in healthcare solid waste management. The continuous assessment of management operations and their current status inside and outside health institutions shows whether there are noticeable developments and improvements in the management of healthcare solid waste and whether they reach acceptable levels to avoid environmental and health risks. Some countries are still plagued and burdened by poverty, resulting in improper burning of all classes of waste with little to no resolution of this issue in sight. The impact of poor waste management has fallen disproportionately on the poverty-stricken communities that have little or no influence on the waste products being illegally dumped near their communities (96).The study illustrated that there is no significant correlation between the occupation of hospital staff and their experience in healthcare solid waste management (The p-value of 0.411). This implies that experience in managing medical waste does not vary systematically with different job roles within the hospital setting. The lack of a significant correlation might be due to a variety of factors, including similar levels of training or exposure to healthcare solid waste across different roles, or a general deficiency in experience among all staff categories. Possible influencing factors due to the similar levels of experience across different occupations could suggest that training and protocols for healthcare solid waste management are uniformly applied, irrespective of job role. Some roles, such as doctors and nurses, might have more direct involvement with medical waste, which could explain

higher experience levels among them compared to other roles. However, the data does not show a statistically significant pattern in this regard. To improve experience levels across all occupations, it is recommended that comprehensive training programs be implemented for all hospital staff. This will ensure that everyone, regardless of their role, is well-versed in healthcare solid waste management practices. The result indicates that while there are differences in experience levels among various hospital occupations, these differences are not statistically significant. This suggests that healthcare solid waste management experience is not strongly associated with job roles. Research on healthcare solid waste management (MWM) in hospitals reveals varying levels of knowledge, attitude, and practices (KAP) among staff. Studies indicate that doctors generally have better understanding and attitudes, while nurses excel in practice. However, overall KAP levels are often inadequate, with many staff lacking proper training in MWM. Factors influencing exposure risks include age and years of service, with older staff and those with less experience being more vulnerable to injuries. Education level and training significantly impact MWM knowledge. Despite awareness of health and environmental impacts among some staff, a considerable portion remains unaware or uncertain about associated risks and policies (91). The study found significant indicate a strong association between participation in training programs and having experience in healthcare solid waste management (p-value (0.000). This suggests that technicians who participate in training programs are more likely to have experience in managing healthcare solid waste compared to those who do not receive training. The data clearly shows that training programs play a crucial role in enhancing the experience of technicians in healthcare solid waste management. Technicians who have undergone training are significantly more likely to report having experience in managing healthcare solid

waste. This highlights the effectiveness of training programs in improving knowledge and practical skills related to healthcare solid waste management. The results emphasize the importance of implementing comprehensive and ongoing training programs for all hospital staff in healthcare solid waste management. Ensuring all technicians receive appropriate training can help increase their experience and competence in handling healthcare solid waste, thereby improving overall waste management practices and reducing health and environmental risks. The study shows a significant gender difference in the practice of wearing protective aprons. A higher proportion of male staff (54.1%) wear protective aprons compared to female staff (17.8%). This significant disparity suggests that gender may influence adherence to protective measures in the hospital setting. The study reveals a significant gender difference in the practice of wearing protective aprons among hospital staff in the Shendi locality, with a higher proportion of male staff adhering to this practice compared to female staff. Addressing this disparity through targeted training, improved access to PPE, and ongoing monitoring can help ensure that all staff members follow best practices for personal protection, enhancing safety within the hospital environment. Multiple studies have demonstrated improvements in participants' understanding and handling of biomedical waste following structured training interventions. Research indicates that healthcare professionals with more work experience tend to have better waste management practices. Overall, healthcare workers who participate in training programs generally demonstrate higher levels of knowledge and better practices in healthcare solid waste management. Regular implementation of well-designed training programs is recommended to enhance occupational safety and reduce environmental risks associated with medical waste (92). The study indicates that there is a statistically

significant correlation between experience in healthcare solid waste management and immunization status (p-value (0.016). Technicians who have experience in healthcare solid waste management are more likely to be vaccinated compared to those without experience. Technicians with experience in healthcare solid waste management are more likely to be vaccinated, highlighting the impact of experience on health-related behaviors. However, vaccination rates among waste handlers remain low, with only 23.7% receiving Hepatitis B vaccine in another study. Personal protective equipment usage is also inadequate, with less than 50% of MWHs wearing gloves or boots (93). The studies highlight the importance of vaccination among healthcare workers (HCWs) and the factors influencing immunization rates. Found that while doctors had the highest vaccination rate (92.5%), many HCWs remained unvaccinated, emphasizing the need for compulsory screening and booster doses. reported similar findings, with doctors having the highest immunization rate (92.4%) among HCWs in two Pakistani hospitals (94). Demonstrated that targeted interventions by pharmacy technicians significantly improved inpatient influenza vaccination rates from 72.2% to 92.9%. Regarding funding, Lydon et al. found evidence that having a specific budget line for vaccine purchasing was associated with increased government allocations for immunization financing. These studies collectively underscore the importance of targeted interventions, regular screening, and dedicated funding to improve vaccination rates among HCWs and the general population (94).

The study reveal a significant strong correlation between an individual's occupation and their practice of using gloves (p-value (0.014)). This suggests that the likelihood of using gloves varies significantly among different job roles within the hospital. High compliance is observed

among doctors, nurses, and lab technicians, whereas lower compliance is noted among medical assistants and health officers. Addressing these discrepancies through targeted standardized protocols can improve safety practices and ensure that all hospital staff adhere to best practices for infection control. Research on protective equipment use in healthcare settings reveals significant gender disparities and various influencing factors. Heo et al. Found that male staff (52.9%) were more likely to wear lead aprons than female staff (39.6%). Factors affecting adherence include job title, hospital type, and exposure frequency. Identified barriers to personal protective equipment use, including work overload, physical structure, and organizational aspects. They emphasized that adherence is influenced by workplace context and individual beliefs. These findings underscore the need for comprehensive strategies to improve protective equipment adherence, considering factors such as gender, job role, and workplace policies (95). The study demonstrates significant and, a clear association between budget allocation and immunization status. Technicians in hospitals with allocated budgets are significantly more likely to be vaccinated compared to those in hospitals without allocated budgets (p-value (0.002)). Technicians in hospitals with budget allocations are more likely to be vaccinated, highlighting the crucial role of financial resources in supporting effective immunization programs. Addressing budgetary constraints and advocating for increased funding can enhance vaccination rates and overall staff health in healthcare settings. Although the p-value of (0.075) does not meet the traditional threshold for statistical significance (0.05), it indicates a trend toward a correlation between follow-up practices and the use of hands to compact waste bags. This suggests that follow-up and monitoring may influence this practice, but the evidence is not strong enough to confirm a significant relationship. This trend highlights the potential influence of

monitoring and follow-up on waste management practices but also suggests that other factors may play a role. Enhancing training, providing adequate resources, and strengthening monitoring practices can help improve waste management protocols and ensure better hygiene and safety standards in hospitals. The study reveals significant a strong association between the use of hands to compact waste bags and the incidence of injuries by other objects, such as needle sticks (p-value (0.004)). This indicates that using hands to compact waste bags is linked to a higher likelihood of sustaining such injuries. The significant correlation between the use of hands to compact waste bags and the incidence of injuries by other objects highlights a critical safety concern. The findings suggest that manual compaction of waste increases the risk of injuries, including needle sticks. Addressing this issue through provide equipment, and stringent safety protocols can help reduce the risk of injuries and enhance overall safety in hospitals.The study indicators that medical waste management in Shendi locality hospitals is unsatisfactory levels in terms of sorting, storage, transportation, and treatment operations. The application of quality management in dealing with medical waste becomes necessary. It is completely clear from the relationships between the various variables presented in this study that we need to develop a comprehensive program for managing medical waste in Shendi locality hospitals that includes implementing more rigorous and standardized sorting protocols to ensure proper segregation of medical waste. Upgrade storage facilities to safely contain medical waste and minimize the risk of contamination or exposure. Develop reliable and secure methods for transporting medical waste from healthcare facilities to treatment or disposal sites. Provide ongoing training for healthcare staff on best practices for healthcare solid waste management. Ensuring the use of effective treatment technologies, such as incineration or

autoclaving, and adhering to regulatory standards for waste disposal. Ensuring all practices meet national and international regulations and guidelines for medical waste management.

The daily waste generation rates observed in these facilities range widely, from a low of 0.9 kg/bed. Day at Military Hospital to a high of 6 kg/bed. Day at Tumor Center. This variability likely reflects differences in hospital size, patient turnover, waste management practices, and the types of medical procedures performed. Waste generation rates in healthcare settings vary significantly based on location, hospital type, and management practices. For example, a study in Nigeria found waste generation rates ranging from 0.56 to 3.45 kg/bed across various hospitals (40). Similarly, studies in India have reported rates between 0.5 and 4.0 kg/bed, reflecting a pattern similar to the range observed in the result (85). When comparing these figures to the data presented, Tumor Hospital's rate of 6 kg/bed is notably higher than what is typically reported in other regions. This may suggest a need for targeted waste reduction strategies at that facility. On the other hand, the rate of 0.9 kg/bed at Military Hospital falls within the lower range of global findings, indicating potentially more efficient waste management practices. The waste generation rates observed in the provided document align with global trends but also highlight the need for hospital-specific interventions to manage and reduce waste, particularly in facilities with higher generation rates.

5.2 Conclusions

Healthcare solid waste generation rates in Shendi locality hospitals fluctuate daily, with an average rate of 33.25 kg/day. Elmiknaimer hospital has the highest rate at 84 kg/day. 70.9% of the study population is aware of general waste, there are significant gaps in awareness of pathological (47.3%) and radioactive waste (80.0%). Only 33.6% of hospitals practice proper waste segregation.64.5% of hospitals do not use color coding for waste segregation, and many lack essential infrastructure such as functional incinerators, autoclaves, and proper disposal facilities.Only 89.1% of hospital staff use gloves, 76.4% use masks, and 30% use aprons. The study highlights the importance of comprehensive training programs to improve protective measures and waste management practices.56% of hospitals have a dedicated budget for healthcare solid waste disposal, indicating recognition of its importance. However, significant investment in waste management facilities is needed. The study emphasizes the risks to healthcare workers from improper waste handling, including needlestick injuries and infections. There is a strong correlation between experience in healthcare waste management and higher vaccination rates among technicians.

5.3 Recommendations:

Based on the finding the study recommended to ministry of health and hospital administration the following;

1. **Standardize Waste Management Practices:**
   - ✓ Implement rigorous and standardized sorting protocols to ensure proper segregation of healthcare solid waste.
   - ✓ Upgrade storage facilities to safely contain medical waste and minimize contamination risks.
   - ✓ Develop reliable and secure methods for transporting healthcare solid waste to treatment or disposal sites.

1. **Enhance Training and Awareness:**

   - ✓ Provide ongoing training for healthcare staff on best practices for medical waste management.
   - ✓ Increase awareness and education on different types of healthcare solid waste and the importance of proper disposal.
   - ✓ Target educational programs to improve understanding of pathological and radioactive waste handling.

2. **Improve Protective Measures:**

   - ✓ Ensure all healthcare workers use appropriate protective gear, such as gloves, masks, and aprons, to minimize exposure risks.
   - ✓ Address gender disparities in the usage of protective aprons and other equipment.
   - ✓ Implement structured protocols to ensure consistent use of protective gear among all staff members.

3. **Adopt Color-Coding Systems:**

   - ✓ Standardize the use of color-coded waste bags to facilitate safer handling and disposal of different waste types.
   - ✓ Increase policy enforcement to ensure adherence to color-coding practices.

4. **Invest in Infrastructure:**

   - ✓ Allocate budget for proper waste disposal facilities, including incinerators and autoclaves, to ensure effective treatment of hazardous waste.
   - ✓ Address deficiencies in essential waste management infrastructure to comply with health and safety regulations.

5. **Promote Vaccination and Health Programs:**
    - Implement comprehensive immunization programs for healthcare workers to reduce the risk of disease transmission.
    - Address budgetary constraints to enhance vaccination rates and overall staff health.
    - Ensure technicians and staff with experience in waste management are more likely to be vaccinated.
6. **Monitor and Enforce Compliance:**

    - ✓ Strengthen monitoring practices to ensure adherence to waste management protocols.
    - ✓ Regularly assess and improve healthcare solid waste management operations both inside and outside healthcare facilities.
    - ✓ Develop clear role definitions and accountability for waste management processes.

7. **Enhance Overall Quality Management:**

    - ✓ Develop a comprehensive program for managing medical waste, ensuring all practices meet national and international regulations.
    - ✓ Apply quality management principles to improve sorting, storage, transportation, and treatment operations.
    - ✓ Provide adequate equipment and stringent safety protocols to reduce the risk of injuries and enhance safety in hospitals.

Appendices

References

Appendices

References

1. Ma, Yufeng, et al. "Suggested guidelines for emergency treatment of medical waste during COVID-19: the Chinese experience." Waste Disposal & Sustainable Energy 2.2 (2020): 81-84.
2. Oduro-Kwarteng, Sampson, RansfordAddai, and Helen MK Essandoh. "Healthcare waste characteristics and management in Kumasi, Ghana." Scientific African 12 (2021): e00784.
3. Alagöz, Aylin Zeren, and GünayKocasoy. "Determination of the best appropriate management methods for the health-care wastes in Istanbul." Waste Management 28.7 (2008): 1227-1235.
4. Shinee, Enkhtsetseg, et al. "Healthcare waste management in the capital city of Mongolia." Waste management 28.2 (2008): 435-441.
5. Bendjoudi, Z., et al. "Healthcare waste management in Algeria and Mostaganem department." Waste management 29.4 (2009): 1383-1387.
6. Bendjoudi, Z., et al. "Healthcare waste management in Algeria and Mostaganem department." Waste management 29.4 (2009): 1383-1387.
7. Rastogi, Vichal, PoojaRastogi, and Shalini Bhatia. "Bacteriological profile of biomedical waste: management guidelines." Journal of Indian Academy of Forensic Medicine 33.2 (2011): 145-148.
8. Katoch, Surjit S. "Biomedical waste classification and prevailing management strategies." Proceedings of the International Conference on Sustainable Solid Waste Management. 2007.
9. Akter, N. "Medical waste management: a review, environmental engineering program, school of environment resources and development." Asian Institute of Technology, Khlongluang, Pathumthani, Thailand (2000).
10. Mastorakis, Nikos E., et al. "Holistic approach of biomedical waste management system about health and environmental risks." Development, Energy, Environment, Economics 5.3 (2011): 287-295.

11. Bokhoree, C., et al. "Assessment of environmental and health risks associated with the management of medical waste in Mauritius." APCBEE procedia 9 (2014): 36-41.
12. Rao, S. K. M., et al. "Biomedical waste management: an infrastructural survey of hospitals." Medical Journal Armed Forces India 60.4 (2004): 379-382.
13. Hassan AA, Tudor T, Vaccari M. Healthcare waste management: A case study from Sudan. Environments. 2018 Aug 5; 5(8):89.
14. Bucătaru C, Săvescu D, Repanovici A, Blaga L, Coman E, Cocuz ME. The implications and effects of medical waste on development of sustainable society—a brief review of the literature. Sustainability. 2021 Mar 17;13(6):3300.
15. Windfeld ES, Brooks MS. Medical waste management–A review. Journal of environmental management. 2015 Nov 1; 163:98-108.
16. Birchard K. Out of sight, out of mind… the medical waste problem. The Lancet. 2002 Jan 5; 359(9300):56.
17. Insa E, Zamorano M, Lopez R. Critical review of medical waste legislation in Spain. Resources, Conservation and Recycling. 2010 Oct 1;54(12):1048-59.
18. Mol MP, Gonçalves JP, Silva EA, Scarponi CF, Greco DB, Cairncross S, Heller L. Seroprevalence of hepatitis B and C among domestic and healthcare waste handlers in Belo Horizonte, Brazil. Waste Management & Research. 2016 Sep;34(9):875-83.
19. U.S. EPA, Solid Waste Management on Tribal Lands.2013 Retrieved February 24, 2015,
20. Xin Y. Comparison of hospital medical waste generation rate based on diagnosis-related groups. Journal of Cleaner Production. 2015 Aug 1;100:202-7.
21. Carvalho A, Mimoso AF, Mendes AN, Matos HA. From a literature review to a framework for environmental process impact assessment index. Journal of Cleaner Production. 2014 Feb 1;64:36-62.
22. Ali Awaad El-Shaer AR, Ahmed Hafez N, El-Wahed A, EzzatAbd El-Aziz A, EweesAmeen I. Health hazards of hospital waste among workers at al-azhar university hospitals. Al-Azhar Medical Journal. 2016 Oct 1;45(4):789-804.

23. FC O, JS O, TG T. A review of medical waste management in South Africa. Open Environmental Sciences. 2018 Jun 20;10(1).
24. Ali M, Wang W, Chaudhry N, Geng Y. Hospital waste management in developing countries: A mini-review. Waste Management & Research. 2017 Jun;35(6):581-92.
25. Caniato, M., Tudor, T., Vaccari, M.,. International governance structures for health-care waste management: a systematic review of scientific literature. J. Environ. Manag.2015 153, 93e107.
26. World Health Organization e WHO. Medical Waste 2019 (accessed 25.05.15.). http://www.who.int/topics/medical_waste/en/.
27. Environmental Research & Education Foundation. Household needles in municipal solid waste (MSW): policy, controls, and material recovery facility (MRF) safety; 2018.
28. S. Sarafraz, M. Khani, K. Yaghmaeian, Quality and quantity survey of hospital wastewaters in Hormozgan province, Iran.J. Environ. Health Sci. Eng. (2007) 43–50.
29. N. Marinkovic, K. Vitale, N.J. Holcer, A. Džakula, T. Pavic, Management of hazardous medical waste in Croatia, Waste Manag. 30. 28 (2008) 1049–1056.
30. A.B. Le, S. Hoboy, A. Germain, H. Miller, R. Thompson, J.J. Herstein, K.C. Jelden, E.L. Beam, S.G. Gibbs, J.J. Lowe, A pilot survey of the US medical waste industry to determine training needs for safely handling highly infectious waste, Am. J. Infect. Control 46 (2018) 133–138.
31. R. Kahhat, J. Kim, M. Xu, B. Allenby, E. Williams, P. Zhang, Exploring e-waste management systems in the United States, Retour. Conserve. Recycle. 52 (2008) 955–964.
32. A. Mohseni Band-pay, M. Majlessi, M. Tabrizi Azad, Performance Evaluation of Non-Incineration Treatment Facilities for Disinfection of Medical Infectious and Sharps Wastes in Educational Hospitals of ShahidBeheshti University of Medical Sciences in 2013, (2013).
33. Menon S, Kumar LS V. Weaponizing radioactive medical waste-The looming threat. International Journal of Nuclear Security. 2019;5(1):4.

34. S. Khan, A. Syed, R. Ahmad, T. A. Rather, M. Ajaz, F. Jan, Radioactive Waste Management in A Hospital. Int. J. Health Sci. 4, 39–46 (2010).
35. American Nuclear Society Center for Nuclear Science and Technology Information, Medical Applications. Know Nucl. (2019),http://nuclearconnect.org/knownuclear/applications/medical-uses).
36. U.S. Food and Drug Administration, Radiation-Emitting Products. FDA (2019), (available at http://www.fda.gov/radiation-emitting-products/medical-imaging/medical-x-ray-imaging).
37. National Institute of Biomedical Imaging and Bioengineering, Nuclear Medicine. NIH (2019), (available at https://www.nibib.nih.gov/science-education/sciencetopics/nuclear-medicine).
38. Abdulla F, Qdais HA, Rabi A. Site investigation on medical waste management practices in northern Jordan. Waste management. 2008 Jan 1;28(2):450-8.
39. Mohamed MO. Assessment of Medical Wastes Management in Borama Hospitals, Awdal Region, Somalia (2013) (Doctoral dissertation, University of Gezira).
40. ChisholmJM, Zamani R, Negm AM, Said N, Abdel daiem MM, Dibaj M, Akrami M. Sustainable waste management of medical waste in African developing countries: A narrative review. Waste Management & Research. 2021 Sep;39(9):1149-63.
41. Azage M. Healthcare waste management practices among healthcare workers in healthcare facilities of Gondar town, Northwest Ethiopia. Health Science Journal. 2013;7(3):0-.
42. Demirbas A. Waste management, waste resource facilities and waste conversion processes. Energy Conversion and Management. 2011 Feb 1;52(2):1280-7.
43. Ansari M, Ehrampoush MH, Farzadkia M, Ahmadi E. Dynamic assessment of economic and environmental performance index and generation, composition, environmental and human health risks of hospital solid waste in developing countries; A state of the art of the review. Environment international. 2019 Nov 1;132:105073.
44. Oroei M, Momeni M, Palenik CJ, Danaei M, Askarian M. A qualitative study of the causes of improper segregation of

infectious waste at Nemazee Hospital, Shiraz, Iran. Journal of infection and public health. 2014 May 1;7(3):192-8.
45. Townend, W. K. "Safe management of wastes from health care activities." Bulletin of the World Health Organization 79 (2001): 171-171.
46. Etim MA, Academe S, Emenike P, Omole D. Application of multi-criteria decision approach in the assessment of medical waste management systems in Nigeria. Sustainability. 2021 Sep 30;13(19):10914.
47. Shivalli, Siddharudha, and H. Sowmyashree. "Occupational exposure to infection: A study on healthcare waste handlers of a tertiary care hospital in South India." The Journal of the Association of Physicians of India, Vol. 63, No. 11, 2015, pp. 24-27.
48. National Research Council Recommendations Concerning Chemical Hygiene in Laboratories. United States Department of Labor, 2013.
49. Medina M. The informal recycling sector in developing countries: organizing waste pickers to enhance their impact [Internet]. Washington, D.C.: The World Bank; 2008 Oct.
50. Zolnikov TR, da Silva RC, Tuesta AA, Marques CP, Cruvinel VR. Ineffective waste site closures in Brazil: a systematic review on continuing health conditions and occupational hazards of waste collectors. Waste Manage. 2018 Oct
51. TarekJebreel, Tareg Al-Sanuorri, Erin M Sorrell, Waste Management Standard Operating Procedure, Global Health Development,2021.
52. Shih LH, Lin YT. Multicriteria optimization for infectious medical waste collection system planning. Practice Periodical Hazardous, Toxic, and Radioactive Waste Management. 2003 Apr;7(2):78-85.
53. Padmanabhan KK, Barik D. Health hazards of medical waste and its disposal. Energy from toxic organic waste for heat and power generation 2019 Jan 1 (pp. 99-118). Woodhead Publishing.
54. Khan BA, Cheng L, Khan AA, Ahmed H. Healthcare waste management in Asian developing countries: A mini-review. Waste management & research. 2019 Sep;37(9):863-75.

55. Olaniyi FC, Ogola JS, Tshitangano TG. Efficiency of health care risk waste management in rural healthcare facilities of South Africa: An assessment of selected facilities in Vhembe District, Limpopo Province. International Journal of Environmental Research and Public Health. 2019 Jun; 16(12):2199.
56. Nehar B, Benamara S, Benhamed N. Hospital Waste Management and the Associated Hazards. Global Partners in Education Journal. 2022 Dec 13;10(2):94-103.
57. ICRC.Medical Waste Management, 19, avenue de la Paix 1202 Geneva, Switzerland ICRC, November 2011.
58. Minghua Z, Xiumin F, Rovetta A, Qichang H, Vicentini F, Bingkai L, Giusti A, Yi L. Municipal solid waste management in Pudong new area, China. Waste management. 2009 Mar 1;29(3):1227-33.
59. Askarian M, Vakili M, Kabir G. Results of a hospital waste survey in private hospitals in Fars province, Iran. Waste management. 2004 Jan 1;24(4):347-52.
60. Tata A, Beone F. Hospital waste sterilization: A technical and economic comparison between radiation and microwaves treatments. Radiation Physics and Chemistry. 1995 Sep 12;46(4-6):1153-7.
61. Birchard K. Out of sight, out of mind… the medical waste problem. The Lancet. 2002 Jan 5;359(9300):56.
62. Rutala WA, Mayhall CG. Medical waste: infection control and hospital epidemiology. Hospital Epidemiology and Infection Control. 1992;13(1):794-7.
63. Lee BK, Ellenbecker MJ, Moure-Ersaso R. Alternatives for treatment and disposal cost reduction of regulated medical wastes. Waste management. 2004 Jan 1;24(2):143-51.
64. Shareefdeen ZM. Medical waste management and control. Journal of Environmental Protection. 2012 Dec 24;3(12):1625.
65.] G. Rutberg, N. Bratsev, A. Safronov, V. Surov and V. Schegolev, "The Technology and Execution of Plasma Chemical Disinfection of Hazardous Medical Waste," Plasma Science, IEEE Transactions, Vol. 30, No. 4, 2002, pp. 1445-1448.
66. Waste Treatment Technology News, the United States Environmental Protection Agency, Environmental Protection Agency Issues, Draft Dioxin Assessment, 2010.

67. N. R. Soelberg, R. A. Rankin, K. M. Klingler, C. W. Lagle and L. L. Byers, “Eliminating Medical Waste Liabilities Through Mobile Maceration and Disinfection,” WM’06 Conference, Tucson, 26 February-2 March 2006.
68. Verma R. Medical waste disposal: incineration and non-incineration technology their effects and prospects. Natural Environment. 2014; 19:195-8.
69. Schecter A, Birnbaum L, Ryan JJ, Constable JD. Dioxins: an overview. Environmental research. 2006 Jul 1; 101(3):419-28.
70. Environment Canada, 2013. Incineration. Retrieved February 26, 2015, from: https://www.ec.gc.ca/toxiques.
71. Pacyna EG, Pacyna JM, Steenhuisen F, Wilson S. Global anthropogenic mercury emission inventory for 2000. Atmospheric environment. 2006 Jul 1;40(22):4048-63.
72. Wolfe MF, Schwarzbach S, Sulaiman RA. Effects of mercury on wildlife: a comprehensive review. Environmental Toxicology and Chemistry: An International Journal. 1998 Feb;17(2):146-60.
73. Kilgroe JD. Control of dioxin, furan, and mercury emissions from municipal waste combustors. Journal of Hazardous Materials. 1996 May 1;47(1-3):163-94.
74. World Health Organization, Health-care Waste Management 2011.
75. Klangsin P, Harding AK. Medical waste treatment and disposal methods used by hospitals in Oregon, Washington, and Idaho. Journal of the Air & waste management Association. 1998 Jun 1;48(6):516-26.
76. Jang YC, Lee C, Yoon OS, Kim H. Medical waste management in Korea. Journal of environmental management. 2006 Jul 1;80(2):107-15.
77. Verma R. Medical waste disposal: incineration and non-incineration technology their effects and prospects. Natural Environment. 2014; 19:195-8.
78. Cheng YW, Sung FC, Yang Y, Lo YH, Chung YT, Li KC. Medical waste production at hospitals and associated factors. Waste Management. 2009 Jan 1;29(1):440-4.
79. Lee CC, Huffman GL. Medical waste management/incineration. Journal of Hazardous Materials. 1996 Jun 1;48(1-3):1-30.

80. Tesfahun E, Kumie A, Legesse W, Kloos H, Beyene A. Assessment of composition and generation rate of healthcare wastes in selected public and private hospitals of Ethiopia. Waste Management & Research. 2014 Mar;32(3):215-20.
81. Abdelrahman, W. Personal Communication, January 1 ,2022. Health and population autharity , Shendi locality, River Nile State, Sudan.
82. Kagonji IS, Manyele SV. Analysis of the measured medical waste generation rate in Tanzanian district hospitals using statistical methods. African Journal of Environmental Science and Technology. 2011;5(10):815-33.
83. Fatima MK. Evaluation of medical solid waste management in some hospitals in Najaf city/Iraq. Kufa J Eng. 2016;7(3):38-54.
84. Zeeshan MF, Al Ibad A, Aziz A, Subhani A, Shah A, Khan T, Ullah H, Qazi U. Practice and enforcement of national Hospital Waste Management 2005 rules in Pakistan. Eastern Mediterranean Health Journal. 2018 May 1;24(5).
85. Hanumantha Rao P. Report: Hospital waste management—awareness and practices: a study of three states in India. Waste management & research. 2008 Jun;26(3):297-303.
86. Naeem S, Waseem S. Assessment of Hospital Waste Management Practices in Public and Private Healthcare establishments of Rahim Yar Khan. Journal of Sheikh Zayed Medical College (JSZMC). 2020 Jul 10;11(01):26-9.
87. Maina JW. Knowledge, attitude and practice of staff on segregation of hospital waste: a case study of a tertiary private hospital in Kenya. Eur Sci J. 2018;14(9):401-17.
88. Loulergue P, Moulin F, Vidal-Trecan G, Absi Z, Demontpion C, Menager C, Gorodetsky M, Gendrel D, Guillevin L, Launay O. Knowledge, attitudes and vaccination coverage of healthcare workers regarding occupational vaccinations. Vaccine. 2009 Jun 24;27(31):4240-3.
89. Taddei C, Ceccherini V, Niccolai G, Porchia BR, Boccalini S, Levi M, Tiscione E, Santini MG, Baretti S, Bonanni P, Bechini A. Attitude toward immunization and risk perception of measles, rubella, mumps, varicella, and pertussis in health care workers

working in 6 hospitals of Florence, Italy 2011. Human vaccines & immunotherapeutics. 2014 Sep 2;10(9):2612-22.
90. Nugraheni T. Identification of Waste Handling Compliance of Sharp Objects at Universitas Gadjah Mada Academic Hospital Yogyakarta. Academic Hospital Journal, 2018.;1(1):15.
91. 11. Ranu R, Santosh K, Manju L. Knowledge, attitude and practice regarding biomedical waste management amongst health care personnel in a Medical College Hospital in Trivandrum. National Journal of Community Medicine. 2016 Jun 30;7(06):457-60.
92. Singh S, Dhillon BS, Shrivastava AK, Kumar B, Bhattacharya S. Effectiveness of a training program about bio-medical waste management on the knowledge and practices of health-care professionals at a tertiary care teaching institute of North India. Journal of Education and Health Promotion. 2020 Jan 1;9(1):127
93. Allaqband UF, Fazili AB, Shah RJ, Ali D, Balwan WK. A study on assessment of practices which pose risk to waste handler in various health care settings of Kashmir valley. Age. 2019;20(6):3-9
94. Hill JD, Anderegg SV, Couldry RJ. Development of a pharmacy technician–driven program to improve vaccination rates at an academic medical center. Hospital Pharmacy. 2017 Oct;52(9):617-22.
95. Heo Y, Chun H, Kang S, Lee W, Jang T, Park J. Relating factors to wearing personal radiation protectors among healthcare professionals. Annals of Occupational and Environmental Medicine. 2016 Dec; 28:1-6.
96. Du Toit K, Bodenstein J. Disposal of medical waste: a legal perspective: forum-medicine and the law. South African Medical Journal. 2014 Jan 1;104(1):14-5.
97. Saeed, S., Fadol, F., Ali, S., Al Maghrabi, F. A., Edris, F., & Sambu, B. M. H. Assessment of knowledge, attitude, and practices of nurses towards health care waste management in Port Sudan city, Sudan 2019-2020. Journal of Health Care and Research, 8(12), (2021).

Appendix I

Faculty of Graduate Studies and scientific research

Survey questionnaire for medical waste management

Hospital name :
Part I Socio demographic information
1/ Gender:

1-Male □ 2- Female □

2/ Education level:

1- Illiterate □ 2- Basic □ 3- Secondary □ 4- graduate □ 5- post graduates. □

3/ Age range of respondents (years) :

1- 15-25yrs □ 2- 26-35yrs □ 3- 36-45yrs □ 4- 46-55yrs □ 5- 56-65yrs □ . 6- Above 65 yrs. □

5- Occupation of respondents

1- Doctor/dentist □ 2- Medical assistant □ 3- nursing □ 4- lab technician □ 5- Medical receptionist □ 6-cleaner worker □ ,

6/ Is there are Experience in Medical Waste Management?

1- Yes □ 2- No □

7/ Has this employee received specialized training in medical waste management?

1- Yes □ 2- No □

8/ Is there a regular training program on waste management approaches for medical personnel (doctors, nurses)?

1- Yes □ 2- No □

9. Is there a regular training program on waste management approaches for technical (support) personnel (equipment maintenance engineers, technicians, cleaners, crematorium workers, etc.)?

1- Yes □ 2- No □ .

10/ Is there a designated employee for the disposal of medical waste at your institution?

1- Yes □ 2- No □

11/ Do you keep records of the volumes of different categories of medical waste?

1- Yes □ 2- No □

12 . Do you have an adequate budget for waste disposal?

1- Yes □ 2- No □

13/ Immunization Status of worker anti infectious medical wastes

1- vaccinated □ 2- Not vaccinated □

14/ Use of PPE among worker

1- Plastic gloves □ 2- Face mask □ 3- Apron □ 4- Protective shoes □ 5- Shades □

Part II: medical waste management

15/ Type of solid waste produced in hospital

1- General □
2- Pathological □
3- Radioactive □
4- Chemical □
5- Infectious □
6- Sharps □
7- Pharmaceutical □
8- Pressurized □

16/ Estimation Quantity of medical waste producing in hospital

1/ <1 kilogram/day □
2/ 1–2 kilograms/ □
3/ 2–3 kilograms/ □
4/ 3–4 kilograms/ □
5/ 4–5 kilograms/ □
6/ >5 kilograms/ □

17/. Types of hazardous waste that are collected separately at your hospital (multiple answer possible)

1-General waste (A) □ 2-Stabbing/Syringes (B) □ 3-Infectious waste (B) □ . 4-Pathological waste (B) □ 5-Hazardous infectious waste (C) □ 6- Chemical wastes (D) □ 7-Pharmaceutical waste (D) □

18/ Presence of color coded labeled containers at the waste generation point

1- Yes □ 2- No □

19/ Medical Waste storage site

1- Inside the health unit □ 2- outside the health unit □

20/ Is medical waste segregated?

1- Yes □ 2- No □ 3- Don't know □

21/ who segregate medical waste?

1- Medical Staff □ 2- Cleaning worker □ 3- Do not know □ 4- Not applicable□

22/ Place of medical waste Segregation:

1- At the beginning near the source □ 2- After waste is collected □ 3-At the waste storage place in the hospital □ 4-Not applicable □ 5- Don't know □

23/ Availability of waste transportation method to Storage point:

1- Yes □ 2- No □

24/ Accessibility of temporary storage area for waste

1- Available □ 2- Not available □

25/ Presence of color coded labeled containers at the temporary storage point

1- Yes □ 2- No □

26/ Is there special mark to show place of storage?

1 Yes □ 2- No □ 3- Don't Know □

27/ Is storage area sufficient inside hospital?

1- Yes □ 2- No □ 3- Don't Know □

28/ For how long, the medical waste used to be storage?

1- 1-2 days □ 2- 3-5 days □ 3- 7 days (one week) □ 4- not available □ 5- Don't Know □

29 / Is storage area of medical waste protected well?

1- Yes □ 2- No □ 3- Don't Know. □

30/ methods of Sharps disposal

1- Safety box □ 2- Ordinary waste bags □

31/ Medical waste disposal method at hospital

1- private infectious waste management company □ 2- Take to hospital incinerator □ 3- Take to out incinerator □ 4- Take to general waste bin □

32/ Availability of incinerator in hospital

1- Present (Functional) □ 2- Not present □

33/ Frequency of medical waste disposal

1- Daily □ 2- 3 times per week □ 3- Twice weekly □

4- Once weekly □ 5- Monthly □

Appendix II

إستبيان بغرض تقييم مخاطر المخلفات الطبية علي عمال النظافة بمستشفيات محلية شندي

1 -العمر: .....

أ.(15 -25) ب -(25 -35) ج.(35 -45) د(أكبر من 45)

2. الجنس أ. ذكر ب. أنثي

3. المستوي التعليمي . أ. امي ب. خلوة ج. أساس د. ثانوي

4. كم عدد ساعات العمل اليومية؟ .....

أ. 8 ساعات. ب. 12 ساعة. ج.24 ساعة.

5. هل تم تدريبك بحيث تستطيع التعامل مع المخلفات الطبية؟

1. نعم 2. لا

إذا كان الجواب نعم:

-أين تم التدريب؟ 1. داخل المستشفي 2. خارج المستشفي

-كم هي مدة التدريب؟ 1. يوم 2. أكثر من يوم

6. هل يتم فصل المخلفات الطبية عن المخلفات العادية؟

1.نعم 2.لا

7. هل يتم تدريب عمال النظافة الجدد على كيفية التعامل مع المخلفات الطبية؟

1. نعم 2. لا 3. لا اداري

8. هل تتعرض الأكياس أو الحاويات التي تنقل بواسطتها النفايات الطبية للتمزق ؟

1. نعم 2. لا

9. هل يتم تعبئة أكياس النفايات أكثر من سعتها؟

1. نعم 2. لا 3 احياناً

10.هل تحمل أكياس النفايات وتنقلها بسهولة من مكان لآخر؟

1. نعم 2. لا 3.أحياناً

11. هل يتم ربط أكياس النفايات بشكل جيد لا يؤدي إلى فتحها أثناء النقل؟

1. نعم 2. لا

12. هل تستخدم معدات الوقاية الشخصية أثناء التعامل مع النفايات الطبية(ملابس واقية، قفازات، حذاء واقي ، كمامات ، طاقية او خوذة)؟

1. نعم 2. لا

13. أين يتم التخلص من الكمامات والقفازات المستعملة؟

1. مع النفايات الطبية 2. مع النفايات الطبية والعادية

3. مع النفايات العادية.

14.هل تضع يدك أحيانا في أكياس النفايات الطبية أو الحاوية لضغطها أو لأي غرض آخر؟

1. نعم 2. لا

15. هل تعرضت للوخز بالإبر بعد استعمالها أثناء العمل؟

1 نعم 2.لا

16. هل تعرضت للجرح بغير الابر أثناء العمل؟

1.نعم 2.لا

17. هل يقوم المسئول عن عمال النفايات الطبية والعادية في المستشفي بالمتابعة والإشراف ؟

1. نعم 2.لا

18. هل تم فحصك قبل التوظيف للتأكد من خلوك من أمراض معينة؟

1. نعم 2.لا

83

19. هل يتم الكشف الدوري لعمال النظافة في المستشفي؟

1. نعم 2. لا

20 - هل تم إعطاؤك تطعيمات معينة لوقايتك من بعض الأمراض المعدية؟

1. نعم 2. لا

Appendix III

Some images that were scanned from locations within the hospitals which data was collected


Nopel


timSafe 5L
Safety Box