

**EVALUATION OF THE IMPLEMENTATION OF BIOSAFETY &
BIOSECURITY PRACTICES AMONG LABORATORY WORKERS IN
NAROK COUNTY HOSPITALS**

BY

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**A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE AWARD OF DEGREE OF DOCTOR OF
PHILOSOPHY IN MEDICAL EDUCATION**

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DECLARATION

DECLARATION BY THE STUDENT

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DEDICATION

This work is hereby dedicated to my family, the Orians', my supervisors together with all Narok County Health workers for their immense support and their counsel during this process. God bless you abundantly.

ABSTRACT

Background: Biosafety and biosecurity (BB) are of paramount importance in putting measures to protect humans, animals, and the environment from biological hazards, as well as preventing the misuse of biological agents. Biosafety training integrates both theoretical knowledge and practical application to help LWs to protect themselves from acquiring the highly infectious agents in biological specimens on daily basis. The implementation of BB is crucial in mitigating laboratory-acquired infections (LAIs) and potential bioterrorism threats. Despite existing WHO and Ministry of Health (MOH) guidelines, there is limited data on the extent of BB implementation among LWs in Narok County hospitals. This study assessed the implementation of BB practices in laboratory settings across the county. This study assessed the implementation of BB among LWs in Narok county hospitals (NCHs).

Objectives: This study is designed to determine the demographic factors, knowledge, skills and altitudes, constraints and compliance of BB of the laboratory workers in NCHs.

Methods: A Mixed-method design was utilized in this study. A total of 102 participants were recruited through census sampling. The participants comprised laboratory workers and laboratory in-charges in both public and private and total hospital laboratories were seventy (70). Eligible participants responded to a structured questionnaire containing both open- and closed-ended questions. The 15 laboratory in-charges were interviewed by the researcher. In addition, site visits were conducted for observation purposes using a checklist completed by the researcher, Data analysis was performed using SPSS for Windows (version 30.0). Descriptive statistics; including frequencies and percentages were computed. Inferential statistics, including Chi-square tests and P-values, were used to examine associations between independent variables (clinical skills learning resource setting and staff views) and the dependent variable (the self-evaluation of clinical skills competence). The ethical clearance MTRH/ was obtained from MU-Institutional Scientific and Ethical Review Committee (ISERC)- No. 0005188, NACOSTI License and permission was obtained from the County Director of Health of Narok county. Written and verbal informed consent was obtained from each participant before entering the study.

Results: A total of 102 participants completed the self-administered study questionnaire. There was significant deference in higher education ($p=0.020$), years of experience ($p=0.033$) and prior BB training ($p<0.001$), while age ($p=0.081$) and gender ($p=0.379$) had no significant influence. Inadequate resources, poor infrastructure, staff shortages, and limited training were major constraints. Out of 102 participants, 27 (26.5%) had high compliance, 44 (43.1%) respondents had moderate compliance while 31 (30.4%) had low compliance. Only 102 (100%) lab workers were observed for skills more emphasis on use of SOPs. 43.66%(1) had LAIs and all 102 had an exposure infectious agent.

Conclusion: High professional level, work experience and additional BB training significantly improved knowledge and practical competence, while age and gender had no significant influence. Inadequate resources, poor infrastructure, staff shortages, and limited training were major constraints.

Recommendations: The national government to strengthen funding targeted to County health governments in matters of biosafety and BB training. Monitoring of BB training by KMLLTB. The county health department to enhance support professional development for LWs and employment of more LWs for better BB implementation.

LIST OF ABBREVIATIONS AND ACRONYMS

AIDS	Acquired Immunodeficiency Syndrome
BB	Biosafety and biosecurity
BBP	Biosafety and biosecurity procedures
BBTM	Biosafety biosecurity training model
BSL	Biosafety level
CDC	Centers for Disease Control
CIPP	Context Input Process Product
DV	Dependent Variable
FGDs	Focus Group Discussions
HCWs	Health Community Workers
HIV	Human Immunodeficiency Virus
IPC	Infection Prevention Control
IREC	Institutional Research Ethics Committee
ISERC	Institutional Scientific and Ethics Review Committee
ISO	International Organization for Standardizations
IV	Independent Variable
KEMRI	Kenya Medical Research Institute
KMLTTB	Kenya Medical Laboratory Technologist and Technician Board
LAIs	Laboratory Associated Infection

LWs	Laboratory Workers
MCQs	Multiple Choice Questions
MLT	Medical Laboratory Technologist
MOH	Ministry of Health
MSH	Management Science for Health
NASCOSTI	National Commission of Science, Technology and Innovation
NCG	Narok County Government
NCHs	Narok County Hospitals
NCRH	Narok County Referral Hospital
PBL	Problem-Based Learning
PEPFAR	President's Emergency Plan for AIDS Relief
PPE	Personal Protective Equipment
QMS	Quality Management System
SAQs	Short Answer Questions
SPSS	Statistical Package for Social Science
TB	Tuberculosis
TOT	Trainer of Trainers
USA	United States of America
VBMs	Valuable Biological Materials
WAI	Work Acquired Infections

WHO	World Health Organization
WISN	Workload Indicator of Staffing Need

OPERATIONAL DEFINITION OF TERMS AS USED IN THIS STUDY

Assessment: This a careful evaluation and analysis of bio-safety and bio-security practices to determine its effectiveness, efficiency, and compliance with the WHO/MoH standards.

Biohazard: Any biological agent capable of causing harm to people, animals, or the environment as used in this study

Biorisk assessment: A systematic, continuous process used in laboratories to identify and evaluate hazards associated with biological agents, combining biosafety

Bio-safety and bio-security Training Model: This is an additional training offered to reduce increased rates of laboratory-acquired infections from clinical laboratories and sometimes termed as occupational exposure among laboratory workers

Compliance: In this study refers to strictly adhering to Biosafety laws, guidelines and regulations.

Conformance: Degree to which a BB, service, and process meets established standards, specifications, or requirements, ensuring consistency and reliability.

Constraining factors: These are external and internal forces, in this study organizational, personal; that act as an impediment to execution of BBP by laboratory worker.

Laboratory Bio-safety: Measures put in place to prevent accidental exposure to or release of pathogens/toxins.

Laboratory Bio-security: control measures to prevent theft, loss, or misuse of biological agents.

Laboratory worker: any trained personnel on matters of laboratory working in the medical laboratory

Levels of training: This refers to the highest levels of training obtained by Medical Laboratory Students. The level of training may range from first year to third year levels in MLSS training.

Medical laboratory Technologist: A trained laboratory professional.

Non-conformity:Refers to what is not right with the lab BB practices

Proficiency: It is a way of measuring how skilled or knowledgeable is the person is in a specific area or task

Risk assessment- Identification of agent risks, evaluating exposure likelihood and applying control measures

Security: Custody for material tracking, Personnel Reliability Programs for access control, and established Incident Response Plans

Standards: This is measuring laid out procedures of biosafety and biosecurity implementation.

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CHAPTER ONE

1.1 INTRODUCTION

This chapter has given the extent in which biosafety and biosecurity (BB) practices has been conducted in other studies. The chapter has provided an introduction, to the study, including the background, statement of the problem, justification, objectives, significance and other related concepts.

1.2 Background Information

Biosafety and biosecurity (BB) are terms used alternatively in many forums. However, biosafety in this study refers to the measures put in place for keeping people, animals, and the environment safe from biological hazards. In contrast, biosecurity is the enactment of preventing the misuse of biological hazards. The measures to put in place to keep people safe are like Personal protective equipment (PPE), in biosecurity, and are the control measures, like restricted access to valuable biological materials (VBM).

Biosecurity can be defined in this study as the prevention of large-scale loss of biological agents, focusing on the environment and human health (Danelyan & Gulyaeva, 2022). Bio security addresses containment principles, technologies, and practices implemented to prevent unintentional exposure to pathogens and toxins, or their accidental release.

Biosafety and biosecurity can be traced back to the time of the two greatest scientists, Louis Pasteur and Robert Koch, in the 19th century. Robert Koch grew microorganisms in the laboratory (Gao *et al* ., 2024). During their laboratory procedures, they were able to define laboratory acquired infections (LAIs) as a

disease caused while working in a clinical laboratory due to exposure to an infectious agent.

The rise of laboratory-acquired infections (LAIs) and the intentional loss of biological materials at different laboratory levels can result in under productivity or death of both laboratory workers (LWs) and the general public due to a lack of BB practices. Microbial- initiated LAIs are serious biohazards not only for the environment but also for public health, in particular, laboratory workers, who are exposed via various routes during their daily work discharge. Hence, the importance of biosafety and biosecurity practices among laboratory workers. Biological risks are a major global problem in the workplace, if biosafety is not properly implemented (Cornish *et al.*, 2021). The latest COVID-19 pandemic has stressed the need for a more extensive understanding of the biosafety and biosecurity practices, due to increased absenteeism in places of work caused by isolation of infected persons (Takala *et al.*, 2023).

According to the World Health Organization (WHO, 2004), biosafety is the safe working practice for handling biological materials, particularly infectious agents. Biosafety also reduces risks of incidents in the laboratory (Callihan *et al.*, 2020). Laboratory-acquired infections and exposure to pathological agents in clinical laboratories can be associated with poor biosafety measures (Peng, Bilal & Iqbal, 2018).

Globally, observations based on the movement of people, animals, plants, and food around the world daily by Messens and his fellow researchers informed the population on the biosecurity of biological agents. At the same time, these movements are occurring, along with the possibility of unintentional co-transport of infectious agents, vectors, and invasive species (Messens *et al.*, 2019). Messens and the group

continued to conclude that there was a need to include standardization and validation which would realize the benefits of biosafety fully, address barriers to data sharing, and establish epidemiological capacity for cluster triage and response. There have been a lot of biosecurity gaps during disease outbreaks like the Ebola virus that need to be addressed (Cornish *et al.*, 2021).

According to the WHO, Americans, accounts for 10% of the global health burden but, have 37% of the world's healthcare workers, while Africa, which accounts for 24% of the global disease burden, has only 3% of healthcare workers (WHO, World Health Statistics, 2023). This 3% healthcare workers where LWs are inclusive in Africa is very low and directly affects the quality of BB practices in healthcare facilities. It also reflects on few LWs trained in BB. World health financing in America is 50% while in Africa, it is approximately 1%, which is driving healthcare workers, including laboratory workers, to move abroad in search of greener pastures, thereby creating a health crisis. This also impacts the quality of BB.

According to Zuo *et al.* (2017), due to increased acquired laboratory infections from hospitals and research laboratories globally, efforts have been made to develop new practices through innovations in biosafety and biosecurity to manage risks and laboratory exposures arising from infectious agents and other hazards. Estimates worldwide are that one in ten healthcare workers (HCWs) contract a sharp injury every year (WHO, 2020).

In Africa, biosafety and biosecurity face significant challenges (Abdi *et al.*, 2024). Abdi and the group recommend that Standard Biosafety and Biosecurity measures to contain hazardous infections are missing across the African continent in the future. Need to form multi-channel full range of clinical and research laboratories in

terms of biosafety and bio risk management, teaching reforms based on skills incorporated in the curriculum (Pedde *et al*, 2022). The finding indicated the importance of accreditation of clinical laboratories based on BB practices.

It was reported that all HCWs are exposed to occupational hazards (Jiang *et al.*, 2018). Jiang *et al.* continue to argue that people in sub-Saharan Africa are at a higher risk of exposure to infectious diseases than those in developed countries, due to the region's higher disease burden and insufficient biosafety and biosecurity practices. Establishment of biosafety levels in clinical laboratories has created biosafety challenges in developing Countries (Gao *et al.*, 2024).

Biosafety and biosecurity Frameworks, Policies, and Institutions in West Africa. These countries have an economic union that agreed that, to be in a position to promote a safe and secure environment, more emphasis should be placed on developing a curriculum for biosafety and biosecurity education. This curriculum should focus on developing skills to maintain responsible health security practices (Abayomi *et al.*, 2022).

The BB training manual model for biosafety and biosecurity in Kenya is derived from the Centers for Disease Control and Prevention's (CDC's) Regional Training and Certification Program for Biosafety and Biosecurity Professionals (RTCP-BBP), and the Nagasaki University of Tropical Medicine – Kenya Medical Research Institute (NUITM-KEMRI) in partnership with the Ministry of Health (MOH). The training model includes: interactive sessions, workshops, and simulations. Kenya began training laboratory workers by 2010 (Muriithi *et al.*, 2018). After the BB training, manuals were provided to facilities for trained personnel to keep as reminders of the training. Despite the manual being in place, it has not been fully implemented in

medical laboratory facilities in Africa (Halatoko *et al.*, 2024). Training of this nature should be geared toward skills and attitudes, followed by efficient support supervision to maintain adherence to the same (Sidding *et al.*, 2025).

Health Care Workers (HCWs) are between twenty-one and thirty-two times more likely to be infected with infectious agents than people in the general population (Acke *et al.*, 2022). In the West Africa Ebola outbreak, during which the case-fatality ratio of Ebola-infected HCWs was reported to be 57%, with all eight HCWs who had been infected in Congo dying, this was reported by WHO (2015). According to Mobula *et al.* (2020), the COVID-19 global pandemic of 2019–2020 and the Ebola outbreak in Congo in 2018–2019 have further increased infections among HCWs

In Kenya the Medical education on biosafety and biosecurity is aimed at producing quality medical laboratory professionals who are skilled in protecting the environment, patients, and themselves from biological agents, while preventing the loss of biological agents from the laboratory (Halatoko *et al.*, 2024). The current learning system in facilities focuses mainly on patient and personal safety, waste segregation, and instrument maintenance, rather than supporting the implementation of the full BB practices.

In Kenya, BB practices call for robust, high-quality data to evaluate the effectiveness and competence of these measures in mitigating workplace hazards. This research therefore is meant to establish in BB implementation (Mutwiri, 2025).

Narok County medical laboratories handle many biological specimens despite their limited human workforce. Fewer laboratory workers are trained in BB, hence majority of LWs do not adhere to safety protocols, leading to outbreaks of preventable diseases. In addition the hospital laboratories experience very high staff turnover due

to low and delayed salaries leading them to look for greener pastures. As a result, non-medical laboratory workers and other healthcare workers support laboratory work without proper BB practices in the laboratories. Employment of more laboratory staff and training them in BB s of paramount importance..

Medical laboratory workers are vulnerable to infections while working, especially when handling outbreaks and when handling highly infectious biological agents (Burtseva *et al.*, 2022). Hence, poor implementation of BB practices will lead to increased cases of LAIs. To implement biosafety and biosecurity practices in laboratories, training and implementation processes are powerful tools. This study, therefore, would evaluate the implementation of biosafety and biosecurity in medical laboratories in Narok County (Bota *et al.*, 2021).

According to Peng, Bilal, and Iqbal (2018), effective training of laboratory workers is important to demonstrate their competence and practice critical thinking, thereby increasing the likelihood of safe laboratory behavior. There are factors contributing to gaps in biosafety and biosecurity implementation among laboratory workers. These factors include poorly defined occupational health and emergency response plans, poor infrastructure, and inadequate availability or use of personal protective equipment (PPE); inadequate and unsustainable training programs; and absence of systematic reporting mechanisms.

Biosafety and biosecurity training in Kenya is available however, a well defined follow-up procedures for its implementation is lacking. More importantly as much the training of BB is of great value, follow-ups and supervision plays a greater for its realization. MSH in Kenya managed the implementation of biosafety training for the public Health system, funded by PEPFAR and CDC, between 2009 and 2015 (Bota *et*

al., 2021). The purpose of this was to strengthen the capacity of the MOH to effectively manage a country-wide, high-performing, sustainable, public health-oriented laboratory system, hence improving patient care and saving lives. This, however, did not last long due to resource scarcity.

Some Infrastructure in most facilities in Kenya does not favor the implementation of good biosafety and biosecurity practices (Mourya *et al.*, 2020). Facility infrastructure contributes a lot to the biosafety and biosafety model (BBM) implementation, mostly on issues regarding accessibility of the laboratory (like non-laboratory staff not allowed), patient waiting rooms well indicated, which are well ventilated and lighted, lockable storage facilities, and enough PPE (gloves, glass goggles, face masks, gowns, boots, among others). Most government facilities rely on hospital supplies of BB tools, which are erratic, and also rely on untrained personnel for biosafety measures. This makes the biosafety implementation process wanting.

This study was to assess the process of biosafety and biosecurity training and practice among hospital laboratory workers in Narok County to enhance laboratory quality. It is based on the Knowledge of laboratory workers' competence in biosafety and biosecurity, as well as their demographic characteristics. Secondly, it assesses the adequacy of the skills and attitudes in line with the WHO/National standard guidelines. Thirdly, it determines the laboratory workers' encounters and, finally, appraises BB compliance with the elements used at Narok County hospitals during biosafety.

1.3 Purpose of the Study

The purpose of the study was to assess the implementation of biosecurity practices among hospital laboratory workers in Narok County. It involved knowledge, skills, and attitudes among the laboratory workers and compliance.

1.4 Problem Statement

Biosafety and biosecurity (BB) measures are integral to protecting laboratory workers (LWs), the public, and the environment from hazardous biological agents [Gao et al., 2024]. In Kenya, the Ministry of Health (MOH) and the World Health Organization (WHO) have established guidelines recommending regular, comprehensive BB training to minimize the risk of laboratory-acquired infections (LAIs) [Muriithi *et al.*, 2018].

Despite the presence of these training frameworks, laboratory workers in Narok County continue to exhibit poor adherence to established safety protocols, exposing them to highly infectious pathogens. For instance, observations reveal high-risk behaviors such as handling high-consequence sputum specimens from suspected multi-drug resistant tuberculosis (MDR-TB) patients bare-handed and without personal protective equipment (PPE)—a condition that is notoriously difficult and costly to treat [Diel *et al.*, 2020].

This failure in adherence significantly spikes the incidence of LAIs [Zuo et al., 2017], compounding the risk of outbreaks that spill over into the community. On a broader scale, these systemic lapses undermine the achievement of Universal Health Coverage (UHC) because local healthcare facilities remain unequipped to safely contain biological agents of severe biosecurity concern, such as Ebola.

While past studies indicate that basic biosafety training programs exist across Kenyan hospitals, Narok County suffers from a distinct lack of standardized, adequate training, critical infrastructure, PPE availability, and optimal staffing. Furthermore, there is no documented empirical evidence assessing the specific constraints and baseline compliance levels of BB implementation in Narok County Hospitals (NCHs).

Therefore, this study seeks to address this gap by evaluating the Knowledge, Attitudes, and Practices (KAP) of laboratory workers using standardized WHO/MOH checklists, identifying the operational constraints to BB implementation, and appraising overall compliance in Narok County.

1.5 Justification

Implementation of biosafety and biosecurity is critical among laboratory workers in particular Narok County hospitals because ; first, in enhancing Biosafety Compliance and Personnel Safety: This study is critically important as it diagnoses why trained laboratory workers continue to bypass vital safety protocols. By revealing specific gaps in Knowledge, Attitudes, and Practices (KAP), the findings will guide the development of target-specific, practical training interventions that shift laboratory culture from passive knowledge to active compliance.

Secondly in mitigating Biosecurity Risks and Public Outbreaks: The unsecure management of pathogens on open laboratory benches represents a major public health vulnerability. This study provides an urgent baseline assessment to help Narok County hospitals enforce strict chain-of-custody and physical security protocols. Securing these agents prevents accidental environmental leakage or malicious acquisition, safeguarding the local community from devastating disease outbreaks like cholera.

Thirdly , informing Local Policy and Resource Allocation: By explicitly identifying institutional constraints—such as chronic PPE shortages and inadequate storage infrastructure—this study provides actionable, evidence-based data for Narok County health departments and facility administrators. It offers a blueprint for strategic

resource distribution and standardized structural upgrades required by WHO and national laboratory guidelines.

Fourthly in Supporting Universal Health Coverage (UHC): Achieving Kenya's Universal Health Coverage goals relies heavily on a safe, resilient, and trusted diagnostic healthcare system. This research directly supports UHC by fostering a secure diagnostic environment where patients can seek evidence-based medical services, and healthcare workers can perform their duties without the threat of preventable occupational infections.

1.6 Objectives

1.6.1 Broad objective

Evaluated the implementation of biosafety and biosecurity practices among laboratory workers in Narok County hospitals.

1.6.2 Specific Objectives

The specific objectives of this study were meant to:

1. Analyze the relationship between laboratory workers' knowledge of biosafety implementation and their sociodemographic characteristics (e.g., age, gender, years of experience, and level of education).
2. Assess laboratory staff skills and knowledge regarding biosafety and biosecurity in the implementation of BB using standardized questionnaires.
3. Identify laboratory workers' constraints (e.g., lack of resources, inadequate training, and poor infrastructure) during the implementation of biosafety and biosecurity practices as per the BB WHO guidelines.
4. Determine the level of compliance with biosafety and biosecurity during their implementation with recommended standards among laboratory workers.

1.7 Research Study Questions

- What were the constraints affecting the implementation of biosafety and biosecurity practices in Narok County?
- To what extent did LWs in NCHs complied with BB practice?

1.8 Hypotheses

In this the research it impressed both the null Hypothesis (H_0) and the alternative hypothesis (H_1). (H_0) assumed that there was no effect, relationship, or difference between variables and alternative Hypothesis (H_1): Proposed that a specific effect, relationship, or difference did exist.

1.8.1 A null hypothesis; H_0

- **Null Hypothesis (H_0):** There is no statistically significant difference between the socio-demographic characteristics of the laboratory workers and their knowledge in biosafety, biosecurity and practice as per curriculum content and methods
- There is no statistically significant difference between laboratory staff skills and knowledge in regard to biosafety and biosecurity, and the implementation of BB using standardized questionnaires

1.8.2 Alternative Hypothesis ; (H_1)

- There is a statistically significant difference between the socio-demographic characteristics of the laboratory workers and their knowledge in biosafety, biosecurity and practice as per curriculum content and methods.
- There is a statistically significant difference between laboratory staff skills and knowledge in regard to biosafety and biosecurity, and the implementation of BB using standardized questionnaires.

1.9 Study Results

The study results were meant to assist the MOH and the stakeholders to:

- Strengthen laboratory workers' knowledge of biosafety and their socio-demographic characteristics (e.g., age, gender, years of experience, and level of education) at the workplace. It was able to identify predictors of knowledge in BB implementation such as worker experience.
- Provide a clear assessment of knowledge, skills and attitude gaps on laboratory workers regarding biosafety and biosecurity in Narok County Hospitals.
- Enhance the biosafety and biosecurity implementation challenges (e.g., provision of PPE resources, adequate BB training, and improved infrastructure) in Narok County Hospitals.
- Strengthen biosafety and biosecurity compliance levels in laboratories and adherence in Narok County Hospitals.

1.9.1 Significance of the study

The study findings were meant to provide evidence-based insights in BB implementation in Narok County Hospitals and to establish national BB guidelines. While seeking to establish BB adherence, it was also able to assess the vulnerability of the laboratory worker to LAIs and establish mitigation measures in place against laboratory-acquired infections (LAIs) and highlighted gaps in existing BB programs. This study involved both public and private/faith-based LWs workers, which adds value to disease control across the county, like *Mycobacterium tuberculosis*, which is an airborne disease. Apart from offering practical recommendations for enhancing biosafety and biosecurity measures, it contributed knowledge to public health while

supporting efforts toward achieving Universal Health Coverage (UHC) through improved laboratory safety standards. By bridging the gap between policy and practice, this research informed decision-making processes at the institutional and policy levels. The information was about improving infrastructure safety, which is by enhancing ventilation systems in the laboratory, providing PPE to all LWs and training them on biosafety and biosecurity for better public health outcomes. This is to support the WHO guidance to have all biomedical laboratories implement regulatory requirements of biosafety and biosecurity (WHO, 2020).

1.10 Scope of the Study

The scope of the study was all laboratory workers' implementation of BB in the clinical laboratories (Lonsdale & Enyedi, 2019).

This research was conducted in Narok County healthcare facilities, conducting laboratory diagnostic services among the laboratory staff workers of Narok County Hospital laboratories. The Narok hospital laboratory workers involved both public and private hospitals, who had the laboratory workers at the time of the study for this noble study. The LWs provided information on various aspects of knowledge, skills, and attitudes on the implementation of Biosafety and biosecurity according to the national guidelines. Narok County has seven sub-counties as of the time of the study, and all these sub-counties had hospital laboratories, which were in a total of 70 laboratories across the entire County.

1.11 Limitations of the Study

A limitation in research is what made the study difficult and how it can be done better in future (Laakso & Schrag, 2018) and (Akanle *et al.*, 2020).

A major limitation of the study was a small sample size of 102, which was not representative of the whole population in the country. A small sample size has limited options for data analysis, and caution was taken to ensure the validity of the analytical methods used (Yang S, & Berdine G. 2023). It is recommended to conduct a "census" that is to conduct research for everyone, rather than a sample, because the sample size was the entire number of laboratory workers in the county at that time.

Self-reported questionnaires are subjective, which might be a limitation. The evaluation of the training on the BB outcome relied on subjective responses. This was resolved by having a focus group discussion and researcher observations (Nyumba *et al.*, 2018).

Also, self-rating of the MLT was very sensitive, and this could lead to response bias. Self-ratings are generally reactive measures; the measurement itself may influence the outcome, since the laboratory workers are not blind to their training condition (Cook *et al.*, 2021). Focus group discussion and observation corrected any of the misinformation, and in most cases, the questionnaires were administered by the research assistants either by phone call or physical administration.

Heavy workload was another limitation for the laboratory worker. In one particular incident, a researcher would find only one staff member on duty with a workload of 200 tests, which made him deny the interview. In such situations, the researcher would leave the questionnaire with the LW and schedule the interviews for a convenient time/day.

Hard to research place was another limitation, Narok County health facilities are diverse. First, throughout the county, the in-charge of laboratory phone numbers of their LWs were provided. This was then followed by researchers booking interviews

on the phone, first, to seek consent and continuing with the interview upon acceptance. Objective four was based on observation. The researcher took advantage of the county supervision teams, especially on the TB/HIV programs and immunization programs, which visited facilities on a weekly basis. Upon arrival in the facilities the research was able to conduct the interview using the checklist.

1.12 Assumptions of the Study

The study assumed that the laboratory workers knew biosafety and biosecurity through training regardless of gender, age, socioeconomic status, level of education, and the number of years they had worked.

Another point was that the workers were implementing biosafety and biosecurity in their various healthcare facilities. It also assumed that there were systems and policies in place for biosafety and biosecurity, such as risk assessment, personal protective equipment, laboratory practice/policies, and biosafety laboratory competencies.

It is important to note that the researcher made assumptions in this study; in reality, they had not been tested or approved. Therefore, the researcher agrees with what some researchers have defined the term by saying that studies are made of assumptions (Delin, Chittleborough, & Delin, 1994).

1.13 Theoretical Framework

Assessment of the biosafety biosecurity model is an evaluation, and hence, the input process, outcome and output model (Bushnell & Smith, 2024) was utilized. However, in the assessment, both formative and summative assessments were used. The formative was first done and then followed by summative into introducing and additional training given to laboratory staff workers (LSW) so that the training looked at one from the formative perspective (evaluation of content and methodologies

used), and the other was summative (effectiveness of the training of laboratory staff workers in biosafety and biosecurity).

The formative assessment of the biosafety and biosecurity training model developed by (Muriithi *et al.* (2018) will be utilized and specifically referenced to the pedagogical knowledge construct and its implication (Baxter *et al.*, 2022; Lehman *et al.*, 2024). This is where the students are given a functional understanding of the basic tenets of the construct as well as its applications.

The Health Belief Model (Green *et al.*, 2020) looks at how people's views on health-related issues, such as biosafety and biosecurity procedures in medical labs, can affect their adoption of healthy behaviors. This allows evaluation of the perception of biosafety and biosecurity practices among the LWs.

The Diffusion of Innovations Theory is an important theory in that it is concerned with how novel concepts, behaviors, or technological advancements spread among people. It can be used to comprehend how new biosafety and biosecurity procedures are adopted and put into operation in medical labs (Hilts *et al.*, 2022) and (Miller, 2018). This will help evaluate how quickly workers accept and implement bio-safety and bio-security practices.

Intentions and conduct are shaped by attitudes, subjective norms, and perceived behavioral control, according to the Theory of Planned Behavior. It helps explain the intent of laboratory staff to adopt and follow bio-safety precautions (Ajzen, 2020).

1.14 Research Philosophical Approach

In any research, a philosophical orientation or paradigm ought to form the main part of the research design (Shan, 2022). A group of assumptions, concepts, beliefs, and practices that amounts to a way of viewing reality is a paradigm. There are two main

paradigms in medical education: the positivist and naturalistic paradigms. In 1637, Descartes formulated a positivist paradigm, positing that there is an objective reality that is directly observable, measurable, and capable of predicting future events. Positivists believe in an objective collection of data, and analysis must be independent of the researcher's opinion. For post-positivists, begin with a theory, explain the phenomenon, and collect data to determine whether the theory is supported or not. Then, they make the necessary changes and go on to collect data to determine whether the theory was supported.

The assumption, then, of post-positivism is that quantitative inquiry is preferable to qualitative inquiry. The natural sciences tend to use the positivist paradigm, while the human and social sciences tend to use the post-positivist paradigm.

This research adopted the Pragmatism paradigm, which is not committed to any one system of philosophy or reality. From a pragmatic perspective, researchers focus on the 'what' and 'how' of the research problem (Dube, Nkomo & Apadile-Thokweng, 2024). As a pragmatic approach, the paradigm is seen as providing the underlying philosophical framework for mixed-methods research; however, some mixed-methods researchers align themselves philosophically with the transformative paradigm, while the pragmatic paradigm can be used with any method.

The pragmatic paradigm places "the research problem" as central and applies all approaches to understanding the problem (Dube, Nkomo & Apadile-Thokweng, 2024). With the research question 'central', data collection and analysis methods are chosen for their likely to provide insights into the question, with no philosophical loyalty to any alternative paradigm.

Pragmatist philosophy holds that human actions can never be separated from past experiences and from the beliefs that have originated from them. Human thoughts are thus intrinsically linked to action. First, “actions cannot be separated from the situations and contexts in which they occur” Second, “actions are linked to consequences in ways that are open to change”, which means it is not possible to experience the same situation twice, hence the findings are provisional. Finally, “actions depend on worldviews that are socially shared sets of beliefs”. Pragmatists believe that no two people have identical experiences, so their worldviews can also not be identical (Almeder, 2019). This is crucial in the current study, where the evaluation of the teaching and assessment of specific biosafety and biosecurity procedures:

- A. The views of LWs about their training reflect the actual teaching and assessment of that aspect of biosafety procedures.
- B. The assessment of self-efficacy in biosafety reflects the potential of the actual performance in biosafety and biosecurity procedures.
- C. Finally, perceived competence is the actual measure of both the actions and beliefs of residents following the training in biosafety, and this will be useful in the objective of the current study.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter reviews the theoretical and empirical literature related to the objectives of the study, with emphasis on biosafety and biosecurity (BB) implementation among laboratory workers in hospital settings. The chapter examines laboratory workers' perceptions of their competence in biosafety and biosecurity practices, as well as factors that determine competence, such as gender, level of training, years of experience, curriculum content, and methodologies utilized during professional training. In addition, the chapter reviews constraints affecting the performance of biosafety and biosecurity procedures (BBP) and evaluates compliance with biosafety standards through adherence to established protocols and guidelines.

Laboratory workers are routinely exposed to biological hazards during specimen collection, processing, storage, and disposal. These exposures increase the risk of laboratory-acquired infections and other occupational hazards if biosafety and biosecurity measures are not adequately implemented. As indicated in Chapter One, one of the greatest threats to laboratory workers in their practical work areas is inadequate implementation of biosafety and biosecurity practices. Therefore, understanding competence levels, compliance behaviors, and barriers to implementation is essential in strengthening laboratory safety systems and minimizing occupational risks.

This chapter further highlights the relationship between medical laboratory science and biosafety, including the handling of infectious materials and containment procedures. The conceptualization of biosafety and biosecurity is discussed to provide a foundation for understanding safe laboratory practices. The review also explores

training approaches and assessment of competence in biosafety and biosecurity practices, with emphasis on knowledge acquisition, practical skills, and adherence to standard operating procedures. The appraisal of biosafety and biosecurity practices in laboratory settings is discussed in detail, focusing on implementation requirements, monitoring mechanisms, and compliance indicators.

Theoretical perspectives guiding the assessment of biosafety and biosecurity practices are also reviewed to provide a framework for evaluating laboratory workers' competence. These perspectives are followed by a review of constraints affecting laboratory workers in implementing biosafety and biosecurity procedures, including institutional, infrastructural, and human resource challenges. Possible strategies to enhance biosafety and biosecurity practices are also examined, drawing from previous studies and recommended guidelines.

The chapter concludes with the conceptual framework adopted for this study, illustrating the relationship between demographic characteristics, knowledge, skills, institutional factors, constraints, and compliance with biosafety and biosecurity practices among laboratory workers in Narok County hospitals. Independent variables included the training of biosafety and biosecurity, the professional level of education, and the personal protective equipment. The dependent variables included compliance, skills and knowledge, among others. Then there were mediating variables, laboratory-acquired infections, pathogen release and occupational hazard. Also, there are moderating variables, such as the personal protective equipment, good laboratory design, workflow, and the WISN.

2.2 Biosafety and Biosecurity Training Model.

The biosafety and biosecurity training model implemented by the NUTM–KEMRI biosafety training program was designed to build capacity among new users of biosafety level three (BSL-3) laboratories. The program focused on equipping laboratory personnel with the necessary knowledge, practical skills, and competencies required for safe handling of high-risk biological agents. The training integrated both theoretical and practical components to ensure that participants not only understood biosafety and biosecurity principles but were also able to apply them in routine laboratory operations. The theoretical component covered core biosafety and biosecurity concepts, risk assessment, containment principles, waste management, emergency response, and laboratory safety procedures, while the practical component emphasized hands-on training within controlled laboratory environments.

The training curriculum followed the World Health Organization biosafety guidelines, local biosafety standards, and ongoing biosafety level three research activities conducted within the facility. The integration of international and local guidelines ensured that the training addressed both global biosafety requirements and context-specific operational needs. In addition, the curriculum was structured to promote competency-based learning, allowing participants to progressively develop skills through demonstration, supervised practice, and continuous assessment. This approach enhanced participants' understanding of biosafety and biosecurity procedures and strengthened their ability to comply with laboratory safety standards during routine work.

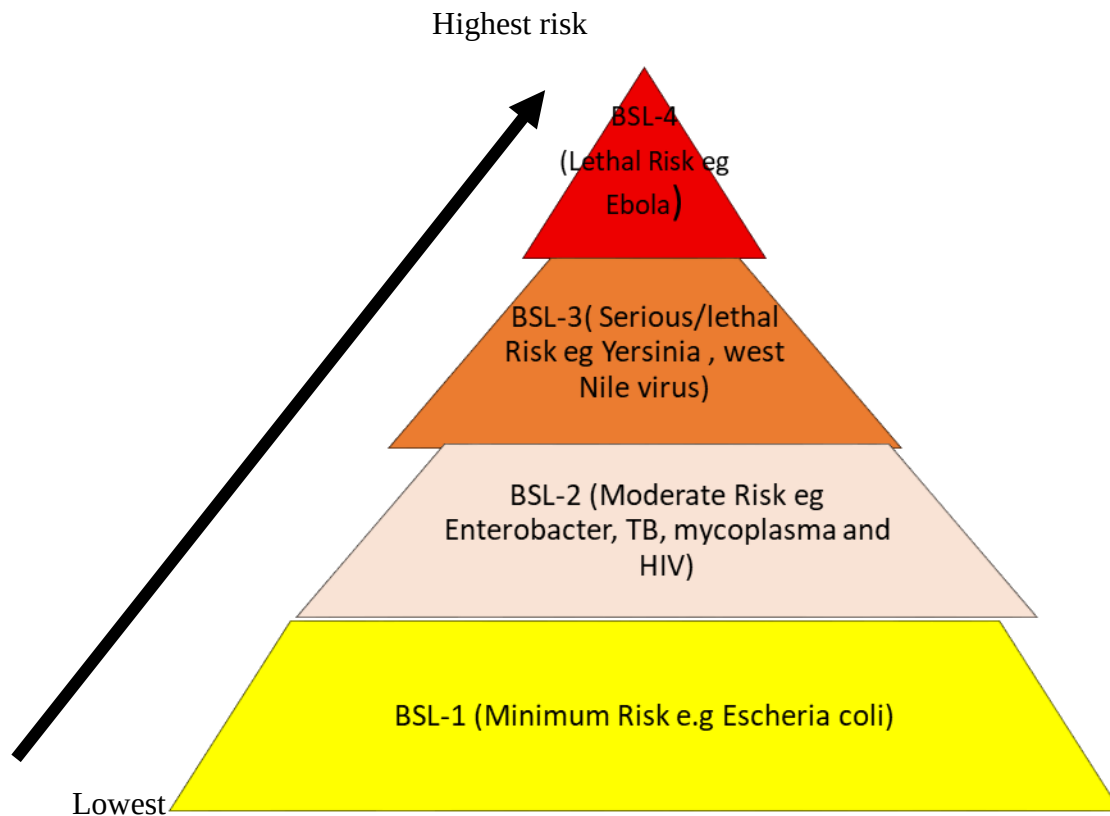


FIGURE 1: PERCEIVED RISK AS PER BSL LEVEL AMONG LWS

Emerging public health issues were also considered during the training to ensure relevance to current and potential biological threats (Murithi et al., 2018). Incorporating emerging public health concerns enabled the training to remain responsive to evolving infectious disease risks and laboratory challenges. Murithi et al. (2018) further noted that the training approach focused on enhancing participants' knowledge of biosafety and biosecurity through structured learning sessions, interactive discussions, and practical demonstrations. The training also aimed at building skills through hands-on practice sessions and mentorship provided during routine laboratory activities. Mentorship and supervised practice allowed participants to gain confidence and competence in implementing biosafety and biosecurity procedures within their respective laboratory settings.

This training model is consistent with findings from a study titled "Strengthening health systems in Africa: a case study of Kenya field epidemiology training program

for local frontline health workers,” which emphasized capacity building and workforce development in African settings (Roka *et al.*, 2017). The study highlighted the importance of structured training programs in improving workforce competency, strengthening health systems, and enhancing preparedness for public health emergencies. Similarly, biosafety and biosecurity training programs contribute to improved laboratory safety, enhanced compliance with biosafety standards, and reduced risk of laboratory-acquired infections. Therefore, structured biosafety and biosecurity training models remain essential in improving laboratory workers’ competence and ensuring safe laboratory practices in healthcare facilities.

2.2.1 Medical Laboratory Science and Biosafety and Biosecurity Relationship

Biosafety refers to the precautions taken to reduce the risk of pathogen contamination in laboratories that handle infectious agents, store or process potentially contaminated materials, or conduct microbiological testing for medical and scientific research (Peng, Bilal & Iqbal, 2018). It also encompasses measures aimed at safeguarding laboratory personnel, the surrounding environment, and the general population from hazardous biological contaminants originating from laboratory activities. These measures include implementation of policies, guidelines, and regulatory frameworks provided by the Ministry of Health authorities, with emphasis on engineering controls such as air handling systems, containment facilities, and proper management of liquid and solid waste (Muriithi *et al.*, 2018). The current study, therefore, seeks to establish biosafety and biosecurity measures undertaken by medical laboratory science staff (MLSS) as prescribed in biosafety and biosecurity models.

Proper implementation of biosafety and biosecurity procedures enhances a laboratory’s ability to respond effectively to biological threats and related risks (Jin &

Linkov, 2021). This involves maintaining secure laboratory environments, safe handling of biological specimens, and adherence to containment protocols. Such procedures include prevention and control of emerging infectious diseases, safe specimen transport, use of personal protective equipment, and protection against biological weapon attacks and bioterrorism threats that may arise from accidental or intentional release of infectious agents. Escapes of infectious materials from laboratories have been associated with potential public health threats and bioterrorism concerns, highlighting the importance of strict biosafety and biosecurity implementation (Byers, 2020; Zaki *et al.*, 2023; Callihan *et al.*, 2021; Mocc6epr, 2024).

To guide laboratory personnel in handling biological hazards, the biosafety and biosecurity manual (BBM) was developed to provide standardized procedures for safe laboratory operations (WHO, 2004). The manual outlines containment practices, risk assessment procedures, and safe handling techniques for biohazardous agents. In addition, the laboratory diagnostic manual supports laboratory workers by providing operational procedures that promote compliance with safety standards and prevent laboratory-associated infections (Fischbach & Dunning, 2019). These prevention measures are particularly beneficial when incorporated into training programs and continuous professional development for laboratory personnel, as they improve competence and strengthen adherence to biosafety and biosecurity practices.

Biosafety and biosecurity procedures form a critical component in the delivery of diagnostic services in clinical laboratories. Laboratory workers are routinely exposed to infectious agents, and inadequate protection increases the risk of occupational infections. Blacksell *et al.* (2023) reported that infections such as Hepatitis B virus

(HBV) and *Mycobacterium tuberculosis* (TB) are associated with laboratory exposure when personnel are not adequately protected. These risks apply to all laboratory workers involved in specimen handling, processing, and disposal. Consequently, implementation of biosafety guidelines within the workplace is essential for protecting laboratory personnel, patients, and the surrounding community.

The biosafety guidelines were developed, which aimed at protecting patients and laboratory personnel while restricting access to unauthorized individuals within clinical laboratory settings (Byers & Harding, 2017). Limiting access to laboratory areas reduces exposure risks and prevents accidental contamination from infectious pathogens (Danelyan & Gulyaeva, 2022). In situations where untrained personnel are attached to hospital laboratories, it is necessary that they undergo orientation and training on biosafety and biosecurity procedures before participating in laboratory activities. Training ensures that personnel understand prevention measures, proper use of protective equipment, and safe handling of specimens within clinical laboratory environments.

The existing biosafety gaps further highlighted and emphasized the need for laboratory personnel to effectively manage biosafety risks while safely conducting patient testing (Cornish et al., 2021). Inadequate training, staff shortages, and heavy workload may result in untrained personnel performing laboratory tasks, thereby increasing biosafety risks. Such situations may compromise adherence to biosafety protocols and increase the likelihood of laboratory-acquired infections. Therefore, strengthening biosafety and biosecurity training, improving staffing levels, and reinforcing compliance with safety procedures are essential in enhancing safe laboratory practice and protecting laboratory workers.

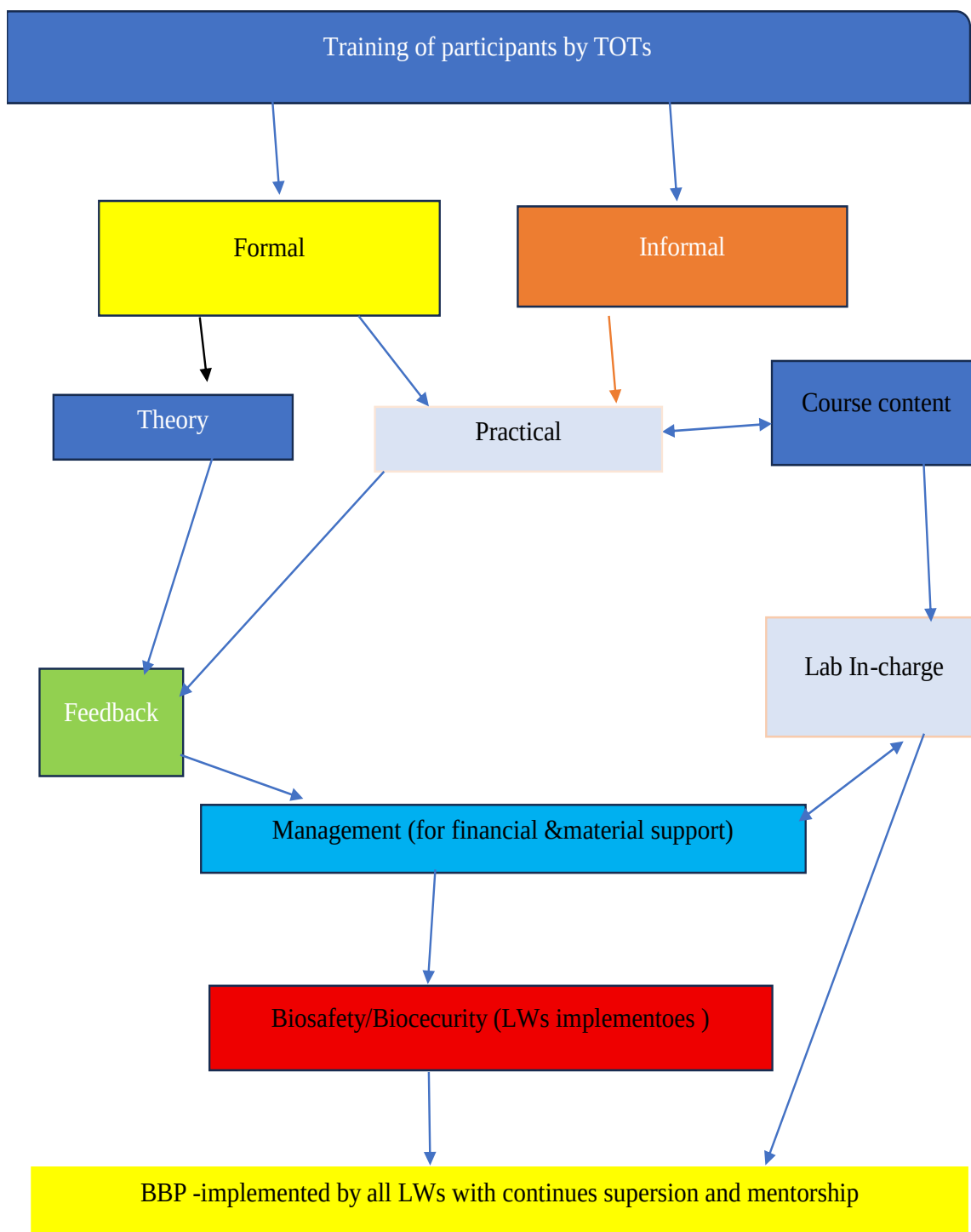


FIGURE 2: SUMMARY OF BB TRAINING AND IMPLEMENTATION

Emerging public health issues were also considered during the training to ensure relevance to current and potential biological threats (Murithi et al., 2018). Incorporating emerging public health concerns enabled the training to remain responsive to evolving infectious disease risks and laboratory challenges. Murithi et al. (2018) further noted that the training approach focused on enhancing participants' knowledge of biosafety and biosecurity through structured learning sessions, interactive discussions, and practical demonstrations. The training also aimed at building skills through hands-on practice sessions and mentorship provided during routine laboratory activities. Mentorship and supervised practice allowed participants to gain confidence and competence in implementing biosafety and biosecurity procedures within their respective laboratory settings.

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Research has identified several theoretical models that explain how individuals adopt and implement health-related behaviors, including biosafety and biosecurity practices

in medical laboratories. One such model is the Health Belief Model developed by Strecher and Rosenstock (1974), which explains how individuals' perceptions of susceptibility, severity, benefits, and barriers influence adoption of preventive health behaviors. In the context of laboratory settings, this model suggests that laboratory workers are more likely to comply with biosafety and biosecurity procedures when they perceive a high risk of infection, understand the severity of laboratory-acquired infections, and recognize the benefits of protective measures. This theoretical perspective aligns with findings by Maseko et al. (2021), who reported that perception of risk significantly influences adoption of preventive health practices in African healthcare settings.

Another relevant framework is the Diffusion of Innovations Theory, which explains how new ideas, practices, and technologies spread within organizations and among individuals. This model can be used to understand how biosafety and biosecurity procedures are introduced, adopted, and institutionalized in medical laboratories (Hilts et al., 2022). According to Dao et al. (2022), the development of a strong biosafety and biosecurity culture within organizations working with biological materials is a fundamental principle of risk management. Such a culture promotes positive attitudes, safe practices, and active involvement of personnel at all organizational levels, thereby improving compliance with biosafety standards.

Biosafety and biosecurity practices are therefore the responsibility of laboratory workers handling biological materials (Perkins et al., 2019). Careless handling of infectious materials may lead to laboratory-acquired infections affecting both laboratory personnel and the surrounding environment. The authors further emphasized the importance of developing a biosafety culture by drawing lessons from

related fields such as security culture and high-reliability organizations. Strengthening biosafety culture promotes accountability, enhances risk awareness, and improves compliance with biosafety procedures among laboratory personnel.

The World Health Organization classifies pathogens into four general risk groups based on virulence, severity of disease, route of transmission, and availability of preventive or therapeutic interventions. This classification addresses risks posed to both laboratory workers and the surrounding community (Zaki et al., 2023). Based on these classifications, biosafety practices are implemented at different biosafety levels depending on the type of microorganisms handled. Biosafety levels range from basic containment to higher containment laboratories designed for handling highly infectious agents. These levels guide laboratory design, operational procedures, and personal protective measures required for safe handling of biological materials.

Preventive measures in biosafety and biosecurity include the use of personal protective equipment such as gloves, laboratory coats, boots, goggles, and masks, as well as the appropriate use of disinfectants (Cornish et al., 2021). Protection of laboratory workers is essential when handling specimens such as blood, urine, and stool, which may contain infectious pathogens. These pathogens may include *Salmonella*, COVID-19, Human Immunodeficiency Virus (HIV), and *Mycobacterium tuberculosis*, among others. Proper handling, containment, and disposal of such specimens reduce the risk of laboratory-acquired infections and environmental contamination.

Proper biosafety and biosecurity procedures enhance laboratory preparedness in responding to biological threats and emerging infectious diseases. These procedures include preventing accidental release of infectious agents, controlling outbreaks, and

protecting against biological weapon attacks and bioterrorism threats. Escapes of infectious materials from laboratories have been associated with increased public health risks, emphasizing the need for strict adherence to biosafety protocols (Byers & Harding, 2017; Zaki, 2023; Callihan *et al.*, 2022; Mossburg *et al.*, 2019).

To guide safe laboratory practice, biosafety and biosecurity manuals were developed to provide standard procedures for handling biological hazards (WHO, 2004). Similarly, the laboratory diagnostic manual provides operational guidelines aimed at promoting compliance and preventing laboratory-associated infections (Fischbach & Dunning, 2019). In Kenya, biosafety guidelines were developed to provide minimum standard requirements for bio risk management in laboratory settings (Muriithi *et al.*, 2018). These guidelines emphasize risk assessment, mitigation measures, and performance evaluation as key components of biosafety and biosecurity implementation.

The first objective of biosafety guidelines focuses on performing effective bio risk assessment to identify gaps in laboratory safety. Previous studies have conducted biosafety assessments in different healthcare settings, including Kisumu East Sub-County Hospital and Garissa Hospital, to evaluate awareness and implementation of biosafety measures (Abonyo, 2017; Jimale, 2019). Additionally, the World Health Organization (2023) monitored bio risk management implementation in African countries, emphasizing strengthening laboratory safety systems. These assessments highlight the importance of evaluating knowledge, training, and compliance among laboratory personnel.

The second objective involves the initiation of mitigation measures to address identified gaps. Bota *et al.* (2021) reported implementation of training-of-trainers

programs in Kenya aimed at equipping personnel with knowledge and skills to sustain long-term biosafety practices. Such training programs strengthen the implementation of biosafety and biosecurity procedures within clinical laboratories. The current study, therefore, seeks to assess implementers of biosafety and biosecurity practices in clinical laboratories.

The third objective focuses on the evaluation of the bio risk system performance. Studies conducted in different regions have assessed biosafety management systems and recommended strengthening biosafety and biosecurity practices to prevent emerging infectious diseases (Brodsky et al., 2021; Bawolakson et al., 2021). Evaluation of biosafety implementation provides evidence for improving laboratory infrastructure, training programs, and compliance monitoring mechanisms. The present study, therefore, focuses on the implementation of biosafety and biosecurity practices from training institutions to clinical laboratory settings.

Effective biosafety and biosecurity implementation requires strong laboratory management systems, defined goals, and appropriate management strategies. A management team should be established to oversee the application of bio risk policies, rules, and regulations within laboratory facilities. These regulations include waste management systems, air control measures, and infrastructure requirements necessary for safe laboratory operations. Adequate physical facilities are essential for managing bio risks and protecting laboratory workers, the environment, and biological materials handled within laboratory settings (Yu et al., 2022).

Implementation of biosafety strategies involves preventing accidental release of harmful biological agents and ensuring secure handling of pathogens. Biosafety focuses on preventing unintentional exposure, while biosecurity includes measures

aimed at preventing theft, misuse, or intentional release of biological agents. These measures are essential in strengthening laboratory safety and minimizing biological risks. The present study, therefore, focuses on laboratory workers in clinical laboratories in Narok County to establish their perceptions, knowledge, and implementation of biosafety and biosecurity practices.

2.2.2 Conceptualizing Biosafety and Biosecurity in the Laboratory

In the clinical laboratory context, biosafety and biosecurity are broad concepts that refer to all measures implemented to promote safe handling of pathogenic microorganisms and hazardous biological waste materials (Perkins, 2019). These concepts are closely related and are sometimes used interchangeably in scientific literature. However, academically, biosafety and biosecurity represent distinct but complementary components of bio risk management. Biosafety primarily focuses on preventing unintentional exposure to biological agents, while biosecurity emphasizes the prevention of unauthorized access, misuse, theft, or intentional release of infectious materials (Lev, 2019). Both concepts work together to reduce laboratory-associated infections and protect laboratory personnel, the public, and the environment from biological risks.

According to Perkins and Bakanidze (2024), biosafety and biosecurity consist of multiple strategic measures that often overlap but share the common goal of controlling laboratory-associated infections. Biosafety includes preventive measures designed to minimize exposure to pathogenic microorganisms and their toxins during laboratory activities (Zaki et al., 2023). These measures include the use of personal protective equipment, safe handling of specimens, containment procedures, and proper waste management. On the other hand, biosecurity involves strategies aimed at

protecting workers, the environment, and the community from loss, theft, misuse, or intentional release of infectious biological agents (Semionovna & Ali, 2020). These measures include restricted laboratory access, specimen tracking systems, inventory management, and secure storage of biological materials.

Biosafety and biosecurity training is commonly conducted in modules and delivered through interactive learning approaches to enhance understanding of safe laboratory practices. Interactive training methods such as demonstrations, simulations, and supervised practice improve knowledge retention and skill acquisition among laboratory workers. However, some training programs, such as Biosafety and Biosecurity Training Course–Global (BBTC-Global), are delivered remotely using interactive learning management systems. While remote learning enhances accessibility, hands-on training remains essential for developing practical competence in biosafety and biosecurity procedures, particularly in clinical laboratory environments where practical skills are required.

Biosafety training from both professional staff and training institutions plays a critical role in preparing students who will become future laboratory professionals. Lack of adequate training poses a challenge, as untrained workers may handle infectious specimens without proper protective equipment due to unavailability, lack of awareness, or poor supervision. Such practices increase the risk of laboratory-acquired infections and environmental contamination. This study, therefore, seeks to assess laboratory workers' understanding of biosafety and biosecurity concepts and evaluate training received before commencement of laboratory duties (Padde *et al.*, 2022).

Clinical laboratories handle highly infectious pathogens, making it essential that all personnel, including support staff, receive appropriate biosafety and biosecurity training before being assigned laboratory duties. However, concerns remain where untrained laboratory workers fail to follow safety procedures such as changing gloves between procedures, wearing closed protective footwear, and avoiding needle recapping. These unsafe practices increase the risk of occupational exposure and spread of infections within laboratory settings. Proper training and supervision are therefore necessary to enhance compliance with biosafety and biosecurity procedures.

The clinical laboratory environment is complex and poses potential exposure risks to both laboratory personnel and the public. Therefore, personnel working in these settings must possess adequate knowledge and skills in biosafety and biosecurity procedures. Although hospital environments cannot be entirely risk-free, the implementation of appropriate biosafety measures significantly reduces exposure risks. The World Health Organization manual provides guidelines that enhance safety and security in containment laboratories when strictly adhered to (WHO, 2021). These guidelines include containment practices, risk assessment procedures, safe specimen handling, and emergency response mechanisms.

The concept of biosafety and biosecurity can also be viewed from different perspectives described in the literature. One perspective is objective biosafety and biosecurity, which focuses on adherence to guidelines and standards designed to strengthen safety in containment laboratories. The World Health Organization manual provides recommendations for safe laboratory practice, including shared responsibilities, training requirements, and institutional oversight (Bull et al., 2020). Additionally, Laboratory Biorisk Management Standards such as CWA 15793:2011

provide a framework for biosafety education, training, and implementation. Despite these international commitments, compliance with training requirements in teaching institutions remains relatively low, and standardized training approaches are still lacking.

Training of laboratory workers on biosafety and biosecurity procedures is essential in equipping them with the knowledge and skills necessary for safe laboratory practice. Such training improves compliance with safety procedures and reduces the risk of laboratory-acquired infections. However, compliance remains low in many biomedical laboratories, increasing the risk of occupational exposure to pathogens such as HIV and other infectious agents. In addition, accidental release of pathogens from laboratories may pose public health risks and contribute to bioterrorism threats (Cornish et al., 2021; García et al., 2023; Abonyo, 2017; Jacob et al., 2024).

Another viewpoint emphasizes prospects in biosafety and biosecurity implementation. Blacksell et al. (2024) discussed laboratory-acquired infections and highlighted the importance of strengthening biosafety systems. Similarly, Mareedu (2021) focused on the development and validation of biosafety climate scales, while Cruz et al. (2018) emphasized strengthening perceptions of clinical laboratory science practice. Across these perspectives, biosafety and biosecurity procedures are considered critical components of laboratory operations. Failure to adequately implement these procedures may contribute to disease outbreaks, occupational infections, and potential bioterrorism risks. The present study, therefore, focuses on biosafety and biosecurity implementation procedures in medical laboratories, with emphasis on training institutions and clinical laboratory settings.

2.2.3 Theoretical Views on Assessment of Biosafety and Biosecurity in Medical Laboratories

There are several theoretical perspectives used to assess biosafety and biosecurity practices in medical laboratories. These theories help explain laboratory workers' knowledge, attitudes, perceptions, and behaviors toward biosafety and biosecurity procedures. They also provide a framework for evaluating competence, compliance, and institutional support in the implementation of biosafety and biosecurity practices. The following theoretical models are relevant to the present study.

2.2.3.1 Health Belief Model (HBM)

The Health Belief Model, developed by Rosenstock (1974), explains how individuals' perceptions of health-related risks influence their adoption of preventive behaviors. In the context of medical laboratories, this model suggests that laboratory workers are more likely to implement biosafety and biosecurity procedures when they perceive themselves to be at risk of infection, recognize the severity of laboratory-acquired infections, and understand the benefits of preventive measures. The model further emphasizes perceived barriers, cues to action, and self-efficacy as determinants of compliance with safety procedures.

Dao et al. (2022) conducted a study in Mali on the state of biosafety and biosecurity implementation. They established that a well-composed and strong biosafety and biosecurity culture is a fundamental risk management principle for organizations working with biological materials. Such a culture contributes to positive attitudes, appropriate approaches, and active involvement of individuals at all levels of the organization. The study was conducted among working medical laboratory science staff, but the same concept is applicable to students undergoing training. This

theoretical perspective, therefore, supports assessment of attitudes, perceptions, and approaches toward biosafety and biosecurity practices within organizations.

Perkins et al. (2019) emphasized that biosafety and biosecurity are the responsibility of laboratory personnel and institutions. The authors recommended that life scientists seeking to strengthen biosafety culture should draw from literature in related areas such as security culture and high-reliability organizations. This supports the need for promoting a strong biosafety culture in both training institutions and clinical laboratory settings.

Mareedu (2021) attempted to quantify biosafety climate and examined factors influencing safety practices during the COVID-19 period in the United States. The study recommended the development and validation of a biosafety climate scale and survey-based analysis of safety perceptions in teaching laboratories. This approach supports the assessment of laboratory workers' perceptions of competence in performing biosafety and biosecurity procedures.

Sun et al. (2021) reported that laboratory safety is a dynamic process that requires continuous inspection and updating rather than a one-time intervention. Continuous training, monitoring, and updating of biosafety procedures are therefore necessary to maintain safe laboratory environments. However, some medical training institutions lack structured provision for continuous learning and updating in biosafety and biosecurity. Laboratory directors and professionals must therefore remain alert to emerging risks and adapt to new challenges while maintaining high levels of safety compliance (Sun et al., 2022).

Callihan et al. (2021) examined biosafety and biosecurity considerations during the COVID-19 pandemic using ISO standards. The authors emphasized ISO 35001 bio-risk management principles, which promote the hierarchy of controls and an iterative Plan-Do-Check-Act (PDCA) process to improve work processes as technical knowledge evolves continuously. Leadership involvement and interaction between management and laboratory personnel were highlighted as important in promoting laboratory safety and the quality of outputs.

2.2.3.2 Diffusion of Innovations Theory

The Diffusion of Innovations Theory explains how new ideas, behaviors, and technological advancements spread within organizations and communities. This theory is relevant in understanding how new biosafety and biosecurity procedures are introduced, adopted, and implemented in medical laboratories. Adoption of biosafety practices depends on awareness, perceived benefits, compatibility with existing practices, and organizational support. García-Avilés (2020) noted that diffusion of innovations influences how new safety procedures are reviewed and operationalized within laboratory environments. This theory, therefore, supports the assessment of the adoption and implementation of biosafety and biosecurity practices among laboratory workers.

2.4 Laboratory Workers' Knowledge and Sociodemographic Characteristics

Laboratory workers' knowledge and sociodemographic characteristics play an important role in the implementation of biosafety and biosecurity practices in clinical laboratories. Adequate knowledge of biosafety procedures enhances compliance with safety standards and reduces the risk of laboratory-acquired infections. However, studies have reported inadequate awareness and knowledge of laboratory safety

aspects among undergraduate students, many of whom later become employed in healthcare facilities. Continuous training is therefore necessary to improve the implementation of biosafety and biosecurity practices among laboratory workers (Abu-Siniyeh & Al-Shehri, 2021). this study addressed the gap in knowledge and practice in all laboratory workers across all levels of education level which was addressed by Abu-Siniyeh & Al-Shehri,.

Health facility managers also play a key role in promoting biosafety and biosecurity practices through training and supportive supervision. Almutairi et al. (2022) emphasized that strategies aimed at improving safety management practices should include regular training programs, institutional support, and organizational commitment. Organizational commitment ensures the availability of resources, the enforcement of safety guidelines, and the monitoring of compliance with biosafety procedures. These factors collectively contribute to improved safety management practices within laboratory settings.

Laboratory workers' perceptions of their competence may vary depending on sociodemographic characteristics. Factors such as gender, educational level, and prior laboratory experience may influence self-assessment of competence and implementation of biosafety practices (Hollis et al., 2017). Understanding these relationships enables institutions to tailor training programs to address the specific needs of different laboratory worker populations. Customized training approaches improve knowledge acquisition, enhance skills development, and strengthen compliance with biosafety and biosecurity procedures. In this study Hollis's did not address the document analysis in which this study addressed.

Reith and Nehring (2024) examined predictors of workers' skills using cognitive and demographic variables and reported that factors such as conceptual knowledge and learning environment significantly influenced competence. However, age and gender were found to be non-significant in student assessment. Similarly, a cross-sectional study using a self-administered questionnaire among nursing students reported that senior students performed better than junior students, suggesting that experience and level of training influence competence (Bifftu et al., 2019). These findings indicate that knowledge and experience contribute to improved implementation of biosafety and biosecurity practices however this study did not use the observation tool to address the compliance which was used in this study.

In the present study, sociodemographic characteristics assessed in relation to biosafety and biosecurity implementation include gender, level of professional training, years of laboratory experience, and additional biosafety and biosecurity training. These variables are important in determining laboratory workers' competence, compliance, and perception of biosafety and biosecurity practices.

Studies have shown that laboratory workers often demonstrate inadequate biosafety and biosecurity skills, which may increase the risk of exposure to infectious pathogens and accidental release of biological agents. Inadequate skills have been associated with poor compliance with safety procedures, improper specimen handling, and ineffective use of personal protective equipment (Siengsan-Lamont & Blacksell, 2018; Muriithi et al., 2018; Perkins et al., 2019; Bota et al., 2021). In addition, laboratory workers may develop anxiety and psychological distress when they perceive themselves to be at risk of infection, especially in settings where safety measures are inadequate.

Lack of training in biosafety skills may lead to improper handling of specimens, unsafe sample collection, and poor waste disposal practices, thereby exposing laboratory workers to infections (Al-Abhar et al., 2017). Although efforts have been made to provide laboratory workers with relevant skills, formal training remains limited in many healthcare facilities. Some laboratory workers use biosafety techniques incorrectly, such as improper use of personal protective equipment, wearing laboratory coats outside hospital facilities, and failure to follow infection prevention protocols. These practices increase the risk of infection transmission to both healthcare workers and the general public (Menon et al., 2022). Newly employed laboratory workers are particularly vulnerable due to limited experience, especially in the absence of mentorship programs.

Mentorship programs have been shown to improve biosafety and biosecurity practices among newly employed staff. Ritterson and Casagrande (2017) reported that mentorship and supervised practice provide opportunities for new employees to develop competence in biosafety procedures. Hospitals are therefore encouraged to provide training and mentorship programs to improve the proper use of personal protective equipment and adherence to safety protocols. Providing opportunities for laboratory workers to express challenges related to biosafety also enhances compliance and improves workplace safety.

Gender differences in perceived competence in biosafety and biosecurity practices have also been explored in the literature. However, there is no consensus on whether gender significantly influences competence. Some studies suggest that gender stereotypes portray women as more careful and empathetic, while men are perceived as less cautious in infection prevention practices (Demtl, 2023; Björklund &

Mattsson, 2024; Santome-Pariona et al., 2023). These perceptions may influence self-reported competence in biosafety practices. However, such findings are often based on self-reported measures that may be biased by social expectations (Shammout, 2023).

Other studies have shown that gender differences may be absent in biological and laboratory tasks, suggesting that competence in biosafety and biosecurity practices may not necessarily depend on gender (Bajjou et al., 2019). Differences observed in some studies may be influenced by assessment methods, small sample sizes, and gender-role stereotypes rather than actual competence. Amar (2019) further reported that sex differences in laboratory procedures vary depending on the method of assessment, and findings may be inconsistent across studies. These inconsistencies suggest that gender may not be a strong determinant of competence in biosafety and biosecurity practices.

Improper use of personal protective equipment has been associated with reduced competence in biosafety practices. Some studies suggest that gender may influence attitudes toward infection prevention, although evidence remains inconclusive. Therefore, gender is considered in this study as a potential determinant of competence in biosafety and biosecurity practices, alongside other factors such as training, experience, and institutional support.

2.4.1 Perception and Competence

Perceived competence refers to an individual's self-assessment of their capabilities and ability to control their environment and perform tasks effectively. It reflects how skilled and confident a person believes they are in performing duties within a specific situation or professional role. Competence, on the other hand, refers to the essential

knowledge, skills, and abilities required for effective job performance (Dikic et al., 2019). It can further be described as the integration of knowledge, attitude, and practical skills required to perform specific tasks in a manner that produces desirable outcomes (White, 2023).

Clinical laboratories play a major role in patient diagnosis, treatment planning, disease surveillance, and prevention of disease (Goudouris, 2021). However, these roles cannot be effectively achieved without the proper implementation of biosafety and biosecurity procedures beginning from the training level. Healthcare workers, including medical laboratory technologists, often work under pressure to improve performance while reducing operational costs. Such pressures may interfere with adherence to biosafety and biosecurity practices. In this study, good performance reflects proper implementation of biosafety and biosecurity procedures by laboratory staff. Although clinical laboratories share some characteristics with traditional production systems, the medical profession requires domain-specific biosafety and biosecurity approaches tailored to laboratory environments.

Perceived competence in biosafety and biosecurity, therefore, refers to laboratory workers' self-assessment of their technical ability, professional attitude, and skills in performing biosafety and biosecurity procedures. In this study, biosafety and biosecurity competence is defined as the degree to which laboratory workers believe they are capable of carrying out biosafety and biosecurity practices effectively. This concept has led to the development of evidence-based guidelines for biosafety practice, including recommendations from the World Health Organization and other regulatory bodies (WHO, 2014; Nakaziba, 2019; Muneer et al., 2021). These guidelines were later developed into consensus statements adopted by institutions

such as KEMRI to guide biosafety and biosecurity training and implementation (Muriithi, 2018). Following the adoption of these guidelines, regions developed structured frameworks for teaching and assessment of biosafety and biosecurity practices in hospital laboratories (Bota et al., 2021). Subsequent training programs were introduced for already employed laboratory workers, and studies such as Jimale (2018) assessed the effectiveness of regulatory frameworks for biosecurity preparedness in hospital settings. However this study will address the importance of training and practice.

Students' and laboratory workers' perceptions are influenced by educational experiences, exposure to practical training, and familiarity with safety procedures (Harris & Smith, 2022). Effective training programs that integrate theoretical knowledge and practical skills have been associated with improved confidence and competence in biosafety and biosecurity practices (Ouma & Waswa, 2022). Training, therefore, plays a crucial role in shaping laboratory workers' perceptions of competence and improving compliance with biosafety procedures.

McClure (2019) conducted a qualitative study among clinical laboratory science students at Texas University to explore attitudes and perceptions toward the profession. Using focus group discussions with standardized questions, the study examined factors influencing career choice and expectations. Although students perceived the career as interesting and motivating, many viewed it as a stepping stone to other healthcare careers due to perceived limited advancement opportunities. The present study utilizes both questionnaires and focus group discussions, together with observation tools, to identify knowledge gaps within the medical laboratory profession and assess perceived competence among laboratory workers. This

approach also helps to evaluate perceptions of the profession among healthcare workers and the general public.

The medical laboratory profession is also expected to manage emotional and professional challenges associated with patient care. However, Adams, Albohn and Adams Jr (2021) reported that emotional aptitude among laboratory workers compared with other healthcare professionals was not significantly different. This suggests that competence in laboratory settings is more strongly influenced by technical knowledge and procedural skills than by emotional factors. The present study, therefore focuses on the application of acquired biosafety and biosecurity skills for the protection of laboratory workers, patients, and the environment.

Competence of laboratory personnel is a complex concept influenced by laboratory environment, training, experience, and institutional support. This study, therefore, seeks to identify consistent methods for assessing competency in the implementation of biosafety and biosecurity practices. The study also aims to identify opportunities for improving laboratory workers' competency assessment. It suggests that direct observation may be used as an effective method for assessing technical skills among medical laboratory technologists (Parikh et al., 2019).

There are several elements of perceived competence related to laboratory practice (Stollenwerk et al., 2022). These elements span across clinical domains common to medical practice and are essential for medical laboratory science training. These domains provide a foundation for teaching and assessment, without which competence in biosafety and biosecurity procedures cannot be achieved. These domains are discussed in the subsequent sections.

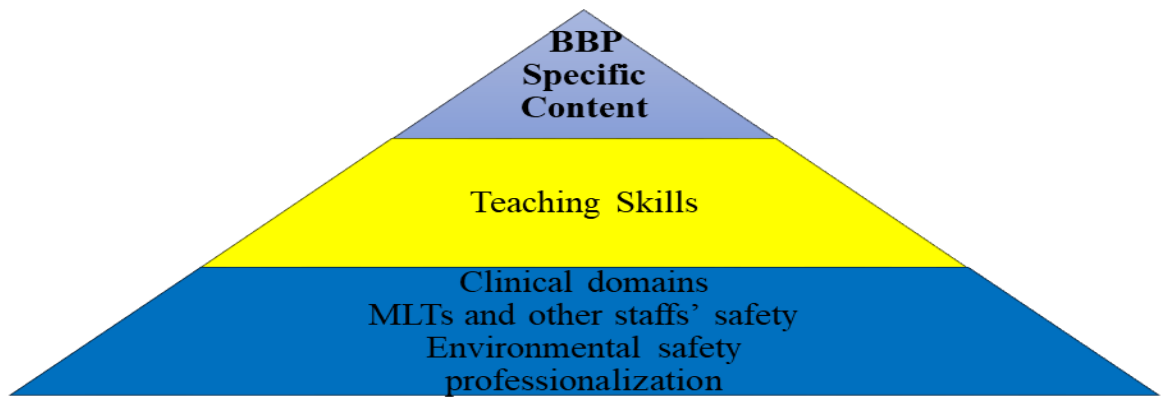


FIGURE 3: BB DOMAIN

The literature looks at components of the base that cut across all medical competencies, followed by a look at communication skills (Graf et al., 2020) in general, which form the technical knowledge of biosafety and biosecurity, and finally, specific content for the biosafety and biosecurity training model.

2.4.2 Clinical Domains Necessary for Biosafety and Biosecurity Procedures

Clinical domains are essential components that influence competence in biosafety and biosecurity procedures within medical laboratories. These domains include communication, professionalism, interpersonal relationships, mentorship, emotional well-being, and adherence to safety guidelines. Together, these elements contribute to the effective implementation of biosafety and biosecurity practices and enhance laboratory workers' competence and compliance.

2.4.2.1 Respect for All

Communication is an important factor in clinical settings, and respect forms a core component of effective communication. Respect for all laboratory workers regardless of background, professional level, or ability promotes teamwork and improves adherence to biosafety and biosecurity procedures (Almutairi et al., 2021). In diverse healthcare environments, cultural awareness and mutual respect among laboratory workers, colleagues, and supervisors are necessary for safe laboratory practice.

Respectful partnerships between laboratory workers and the working environment promote cooperation, improve communication, and strengthen adherence to biosafety and biosecurity guidelines.

Theoretical and empirical evidence on communication skills highlights their importance in clinical practice and professional development (Wei & Stewart, 2023; Shariff & Kimani, 2022; Tavakoli, 2022). Effective communication enhances understanding of safety procedures, promotes teamwork, and improves learning outcomes. Respect for self and others is therefore essential in promoting biosafety and biosecurity competence. Interpersonal relationships among laboratory workers influence satisfaction, motivation, and learning outcomes, which ultimately affect the implementation of biosafety and biosecurity procedures. Positive interpersonal dynamics contribute to improved adherence to safety practices and enhanced laboratory worker satisfaction.

2.4.2.2 Professionalism in Practice

Professionalism is a key component in achieving biosafety and biosecurity compliance in laboratory settings. Proper use of personal protective equipment while handling specimens demonstrates awareness of infection prevention practices and commitment to safety (Rofifa, Alayyannur & Haqi, 2019). Professional conduct builds trust among laboratory workers, supervisors, and patients, and promotes a culture of safety within laboratory environments. Professionalism also enhances teamwork and improves adherence to biosafety guidelines.

Honesty and trust between laboratory workers and mentors influence biosafety outcomes and worker satisfaction. Senior laboratory personnel who promote trust, effective communication, and proper use of personal protective equipment foster

cooperation and strengthen adherence to biosafety procedures (Murithi et al., 2018). Participatory decision-making further enhances compliance with biosafety practices. When laboratory workers are involved in decision-making processes, their satisfaction increases and they become more committed to implementing safety procedures (Watson, 2018).

Reciprocal relationships between laboratory workers and mentors encourage active participation, confidence, and adherence to biosafety procedures. Laboratory workers who engage in discussions with supervisors regarding biosafety strategies are more likely to follow recommended practices (Lee et al., 2021). Mentor–worker interaction, often referred to as concordance, promotes better understanding of procedures and enhances compliance. Through dialogue and collaboration, laboratory workers develop a better understanding of biosafety guidelines and are more likely to adhere to recommended practices.

Mutual agreement and collaboration between laboratory workers and mentors contribute to improved biosafety outcomes. Reciprocal exchange of information is a vital component in decision-making processes where laboratory workers are actively involved. Such collaboration improves satisfaction and promotes responsibility in implementing biosafety and biosecurity procedures. This is particularly important when handling highly infectious pathogens where adherence to safety procedures is critical (Jalloh, Vernooij & Street, 2024).

Beliefs, attitudes, and social influences also affect laboratory workers' willingness to comply with biosafety procedures. Conflicting views among colleagues or a lack of support may hinder adherence to safety practices. Use of protective equipment such as face masks and goggles may cause discomfort or anxiety, which may reduce

compliance with biosafety guidelines (Cornish et al., 2021). Mentor–mentee congruence in preferences for biosafety involvement has been shown to be more important than demographic similarities such as age or gender (Ikram, 2021). Trust between laboratory workers and mentors is therefore a strong predictor of compliance with biosafety recommendations (Freese & Bekebrede, 2022).

Mental health factors such as depression may also influence biosafety compliance. Studies have shown that depression is associated with reduced concentration, anxiety, fatigue, and decreased motivation, which may affect adherence to safety procedures (Galván-Ramírez et al., 2023). Inadequate or poor-quality personal protective equipment further increases occupational risk. Some studies reported that healthcare workers often acquire additional protective equipment due to insufficient institutional supply (Rofifa, Alayyannur & Haqi, 2019). Depression has also been associated with poor health outcomes and reduced adherence to safety practices (Grotmol, 2017; Higgins et al., 2022).

Accurate assessment of biosafety and biosecurity implementation requires trust and open communication between laboratory workers and mentors. Laboratory workers are more likely to report non-conformity when they feel supported and not criticized. Simple, non-threatening assessment methods improve the accuracy of self-reported compliance and enhance understanding of barriers to implementation (Seyedi et al., 2020; Honebein, 1996; Hallerman et al., 2021). These assessments allow identification of beliefs, attitudes, and emotional challenges affecting compliance with biosafety and biosecurity procedures.

Effective implementation of biosafety and biosecurity procedures requires tailored interventions that address individual laboratory worker needs. Some workers may

require mentorship and reminders, while others may lack access to protective equipment or adequate training. Institutional support, mentorship, and collaboration remain central to improving biosafety and biosecurity practices (Viner et al., 2022; Donkin et al., 2019; Hubbard et al., 2017). Strong mentor–worker partnerships promote participation, engagement, and shared responsibility in implementing biosafety and biosecurity procedures, ultimately leading to improved safety outcomes in laboratory settings.

2.5 Laboratory Workers' Knowledge and Sociodemographic Characteristics

Laboratory workers' knowledge and sociodemographic characteristics play a critical role in the implementation of biosafety and biosecurity practices in clinical laboratories. Adequate knowledge of biosafety and biosecurity procedures enhances compliance with safety standards, reduces laboratory-acquired infections, and promotes safe handling of biological specimens. However, studies have reported inadequate awareness and knowledge of laboratory safety aspects among undergraduate students, many of whom later become employed in healthcare facilities. Continuous training is therefore necessary to improve biosafety and biosecurity implementation among laboratory workers.

Health facility managers also play an important role in promoting biosafety and biosecurity practices. Organizational commitment, provision of training, supportive supervision, and enforcement of safety guidelines are essential in improving safety management practices within laboratory settings. Regular training programs and institutional support enhance knowledge acquisition, strengthen practical skills, and improve compliance with biosafety and biosecurity procedures.

Laboratory workers' perceptions of competence may vary depending on sociodemographic characteristics such as gender, educational level, years of experience, and prior training. These factors influence self-assessment of competence and implementation of biosafety practices. Understanding these relationships enables institutions to tailor training programs to address the specific needs of different laboratory worker populations. Customized training approaches improve knowledge, strengthen practical skills, and enhance compliance with biosafety and biosecurity procedures.

Studies examining predictors of workers' skills using cognitive and demographic variables have shown that conceptual knowledge, educational exposure, and experience significantly influence competence. However, age and gender were found to be non-significant in some assessments. Similarly, cross-sectional studies among healthcare trainees reported that senior participants performed better than junior participants, suggesting that experience and level of training influence competence in biosafety and biosecurity practices. These findings indicate that knowledge and experience contribute to improved implementation of biosafety and biosecurity procedures.

In this study, sociodemographic characteristics assessed in relation to biosafety and biosecurity implementation include gender, level of professional training, years worked in the laboratory, and additional biosafety and biosecurity training. These variables are important in determining laboratory workers' competence, compliance, and perception of biosafety and biosecurity practices. Understanding these factors helps identify training gaps and informs the development of targeted interventions.

Studies have also shown that laboratory workers often demonstrate inadequate biosafety and biosecurity skills, which may increase the risk of exposure to infectious pathogens and accidental release of biological agents. Inadequate skills have been associated with poor compliance with safety procedures, improper specimen handling, and ineffective use of personal protective equipment. These gaps may lead to occupational infections, psychological stress, and reduced confidence among laboratory workers. Lack of formal biosafety training further contributes to improper handling of specimens, unsafe disposal practices, and increased risk of infection.

Newly employed laboratory workers are particularly vulnerable due to limited experience, especially in the absence of mentorship programs. Mentorship and supervised practice improve competence in biosafety procedures and enhance compliance with safety protocols. Hospitals are therefore encouraged to provide structured orientation and mentorship programs to support new employees. Opportunities for laboratory workers to express challenges related to biosafety practices also improve adherence and strengthen workplace safety.

Gender differences in perceived competence in biosafety and biosecurity practices have also been explored in the literature. Some studies suggest that gender stereotypes portray women as more careful and empathetic, while men are perceived as less cautious in infection prevention practices. However, other studies have shown that gender differences may be absent in biological and laboratory tasks, suggesting that competence in biosafety and biosecurity practices may not necessarily depend on gender. These inconsistencies indicate that gender may not be a strong determinant of competence, and other factors such as training, experience, and institutional support may play a more significant role.

Improper use of personal protective equipment has also been associated with reduced competence in biosafety practices. Some laboratory workers fail to use protective equipment correctly, wear laboratory coats outside hospital facilities, or fail to follow infection prevention protocols. These practices increase the risk of infection transmission to healthcare workers and the public. Therefore, training, supervision, and institutional support remain essential in improving laboratory workers' knowledge and competence in biosafety and biosecurity practices.

2.5.1 Biosafety Levels

Biosafety Levels (BSL) are ranks given to laboratories depending on the type of microorganisms they handle. CDC decided to define containment precautions, and they ranked laboratories from Biosafety Level 1 to 4 (BSL1-4). The purpose of ranking laboratories on biosafety levels is to help them have knowledge and skills on how to manage laboratory risks based on the type of biological agent, pathogenicity, virulence and modes of transmission (Joseph, T., 2021; Bayot, M. L., & King, K. C., 2022).

The BS-1 handles non-pathogenic agents like *Escherichia coli*. *Escherichia coli* is a well-characterized pathogen that causes no severe harm in adults. The common PPE is a dust coat and gloves, and can be worked on an open bench. It has the lowest risk.

BS-2 is for processing biological agents that pose a moderate hazard to a laboratory worker and also the surrounding environment. This type of agent can be like *Staphylococcus aureus*. An autoclave is a good piece of equipment for the sterilization of waste and biosafety cabinets in case of potential splashes. Access can be limited.

BSL-3—This is meant for agents that bring about serious and lethal diseases whose mode of transmission is through inhalation. Such agents are like *Mycobacterium tuberculosis* and SARS-CoV-2. Controlled access is applicable alongside special types of ventilation systems and PPE like respirators (Joseph, T., 2021). Joseph continues to highlight the microorganism processed and facilities in BSL-3 need to be assessed on bio risk management.

BSL-4 is one of the biosafety levels that pose a maximum risk, and the biological agents handled here are life-threatening and produce very high transmission rates. These biological agents, in most cases, do not have either a vaccine or a treatment. An example of such an agent is the Ebola virus. Staff must wear full-body, air-supplied positive pressure suits and work in a separate, highly secured building.

Ranging from basic training labs (BSL-1) to high-containment facilities (BSL-4) for lethal pathogens, each level adds more stringent PPE, specialized equipment, and facility design controls

2.5.2 Age and Biosafety and biosecurity Knowledge

Age refers to the number of years a person has lived since birth. Because BB practices are skills and attitudes, my assumption is that age can influence the BB implementation. Age has no statistical influence on biosafety and biosecurity (Tran, A., 2025). Tran continues to say that knowledge was the same across all ages. Recruitment for biosafety and biosecurity training includes all age groups. A study was on the characterization of laboratory workers (Emery et al., 2020). According to Ramos, H. L., Diola, J., & Ortega, M. C. (2025, age was not significant in biosafety adherence procedures. Most studies had indicated that age is not significant, but the researcher, due to common knowledge, which demonstrates that old is gold, wanted to

establish any of the missed opportunities. The study, therefore, assessed whether knowledge of BB was significant in its implementation.

2.5.3 Gender and Biosafety and Biosecurity

Gender defines the roles that are performed by either men or women. The laboratory workers are composed of both genders; gender played a great role in the adherence to biosafety protocols and practices (Ramos, H. L., Diola, J., & Ortega, M. C., 2025). In this study, women performed better than men in awareness of biosafety and biosecurity. Some literature says all genders are the same in terms of skills and attitude of BB. The issue of gender did matter in the biosafety and biosecurity practices (Tang et al., 2024). Lessons learned in biosafety and biosecurity were the same for all genders (Cornish et al., 2021). The studies done on gender were not the same for all genders in their findings. This study assessed the knowledge, practice and attitude on gender to establish whether there is statistical significance among laboratory workers based on gender. The findings will enrich the existing literature for future references.

2.5.4 Work experience in years and biosafety and biosecurity

Work experience refers to the number of years in the field of work. In this study, worker experience is the number of years the laboratory worker has worked in the laboratory. Years of experience played a greater role in the biosafety implementation process (Cornish et al., 2021). In this study of Cornish and colleagues, the issue of adherence to PPE was higher in laboratory workers who had worked for more than 10 years. Knowledge is gained by years of experience (Halatok et al., 2024). The more years a laboratory works, the more experience it has in terms of safety (Bajjou et al., 2019). Biosafety knowledge, skill and attitudes were excellent in the senior staff who worked more. This study, which says ‘experience is the best teacher’, sought to find

out if he can still uphold despite many studies agreeing that years of experience perform better. Therefore, the study assessed the knowledge level of laboratory workers in Narok County Hospitals.

2.5.5 Level of Professional education and biosafety and biosecurity

The professional level refers to the highest educational level attained. In this study of BB implementation, the professional level of a laboratory worker is examined in terms of level of training. The levels of training in Narok County hospital were from certificate, diploma, bachelor's, and above bachelor's. Several studies have been done; the higher the level of education in the profession, the better the biosafety and biosecurity practices (Ahmed et al., 2022). The laboratory workers with a doctorate in research laboratories adhered more to biosafety procedures (Tang et al., 2024). The higher the knowledge level in the profession, the lower the laboratory-acquired infections (OLU et al., 2025). The laboratory workers with higher education were better managers and trainers in the issue of biosafety biosecurity (Cornish et al., 2021). Clinical laboratories are best designed with managers who have high professional development (Beeckman, D. S., & Rüdelsheim, P., 2020). The Narok County, with different levels of professional education, meant the objective.

This study, therefore, sought to assess the biosafety and biosecurity implementation among laboratory workers in Narok County Hospital based on the professional education. The findings are meant to inform the policy and decision makers and the county government of Narok to implement the findings for better diagnostic services in the laboratory and for protecting, LW: the patient and the environment.

2.6 Curriculum Content and Methodologies

Curriculum content and teaching methodologies play a critical role in shaping competence in biosafety and biosecurity among laboratory workers. Effective training requires a structured biosafety and biosecurity training model (BBTM) that integrates theoretical knowledge with practical application. Understanding the technical aspects of what medical laboratory personnel should learn and apply during biosafety and biosecurity training is essential in promoting safe laboratory practices. The suitability of curriculum content and instructional methodologies used in biosafety and biosecurity training determines the effectiveness of knowledge acquisition, skill development, and compliance with safety procedures (Maruta et al., 2023). A well-designed curriculum, therefore, ensures that laboratory workers acquire the competencies required to handle infectious materials and minimize laboratory-associated risks safely.

Studies have emphasized the importance of incorporating realistic hands-on activities, case studies, and simulations in biosafety training. These approaches enhance learners' understanding of safety procedures and improve retention of knowledge. Practical exposure enables learners to apply biosafety principles in real laboratory settings and strengthens competence in handling hazardous biological materials (Garcia et al., 2020). A comprehensive curriculum should therefore include fundamental laboratory procedures, risk assessment techniques, containment practices, emergency response procedures, waste management, and advanced biosafety and biosecurity practices. Integration of these components ensures that learners develop both theoretical understanding and practical competence.

Blended learning approaches have increasingly been adopted in medical laboratory education. According to Chen et al. (2020), blended learning integrates online self-learning with teacher–student interactions in classroom settings. This approach enhances students’ ability for self-directed learning, promotes problem-solving skills, and improves learning effectiveness. In the same study, 63% of participants agreed that blended laboratory courses were more effective in achieving learning objectives compared to traditional teaching methods. Instructors also reported that students taught using blended learning demonstrated improved motivation toward experimental procedures, increased confidence, and enhanced hands-on abilities compared to students taught using conventional face-to-face approaches. These findings highlight the importance of integrating blended learning strategies in biosafety and biosecurity training.

Visual feedback has also been shown to enhance learning in medical laboratory training. Donkin et al. (2019) reported that visual feedback improves comprehension of laboratory procedures and enhances the acquisition of technical skills. Similarly, a cross-sectional study comparing asynchronous learning (pre-recorded lectures shared through messaging platforms) and synchronous learning (live online lectures) reported that synchronous learning improved clarity of concepts and examination performance (Yada et al., 2021). These findings suggest that interactive teaching methods improve understanding of biosafety concepts and enhance competence. The present study, therefore, examines various teaching methodologies used in biosafety and biosecurity training, with emphasis on the adequacy of curriculum content.

Group discussion methods have also been shown to improve learning outcomes in medical laboratory education. Fattahi et al. (2021) compared group discussion and

lecture-based teaching methods and found that group discussions were superior in promoting learning efficacy and strengthening group relationships. Collaborative learning allows students to share experiences, discuss biosafety challenges, and develop practical solutions. Such interactions improve understanding of biosafety and biosecurity procedures and enhance teamwork in laboratory environments.

Problem-based learning is another teaching methodology that improves students' participation and academic performance. Anyaehie et al. (2021) reported that problem-based learning improves attendance, participation, and examination performance in medical laboratory courses. Laboratory training is inherently based on active learning and hands-on practice. Mustafa et al. (2024) investigated supervised, unsupervised, and reinforcement learning approaches in laboratory medicine training and concluded that supervised learning and reinforcement approaches were more effective in improving competence. These findings suggest that supervised training, mentorship, and guided practice are essential in biosafety and biosecurity training. The present study, therefore, examines the implementation of the biosafety and biosecurity training model during student attachment and clinical practice.

Basic medical laboratory courses play an important role in medical education and provide foundational knowledge required for laboratory practice. Student-centered and active learning strategies have increasingly been incorporated into medical education; however, their application in basic medical laboratory courses remains limited. Shen et al. (2022) and Chen et al. (2020) advocated for the adoption of blended learning strategies in biosafety and biosecurity training curricula. Incorporation of these strategies enhances learning outcomes and improves competence in biosafety procedures.

The biosafety training program developed by NUITM–KEMRI aimed at training new biosafety level three (BSL-3) laboratory workers before they begin working in high-containment laboratories. The program was designed to strengthen biosafety and biosecurity practices in research and diagnostic settings (Bundi et al., 2014). The training content was primarily based on the WHO Laboratory Biosafety Manual, which provides guidelines on basic laboratory biosafety practices, containment principles, and procedures for preventing unintentional exposure to biological agents and toxins (Bull et al., 2021). This structured training approach ensures that laboratory workers acquire standardized competencies required for safe laboratory operations.

Biosafety and biosecurity remain major global concerns in clinical and academic laboratories. Education on standardized laboratory practices is therefore mandatory and should be delivered in comprehensive, interactive, and learner-centered formats. Effective curriculum content should address risk assessment, containment practices, emergency response, personal protective equipment, waste management, and regulatory compliance. The objective of this study is to establish the adequacy of curriculum content and teaching methodologies used in hospital training institutions to ensure effective implementation of biosafety and biosecurity training models.

2.7 Constraints Encountered in Performing Biosafety and Biosecurity

Constraints are factors that directly or indirectly affect the performance of tasks and may influence competence in biosafety and biosecurity procedures. In clinical laboratory settings, constraints may limit compliance with safety guidelines, reduce adherence to biosafety practices, and increase the risk of laboratory-acquired infections. Understanding these constraints is essential in identifying barriers to the

implementation of biosafety and biosecurity practices. This section reviews constraints identified in the literature and highlights those most likely to influence biosafety and biosecurity implementation in medical laboratory settings.

Constraints affecting the performance of biosafety and biosecurity procedures may arise from policy, resource, and market-related factors. Qin and Sun (2019) identified three main types of constraints: policy constraints, resource constraints, and market constraints. Policy constraints occur when formal or informal rules limit operational capacity or restrict the implementation of procedures. These may include institutional policies, operational guidelines, regulatory requirements, and performance measurement systems. Such policies may unintentionally reduce system performance when they restrict flexibility or limit access to resources required for safe laboratory practice. Studies have shown that rigid operating policies and measurement systems may limit productivity and reduce effective implementation of safety procedures (Glanville et al., 2023; Croker et al., 2021). These limitations may affect the ability of laboratory workers to comply with biosafety and biosecurity guidelines.

Human resource constraints arise when staffing capacity is less than the workload required for safe laboratory operations. Inadequate staffing may lead to increased workload, fatigue, and reduced compliance with biosafety procedures. Laboratory workers operating under high workload conditions may bypass safety procedures such as the use of personal protective equipment or adherence to standard operating procedures. This increases the risk of exposure to infectious agents and compromises biosafety implementation. In contrast, market constraints occur when available capacity exceeds demand, resulting in underutilization of resources. Although market

constraints are less common in clinical laboratories, they may influence the allocation of resources and prioritization of safety measures.

Performance measurement systems also influence the behavior of laboratory workers. Childerhouse et al. (2020) noted that individuals tend to act based on how performance is measured. When measurement systems emphasize productivity rather than safety, laboratory workers may prioritize speed over compliance with biosafety procedures. This may lead to local optimization rather than the achievement of global safety goals. Such measurement practices may create constraints when environmental conditions change or when safety requirements increase (Ronen, Coman & Leshno, 2024). In biosafety contexts, laboratory workers may find it easier to receive patient specimens without gloves to save time, although proper biosafety practice requires the use of personal protective equipment. Such situations illustrate that policy constraints were operational expectations that conflict with safety requirements.

Policy constraints are often considered the most common form of constraints in biosafety implementation. Some authors argue that policy constraints may also create resource constraints by limiting access to equipment, training, and infrastructure required for safe laboratory practice (Rahman et al., 2024). For example, institutional policies that do not prioritize biosafety training may result in limited knowledge among laboratory workers. Similarly, a lack of clear guidelines on the use of personal protective equipment may lead to inconsistent compliance. These policy-related limitations may ultimately affect the competence and implementation of biosafety and biosecurity procedures.

In addition, constraints may also arise from inadequate infrastructure, limited availability of personal protective equipment, insufficient training opportunities, and a

lack of supportive supervision. These constraints may reduce compliance with biosafety guidelines and increase occupational risks. Institutional commitment, adequate resource allocation, and supportive policies are therefore necessary to address constraints affecting biosafety and biosecurity implementation. Identifying these constraints is important in developing strategies aimed at improving competence and strengthening biosafety practices among laboratory workers.

2.7.1 Formal Training Constraints

Despite the existence of international initiatives and national regulatory frameworks, biosafety and biosecurity challenges continue to be reported in many laboratory settings. One of the major constraints affecting the implementation of biosafety and biosecurity procedures is inadequate formal training among medical laboratory technologists and other laboratory staff. Formal training is essential in equipping laboratory workers with the knowledge, skills, and attitudes required for safe handling of infectious materials. However, biosafety and biosecurity training programs in Kenya have largely targeted already employed laboratory personnel, particularly those working under Ministry of Health facilities (Bota et al., 2021; Rutebemberwa et al., 2020; Maruta et al., 2023). This approach leaves gaps in training for students, interns, and newly recruited laboratory staff who may begin working without adequate preparation in biosafety and biosecurity procedures.

In many instances, biosafety and biosecurity training programs are sponsored by non-governmental organizations, which limits sustainability and coverage. Lack of institutionalized training programs within medical training institutions further contributes to inadequate competence in biosafety practices. An assessment conducted in Kenya in 2013 indicated that between 18% and 64% of laboratory facilities did not

practice adequate waste management, infection prevention, and compliance measures. These findings highlight gaps in biosafety implementation and emphasize the need for structured training programs (Abonyo, 2017). Free trainings can bring a challenge in the sense that people do not take free things seriously (Cornish et al., 2021). Biosafety and biosecurity training should strengthen the gaps in adherence and skills (Sidding et al., 2025). A training review study of biosafety recognized the need for the establishment of strong regulatory bodies, to have strategic plans and a standardized training curriculum (Abidemi et al., 2024). Adequate training of laboratory staff on biosafety and biosecurity procedures, infection prevention, and compliance practices is therefore necessary to improve laboratory safety.

Financial limitations and job insecurity further compound training constraints. Limited funding restricts the availability of training opportunities, while contractual employment arrangements may reduce motivation for continuous professional development. Laboratory workers may therefore lack access to refresher training and competency-based assessment programs.

The laboratory workers' challenges include, apart from the B training, the laboratory design and workflow, and access to electricity because of the equipment, such as a refrigerator and centrifuge, among others. Others are the heavy workload, resulting in stress and burnout. Stress and burnout can lead to the pledge of biosafety and biosecurity practices (Peng et al., 2018).

This study, therefore, seeks to determine whether biosafety and biosecurity training models are implemented in medical laboratories and whether training institutions provide theoretical, practical, or role-playing approaches to biosafety and biosecurity procedures. The study also examines whether problem-based learning approaches are

used in medical training colleges, as these approaches enhance the development of practical skills required for biosafety and biosecurity procedures.

A further dimension of formal training constraints relates to the quality, consistency, and pedagogical design of biosafety and biosecurity education delivered to laboratory personnel. While the availability of training is often emphasized, the instructional methodology and competency outcomes are equally critical in determining effectiveness. Evidence from global health workforce studies shows that many biosafety trainings rely heavily on didactic, lecture-based approaches that prioritize theoretical knowledge over hands-on skill acquisition and behavioral change (World Health Organization, 2022).

This creates a disconnect between what laboratory workers know and what they are able to implement in real-world laboratory environments, particularly in high-risk or resource-limited settings. Competency-based training models, which incorporate simulations, drills, mentorship, and continuous assessment, have been shown to significantly improve adherence to biosafety protocols compared to traditional methods (Iliyasu et al., 2022; Olowokure et al., 2021). However, such models require structured curricula, trained facilitators, and sustained institutional support—factors that are often lacking in many Kenyan training institutions. Additionally, the absence of standardized national accreditation mechanisms for biosafety training results in variability in content delivery, duration, and evaluation across institutions, leading to inconsistent competency levels among graduates. Studies further indicate that adult learning principles—such as experiential learning, feedback loops, and contextual problem-solving—are rarely integrated into laboratory training programs, despite their proven effectiveness in healthcare education (Knowles et al., 2020).

The rapid evolution of emerging infectious diseases, including experiences from the COVID-19 pandemic, has further underscored the necessity for adaptive, responsive, and continuously updated training systems that can equip laboratory personnel with current biosafety practices. Without regular curriculum review and integration of emerging biosafety risks, training programs risk becoming obsolete and misaligned with current laboratory challenges. Therefore, strengthening formal training requires not only increased access but also deliberate investment in competency-based, standardized, and context-specific training frameworks that align with international biosafety guidelines while addressing local operational realities. Such reforms would ensure that laboratory personnel are not only knowledgeable but also proficient and confident in implementing biosafety and biosecurity measures in diverse laboratory settings.

2.7.2 Time Constraints

Time constraints represent another significant barrier to the effective implementation of biosafety and biosecurity procedures. Medical laboratory work involves strict timelines for specimen processing, analysis, and reporting of results. Laboratory workers are therefore required to balance accuracy, speed, and safety. Although laboratory personnel are trained in time management, heavy workload and staffing shortages may limit adherence to biosafety procedures. Under time pressure, laboratory workers may prioritize rapid completion of tasks over compliance with safety guidelines.

Some laboratory workers may bypass essential biosafety procedures such as proper use of personal protective equipment, hand hygiene, or adherence to standard operating procedures in order to save time. Such practices increase the risk of

exposure to infectious agents and compromise laboratory safety. In addition, time constraints may reduce opportunities for training, supervision, and mentoring of junior staff. This study, therefore, seeks to determine how laboratory workers prioritize biosafety and biosecurity procedures in relation to other routine laboratory activities and workload demands (Kiwauka et al., 2022).

An additional layer to time-related barriers concerns the organizational and systemic inefficiencies that amplify workload pressure and reduce the practical feasibility of adhering to biosafety and biosecurity protocols. In many laboratory settings, especially in low- and middle-income countries, workflow processes are not optimally designed to integrate safety procedures into routine operations. For example, poorly structured specimen flow, limited automation, and inadequate staffing models often result in task congestion during peak hours, forcing laboratory personnel to operate under sustained time pressure.

According to the World Health Organization (2021), inefficient laboratory systems contribute significantly to reduced compliance with safety standards, as workers are compelled to adopt shortcuts to maintain turnaround times. Furthermore, a lack of task delegation and role clarity within laboratory teams may lead to duplication of duties or uneven workload distribution, further intensifying time constraints. Evidence suggests that when biosafety procedures are perceived as time-consuming or disruptive to workflow, their consistent application declines, particularly in high-throughput laboratories (Nkengasong et al., 2020). This challenge is compounded by the absence of an embedded safety culture within institutions, where performance metrics often emphasize productivity indicators such as turnaround time rather than compliance with biosafety standards.

Additionally, digital health interventions such as laboratory information management systems (LIMS), which could streamline processes and reduce manual workload, remain underutilized in many settings, thereby prolonging procedural steps and increasing fatigue among staff. Studies have also demonstrated that prolonged working hours and inadequate rest periods contribute to cognitive overload and decision fatigue, conditions that are strongly associated with lapses in safety practices (Carayon et al., 2021). The experience during the COVID-19 pandemic further highlighted how surge testing demands can overwhelm laboratory systems, leading to compromised adherence to biosafety protocols due to urgency and volume pressures. Therefore, addressing time constraints requires not only individual-level interventions such as time management training but also systemic reforms, including workflow optimization, staffing adequacy, integration of safety into performance metrics, and adoption of supportive technologies. These measures are essential to ensure that biosafety and biosecurity practices are seamlessly incorporated into routine laboratory operations rather than being perceived as additional or optional tasks.

2.7.3 Procédure Compétence Constraints

Procedure competence constraints arise when laboratory workers lack adequate skills or fail to follow established biosafety and biosecurity procedures. Both biosafety risks (accidental exposure) and biosecurity risks (intentional misuse) fall under the broader concept of bio risk management. Biosafety and biosecurity procedures are usually standardized and documented in standard operating procedures (SOPs). These procedures are observable and measurable, making adherence essential for safe laboratory practice (Chaleabo, 2022). The SOPs give guidance on the step-by-step procedure performance. This step enables a laboratory worker to follow this step correctly and provide efficient results.

Failure to follow SOPs may result from inadequate training, poor supervision, lack of awareness, or insufficient availability of procedural guidelines. Laboratory workers may perform procedures incorrectly, omit safety steps, or fail to use recommended protective equipment. Such practices increase the risk of laboratory-acquired infections and compromise biosafety implementation. This study, therefore, seeks to determine whether applicable SOPs are available and followed during laboratory procedures, and whether laboratory workers demonstrate competence in implementing biosafety and biosecurity procedures. The researcher, therefore, assessed the availability and adherence of standard operating procedures in the BB implementation among laboratory workers in the Narok hospitals.

An additional dimension of procedure competence constraints relates to the gap between documented procedures and actual practice, often referred to as the “know–do gap” in healthcare systems. While standard operating procedures (SOPs) are designed to ensure uniformity and safety, their effectiveness depends heavily on consistent interpretation, contextual adaptation, and reinforcement within the laboratory environment. In many settings, SOPs may be available but not actively integrated into daily workflows, resulting in partial or selective adherence.

According to the World Health Organization (2020), effective biosafety implementation requires not only the presence of SOPs but also continuous competency assessment, supportive supervision, and routine audits to ensure compliance. However, in resource-limited settings, supervisory structures are often weak or overstretched, reducing opportunities for observation, correction, and feedback. This leads to normalization of unsafe practices over time, where deviations from SOPs become routine rather than exceptional. Additionally, variations in

individual skill levels, experience, and risk perception among laboratory workers contribute to inconsistent application of procedures.

For instance, more experienced staff may rely on habitual practices rather than strictly following updated SOPs, while less experienced personnel may lack confidence or clarity in executing procedures correctly (Gershon et al., 2019). The absence of structured competency verification systems—such as periodic proficiency testing, simulations, or certification—further exacerbates this issue, as there is limited accountability for maintaining procedural standards. Moreover, language barriers, technical complexity of SOP documents, and lack of user-friendly formats can hinder comprehension and practical application, particularly among trainees and support staff. The rapid emergence of new infectious diseases, as seen during the COVID-19 pandemic, has also required frequent updates to laboratory procedures, creating additional challenges in keeping all personnel adequately informed and competent.

Without effective change management strategies, including training updates and clear communication, laboratory workers may continue using outdated or incorrect procedures. Therefore, strengthening procedure competence requires a multifaceted approach that goes beyond SOP availability to include continuous skills assessment, active supervision, simplification and standardization of procedural documents, and fostering a culture of accountability and safety. Such measures are essential to bridge the gap between knowledge and practice and to ensure consistent adherence to biosafety and biosecurity procedures in laboratory settings.

2.7.4 Laboratory Biosafety -Related Constraints

Laboratory-related constraints refer to infrastructural, environmental, and operational challenges that affect biosafety and biosecurity implementation. Laboratory biosafety

and biosecurity have become fundamental components of bioscience laboratory operations. The World Health Organization first published the Laboratory Biosafety Manual in 1993, followed by guidance on laboratory biosecurity in 2006. These guidelines provide recommendations for safe laboratory design, containment practices, waste management, and the use of personal protective equipment

Laboratory infrastructure in reference to laboratory design and workflow is a challenge in many clinical laboratories, making the Labs not to adhere to biosafety and biosecurity rules and procedures (Cornish et al., 2021). Narok County hospitals have limited infrastructure challenges that this researcher wants to verify and give recommendations on.

However, the availability and implementation of biosafety guidelines vary across laboratory settings. Some laboratories lack updated biosafety manuals, safety signage, containment equipment, and proper waste management systems (Gao et al., 2025). Inadequate laboratory infrastructure may limit compliance with biosafety procedures. This study, therefore, seeks to determine whether biosafety guidelines are available in laboratories, whether laboratory workers are aware of these guidelines, and whether they are followed in routine practice.

Research has shown that insufficient resources, limited time, and lack of supervision may hamper implementation of safety practices (Byrne et al., 2019; Jones, 2019). Inadequate collaboration between healthcare facilities and county health management may further limit implementation of biosafety programs (Tang et al., 2024). Strengthening cooperation between laboratories and health management authorities within the Ministry of Health is therefore necessary to improve biosafety and

biosecurity practices. The implementation assessment of the same will highlight any gaps and direct the way forward.

An additional perspective on laboratory biosafety-related constraints focuses on the interaction between infrastructure limitations and institutional safety culture, which collectively determine how effectively biosafety and biosecurity measures are implemented. While physical resources such as containment equipment, ventilation systems, and waste disposal facilities are essential, their presence alone does not guarantee safe laboratory practice. The World Health Organization (2020) emphasizes that biosafety is achieved through a systems approach that integrates infrastructure, human behavior, and organizational governance. In many laboratories, particularly in resource-constrained settings, deficiencies such as inadequate space, poor ventilation, unreliable power supply, and limited access to water and sanitation services directly compromise the functionality of biosafety equipment and adherence to protocols.

For instance, intermittent electricity supply may disrupt the operation of critical equipment such as biosafety cabinets, refrigerators, and autoclaves, thereby increasing the risk of exposure to infectious materials. Additionally, overcrowded laboratory layouts and poor workflow design can lead to cross-contamination and accidental exposure, as clean and contaminated processes are not adequately separated. Beyond physical infrastructure, weak institutional enforcement mechanisms—such as lack of routine inspections, absence of biosafety committees, and limited accountability structures—further undermine compliance with established guidelines (Kibutu et al., 2022). Evidence also indicates that laboratories with strong leadership engagement and clear governance frameworks demonstrate higher levels of biosafety compliance compared to those where safety is treated as a secondary priority (Zaki et al., 2021).

The experience during the COVID-19 pandemic highlighted how fragile laboratory systems can become under pressure, with surges in testing overwhelming existing infrastructure and exposing gaps in preparedness, supply chains, and waste management systems. Furthermore, inequities in resource allocation between urban and rural laboratories exacerbate disparities in biosafety implementation, leaving peripheral facilities more vulnerable to risks. Addressing these constraints, therefore, requires a holistic strategy that combines investment in infrastructure with strengthening of governance systems, regular monitoring and evaluation, and promotion of a positive safety culture within laboratories. Such an approach ensures that biosafety and biosecurity are not only supported by adequate physical resources but are also embedded within the operational and managerial practices of laboratory systems.

2.7.5 Personnel Factors

Personnel factors also influence the implementation of biosafety and biosecurity procedures. Laboratory workers interact with colleagues, supervisors, and other healthcare professionals in performing laboratory tasks. Effective communication among staff is therefore important in promoting compliance with biosafety procedures. However, variations in training level, professional background, gender, and cultural differences may influence communication and teamwork. The individual laboratory worker's attitude as a factor contributes a lot to laboratory biosafety practices (Padde et al., 2022).

Some countries and healthcare facilities lack comprehensive biosafety regulations, which may lead to inconsistent implementation of safety procedures (Beeckman & Rüdelsheim, 2020; Rapaport, 2021). Differences in supervisory practices,

communication styles, and leadership approaches may also affect adherence to biosafety guidelines. Poor communication between laboratory staff may lead to misunderstandings, inconsistent practices, and reduced compliance with biosafety procedures (Diao et al., 2022).

This study, therefore, seeks to determine how laboratory personnel handle biosafety and biosecurity procedures and how communication among staff influences compliance. The study also examines whether factors such as age, gender, professional background, and institutional culture affect the implementation of biosafety and biosecurity practices. Understanding personnel-related constraints is important in developing strategies aimed at improving teamwork, communication, and compliance with biosafety guidelines. The gaps observed and found will be given to the Narok County Ministry of Health, in particular the laboratory department, to work on them in order to prevent the same occurrences in future.

An additional dimension of personnel-related constraints concerns the psychosocial and behavioral determinants that shape individual and team compliance with biosafety and biosecurity practices. While technical knowledge and communication structures are important, human factors such as risk perception, motivation, attitudes toward safety, and perceived organizational support play a critical role in influencing day-to-day behavior in laboratory settings. According to the World Health Organization (2021), a strong safety culture—characterized by shared values, open communication, and non-punitive reporting systems—is essential for sustaining adherence to biosafety protocols. In environments where errors are stigmatized or punished, laboratory workers may conceal mistakes or near-misses, limiting opportunities for learning and system improvement.

Additionally, hierarchical workplace structures may discourage junior staff from questioning unsafe practices performed by senior colleagues, thereby perpetuating procedural non-compliance. Individual-level factors such as fatigue, stress, and job dissatisfaction further influence adherence to safety measures, as overworked or disengaged personnel are more likely to overlook critical biosafety steps (Hall et al., 2016). Cognitive biases, including overconfidence and familiarity with routine tasks, may also lead experienced laboratory workers to underestimate risks and deviate from established protocols. Moreover, differences in professional training backgrounds—such as variations between diploma, degree, and postgraduate training—can result in inconsistent understanding and prioritization of biosafety practices. Gender dynamics and cultural norms may additionally influence communication patterns, decision-making, and willingness to report safety concerns, particularly in settings where power distance is high.

The challenges observed during the COVID-19 pandemic further demonstrated how fear of infection, stigma, and psychological distress among healthcare workers can negatively affect adherence to safety protocols and teamwork. Addressing these personnel-related constraints, therefore, requires targeted interventions that go beyond technical training to include behavioral change strategies, leadership development, team-building initiatives, and establishment of supportive reporting systems. Encouraging participatory approaches, where laboratory workers are actively involved in safety planning and decision-making, can also enhance ownership and compliance. Ultimately, strengthening personnel factors involves fostering an organizational culture that prioritizes safety, values open communication, and supports the well-being of laboratory workers as a foundation for effective biosafety and biosecurity implementation.

2.7.6 Workload on Laboratory workers

Workload in every clinical laboratory sector is allocated in terms of hours and the number of tests performed individually per day. The Kenya Medical Laboratory Technician and Technologist Board describes the term "workload" (KMLTB ACT, 2022). Workload is therefore calculated by the Workload Indicator of Staffing Needs (WISN) (Thomas et al., 2025). The workload for the laboratory, therefore, existed at 75 tests per day for each LW. The study based on the workload in Narok County was assessed from each laboratory work against the number of tests performed daily. This is meant to inform policymakers and management on employing laboratory workers based on the WISN. The study was assessed through the focus interviews to establish whether the non-laboratory professionals were inclusive of the laboratory worker during the staff appraisal process. Suppose the findings are found; they would advise on the work ethics. Ideally, laboratory biosafety and other diagnostic procedures are purely on the laboratory workers because they are licensed in the same (Rajan, D., 2023). Rajan goes on to say that biosafety is based on professionalism.

The study established that the workload was cutting across all other cadres; however, laboratory workers were more affected. A large volume of workload in the laboratories reflects great staff shortages, extended working hours, and extensive environmental pressure. Studies indicate that these laboratory workers, because of processing a high volume of patients' specimens, process up to 48 per week (Thomas et al., 2025). The World Health Organization has produced a manual on how to calculate workload for laboratory workers based on WISN (WHO, 2023). Employers must use that formula to avoid overworking the LWs. In the processing of overworking these LWS, the biosafety and biosecurity will be compromised. The formula works for every LW. On the contrary, private hospitals, where they always

have a heavy workload, did not bother them so much, because this meant something in their institution. So, a heavy workload was applicable among the public hospital laboratory workers. This study recommends the WISN for any employment of LWs.

2.8 Compliance with Laboratory Biosafety and Biosecurity among Laboratory Workers

Compliance is the adherence to the laid-out standard procedures and practices (Cornish et al., 2021). In the biosafety biosecurity compliance is key towards the prevention of laboratory-acquired infections and accountability of valuable biological materials within the laboratory. Therefore, compliance with biosafety and biosecurity practices is essential for ensuring safe handling of biological materials in laboratory environments. If compliance involves adherence to established guidelines, regulatory frameworks, and institutional policies designed to minimize biological risks and prevent laboratory-acquired infections, it must be treated with the greatest respect it deserves. In Kenya, assessment of biosafety and biosecurity implementation has led to the establishment of regulatory frameworks aimed at ensuring safe handling, use, and introduction of genetically modified organisms and other biohazards (Muriithi et al., 2024). The National Biosafety Authority is responsible for oversight of biosafety and biosecurity matters in Kenya. Compliance with biosafety practices is guided by regulations outlined in the Biosafety Act, 2009, together with national laboratory biosafety and biosecurity guidelines. These regulations promote regular assessment of biosafety procedures, monitoring of compliance, and enforcement of safety standards in laboratory settings. According to the World Health Organization, the framework of BB must be developed for countries that do not have it and for those that already have it to review (WHO., 2020). The outbreak of Covid -19 caught the laboratory workers off guard, and this forced them to revise and strengthen the already existing biosafety

and biosecurity. While the entire population of health workers was working from home, the laboratory workers worked tirelessly in the laboratory. This confirms that the element of biosafety and biosecurity implementation in laboratories is not only a matter of knowledge but a practice, and must be mandatory.

Compliance with biosafety and biosecurity practices ensures that laboratory workers adhere to safe laboratory procedures, implement risk management strategies, and follow containment guidelines. Regular assessment of compliance helps identify gaps in implementation and informs the development of corrective measures. Compliance is therefore an important component in evaluating biosafety and biosecurity implementation among laboratory workers. In this study, the issue of compliance was addressed independently.

2.8.1 Compliance

Biosafety and biosecurity compliance involve a range of measures designed to protect laboratory personnel, the environment, and the public from unintentional exposure to biological agents or misuse of hazardous materials. Key components of compliance include conducting a risk assessment by the laboratory worker, implementation of containment and safety measures, training, emergency preparedness, and adherence to regulatory requirements. From the proper and consistent use of PPE to the following of SOPs are all primary elements of the BB practice. Waste management is another important aspect of biosafety. Availability of safe/clean water and provision of safe hand washing work together towards attaining biosafety practices (Ahmed et al., 2022). this study addressed the issue of PPE , SOPs and how the were really applied in the laboratories.

These components work together to strengthen laboratory safety and reduce risks associated with handling infectious materials. Compliance with these measures ensures that laboratory workers follow established procedures and maintain safe laboratory practices.

Risk assessment is one of the constraints addressed in compliance. It is, therefore, a fundamental component of biosafety and biosecurity. It involves identifying potential hazards associated with handling, storing, and transporting biological agents. Risk assessment also includes evaluation of vulnerabilities within laboratory systems to determine weaknesses that may expose laboratory personnel or the environment to biological risks. Once hazards and vulnerabilities are identified, mitigation strategies are implemented to minimize or eliminate identified risks. These strategies may include engineering controls, administrative measures, and the use of personal protective equipment. Effective risk assessment, therefore, enhances compliance and promotes safe laboratory practice (East Africa Training Consortium, 2019).

In addition, risk assessment should be conducted regularly to account for changes in laboratory procedures, the introduction of new equipment, or the handling of new biological agents. Continuous risk assessment helps laboratories maintain preparedness and improve implementation of biosafety and biosecurity procedures. In this study, compliance with risk assessment practices is appraised as a key indicator of biosafety and biosecurity implementation among laboratory workers.

2.8.2 Implementation of Containment and Safety Measures

Implementation of containment and safety measures is another critical component of biosafety and biosecurity compliance. Containment strategies are categorised into primary containment, secondary containment, and personal protective equipment.

Primary containment involves the use of biological safety cabinets and specialised equipment designed to prevent the escape of biological materials. This also includes the use of biosafety level laboratories designed according to the risk level of pathogens handled. These facilities provide controlled environments for safe handling of infectious agents.

Secondary containment involves facility design and operational procedures aimed at preventing the spread of biological agents beyond primary containment areas. These measures include appropriate ventilation systems, waste disposal procedures, decontamination protocols, and restricted access to laboratory areas. Secondary containment, therefore, provides an additional layer of protection for laboratory personnel and the surrounding environment.

Personal protective equipment forms an important component of containment and safety measures. Provision and proper use of personal protective equipment, such as laboratory coats, gloves, eye protection, masks, and respirators, helps reduce exposure to infectious agents. Availability and correct use of protective equipment are therefore essential in ensuring compliance with biosafety and biosecurity procedures (International Livestock Research Institute, 2023).

2.8.3 Training

Training is a key component of biosafety and biosecurity compliance. Training programs educate laboratory personnel on hazard identification, risk assessment, emergency response, and safe laboratory practices. Training also ensures that personnel demonstrate competency in assigned tasks and responsibilities. Effective training programs integrate theoretical knowledge with practical application to ensure

laboratory workers can apply biosafety principles in routine laboratory operations (Muriithi et al., 2018).

Training also enhances awareness of biosafety guidelines and promotes adherence to standard operating procedures. Laboratory workers who receive regular training are more likely to comply with biosafety practices and demonstrate competence in handling biological materials. A study conducted in Morocco among nurses working in level 2 and level 3 containment facilities recommended that biosafety training curricula should integrate theoretical instruction with practical training. The study further recommended that biosafety training be mandatory as part of institutional safety culture (Bajjou et al., 2020). These findings emphasise the importance of training in improving compliance with biosafety and biosecurity practices, particularly in laboratory environments where biological specimens are handled daily.

2.8.4 Emergency and Incident Response

Emergency and incident response is an essential component of biosafety and biosecurity compliance in laboratory settings. Development of an emergency response plan is critical, as it outlines procedures for managing accidental releases, exposures, spills, injuries, and other laboratory-related emergencies. An effective emergency plan guides immediate actions to minimise risk to laboratory personnel, the environment, and surrounding communities. Such actions include alerting nearby personnel, restricting access to affected areas, and using appropriate personal protective equipment before initiating response procedures. In cases involving hazardous spills or injuries, evacuation of the affected area and contacting emergency services may be required. For smaller spills, appropriate neutralisation, absorption, and disposal procedures should be followed depending on the type of biological or chemical hazard involved.

Laboratory spills are common occurrences, and inadequate response may increase exposure risks and institutional liability. Strengthening spill response strategies and ensuring the availability of spill kits and emergency guidelines are therefore important components of biosafety compliance (Almoabadi et al., 2024). Incident reporting systems should also be established to encourage reporting of laboratory accidents, near misses, and breaches of biosafety procedures. Reporting promotes learning from incidents and supports the implementation of corrective actions. Regular emergency drills and simulation exercises are recommended to ensure preparedness and improve response capacity among laboratory personnel (Abedsoltan & Shiflett, 2024). In this study, emergency preparedness and incident response are assessed as key components of compliance with biosafety and biosecurity practices in laboratories within Narok County hospitals.

2.8.5 Regular Adherence

Regular adherence to biosafety and biosecurity practices refers to continuous conformity with established regulations, guidelines, and institutional policies governing laboratory safety. Biosafety practices are typically regulated at national, regional, and institutional levels to ensure standardised implementation of safety procedures (Njenga, 2022). Regular adherence requires consistent implementation of risk assessment procedures, use of personal protective equipment, adherence to standard operating procedures, and compliance with training requirements.

Studies assessing biosafety and biosecurity protocols have emphasised the need for strong institutional policies to improve compliance in laboratory settings. Implementing comprehensive biosafety policies promotes adherence to safety standards and enhances laboratory safety practices (Sessou et al., 2025). This study,

therefore, assesses compliance with biosafety and biosecurity practices among laboratory workers in Narok County hospitals to determine adherence to established biosafety protocols.

Risk assessment and risk management are also important components of regular adherence. Identification of potential biohazards and implementation of mitigation measures help reduce exposure risks. Integration of quality management systems in laboratory processes improves compliance with biosafety procedures. Risk management techniques applied at different phases of laboratory testing help identify causes of hazards, evaluate consequences, and implement appropriate control measures (Tziakou, Fragkaki & Platis, 2023). Continuous monitoring and evaluation, therefore, enhances compliance with biosafety and biosecurity practices.

Training of laboratory workers also contributes to regular adherence to biosafety guidelines. Continuous training familiarizes personnel with risks and the safe handling of biological materials. During the COVID-19 pandemic, studies reported increased adherence to infection control guidelines among laboratory personnel, highlighting the importance of awareness and training in improving compliance (Nimer *et al.*, 2021). Regular refresher training programs, therefore, strengthen adherence to biosafety and biosecurity procedures.

Standard Operating Procedures (SOPs) are essential tools for ensuring regular adherence to biosafety and biosecurity practices. SOPs provide detailed written guidelines for performing laboratory procedures consistently and accurately. These procedures help reduce errors, improve quality, and provide a framework for training and compliance. A study conducted in Bomet County reported that professional education, leadership factors, and work environment influenced adherence to standard

operating procedures among laboratory personnel (Chaleabo, 2022). This study, therefore, evaluates compliance with SOPs as part of biosafety and biosecurity implementation among laboratory workers in Narok County.

2.9 The Conceptual Framework

The study conceptual frame work is informed by the study variables. Bio safety practices and biosecurity measures, training, laboratory practice, and laboratory baseline profile were core variables in this study. BB trainee delivery and evaluation will be exhaustively assessed in the reference of their training, their current level of competence , trainee reactions, beliefs and attitudes and the context to establish any constraining factors that may inhibit the performance of biosafety and biosecurity.

In brief, this study will evaluate the training of LWs in clinical laboratory facilities in performing BB procedures. Having in mind that the factors that the study will adopt will be the Input-Process-Outcome (IPO) model developed by (Bushnell, 1990). This is a system-based approach model, used mostly in in-depth evaluation of training from development through delivery and impact (Bushnell 1990, Eseryel 2002). Four levels of assessment are allowed by the IPO model and all are done simultaneously. Any factors that may prevent the successful implementation will be reviewed. Exploration of the program indicators will be at first level; this will be before the evaluation. These will be like characteristics of BB Core model, Training curriculum and content(BSL,containment & SOPs), Laboratory resources (human, facilities equipment and budget) and trainee baseline profile(prior knowledge, experience & roles. This will be the input in this model

The second level will involve the evaluation of the actual training. This will include modes of training training delivery and evaluation; method of delivery:(lecturer,

simulations and practicals), modes :(virtual,physical hands on, blended) and assessment :(WHO/MOH tool, scales grading and observation checklists) .this is the process of the model.

The third level is the output in which the competence gained ; Trainee reactions (satisfaction scores, perceived utility of training) and knowledge & skills achieved:(certificate, skills and attitudes),

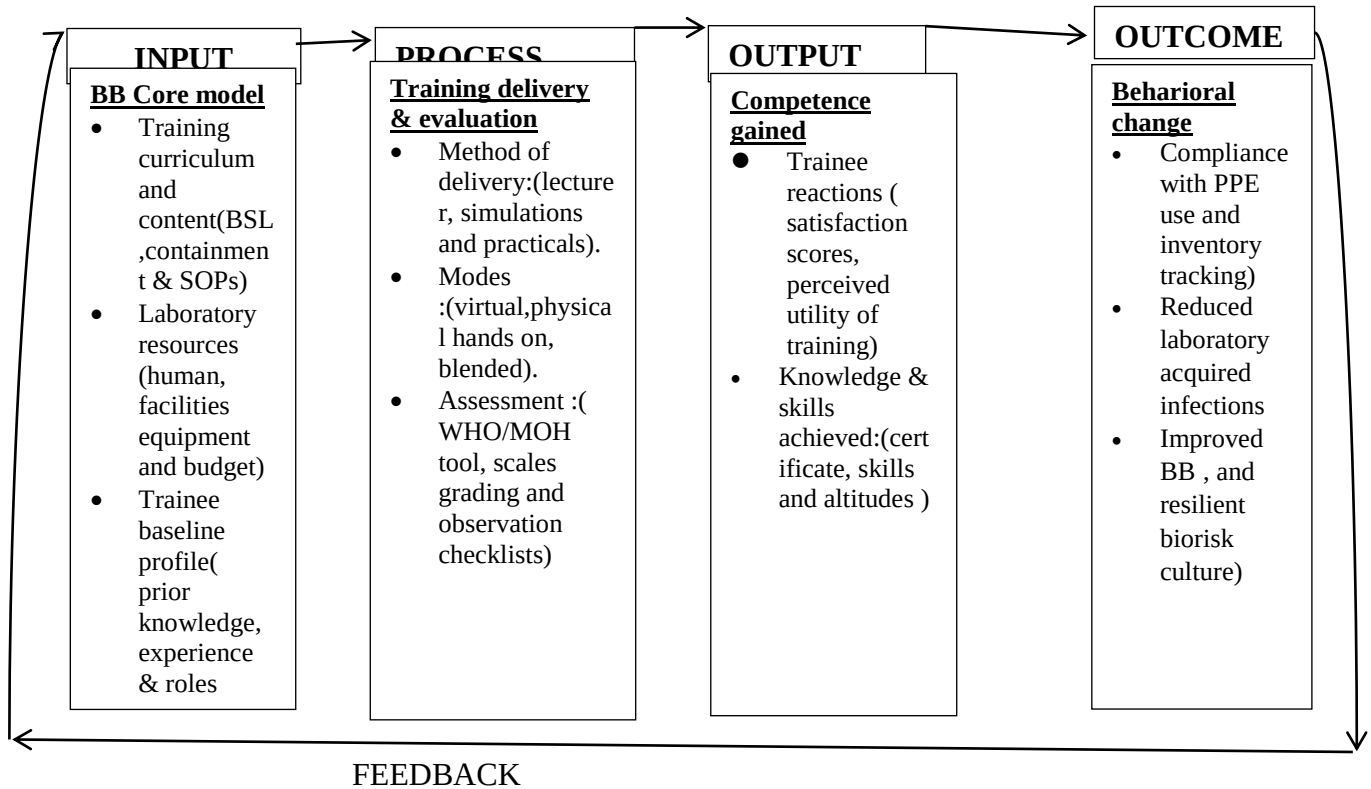
Finally is the outcome which is the Behavioral change ; these are compliance with PPE use and inventory tracking, reduced laboratory acquired infections and improved BB , and resilient biorisk culture) Assessed tools on issues of biosafety and biosecurity will be developed using- a grading scale will be used adopted from (Padde *et al.*, 2022).

Figure 5. below illustrates the IPO model as it relates to variable in this study. It is worth

noting that feedback loops at all phases means that the findings should be able to generate conclusions and recommendations that will be significant for curriculum developers, trainers and other professionals in medical education who stakeholders in various levels. performance of BB tasks by LWs. The need for BB tasks in medical profession cannot be overemphasized and opportunities are there for LW presenting with LAIs. The extent to which BB are equipped with the knowledge and skills to do this BB is another question altogether, as it seems that many are not adequately competent. Training opportunities for LWs to gain skills to perform BB news do exist, with nature mode and content among different institutions varying to a certain degree. Training using guidelines have been documented in KMLTTB however this has not been done in many LWs. Certain barriers have been identified in literature, which work against the effective performance of BB by LWs. These barriers can be

personal, organizational or administrative. In conclusion, the conceptualization of the variables in this study has been described in detailed.

FIGURE 4: CONCEPTUAL FRAMEWORK / MODEL (ORINA,2026)



2.9 Conclusion

The literature reviewed in this chapter highlights the importance of biosafety and biosecurity education, training, and compliance in improving laboratory safety. Smith et al. (2018) emphasized the need for enhanced biosafety education and training among laboratory workers. The findings from previous studies suggest that discrepancies often exist between theoretical knowledge and actual implementation of biosafety practices. Bridging this gap requires incorporating practical exercises, hands-on training, and competency-based assessment into training curricula. Such approaches enhance laboratory workers' readiness to implement biosafety and biosecurity procedures effectively.

Cross-sectional surveys among medical laboratory technologists have reported varying levels of awareness and compliance with biosafety measures (Williams et al., 2017). Although some laboratory workers demonstrate favorable attitudes toward biosafety practices, gaps remain in adherence to safety protocols. These findings highlight the need for targeted interventions to improve awareness, correct misconceptions, and strengthen compliance with biosafety guidelines. Educational programs should therefore emphasize the importance of biosafety practices to prevent laboratory-acquired infections and protect public health.

Compliance is a key element in biosafety and biosecurity because it involves adherence to biosafety and biosecurity protocols at the workplace (Gao et al., 2024). There is always the issue that knowledge and skills of practice are different things. Knowledge is understanding the procedures about a certain practice, while a skill is how you do it. So, compliance has more to do with skills and is therefore suitable for Biosafety and biosafety practices. It is therefore important to always be on your toes concerning biosecurity checks to ensure compliance. This study assessed compliance using the WHO/MOH standardized checklists.

Garcia *et al.* (2020) highlighted the importance of integrating biosafety training into medical laboratory curricula. The incorporation of practical exercises enables learners to apply theoretical knowledge in controlled environments and improves their competence in handling biohazardous materials. Such integration promotes 2024' ss responsible laboratory practice and strengthens biosafety culture among laboratory personnel. Continuous inclusion of practical biosafety training is therefore necessary to prepare laboratory workers to handle biological agents safely.

Chowdhury *et al.* (2017) explored laboratory staff perspectives on dual-use research of concern and emphasized the need for clear regulations, ethical frameworks, and improved awareness. Open dialogue and collaboration among researchers, regulatory agencies, and security experts were recommended to strengthen biosafety and biosecurity practices. Addressing these issues contributes to the ethical advancement of scientific research while minimizing biological risks.

Jones *et al.* and Ormond *et al.* (2019) further highlighted challenges faced by laboratory workers in implementing biosafety protocols, including limited resources, inadequate communication, and insufficient training. Addressing these challenges requires improved resource allocation, continuous professional development, and interdisciplinary collaboration. Strengthening these components enhances biosafety implementation, improves compliance, and promotes safety among laboratory personnel. The chapter concludes with the conceptual framework showing the variable relationships .

CHAPTER THREE

3.0 RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter examines the study design and methods applied to meet the objectives of this study. It relates to the philosophical orientation, research methods, research design, area of study, target population, sample and sampling techniques, data collection instruments, validity and reliability of the instruments, data collection procedures and methodologies, and data analysis procedures. It also accounts for the ethical consideration of both institutions of research, the university and participants' consent.

3.2 Research Design

The research design here was the strategic framework that guided the researcher on the use of research tools , data collection and analyzing of the same. This study impressed the use of cross-sectional descriptive study which helped the research to collect and analyze data from a population at a single specific point in time.

3.2.1 Research Approach

The study used a mixed-methods approach to collect data, including phenomenological design in consistent with its objectives (Chih-Pei, H. U., & Chang, Y. Y., 2017). The mixed-methods approach involved sequential and conversational approaches. The study followed a sequential design, in which quantitative data were collected first, followed by qualitative data (Chih-Pei, H. U., & Chang, Y. Y., 2017). The qualitative data added context to the quantitative data, enhancing and enriching the findings and helping generate new knowledge.

3.2.2 Research Design

A research design is a detailed plan that outlines how a study was conducted to answer the questions raised in research, from assumptions to methods of data collection and analysis (Creswell, J. W., & Clark, V. L. P., 2017). Based on the definition above, the literature, and the chosen philosophical paradigm, the most suitable research design for this study was the mixed-methods approach, which combined qualitative and quantitative designs. The mixed-methods approach was further defined as a combination of qualitative and quantitative data collection and analysis within a single study to gain greater insight into a research problem. The use of both approaches strengthened their strengths and, at the same time, mitigated their weaknesses (Brannen, 2005; Creswell & Plano Clark, 2018).

This design involved collecting both quantitative and qualitative data, which were then merged to provide a comprehensive analysis of the application and opportunities for implementing biosafety and biosecurity in Narok County hospitals among laboratory workers in Kenya.

A quantitative research design/strategy (cross-sectional survey) was used to gather numerical descriptions of the level of application of biosecurity practices and opportunities for their implementation among all laboratory in-charges and TOTs in the Narok County Hospitals. A qualitative research design/strategy (phenomenological research) was used to elicit laboratory workers' perspectives on biosecurity and biosafety practices. The qualitative approach complemented the quantitative strategy. The triangulation of all data (qualitative and quantitative) led to a credible understanding of the study. This design was chosen because its overall strength is greater than either qualitative or quantitative research (Creswell, J. W., & Clark, V. L. P., 2017). Mixed methods also reflected how individuals naturally

collected data by integrating quantitative and qualitative data (Clark, V. L. P., 2017). A mixed-method design was key in this research in the sense that it facilitated the researcher to collect rich, detailed data.

3.2.2.1 Surveys

Participants, based on their knowledge, responded with information from their experience that directly aligned with the research's issues of interest (Pretorius *et al.*, 2019). The four types of data collection procedures used in surveys: self-administered questionnaires, interviews, structured document reviews to collect financial data, medical or school information, and structured observations (Al-Khatib *et al.*, 2024). This study adopted a survey design; questionnaires, observations, and focus group discussions were used to collect data, and document analysis was used to examine existing factors related to training needs, constraints, and the perceived competence of medical laboratory workers.

3.2.2.2 Descriptive Design

This study utilized a descriptive study design. Descriptive research offered exact details about a person, an event, or a state of affairs ((Kaur, 2023), (Kim, Sefcik & Bradway, 2017), (Jafri, Ahmed & Siddiqui, 2020), (Arifin, Yusuf & Yuwono, 2021), & Delahunty-Pike *et al.*, 2023)). the primary goal of descriptive research was to accurately describe a subject/object (Procter, 2018). The method for gathering, evaluating, interpreting, and reporting data in research investigations is known as research design (Macke, 2017). It was the overarching strategy for linking the relevant with the conceptual research topics.

The independent variables were not available for manipulation. For example, it was not possible to experimentally manipulate respondents' ages—the descriptive study design aimed to identify a causal relationship between the independent and dependent



3.3 Study Site

This study was conducted across all medical laboratories at Narok County Hospitals. Narok County was within the South Rift region and had a population of 1,130,703, with a population growth rate of around 21% at the time of this study. The following healthcare facilities provided laboratory services to the population: 39 biosafety level 1, and 31 biosafety level 2. Regarding personnel, the county had a workforce of 977 healthcare workers, comprising 116 laboratory workers where by 81 LWs were in public hospitals and 35 LWs in private hospitals (Copyright: Narok County Government). It is important to note that only 71 and 31 LWs were present in public and private hospitals during the time of study.

However, the researchers chose Narok County hospitals because of different biosafety levels. Narok County referral hospital was undergoing ISO certification. Narok had skilled personnel and educators in biosafety and biosecurity who could offer helpful advice and direction during the study. The pilot study was conducted at Masai Mara University Hospital.

3.4 Study Population

It involved laboratory workers across all the laboratories in Narok County Hospital. These hospitals included Narok County Referral Hospital, Kilgoris, Transmara West sub-county, Nairagie Enkare sub-county, Ololulunga sub-county, Golgorian sub-county, Ewaso Ngiro, Ongata, Baraka (private), Medicacia (private), the Aga Khan (private), Nasha Lengot Medical Centre (private), The Shephard, St. Mary's Catholic Kilgoris (mission), Manyatta (private), and Premier Care (private). Also, the following Health centers had laboratories: Sogoi, Enabelbel, Murwadikir, Salatunka, and Lemiso. Narosura, Morijo, Entasekera, Iindungiso, Oloolaiser, Masantare, Maasai Mara University and Olu Kurunto. All the LWs in Narok hospitals, as well as the

laboratory in charge, were included in the study. Their level of education was considered because it contributed to the individual's perception of new ideas. There were different levels of training, starting from certificates to the higher levels: diploma, undergraduate, and postgraduate degree holders. All the laboratory professionals had one of those qualifications. All the Laboratory workers in Narok County Hospital laboratories were part of the study , that includes laboratory incharges and TOTs. The study was not done in collaboration or in comparison with other departments, institutions or other organizational bodies like Non- governmental organizations (NGOs).

The study targeted the laboratory workers because of their nature of work: collecting patient specimens, analyzing them, managing wastes, and archiving the specimens for future reference. These biological specimens were considered highly infectious, and if not handled with appropriate biosafety measures, they posed an infection threat to LWs. The laboratory in-charges were the overall managers in these laboratories who had the responsibility of coordinating all the laboratory matters in the hospitals, hence were part of the study.

3.5 Inclusion and Exclusion Criteria

3.5.1 Inclusion Criteria

Laboratory workers in Narok County in both public and private hospitals who were registered by KMLTTB were included in the study.

3.5.2 Exclusion criteria

Laboratory workers who were on leave, suspended, or no longer working in the medical laboratories were excluded from the study. Hospital workers found in the laboratory during the time of the study, but not known as laboratory workers in Narok hospitals.

3.6 Sample Size Determination (census)

Census for sample size determination was used because the LWs' population was small and manageable improving representativeness. Also, the sample size was defined as the number of the target population or observations that must be included in a study, which was a representative of a larger population. Sample size was critical in determining the validity and reliability of research findings.

According to Ismail, N., Kinchin, G., & Edwards, J. A. (2018), extant literature suggested that a pilot study sample should be 10% of the sample projected for the larger parent study (Connelly, 2008). The total population of the participants in the selected hospital laboratories was 102 LWs (of whom 10 participants participated in the pilot study (10% of 102 taken from the two BSLs and hence excluded from the actual study). 14 LWs were not available during the time of study; some were on leave, some were on sick leave, and others were attending to unavoidable circumstances such as a funeral. They were not found even during the return visit by the researcher. The remaining 102 participants took part in the main study, which is considered to be a small number, giving justification to take the whole population as the sample; hence, the census method was used.

The laboratory in-charges were considered medical laboratory professionals in this study, only that they had been given this designation to ensure smooth flow of work and to assign responsibility, hence forming part of the total population. The laboratory in-charges were medical laboratory professionals who had been given this designation to ensure the smooth flow of work and to assign responsibility, hence forming part of the total population. The Laboratory in-charges and TOTs (see appendix 9A) should understand that they are the laboratory managers and trainers, hence their

responsibility to monitor bio-safety and bio-security practices and report any non-conformity. This enabled them to be part of the population involved in the study.

3.7 Data Collection Methods

The research instruments used included: structured questionnaires, interviews, site visits, and

Checklists. The tools chosen enabled the researcher to use a mixed-method type of research. The questionnaire contained both open-ended and closed-ended questions—the interview sought both qualitative and quantitative data. Quantitative interviews were similar to qualitative interviews in that they involved some researcher/respondent interaction. However, the process of conducting and analyzing findings from quantitative interviews differed in several ways from that of qualitative interviews. The respondents for the interview were in charge of the laboratories. The researcher carried out observations during the site visits as well as administered the checklist, as explained under each tool.

3.7.1 Quantitative Data

Quantitative Data collected in this study were from LWs working in Narok County hospitals. These data were based on the study's objectives. The following quantitative data were collected:

1. Sociodemographic Data of Laboratory Workers

- Age
- Gender
- Years of experience
- Level of education

- Type of healthcare facility (public vs. private)

2. Knowledge and Awareness of Biosafety and Biosecurity

- Scores from standardized biosafety and biosecurity knowledge assessments
- Training history (e.g., number of training sessions attended, date of last training)
- Self-reported confidence levels in implementing biosafety measures (measured using Likert scales)

3. Implementation of Biosafety and Biosecurity Practices

- Frequency of adherence to biosafety protocols (e.g., use of PPE, hand hygiene, disinfection procedures)
- Compliance rates with WHO and MOH biosafety guidelines
- Presence of risk assessment protocols in laboratories

4. Constraints Affecting Implementation

- Availability of biosafety resources (e.g., PPE stock levels, availability of biosafety cabinets)
- Perceived institutional support (e.g., financial and material support)
- Workplace challenges related to biosafety and biosecurity (measured through structured survey questions)

5. Outcome Measures

- Incidence of laboratory-acquired infections (self-reported or recorded)

Number of reported biosafety-related incidents in the past.

3.7.2 Qualitative Data

The qualitative component provided deeper insights into the implementation of bio-safety and bio-security practices. The study collected the following qualitative data:

1. Perceptions and Experiences of Laboratory Workers

- Perceived effectiveness of biosafety and biosecurity training programs
- Personal experiences with biosafety and biosecurity challenges in the workplace
- Attitudes towards biosafety regulations and their enforcement

2. Barriers to Implementation

- Laboratory workers' perspectives on the main challenges in adhering to biosafety protocols
- Institutional factors affecting biosafety compliance (e.g., leadership support, organizational culture)
- Ethical and cultural considerations influencing biosafety practices

3. Suggestions for Improvement

- Recommendations from laboratory workers on how to enhance biosafety training
- Proposed strategies for improving biosafety infrastructure and policy enforcement
- Perspectives on policy changes that could strengthen biosafety and biosecurity implementation
-

4. **Observational Data**

- Researcher observations of actual biosafety practices in laboratories (e.g., PPE use, laboratory design and workflow, decontamination procedures)
- Differences between self-reported practices and observed behaviors

5. **Insights from Key Informants (Supervisors, Policy Makers, Trainers)**

- Views on current training effectiveness and gaps
- Institutional policies and support mechanisms are in place for biosafety and biosecurity.
- Challenges in enforcing biosafety compliance

These qualitative data will be collected through interviews, focus group discussions, and direct observations to complement and provide context to the quantitative findings.

3.7 Data Collection Instruments

3.7.1 Quantitative data collection instruments.

Data were collected using research-administered structured questionnaires, which assessed laboratory workers' self-efficacy, knowledge, skills, attitudes, and adherence to biosafety and biosecurity protocols. The questionnaire included both closed-ended and Likert-scale questions, which quantified responses effectively.

The researcher-administered approach ensured participant privacy and minimized self-bias. For enhanced reliability and validity, the questionnaire was adapted from previously validated biosafety and biosecurity assessment tools and refined through a pilot study before full deployment.

The questionnaire was distributed physically and electronically, maximizing response rates. Measures such as follow-up reminders were implemented, which improved participant engagement and ensured adequate data collection.

3.7.2 Self-Efficacy scale

A 20-item, 5-point Likert scale self-efficacy instrument was used to assess participants' confidence in their ability to successfully perform biosafety procedures. Responses ranged from "strongly disagree" (1) to "strongly agree" (5) (Appendix 5).

This instrument, originally developed by Cole (2022), was designed to evaluate self-efficacy in course-based research modules in introductory biology. It was adopted and used in this study to measure laboratory workers' perceived competence in implementing biosafety and biosecurity practices.

3.8 Qualitative data collection instruments

Qualitative data were collected using four instruments developed by the researcher based on a review of the literature. These instruments included:

1. Questionnaire—open-ended questions (with space for a written response) yielded descriptive insight into the implementation of BB. It facilitated the self-expression of the laboratory worker in the practice of BB.
2. Interview Guide – Structured to gather in-depth insights from individual participants regarding their experiences and perceptions of biosafety and biosecurity practices.
3. Focus Group Discussion (FGD) Guide – Facilitated group discussions among laboratory workers exploring shared experiences, challenges, and perspectives on biosafety implementation.
4. Document Analysis Guide – Used to examine relevant institutional records, policies, and reports to assess the extent of biosafety and biosecurity compliance.

3.8.1 Questionnaire

A questionnaire was used as an investigation tool that consisted of inquiries designed in line with the study objectives, helping the researcher collect data for analysis and thereafter guide the writing of the findings. Advantages of using questionnaires for qualitative data collection include: enabling the collection of rich, insightful responses and contextual information from many different respondents, particularly through open-ended questions, and at the same time offering benefits like scalability, cost-effectiveness, respondent anonymity, and efficient remote data collection. Some of the disadvantages of using questionnaires included: closed-ended questions, which were difficult to construct because categories must be well thought out, and responding to open-ended questions was time-consuming. This eliminated some respondents. This tool was administered to the laboratory workers by the researcher, whom the research assistants assisted.

3.8.2 Interview Guides

The study used interview guides, which were also semi-structured interviews, to seek information from the laboratory heads and TOTs who taught biosafety and biosecurity (appendix 10a).

3.8 3 Document Analysis

The most current MOH biosafety and biosecurity curriculum document concerning the training of MLS on biosafety and biosecurity was analyzed. A checklist that was used comprised areas that literature had identified as critical in the training of MLS in Biosafety and biosecurity management. Analysis was done based on content, modes of teaching, methodologies and relevance of biosafety and biosecurity. (Appendix 8).

3.8.4 Focus group interviews

The focus group as a method of data collection involved small groups of individuals who were chosen due to their knowledge about the topic of interest (Adler, K., Salanterä & Zumstein-Shaha, 2019). This study identified two groups of LWS who participated in the focus group interview. One group composed of four LWS trained on BB, of the four, two were TOTs, and two were not TOTs (N=4). Another group composed of four (N=4), of whom had not had any training on BB, made a total of eight (8) participants. FGD participants (N=8). They were asked questions about the training for those trained and the others about the constraints of BB and their perception. Two laboratory incharges were among the two who were not trained in BB. (Appendix 10b)

The researcher directed the discussions but never participated on the discussions. In this research led discussions, the verbal communication was captured by use of audio tapes and the non verbal by video visual. The high quality digital audio recorder was placed in the center of the table and a back up of audio recording was done by techno spark smart phone in case the first one failed.

3.8.5 Observation

Observation was a way to gather data by watching people and events or noting physical characteristics in their natural setting. Observations here were overt (subjects knew they were being observed) and, at the same time, covert, especially on individuals who were doing procedures during the study (did not know they were being observed).

The researcher sought permission from the medical director in charge of the County in writing and was allowed to carry out research in a section of laboratories, as well as use the heads of laboratories' staff and TOTs as research participants (appendix 9).

This request indicated the various data collection tools that were included. The researcher physically visited the institutions in order to observe biosafety and biosecurity procedures in the hospital laboratories and collected evidence of the BB implementation and outcomes. However, the advantages of site visits included the ability to collect accurate information. Disadvantages of site visits included: time-consuming and expensive.

3.8.6 Checklists

The checklists had one section with five items that collected information on the type of physical facilities, location of facilities, adequacy of facilities, condition of facilities, and appropriateness of the facilities. Advantages of using a checklist include helping to produce a higher degree of awareness of the activity in question and helping people in responsible positions to become more aware of what they should be looking for. Disadvantages of using a checklist: Descriptive checklists were exhaustive, and the inability to relate individual activities to environmental components affected by these activities. The laboratory filled the checklists for the researcher once on site; the checklists were self-explanatory.

3.8.7 Quantitative Data Sampling

The census sampling method also selected participants for FGDs along the themes represented by the objectives on the sufficiency of the biosafety and biosecurity. The census identified heads of the hospital laboratories who supervised the LWs or trained on BB, who provided information on training needs and constraints. The document used was the Ministry of Health WHO/MOH Biosafety and Biosecurity Training Model.

3.8.8 Qualitative Data Sampling

The census also selected participants for FGDs along the themes represented by the objectives on the sufficiency of the biosafety and biosecurity. This technique selected key informants (MLT supervisors, trainers and policymakers.) Additionally, the census identified heads of the hospital laboratories who supervised the LWs or trained on BB to provide further information on training needs. The document used was the Ministry of Health WHO/MOH Biosafety and Biosecurity Training Model.

3.9 Pilot Study

The pilot study was done for Validity and reliability.

Validity is defined as the extent to which a test measures the construct or variable which it purports to measure (Lee, 2010). Lee contends that content validity is an appropriate method of establishing the validity of a set of tests seeking to ascertain performance. Content validity is the extent to which the measurement adequately samples the content domain.

A good way to establish content validity is to consult the professionals in that field. After adopting the MLT, BTTP and MRBL, the researcher sought LWs' views on the implementation of BB and TOTs in Narok hospitals. The questionnaires were adopted and customized locally by pretesting on a pilot study. The original validity, as in where they were developed for BTTP's reliability, was obtained by calculating Cronbach's coefficient alpha and reported 0.89 for the sample of LWS and 0.87 for the TOT (ISO, 2022).

Convergent validity was validated by higher correlations between MLT knowledge on biosafety ($r = 0.48$ for medical students, $r = 0.56$ for internal medicine residents)

Reliability, on the other hand, refers to the extent to which an assessment is free from error, accurate and provides consistent results (Lee, 2010). Lee suggests the use of the

test-retest reliability coefficient in ascertaining reliability. A test-retest reliability coefficient is obtained by administering the same test on two different occasions and then correlating the scores obtained on each occasion. Lee further recommends the Pearson Product-Moment Correlation to calculate the reliability coefficient. In line with this, the researcher administered the test to a group of 10 LWS in Ewaso Ngiro within the duration of one week. The correlation coefficient was calculated based on the two sets of scores obtained from this population. The correlation coefficient was medical laboratory knowledge 0.982; Biosafety training techniques and practice, 0.935; Monroon rating on biosafety level 0.626; Ashworth and colleagues (Answorth, 1984) reported a reliability coefficient of $r = .88$, which is an indication of high internal consistency of individual items on the BTTP. The average item variance was reported at .86 and the average inter-item correlation was .19. The BTTP showed acceptable levels of reliability (Cronbach alpha = 0.78) in a study that assessed Biosafety and Biosecurity Engagements among Workers in some Institutional Research Laboratories (Private and Public) in Abuja, Nigeria. (OLU et al., 2024). Lee recommends that correlation values higher than .80 are sufficient to qualify the test as reliable. Based on these MLTs, BTTP and MRBL were deemed reliable to test the suitability of BB implementation among LWs. The results of the pilot study showed that Cronbach's alpha for the MLT was 0.982; BTTP was 0.935; Monroon's rating of biosafety level was 0.626.

There are different reports about the acceptable values of alpha, ranging from 0.70 to 0.95. A low value of alpha could be due to a low number of questions, poor interrelatedness between items or heterogeneous constructs. For example, if a low alpha is due to poor correlation between items, then some should be revised or discarded. This specifically applies to BB practice, which has knowledge, skill, and

altitude which are not similar. Researchers' cautions about abandoning an instrument based on these Cronbach's alpha scores unless they are grounded in the 'tau equivalent model,' which assumes that each test item measures the same latent trait on the same scale. Therefore, if multiple factors/traits underlie the items on a scale, as revealed by Factor Analysis, this assumption is violated, and alpha underestimates the reliability of the test. (Hoekstra, 2019).

The data collection tools were pre-tested within Narok hospitals of BSL 1 and 2 of 10 LWs who were later excluded from the actual study. The data collection tools were used to help the researcher determine if the questions were appropriate and to assess how long it took to administer the tools. The pilot study comprised several components, which included: determination of the feasibility of the study protocol, Recruitment of subjects, testing the measurement instruments (questionnaire, observation checklist, and interview), and data entry and analysis.

A pilot study was a 'small study carried out by the researcher to test research protocols, data collection instruments, sample recruitment strategies, and other research techniques in preparation for a larger study. Before the pilot study began, researchers fully understood the clear purpose and question of the study; they were made aware of the procedures involved in the main study through the pilot study, which aided in the selection of the research method most suitable for answering the research question in the main trial (Thabane et al, 2019). It was one of the important stages in this research project and was conducted to identify potential problem areas and deficiencies, which aided in the research modification of the main study. It also helped members of the research team become familiar with the procedures in the protocol. It helped them decide between two competing study methods, that is, using

interviews rather than a questionnaire (Hollman, Davenport & Rhodes, 2024). The existing literature suggested that a pilot study sample should be 10% of the sample projected for the larger parent study (Connelly et al., 2018). A sample size of 10 staff was used in the pilot study. This was arrived at by applying the recommendations by Connelly et al (2018).

Instruments and protocol prior to implementation during the full study. It assisted in planning and monitoring. The analyzed data from the pilot study were part of evaluating the feasibility of the method, and procedures for the larger study, which was meant to identify potential flaws in the research design. It also refined data collection tools, observation issues like participant recruitment, and optimized the overall methodology and logistics of the main study. This data, therefore, was not used to test the hypotheses.

The pilot study was for validity and reliability

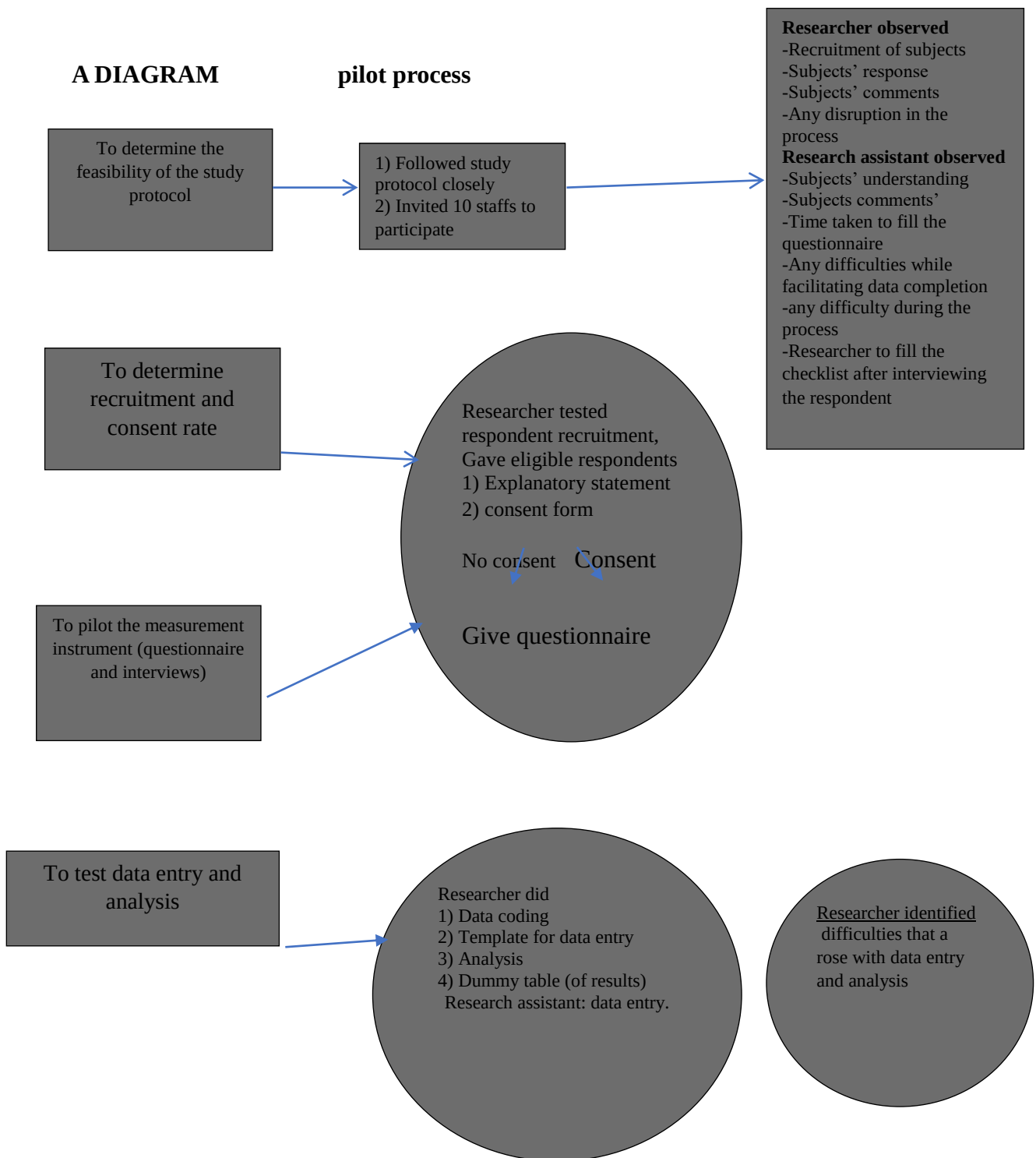


FIGURE 6: PILOT PROCESS

Flow chart of the pilot study: Adopted from (Thabane et al, 2010).

3.9.1 Summary of the pilot flow chart above

- **To determine the feasibility of the study protocol,** A pilot study was conducted in NCRH from 1st April to 30th June 2025. In this pilot, the provisional study protocol was strictly adhered to; that is, a small-scale version of the complete questionnaire was tested, from staff recruitment to data analysis. The researcher enrolled 8 staff from the involved department. Training of the research assistants was conducted, establishing their understanding of the research aims and protocol and determining the number of research assistants needed for the study.
- **Recruitment of subjects:** A participation invitation letter from the researcher was sent prior to the laboratory in-charges, requesting the invitee to kindly take part in the research study. The NCRH Laboratory in charge invited the staff for a meeting with the researcher, who in turn explained the aim and the process to participate in the study. The researcher gave adequate time to the staff to decide whether they wished to participate or not. Respondents demonstrated their desire to participate by signing the consent form, which was given to them by the researcher, assisted by the research assistants. Afterwards, the participants who consented to participate were given the questionnaire to fill out by the research assistant. The researcher recorded the response rate, and the research assistant observed that the filling of the questionnaire process of data collection progressed smoothly. At this point, the principal was given freedom to remain or leave at their pleasure, hence assured freedom to the participants as well as the researcher and research assistants.
- **Testing the measurement instrument:** The measurement instrument (a questionnaire) required self-completion by the staff with the assistance of research assistants. An important factor was to ensure that the questionnaire items

accurately addressed the research questions. The pilot also tested whether the questionnaire and checklist were comprehensive and appropriate, and that the questions were well defined, clearly understood and presented consistently. Respondent information statements and consent forms were also tested for comprehension.

- The questionnaire was divided into 7 sections which were related to a) socio-demographic characteristics of respondents; b) Laboratory worker beliefs c) Maroon rating on biosafety and biosecurity level scale (MRB) d) biosafety and biosecurity training techniques and practice (BBTTP) e) interview guide for both the trainer and trainee f) the focus group discussion g) summary of the questionnaire. All the comments from the respondents were taken into consideration and errors were amended and re-piloted until no further changes were considered necessary.

Data entry and analysis: Data from the 6 subjects were sorted, coded and entered into a computer by a research assistant who was not involved in data collection. Entry was direct into the Statistical Package for Social Sciences (SPSS) program, with specific codes used for each questionnaire and checklist item. Data was then analyzed using SPSS version 28. The analysis was mainly descriptive, with data from the 5 sections analyzed as indicated below.

3.10 Data Collection Procedures

The researcher made an initial contact with the supervisors in Narok County hospitals to get information and seek appointments. LWs, through their representatives and other technical staff, were first told about the research and the importance of having skills in biosafety. All who were interested were given a coded questionnaire, which had consent and data collection instruments, on a first-come, first-served basis. The

staff mobile telephone number and e-mail address were taken at the time of recruitment; this was written on a separate piece of paper that was destroyed after the analysis of data. The researcher and his assistant then collected the questionnaires.

3.10.1 Quantitative Data Collection Procedures

The researcher made an initial contact with the supervisors, in Narok county hospitals to get information and seek appointments. LWs through their representatives and other technical staffs were first told about the research and the importance of having skills in biosafety. All who were interested were given coded questionnaires which had consent and data collection instruments, on a first come first served basis. The staff mobile telephone number and e-mail address was taken at the time of recruitment; this was written on a separate piece of paper that was destroyed after the analysis of data. The researcher and his assistant then collected the questionnaires. In summary data was collected, cleaned and coded.

3.10.2 The Laboratory workers beliefs of Biosafety and biosecurity (LWB)

The laboratory belief scale was developed by the biosafety and biosecurity (Muriithi et al., 2017), and it was designed to assess the laboratory workers on biosafety and biosecurity practices in the laboratory. The LWB is a 10-item, researcher-report scale that determines an LW's position in terms of acceptance versus rejection on BBP (Appendix 6). This instrument used a 5-point Likert scale ranging from "strongly disagree" (1) to "strongly agree" (5). The maximum score was 100. Normed scores were 75. The higher the score, the higher the BBP of the resident, which meant that the laboratory workers thought well of BBP in both the laboratory and the environment

3.11 Data Management: Databases

The collected primary data were systematically sorted and organized to facilitate analysis. All responses were reviewed for completeness, edited for accuracy, and coded according to the study objectives before data entry.

3.12 Data Analysis Procedures

Data analysis involved categorizing, processing, and summarizing data to address the research questions (Gurmu, 2020). As a mixed-methods study, both qualitative and quantitative analysis techniques were applied to ensure a comprehensive interpretation of the findings. The data was analyzed using SPSS statistics version 30.0.

3.12.1 Quantitative data analysis and presentations

The collected questionnaire data were reviewed for completeness by the researcher before being entered into a computerized database. The data were then exported to Statistical Package for the Social Sciences (SPSS) statistics version 30.0 for analysis.

Chi square analysis was conducted using frequency tables, measures of central tendency (mean), and measures of dispersion (standard deviation). Chi square was used due to its ability to measure and compare frequencies, generating p-values for significance. Anova statistical method used to compare the means of three or more independent groups to determine if at least one pair is significantly different. Bivariate analysis was performed to examine relationships between variables using t-tests for independent samples. These tests compared differences in mean competence scores among MLTs and laboratory workers based on factors such as gender, additional training, and level of training. Multivariate analysis was conducted to assess relationships between multiple variables simultaneously. This analysis supported the achievement of Objectives 1, 2 and 3. All statistical tests were considered significant

at a 95% confidence level ($p < 0.05$). The findings were presented using tables and figures for clarity and ease of interpretation.

3.13.2 Qualitative data analysis

All interviews were recorded using a digital recording device and transcribed into a field notebook specifically designated for this process. Data analysis began immediately after each interview, starting with careful listening, reading, and re-reading of the transcripts. Summaries of each transcript were generated, compared, and contrasted through a process of constant comparison (Lincoln, 1985). In summary recorded data were transcribed verbatim and imported to SPSS qualitative software version 30 for analysis.

The data were systematically coded into categories, which were then grouped to identify meaningful patterns and relationships. This categorization allowed for the verification of associations between different categories, which led to the derivation of specific themes. Thematic analysis, as described by Jawn (2010), was applied to identify patterns relevant to the study objectives. These patterns were organized into themes, which were later reported and interpreted. Similarly, thematic analysis was conducted on curriculum documents, facilitating a comparison between the documented training guidelines and the curriculum for medical laboratory technologists (MLTs) discussed in the literature review. This approach enhanced the interpretation of data obtained from document analysis. Data were coded separately by the principal investigator and research assistant. Initial codes were discussed between the two coders and with the research team for comparison, concurrence, and to identify initial themes; some codes were modified, while others were dropped.

To ensure rigor in the study, credibility, auditability, and fittingness were addressed (Wathen & Burkell, 2002). Credibility was maintained through continuous immersion in the data, both individually by the researcher and in collaboration with a research assistant. Regular consultations with biosafety and biosecurity experts from KEMRI/CDC and the Ministry of Health (MOH) further strengthened the study's reliability.

An audit trail was maintained through detailed summaries documenting how data abstraction and reduction were conducted. Fittingness was ensured by discussing the findings in relation to existing research, using the literature to support or challenge emerging concepts. A structured checklist was used to identify points of convergence between the literature, the MOH guidelines, and the Kenya Medical Laboratory Technologists and Technicians curriculum. Identified themes were systematically reported and interpreted accordingly.

In conclusion similar codes were grouped to form themes and sub-themes.

The final identified themes were grounded into the data.

3.14 Data Présentations

Following data analysis, the results were summarized and presented using frequency tables, percentages, and pie charts, enhancing clarity and ease of interpretation.

3.15 Ethical Considérations

Permit number FAN: 5188 was obtained from Ethical approval to conduct the study was sought from the Institutional Scientific & Ethics Review Committee (ISERC) at the Moi Teaching and Referral Hospital/ Moi University School of Medicine (MTRH/MU) (appendix-14). The license No: NACOSTI/P/25/4180493 from the National Commission of Science, Technology, and Innovations (NACOSTI)

(Appendix 12) dated 15th October, 2025. Permission to conduct the study was obtained from the County Director of Health (CDH) of Narok County Government, reference no. DIR/NRK CNTY/MOH/60/VOL.VIII/224, where the study was carried out.

All the participants in the study gave informed consent (Appendix 13). At the end of the study, conclusions were made concerning the study subject. Any information that could be used to link the respondents to the research data collected was destroyed. Only individuals who had freely consented were permitted to participate in the study, and no one was given incentives or coerced to participate.

Participants were also informed that they had the right to withdraw at any point in the study. Confidentiality and Anonymity: The identities and replies of respondents were confidential. Participant logs, the only link between identifying information and code numbers, and all data were kept in a locked file cabinet. Only the researcher had access to the files. The code books that linked the participants' names with the code were destroyed once they were checked for accuracy. Participants were also informed that they will have the right to withdraw at any point in the study.

Confidentiality and Anonymity: Respondents' identities and replies were confidential. No victimization of any participant for taking part in this study because all the authorities were informed prior to the study, including those who did not take part. However, only the researcher accessed the files. The code books that linked the participants' names with the code were destroyed once they were checked for accuracy. The full contacts of the researcher were also included.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

This chapter reports the results of quantitative, qualitative and phenomenological data analysis pertaining to the objectives of this study. The reporting of statistical results in this chapter follows a consistent pattern: a restatement of the research objectives, after which pertinent descriptive statistics, inferential, and appropriate interpretations are presented. Descriptive statistics is usually the first step in any statistical analysis, regardless of simplicity or complexity. Descriptive statistics are helpful to condense data in an organized manner by expressing the relationship between variables in a sample or population (Kaur, P., Stoltzfus, J., & Yellapu, V., 2018). It is important to note at this time that the implementation and practice of biosafety and biosecurity are contained in the three components, namely, knowledge, skills, and attitude. Each of these traits was measured and analyzed separately using the instrument indicated above and acted upon above.

4.2 Analysis of demographic characteristics of respondents

The reporting of the results of quantitative data opens with a demographic description of participants who were involved in the data collection. The participants are described here by gender, age, professional qualification, years of experience, and bio-safety training. 102 questionnaires were entered into the database and had complete and valid responses for the key study variables and were therefore included in the final analysis. There were no system-missing cases consistent with SPSS version 31 default data handling procedures.

Table 4. 1: Demographics Characteristics of the Respondents (N = 102)

Variable		Number	Percentage (%)
Affiliation	Public	71	69.61
	Private/ faith based	31	30.39
Gender	Male	59	57.84
	Female	43	42.16
Age in years	20-29	32	31.40
	30-39	49	48.00
	40-49	18	17.70
	>50	3	2.90
Level of professional training	< diploma	10	9.80
	Diploma	66	64.70
	Bachelor' s	20	19.60
	> Bachelor' s	6	5.90
Years of experience in years	< 4	28	27.50
	5-9	28	27.50
	10-14	26	25.50
	> 15	20	19.50
Any additional training	Yes, BB for 1 week	27	26.50
	None	74	72.50
	Yes, risk management	1	1.00

Table 4.1 shows demographic characteristics of laboratory workers. All the LWs had professional training and were registered by KMLTTB. A total of 102 participants were recruited for the study. LWs in public hospital laboratories were 71 (69.61%), while in private and faith-based hospitals, they were 31 (30.39%). Based on gender, males were more than females, 59 (57.84%) and 43 (42.16%), respectively.

Age groups were also analyzed, and it was found that LWs (30-39 years) were 49 (48.00%), followed by the age group between 20-29 years, 32 (31.40%), 40-49 years were 18 (17.70%), and the least were those aged greater than 50 years, who were 3 (2.90%). 10 (9.80%) had a certificate level of training, 6 (5.90%) had a level above a bachelor's degree, 20 (19.6%) had a bachelor's level of training, and the majority, 66 (64.70%), had a diploma level of training.

In terms of years of experience, the majority had worked for <4 years, that is, 28 (27.50%), which was similar to those who had worked for 5-9 years, and the least worked for more than 15 years, that is, 20 (19.5%). Then the rest, 26 (25.5%), had worked for 10-14 years.

Those who had had additional training in biosafety and biosecurity were only 27 (26.50%), compared to those who had not, 74 (72.50%), and only 1 (1%) had had a risk management course as additional training. BB training from the FGD indicated there was little support from the county government and whoever wanted to have a training of the same was majorly based on their own initiative and support.

Laboratory workers for focus group discussions (FGDs) were divided into two groups among those numbered above. Group discussions: one consisted of four LWs with no additional training on BB, and the other consisted of four LWs with additional training in BB, making a total of eight LWs in FGD. Those trained appreciated the knowledge given.

One of the objectives of this study was to evaluate laboratory staff proficiency regarding biosafety and biosecurity, using standardized questionnaires and practical assessments as per their training to be competent in practicing BB. To achieve this objective,

Two methods of data analysis were used: document analysis of the biosafety checklist of laboratory ISO 15189 accreditation, which is the international standard for medical laboratories, demonstrating competence and quality; and the core curriculum from the Kenya Medical Laboratory Technologist and Technician Board. (Appendix 8) shows the document analysis guide that contains the key content areas that have been

utilized in the training of laboratory workers in implementing the biosafety and biosecurity practices in the laboratory.

4.2.1 Documents

An examination of the course content and methodologies utilized in training LWs and the implementation and practice of BB as per the bio-safety curriculum was conducted at Narok County Referral Hospital. Of the three TOTs, two were male, and one was female. Four of the LWs were female, and 4 were males.

One of the objectives of this study was to evaluate laboratory staff knowledge and skills regarding bio-safety and bio-security, using standardized questionnaires and practical assessments as per their training to be competent in practicing BB. To achieve this objective,

Two methods of data analysis were used: document analysis of the Biosafety checklist of laboratory ISO 15189 accreditation, which is the international standard for medical laboratories, demonstrating competence and quality and the core curriculum from the biosafety in Kenya. And indeed those trained demonstrated competence and knowledge in BB implementation.

The Medical Laboratory Technologist and Technician Board (Appendix 8) shows the document analysis guide that contains the key content areas that have been utilized in the training of laboratory workers in implementing the bio-safety and bio-security practices in the laboratory.

Summary of the documents

The Kenya Medical Laboratory Technician and Technologist Board Practitioners' Core Curriculum

1 Current (revised, 24th December, 2022).

Kenya biosafety and biosafety training curriculum. Approved 2022.

A checklist of laboratory ISO 15189 accreditation (2025)

The Narok County laboratory data on BB-trained personnel (2025).

4.2.2: Laboratory workers as per Sub-County

All the laboratory workers in the county were counted to establish the distribution of the 102 LWs across the county. Also, it was meant to establish whether the health facilities had laboratory personnel in order to be reached and interviewed about the BB implementation study (Appendix 6).

Table 4.2 Laboratory workers by Sub-county (N=102)

Sub county hospitals	Number of staffs	%
Narok East hospitals	11	10.78
Narok central	37	36.27
Narok North	4	3.92
Narok west	12	11.76
Narok South	13	12.75
Transmara east	10	9.80
Transmara	15	14.71
Male	59	57.84
Female	43	42.16

Table 4.2 shows the 7 sub-counties of Narok County, where the laboratory workers were working. Narok North had the lowest LWs (4, 3.92%), which were a way apart from each, followed by Transmara East with 10 (9.80%), 11 (10.78%), 12 (11.76%), 13 (12.75%), 15 (14.71%), and 37 (36.27%); and then Narok East, Narok West, Narok South, Transmara (Kilgoris) and Narok Central, where Narok County Referral Hospital is located.

4.3 Objective one results and Interpretation

Objective number 1 was ‘To Appraise the relationship between laboratory workers' knowledge on bio-safety implementation and their socio-demographic characteristics (e.g., age, gender, years of experience, and level of education).’ To achieve this

objective, LWs were grouped according to their demographic characteristics: gender, level of training, professional level of education, years of experience, and additional BB training (appendix 4). The purpose of grouping was because LWs were not the same demographically. This was also, meant to identify predictors of knowledge and guide targeted interventions.

These were then grouped and compared, and inferential statistical analysis was done to determine whether the differences were significant. To appraise the relation of knowledge and demographic characteristics in the BB implementation.

Table 4. 3:A Association between Knowledge Level and Socio-demographic Characteristics (N = 102)

Variable	χ^2	Df	P
Gender	1.94	2	.379
Age group	9.21	4	.081
Education level	15.02	6	.020*
Years of experience	12.11	6	.033*
Trained on BB	18.7	2	<0.001

Note: χ^2 = Chi-square statistic; df = degrees of freedom.

P < .05 indicates statistical significance.

The above table 4.3 shows the LWs relationship between their knowledge and socio-demographic characteristics, indicating that level of education (χ^2 (6) =15.02, p=0.020), years of experience (χ^2 (6) =12.11, p=0.033) and training on BB (χ^2 (2) =18.7, p=<0.001) were statistically significant, which implies that there is an association between laboratory workers' knowledge on bio-safety and bio-security practices.

Gender and age were not significantly associated with knowledge level (χ^2 (2) =1.94, p=.379, χ^2 (4) =9.21, p=0.081, respectively)

These findings implied that respondents' age or gender did not influence laboratory workers' knowledge. The distribution of knowledge across the two variables was even. The level of education showed strong statistical significance: LWs with higher qualifications had greater knowledge than those with lower qualifications. Similarly, years of experience had a significant impact on knowledge, with those with more than 10 years of field experience demonstrating greater knowledge and understanding than graduates and those with fewer years of field experience. Training on BB was a major boost to knowledge, as shown by the strong statistical significance above. This showed the need to emphasize training more workers in BB. One of the laboratory worker “ my years of experience in the laboratory has improved my knowledge in BB”. this was in response to number of years worked in the lab.

Table 4.3B: Comparison of knowledge level by gender

Variable	Gender				
	N	$\bar{x}$	SD	T-test	p-value
Male	59	9.58	7.22	0.662	0.551
Female	43	10.42	5.63		

A p-value of <0.05 was considered statistically significant.

The table above compares knowledge levels between males and females. It indicated no statistical significance between males and females in terms of knowledge level (p-value = 0.551). One assumption of this finding is that there would be no statistical significance even if females had slightly higher means than males, with a very small difference that would not qualify as significant under chi-square statistics.

4.4 Objective two

The objective was to assess laboratory staff's skills and knowledge in biosafety and biosecurity during BB implementation using standardized questionnaires and practical assessments. This objective quite different from objective one in that objective 1

identifies predictors of knowledge while objective 2 evaluates competencies across domains.

To achieve this objective, BB knowledge is based on Bio-safety Training Techniques and Practice (BTTP), Appendix 8.

Laboratory workers' knowledge was assessed using three variables: by level of professional training, age group and years of experience. The three variables had 7 domains each of Biosafety training techniques and practice (BTTP).

The seven domains, number one, is management: assessment of management was based on the provision and implementation of BB policy, the provision of PPE, the appointment of a safety officer, a backup system for sensitive information, including confidential information, and procedures for individual access to confidential information. Others include the availability of SOPs for Valuable Biological Materials (VBM) and guidelines restricting unauthorized personnel from labs.

Domain two is biosecurity: bio- the elements assessed were formal training on BB, whether LWs were oriented on BB before starting work in the lab, and whether there was mentorship on BB at work, among others.

Accountability for lab materials ranked third: this included laboratory inventory updates for valuable biological materials, procedures to prevent intentional escape of biological materials from the laboratory, and the availability of biohazard signage and storage for biological specimens.

Physical facility was the fourth domain: the elements were weather, enforcement of access control policy, and the presence of strategically placed closed-circuit televisions (CCTVs).

The facility had an intrusion detection system to detect unauthorized entry and biological agents.

Identification for both LWs and visitors was available, and the lab had self-closing, lockable doors.

Personal reliability was domain five: some of the elements were formal screening processes, including credentials, skills, and personnel traits, based on risk assessment, which are done in this place. And health assessments, including psychological and mental, are done before employment'

BB training and practice ranked sixth: the element was whether training, materials, trainers, and practice were provided.

Involving clinical mentors) Based on the bio-safety bio-security, this was the last domain to assess the trainers themselves, if they were competent in all the BB curriculum and practice

All seven domains' assessments responses were rated from 1= strongly agree; 2= Agree; 3= Indifferent; 4= Disagree 5= strongly Disagree.

The summary of all domains was summarized as poor, moderate or adequate knowledge. First, it started with a summary, followed by each item. In the summary, each correct response was assigned 1 point, while each incorrect response was assigned 0 points. The total knowledge score ranged from 0 to 100 and was categorized into poor ($\leq 50\%$), moderate (51–74%), and adequate ($\geq 75\%$) levels of knowledge.

TABLE4.5 Summary of Level of Knowledge on Bio-safety and Bio-security (N = 102)

Knowledge level	N	%
Poor	28	27.5
Moderate	39	38.2
Adequate	35	34.3

The performance based on knowledge level in bio-safety: 28 (27.5%) had poor knowledge, 39 (38.2%) had moderate knowledge, and 35 (34.3%) had adequate knowledge. From this deduction, a total of 74 (72.5%) respondents had moderate knowledge (>51%), indicating that quite a good number were well informed about their practice. This left a gap in training the other 28 (27.5%) to improve services overall.

NB

In this section, sample sizes vary depending on the variable being analysed and the subgroup analysis.

4.4.1 Knowledge and skills of bb based on level of professional training

After summarizing the seven domains, each was examined at the level of professional training. This was meant to gauge LWs' knowledge and skills in biosafety using a standardised assessment based on level of professional training. High levels of professional knowledge yielded good results (Tran A., 2025). The professional training levels analysed were <diploma, bachelor's, and > bachelor of LWs.

Table 4. 6: Level of professional training on management, bio-SECURITY AND accountability of lab materials

Variable	Management					Bio-security					Accountability of lab materials				
	N	$\bar{x}$	SD	F	p-value	N	$\bar{x}$	SD	F	P-value	N	$\bar{x}$	SD	F	P-value
<Diploma	10	26.40	7.00	1.51	0.203	10	17.40	5.87	2.08	0.088	10	19.60	7.12	3.98	0.005
Diploma	66	23.76	9.22			66	17.14	7.09			66	15.12	8.53		
Bachelor	20	21.65	8.66			20	14.35	6.24			20	18.05	7.29		
>Bachelor	6	16.83	10.61			6	10.83	7.65			6	8.50	7.89		

Table 4.6 presents the relationship between the level of professional training and laboratory workers' performance in three domains: management, biosecurity, and accountability of laboratory materials among 102 respondents. The analysis compares mean scores ($\bar{x}$), standard deviations (SD), and analysis of variance (ANOVA) results across four categories of professional training: <Diploma, Diploma, Bachelor, and >Bachelor levels.

In the management domain, <Diploma holders (n=10) recorded the highest mean score ($\bar{x}$ = 26.40, SD = 7.00), followed by Diploma holders (n=66) with a mean of $\bar{x}$ = 25.4 and SD = 9.2. Bachelor degree holders (n=20) had a mean score of $\bar{x}$ = 23.15 (SD = 8.6), while those with >Bachelor qualifications (n=6) recorded the lowest mean score ($\bar{x}$ = 15.83, SD = 10.61). Despite observed differences in mean scores across the categories, the ANOVA test ($F(3, 98) = 1.51$, $p = 0.208$) indicates that the differences were not statistically significant ($p > 0.05$). This shows that management performance scores did not vary significantly across different levels of professional training.

In the biosecurity domain, a similar trend was observed. <Diploma holders recorded a mean score of $\bar{x}$ = 17.40 (SD = 5.87), Diploma holders had a mean of $\bar{x}$ = 17.14 (SD = 7.09), Bachelor holders recorded $\bar{x}$ = 14.35 (SD = 6.24), and >Bachelor holders had

the lowest mean score of $\bar{x} = 10.83$ ($SD = 7.65$). The ANOVA results ($F(3, 98) = 2.08$, $p = 0.088$) indicate that these differences were not statistically significant, as the p-value exceeded the 0.05 threshold. This indicates that bio-security performance scores were relatively similar across all levels of professional training.

In contrast, the accountability of the laboratory materials domain showed statistically significant differences across training levels. <Diploma holders recorded the highest mean score ($\bar{x} = 19.60$, $SD = 7.12$), followed by Bachelor degree holders ($\bar{x} = 18.05$, $SD = 7.29$), Diploma holders ($\bar{x} = 15.12$, $SD = 8.53$), and >Bachelor holders ($\bar{x} = 8.50$, $SD = 7.89$). The ANOVA test yielded ($F(3, 98) = 3.98$, $p = 0.005$), which is statistically significant ($p < 0.05$). This indicates that accountability scores varied significantly across the different levels of professional training.

Overall, the results show that while there were observable variations in mean scores across training categories in all three domains, only the accountability of laboratory materials demonstrated statistically significant differences. The management and bio-security domains did not show statistically significant variation across the levels of professional training.

Further examination of the distribution of scores indicates that the variability within groups, as reflected by the standard deviation values, was relatively wide across all categories. For instance, higher SD values in some categories suggest dispersion of scores within groups, indicating that individual performance varied even within the same level of professional training. This pattern was observed across all three domains.

Additionally, the sample distribution across training levels was uneven, with Diploma holders forming the majority ($n=66$), followed by Bachelor holders ($n=20$), <Diploma

holders (n=10), and >Bachelor holders (n=6). This variation in group sizes is reflected in the descriptive statistics presented in the table. Despite differences in sample size, the ANOVA accounted for group variability when determining significance.

The results further indicate that although higher mean scores were recorded in certain categories, such as the <Diploma in management and accountability> domain, these differences were not consistently reflected across all domains. The lack of statistical significance in the management and biosecurity domains confirms that the observed differences in mean scores were insufficient to establish a statistically meaningful relationship with the level of professional training.

In summary, Table 4.6 shows that professional training level was significantly associated with accountability for laboratory materials. In contrast, no statistically significant association was observed in the management and biosecurity domains. The findings are based on a comparison of mean scores, variability measures, and ANOVA results across the four training categories.

Table 4.7: Level of professional education based on physical facility, personal reliability and bb training and practice.

Variable	Physical facility					Personal reliability					BB Training and practice				
	N	$\bar{x}$	SD	F	p-value	N	$\bar{x}$	SD	F	P-value	N	$\bar{x}$	SD	F	P-value
<Diploma	1	18.2	6.36	4.62	0.00	1	24.1	6.70	5.3	<0.00	1	9.20	6.9	4.8	0.00
	0	0			2	0	0		4	1	0		9	5	1
Diploma	6	17.3	12.9			6	19.2	11.0			6	9.70	6.9		
	6	5	0			6	8	2			6		1		
Bachelors	2	22.3	8.14			2	21.9	8.66			2	12.7	4.1		
	0	0				0	0				0	5	2		
>Bachelors	6	9.17	9.85			6	11.3	9.45			6	4.33	5.4		
						3							3		

The table 4.7 presents the influence of 4 professional educational levels on knowledge regarding physical facilities, personal reliability, and BB training and practice, with N=102. There was the strongest association with LWs' personal reliability, $F(3, 98) = 4.62$, $p < 0.001$, suggesting that the level of professional training

had a direct influence on personal reliability. The mean ranking also gave the 10 diploma LWs the top-most rank, $\bar{x}=24.10$. It is fair to note that this group of professionals were the second least in this sub group making them attain such enormous mean, the 20 degree holders took second position, $\bar{x}=21.90$ then the third rank was the 66 diploma holders, $\bar{x}=19.28$ which shows almost equal reliability with the degree holders, the fourth rank was the 6 LWs with >bachelors, $\bar{x}=11.3$ and this can probably be explained by change of roles based on seniority as per the educational level thus detaching from some routine practices that enhance personal reliability.

The association with BB training and practice was stronger, $F(3, 98) = 4.85$, $p = 0.001$, and was also stronger for the mixed ranking. The 20 Bachelor's degree holders had the top-most rank, $\bar{x}=12.75$; the 66 diploma holders came second, $\bar{x}=9.70$; and the 10 <diploma LWs ranked third, with $\bar{x}=9.20$, a very small difference from the second rank, which suggests almost equal strengths in BB training and practice. The 6 bachelor LWs ranked last, with $\bar{x}=4.33$, indicating the least knowledge of the BB training and practice. This is best explained by the roles assigned to them based on their training seniority: they do not normally involve hands-on experience but mentorship and management, thus the lowest rank. Generally, the level of professional training affected knowledge and skills in BB training and practice.

On the other hand, the level of professional training had a relatively strong influence on the physical facility and on knowledge and skills in handling laboratory facilities, $F(3, 98) = 4.62$, $p = 0.002$. Similarly, as in the other 2 comparisons, a mixed ranking was shown. The 20 bachelor's holders ranked highest, $\bar{x}=22.30$, followed closely by 10 LWs with a diploma, $\bar{x}=18.20$, then by the 66 diploma holders, $\bar{x}=17.35$, and, in fourth place, the LWs with > bachelor's, $\bar{x}=9.17$. Generally, the level of professional

training showed great responsibility in handling physical facilities, with those with diplomas and bachelor's degrees being the most reliable in this domain.

There was a significant difference across all domains in terms of knowledge and skills, with $p=0.002$, $p<0.001$, and $p=0.001$ for physical facility, personal reliability, and BB training and practice, respectively.

Table 4.8: Level of professional training based on involvement of mentors.

Variable	Involving clinical mentors				
	N	$\bar{x}$	SD	F	p-value
<Diploma	10	7.10	6.12	2.98	0.022
Diploma	66	9.18	8.09		
Bachelor	20	10.25	6.08		
>Bachelor	6	7.00	8.83		

Table 4.8 above presents an analysis of respondents' performance in involving clinical mentors based on professional educational level. There was strong statistical significance, $F(3, 98) =$, $p = 0.022$. Bachelor's degree holders showed the highest engagement with clinical mentors, with $\bar{x}=10.25$, indicating the ability to research far and wide and to consult to bridge the gap between theory and practice. At the same time, the rest of the professionals had almost equal means, suggesting some uniformity in the involvement of clinical mentors. Those with >bachelors appeared to rank lowest, $\bar{x}=7.00$, but this was likely because they were the ones used as mentors, and there were very few people acquainted with their level of training. This suggests that those with more theoretical, technical and practice-based training are more engaged in hands-on clinical methods coupled with knowledge.

In summary, the results reveal that the level of professional training significantly affects several BTTP domains; those with a diploma and a bachelor's degree are often seen as more reliable in these 7 domains. This pattern indicates that theoretical,

practical, skill-oriented training contributed more to effectiveness in technical and operational domains than lower academic qualifications. The findings emphasise the importance of maintaining strong practical and theoretical components within professional education programs to enhance performance in applied settings.

4.4.2 Knowledge and skills on BB based on age groups

The groups' knowledge and skills were evaluated using a standardised questionnaire and then analysed. This was meant to determine whether BB's knowledge and skills were the same across age groups. Studies have shown no statistically significant difference in age among BB participants (Tran A., 2025). This was also done in the order of the seven domains as per the 4 age groups.

Table 4. 9: Age groups on Management, Bio-Security & Accountability for lab materials {n=102}

Variable	Management					Bio-security					Accountability for lab materials				
	N	$\bar{x}$	SD	F	p-value	N	$\bar{x}$	SD	F	P-value	N	$\bar{x}$	SD	F	P-value
20-29	3	22.4	9.0	1.1	0.32	3	15.0	6.9	0.9	>0.0	3	14.1	8.9	0.8	>0.0
	2	1	2	2	0	2	3	1	4	5	2	3	2	9	5
20-39	4	23.8	8.9			4	16.9	7.0			4	15.3	8.4		
	9	8	6			9	4	1			9	3	6		
40-49	1	21.5	9.8			1	15.6	7.4			1	13.7	9.4		
	8	6	8			8	1	2			8	2	1		
>50	3	24.6	6.4			3	18.3	6.1			3	16.6	7.0		
	7	3				3	1				7	2			

Table 4.9 presents the analysis of the influence of age groups on laboratory workers'

knowledge and skills across three domains: management, biosecurity, and accountability of laboratory materials among 102 respondents. The analysis includes mean scores ($\bar{x}$), standard deviations (SD), and ANOVA test results across four age categories: 20–29, 30–39, 40–49, and >50 years.

In the management domain, the ANOVA results indicate no statistically significant difference across age groups ($F(3, 98) = 1.12, p = 0.32$). The mean scores show slight variation, with respondents aged >50 years ($n=3$) recording the highest mean score ($\bar{x}$

= 24.67, SD = 6.43). Respondents aged 30–39 years (n=49) recorded a mean score of $\bar{x} = 23.88$ (SD = 8.96), followed by those aged 20–29 years (n=32) with $\bar{x} = 22.41$ (SD = 9.02). The 40–49 age group (n=18) recorded the lowest mean score ($\bar{x} = 21.56$, SD = 9.88). Despite these differences in mean values, the p-value of 0.06 indicates that the differences are not statistically significant.

In the bio-security domain, a similar pattern is observed. The ANOVA result ($F(3, 98) = 0.94$, $p > 0.05$) indicates no statistically significant difference across age groups. The mean scores across the categories show minimal variation, with values distributed closely across all age groups. This indicates that bio-security knowledge and skills were relatively consistent among respondents regardless of age category.

In the accountability of laboratory materials domain, the ANOVA results also indicate no statistically significant difference across age groups ($F(3, 98) = 0.89$, $p > 0.05$). The mean scores across the age categories show minor variation, but these differences are not sufficient to establish statistical significance. The distribution of accountability scores appears across the four age groups.

Across all three domains, the results consistently show that age was not significantly associated with knowledge and skills in management, biosecurity, or accountability for laboratory materials. Although slight differences in mean scores were observed, these variations did not meet the threshold for statistical significance.

The distribution of respondents across age groups shows that the majority were aged 30–39 years (n=49), followed by 20–29 years (n=32), 40–49 years (n=18), and >50 years (n=3). This uneven distribution is reflected in the descriptive statistics presented in the table. Despite the smaller sample size in the >50 age group, the ANOVA

analysis accounts for variability across groups when determining statistical significance.

The standard deviation values across age groups indicate variability within each category. For instance, relatively higher SD values in some groups, particularly in the management domain, suggest dispersion of individual scores within age categories. Similar variability is observed in the bio-security and accountability domains, indicating differences in individual performance within the same age group.

Overall, Table 4.9 shows that knowledge and skills across the management, biosecurity, and accountability domains were relatively consistent across age groups, with no statistically significant differences observed. The findings are based on comparisons of mean scores, within-group variability, and ANOVA results across the four age categories.

Table 4.10 Age Group based on Physical facility, Personal reliability &BB training and practice

Variable	Physical facility					Personal reliability					BB training and practice				
	N	$\bar{x}$	SD	F	p-value	N	$\bar{x}$	SD	F	P-value	N	$\bar{x}$	SD	F	P-value
20-29	32	12.6	9.21	1.3	>0.0	32	17.2	11.1	1.2	>0.0	32	12.5	4.90	2.0	>0.0
	6			8	5	8	8	4	1	5	3			4	5
20-39	49	13.2	10.0			49	18.3	10.7			49	9.33	6.51		
	9		3			1	6								
40-49	18	11.4	11.0			18	15.0	12.0			18	6.56	7.91		
	4		2			6	4								
>50	3	16.3	7.57			3	20.3	9.07			3	12.3	6.11		
	3					3	3				3	3			

Table 4.10 presents the analysis of the influence of age groups on laboratory workers'

knowledge and skills across three domains: physical facility, personal reliability, and biosafety (BB) training and practice among 102 respondents. The analysis includes mean scores ($\bar{x}$), standard deviations (SD), and ANOVA results across four age categories: 20–29, 30–39, 40–49, and >50 years.

In the physical facility domain, the ANOVA results indicate no statistically significant difference across age groups ($F(3, 98) = 1.38, p > 0.05$). The mean scores show slight variation across the categories. Respondents aged >50 years ($n=3$) recorded the highest mean score ($\bar{x} = 16.33, SD = 7.57$), followed by those aged 30–39 years ($n=49$) with a mean of $\bar{x} = 13.29 (SD = 10.03)$. The 20–29 age group ($n=32$) recorded a mean score of $\bar{x} = 12.66 (SD = 9.21)$, while respondents aged 40–49 years ($n=18$) had the lowest mean score ($\bar{x} = 11.44, SD = 11.02$). Despite these differences in mean values, the p-value indicates that the variation is not statistically significant.

In the personal reliability domain, the ANOVA results also show no statistically significant difference across age groups ($F(3, 98) = 1.21, p > 0.05$). The mean scores demonstrate some variation, with the >50 age group recording the highest mean ($\bar{x} = 30.33, SD = 9.07$). This is followed by the 30–39 age group ($\bar{x} = 18.31, SD = 10.76$), the 20–29 age group ($\bar{x} = 17.28, SD = 11.14$), and the 40–49 age group ($\bar{x} = 15.06, SD = 12.04$). These differences, however, do not reach statistical significance.

In the BB training and practice domain, the ANOVA results indicate no statistically significant difference across age groups ($F(3, 98) = 2.04, p > 0.05$). The mean scores across the age categories are relatively comparable, showing only minor variation. This suggests that knowledge and skills related to BB training and practice were distributed similarly across the different age groups.

Across all three domains, the results consistently show that age group was not significantly associated with knowledge and skills related to physical facility, personal reliability, and BB training and practice. Although slight variations in mean scores were observed across the age categories, these differences were not statistically significant.

The distribution of respondents across age groups shows that the largest proportion was aged 30–39 years ($n=49$), followed by 20–29 years ($n=32$), 40–49 years ($n=18$), and >50 years ($n=3$). This uneven distribution is reflected in the descriptive statistics presented. The relatively small sample size in the >50 age group is noted in the table, and the variability within this group is reflected in the standard deviation values.

The standard deviation values across age groups indicate variability within each age group. Higher SD values in some groups, particularly in the personal reliability domain, suggest a wider spread of individual scores within those age groups. Similar variability is observed across the physical facility and BB training domains.

Overall, Table 4.10 shows that knowledge and skills across physical facility, personal reliability, and BB training and practice domains were relatively consistent across different age groups, with no statistically significant differences observed. These findings are based on comparisons of mean scores, within-group variability, and ANOVA results across the four age categories.

Table 4.11: Age group based on involvement of clinical mentors

Variable	Involving clinical mentors				
	N	$\bar{x}$	SD	F	p-value
20-29	32	9.69	5.47	1.67	>0.05
20-39	49	9.47	8.49		
40-49	18	5.72	7.39		
>50	3	15.67	7.23		

Table 4.13 presents data analysis on the influence of age on clinical mentors' involvement in BB as a domain. The age group 40-49 had the lowest mean, $\bar{x}=5.72$; the second-lowest was 30-39 years, $\bar{x}=9.47$; the third-lowest was 20-29 years, $\bar{x}=9.69$; and the highest was >50 years, $\bar{x}=15.67$. These means were almost equal, and their difference was not statistically significant, $F(3, 98) = 1.67$, $p > 0.05$, indicating that the mentors were engaged with all age groups.

4.4.3 Knowledge and skills on BB based on years of experience

The years of experience correlate with the level of knowledge and skills, which were analyzed using a standardized questionnaire. This was meant to determine whether years of experience influenced the knowledge, attitude, and practice (KAP) among laboratory workers. Studies have shown statistical significance whereby more years of experience implied better knowledge on occupational hazards and safety measures (Bajjou et al., 2019), then another study concluded that KAP levels were significantly associated with years of experience, though sometimes declining with long duration (Perera et al., 2020). This was evaluated under the 7 domains at every professional level.

Table 4.12: Knowledge and skills based on years of experience

Variable	Management					Bio-security					Accountability for lab materials				
	N	$\bar{x}$	SD	F	p-value	N	$\bar{x}$	S	F	P-value	N	$\bar{x}$	S	F	P-value
<4 years	28	23.56	4.81	2.61	0.039	28	17.96	6.22	5.04	0.001	28	21.11	6.90	5.67	<0.001
5-9 years	28	20.09	7.73			28	15.00	5.88			28	16.41	8.25		
10-14 years	26	25.69	8.36			26	18.80	6.94			26	13.16	8.34		
>15 years	20	21.97	10.91			20	12.11	6.48			20	11.58	9.08		

Table 4.12 presents the analysis of the influence of years of experience on laboratory workers' knowledge and skills across three domains: management, biosecurity, and accountability of laboratory materials among 102 respondents. The analysis includes mean scores ($\bar{x}$), standard deviations (SD), and ANOVA results across four experience categories: <4 years, 5–9 years, 10–14 years, and >15 years.

In the accountability of laboratory materials domain, the ANOVA results indicate a statistically significant difference across experience groups ($F(3, 98) = 5.67, p <$

0.001). Laboratory workers with <4 years of experience recorded the highest mean score ($\bar{x} = 21.11$, $SD = 6.9$), followed by those with 5–9 years ($\bar{x} = 16.41$, $SD = 8.25$). Respondents with 10–14 years of experience had a mean score of $\bar{x} = 13.16$ ($SD = 8.34$), while those with >15 years recorded the lowest mean ($\bar{x} = 11.58$, $SD = 9.08$). These results indicate variation in accountability scores across the experience categories.

In the bio-security domain, the ANOVA results also show a statistically significant difference ($F(3, 98) = 5.04$, $p = 0.001$). Respondents with 10–14 years of experience recorded the highest mean score ($\bar{x} = 18.80$, $SD = 6.94$), followed by those with <4 years ($\bar{x} = 17.96$, $SD = 6.20$). The 5–9 years group recorded a mean score of $\bar{x} = 15.00$ ($SD = 8.08$), while respondents with >15 years of experience had the lowest mean score ($\bar{x} = 12.11$, $SD = 6.48$). These values indicate variability in bio-security scores across the different experience groups.

In the management domain, the ANOVA results indicate a statistically significant difference across the experience categories ($F(3, 98) = 2.61$, $p = 0.039$). Respondents with 10–14 years of experience recorded the highest mean score ($\bar{x} = 25.69$, $SD = 8.36$), followed by those with <4 years ($\bar{x} = 23.56$, $SD = 4.81$). Those with >15 years recorded a mean score of $\bar{x} = 21.97$ ($SD = 10.91$), while respondents with 5–9 years of experience had a mean score of $\bar{x} = 20.09$ ($SD = 7.73$). These differences indicate variation in management scores across the experience levels.

Across all three domains, the ANOVA results indicate that years of experience were significantly associated with knowledge and skills in management, biosecurity, and accountability of laboratory materials, with all p-values less than 0.05. This

demonstrates that variations in experience levels correspond to measurable differences in performance across the domains assessed.

The distribution of respondents across experience categories shows that the largest groups were <4 years (n=28) and 5–9 years (n=28), followed by 10–14 years (n=26) and >15 years (n=20). This relatively balanced distribution is reflected in the descriptive statistics presented in the table.

The standard deviation values across the experience groups indicate variability within each category. Higher SD values in some groups, particularly in the management domain for respondents with >15 years of experience (SD = 10.91), suggest wider dispersion of scores within that group. Similar variability is observed across biosecurity and accountability domains.

Overall, Table 4.12 shows that knowledge and skills across management, bio-security, and accountability domains varied significantly across different levels of years of experience, as demonstrated by differences in mean scores, variability within groups, and statistically significant ANOVA results.

Table 4.13: Knowledge and skills based on years of experience on physical facility, personal reliability and BB training and practice

Variable	Physical facility					Personal reliability					BB training and practice				
	N	$\bar{x}$	SD	F	p-value	N	$\bar{x}$	SD	F	P-value	N	$\bar{x}$	SD	F	P-value
<4 years	2	19.5	6.02	6.9	<0.00	2	26.9	5.40	7.1	<0.00	2	13.8	3.5	5.7	<0.00
	8	2		3	1	8	6		5	1	8	1	0	0	1
5-9 years	2	16.7	7.98			2	21.5	9.22			2	12.5	4.9		
	8	2				8	3				8	3	0		
10-14 years	2	12.8	10.2			2	17.4	12.9			2	9.33	6.5		
	6	8	5			6	3	5			6		1		
>15 years	2	10.2	8.61			2	12.3	11.0			2	6.51	7.3		
	0	5				0	1	8			0		3		

Table 4.13 above presents the influence of years of experience (in 4 bands) on knowledge and skills in physical facilities, personal reliability, and BB training and practice, with N=102. There was significant statistical significance in all 3 domains (p <). There were statistical differences as follows: in the physical facility, F (3,98)

=6.93, $p < 0.001$; in personal reliability, $F(3,98) = 7.15$, $p < 0.001$; and lastly in BB training and practice, $F(3,98) = 5.70$, $p < 0.001$. This outcome highlighted the importance of considering years of experience when assigning roles or hiring LWs across the 3 domains. However, the means also included another summary indicating which group was best in each domain. The LWs with <4 years of experience, comprising 28 respondents, ranked highest across all 3 domains (physical facility $\bar{x}=19.52$, personal reliability $\bar{x}=26.96$, and BB training and practice $\bar{x}=13.81$). This implied that junior staff were more conversant with these relevant fields, thus getting the best scores. They could also be on the advantageous side, having been trained more recently than other senior staff, and were also subjected to close supervision by senior staff, thus achieving better performance. The band ranked second across all 3 domains, with 28 LWs with 5-9 years of experience (physical facility $\bar{x}=16.72$, personal reliability $\bar{x}=21.53$, and BB training and practice $\bar{x}=12.53$). The band of 26 LWs with 10-14 years of experience were ranked third (physical facility $\bar{x}=12.88$, personal reliability $\bar{x}=17.43$ and BB training and practice $\bar{x}=9.33$). Lastly, the senior-most staff were ranked last across all domains (physical facility $\bar{x}=10.25$, personal reliability $\bar{x}=12.31$, and BB training and practice $\bar{x}=6.51$).

These means in the third and fourth ranks were relatively lower and had higher standard deviations than those in the first 2 experience bands. This summary clearly shows that junior staff with <9 years of experience had greater knowledge, suggesting that, as individuals gain more years of experience, their personal reliability, knowledge of physical facilities, and awareness of BB training and practice tend to decline. The P value was less than 0.001 across all domains, indicating that the differences between experience groups were statistically significant. The observed differences are very unlikely to have occurred by chance.

Table 4.14: Knowledge and skills based on years of experience on involving clinical mentors.

Variable	Involving clinical mentors				
	N	$\bar{x}$	SD	F	p-value
<4 years	28	14.22	6.84	4.30	0.003
5-9 years	28	9.69	5.47		
10-14 years	26	9.47	8.49		
>15 years	20	6.88	7.19		

Table 4.14 above presents the influence of years of experience (in 4 bands) on clinical mentors' involvement among LWs (N=102). There was a relatively strong statistical difference, $F(3, 98) = 4.30$, $p = 0.003$. This implied that years of experience influenced clinical mentors' engagement. In the ranking, the junior staff <4 years of experience or less, with 28 respondents, $\bar{x}=14.22$, were the topmost and followed by those with 5-9 years of experience, 28 respondents, $\bar{x}=9.69$. The third ranking band had 26 respondents with 10-14 years of experience, with $\bar{x}=9.47$, and the last band had >15 years of experience, with $\bar{x}=6.88$.

This trend revealed that as years increased, there was a decline in the involvement of clinical mentors, while junior staff showed an increasing trend in consultation and seeking guidance. The second and third ranking bands, that is, 5-9 years and 10-14 years of experience, showed almost equal tendencies to involve clinical mentors. The senior most staff were not used to this because of the probability of being the mentors around or most of the people with same standard or more years of experience regularly got different assignment in the field ministry high end offices, or retired,, or the individual LWs did not want to consult because they were old enough in the profession thus tend to believe they did not need mentor involvement.

4.5 Objective Three RESULTS

The third objective was stated “To establish the laboratory workers’ constraints among LWs in NCHs on the implementation of BB.”

This section aims to achieve that objective by identifying the constraints laboratory workers face when implementing biosafety and biosecurity practices. The following are the workplace constraints for LWs assessed: PPE resources, training on BB and on-site mentorship, laboratory design and workflow, and laboratory workload and staffing. Also assessed were the LAIs and workplace exposures to determine if any of the LWs had been exposed to any biological agents. To achieve this, the study used a questionnaire (Appendix 9a) on constraints and bio-risk assessment. The responses were given as yes or no. The constraints were compared between private hospitals. There were 31 LWs (30.39%) in private hospitals and 71 in public Hospitals across the County. Involving public and private laboratories in BB implementation is significant for disease control, as a study conducted in Kenya (Ogaro et al., 2018) found. One of the studies in 100 facilities in Uganda recommended that the Ministry of Health develop a work-based staffing model to facilitate adequate laboratory workers working in all Hospital departments (Kiwanuka et al., 2020). Such recommendations imply that more research is needed to determine whether they were implemented and to identify any other constraints that were not clearly brought up for addressing.

Constraints impede the implementation of bio-safety and bio-security practices. This was done subjectively (purely based on respondents' interpretations, feelings, or judgments) rather than on universally verifiable facts about the constraints matter.

Four major constraints were evaluated, and the related questions are included in the table below. For more insight into LW workload and staffing, the workload and staffing were calculated using the Workload Indicator for Staffing Need (WISN), adopted from WHO and supported by KMLTTB.

Table 4.15 A: Constraints among LWs in both public and private Hospitals (N=102)

On daily work, how do you get your PPE and use (e.g. gloves) using ISO standards					
	Public LWs (N=71)		Private LWs (N=31)		Conformance % public private
	Yes	No	Yes	No	
Do you wear a well-buttoned a dust coat while at work?	71(100%)	0(%)	31(100%)	0%	38.58 60
Are PPE always available	15 (21.12%)	56 (78.88%)	26(83.87%)	5 (16.13%)	
Do you use one pair glove for many procedures?	56 (78.88%)	15(21.12%)	6(83.87%)	25 (16.13%)	
Only change gloves when torn/spills?	50 (70.48%)	21(29.52%)	5(16.13%)	26 (83.87%)	
Do you use face masks/glass when working with infectious specimens?	15 (21.12%)	56 (78.88%)	5 (16.13%)	26 (83.87%)	
About BB formal training and on job training					
Are you formally trained in BB	21(29.52%)	50 (70.48%)	6(19.35 %)	25 (80.65%)	
On job mentor-ship	15(21.13%)	56(78.87%)	6(9.68%)	25 (80.65%)	

Table 4.15 B: Constraints among LWs in both public and private Hospitals

About laboratory design and work flow (according to ISO 15189:2022 clause 6.3 (facilities and environment)						
	Public LWS		Private LWs		Conformance %	
	Yes	No	Yes	No	public	private
Is there effective separation between neighboring areas within the lab?	20(28.17%)	51(71.83%)	12(38.71%)	19(61.29%)	40.58	37.67
Does the layout promote a logical flow from sample receipt, to pre-analytical handling, analysis, and post-analytical storage?	20(28.17%)	51(71.83%)	12(38.71%)	19(61.29%)		
Are patient sample collection areas separate from the main laboratory ?	20(28.17%)	51(71.83%)	7(22.58%)	24(77.42%)		
Is there sufficient space allocated for staff to perform tasks without compromising quality or safety?	20(28.17%)	51(71.83%)	19(61.29%)	12(38.71%)		
Does the design include systems to monitor, control, and record environmental conditions	15(21.13%)	56 (78.87%)	19(61.29%)	12(38.71%)		
Are HVAC systems designed to manage air quality, pressure cascades?	15(21.13%)	56 (78.87%)	7(22.58%)	24(77.42%)		
Are surfaces (benches, walls,	69(91.18%)	2(2.81%)	31(100%)	0(0%)		

floors) non-porous, resistant to disinfectants, and easy to clean, particularly in high-risk areas?					
Are there secure access and egress mechanisms in place to control entry to the laboratory?	15(21.13%)	56 (78.87%)	11(35.48%)	20(64.52%)	
Are eye wash stations, emergency showers, fire extinguishers, and spill kits appropriately located and accessible?	15(21.13%)	56 (78.87%)	3(9.68%)	28(90.32%)	
Are there designated, secure storage areas for hazardous materials and biological waste?	15(21.13%)	56 (78.87%)	19(61.29%)	12(38.71%)	P
Is there adequate power supply and a backup generator system for critical equipment	60(84.51%)	11(15.49%)	19(61.29%)	12(38.71%)	
Is there running water	69(97.18%)	2(2.83%)	25(80.65)	25(80.65)	

Table 4.15 C: Constraints among LWs in both public and private Hospitals

About work-load and staffing (Kenyan clinical laboratory requires aligning laboratory workers with work load)WHO-workload indicator of staffing Need(20,000 tests for one LW per 1 year)1667 per a month, 75 test per day						
	Public LWs		Private LWs		conformance public private % %	
Are registered by KMLTTB?	71(100%)	0(0%)	31(100%)	0(0%)	41.68	52.36%
Are you aware of WISN?	21(29.52%)	50 (70.48%)	6(19.35 %)	25 (80.65%)		
Do you work for 8 Hrs. a day?	27(38.03%)	44(61.97%)	11(35.48%)	20(64.52%)		
Do you work less than 8 Hrs. a day	0(0%)	71(100%)	0(0%)	31(100%)		
Do perform less than 75 tests a day	21(29.52%)	50 (70.48%)	11(35.48%)	20(64.52%)		
Do you go for leave yearly ?	35(49.30%)	36(50.70%)	22(70.97%)	9(29.03%)		
Have ever been absent on duty because fatigue or burnout?	56(78.87%)	15(21.13%)	1(2.23%)	30(96.77%)		
What are some of the LAIs and work place exposures ?						
Are you aware of any reporting procedure of needle stick/or injury /any exposure of infectious specimen?	71(100%)	0(0%)	22(70.97%)	9(29.03%)	Conformance public Private 58.89 75.81% %	
Have ever documented any exposure of infectious specimens?	31(43.66%)	40(56.44%)	19(61.29%)	12(38.71%)		
Are there aerosol-generating procedures?	71(100%)	0(0%)	28(90.32%)	3(9.68%)		
"Is post-exposure prophylaxis (PEP) available for HIV in your facility ?	68(95.77%)	3(4.23%)	25(80.65%)	6(19.35%)		

Table 4.15 above analyses four constraints that impair the implementation of BB measures. Regarding PPE as a constraint, all LWs said yes to wearing lab coats at the workplace: 71 (100%) in public and 31 (100%) in private. However, regarding PPE availability, private LWs (26, 83.87%) responded yes, compared to their counterparts, public LWs (15, 21.12%). At the same time, 56 (78.88%) and 5 (16.13%) in both the public and private sectors responded 'no' to the availability of PPE. This can be associated with procurement procedures in public facilities or with delays in funding for the same. Regarding using gloves for many procedures and only changing gloves

when torn or have spills, the public rated the highest by saying no, 56 (78.88%) and 50 (70.48%), but this indicates transferring microorganisms from one patient/specimen to another because of the scarcity of PPE.

On the contrary, the private 5 (16.13%) and 5 (16.13%) in the same locality, respectively, indicated good practice and contained microorganisms within the same locality. Another element on PPE, whether LWs used other face masks, glass goggles for prevention of infectious biological specimens which would produce aerosols and cause LAIs on an individual, 26 (83.87%) & 56 (78.88%) said no in private and public, respectively, indicating that in both public and private, they did not take precautions against infectious aerosols and LAIs and pathogen exposure at work place. However, LWs 15 (21.12%) in public & 5 (16.135%) in private always took precautions by putting on face masks and goggles to prevent the same. In summary, PPE in public hospitals was at 38.58 conformance, whereas LWs in private hospitals were higher at (60%).

The BB training was considered additional training for their profession. Out of the 27 LWs who had been trained at the time of the study, 21 were from the public sector and only 6 from the private sector. In the public sector, the 21 trained LWs represented only 29.58% of the total 71 LWs, implying that 50 (70.42%) LWs had not received the training. In the private sector, only 6 (19.35%) had received BB training, and 25 (80.65%) had not. The contrast here was bigger; the private hospitals were hiring based on professional training of the LWs and did not focus on BB training as additional training for their LWs. BB training should be a basic requirement for LWs to improve performance and efficiency in both the public and private sectors. Nevertheless, some of the LWs gained knowledge and skills in BB through

mentorship, with those in public having the highest (15; 21.13%) and those in private having 3 (9.68%).

The laboratory design and workflow were another area where constraints were assessed. The assessment was conducted in accordance with ISO 15189:2022, clause 6.3 (facilities and environment). The following are the results;

On whether there was effective separation between neighboring areas within the lab, both public and private scored almost the same on saying yes, 12(38.71%) out of 31 in private and 20(28.17%) out of 71 LWs. 51(71.83%) public LWs & 19(61.29%) private LWs responded no. This suggests the possibility of people walking freely in the laboratory, posing a high risk; hence, the pledge to implement BB. This scoring was the same for whether the laboratory layout promoted a logical flow from sample receipt through pre-analytical handling, analysis, and post-analytical storage.

The issue of on patient sample collection areas whether they were separate from the main laboratory, no responses were all above 70% by both public and private LWs, 51(71.83%) & 24(77.42%) respectively, while the yes responses were, 20(28.17%) public and 7(22.58%) private LWs indicating possible escape of biological specimen's if accidentally acquiring biological agents. The responses on the issue of patient sample collection areas, whether they are separate from the main laboratory and whether there was sufficient space allocated for staff to perform tasks without compromising quality or safety were the same. indicating that staff compromised quality and safety more often.

The responses to whether 1) Laboratory design included systems to monitor, control, and record environmental conditions, 2) Record environmental conditions, heating-ventilation and air conditioning (HVAC) systems were designed to manage air

quality, pressure cascades, 3). There were secure access and egress mechanisms in place to control entry to the laboratory, 4). Eye wash stations, emergency showers, fire extinguishers, and spill kits were appropriately located and accessible, 5). Were there designated, secure storage areas for hazardous materials and biological waste, and 6). Whether fume hoods or bio-safety cabinets were provided and correctly ventilated for handling chemical or biological agents, their responses were the same across the board among public LWs. These responses were as follows: 56 (78.87%) with no responses and 15 (21.13%).

Same questions were asked among private LWs but had their different responses, the yes responses were highest was 19(61.29%) which was on whether; laboratory design included systems to monitor, control, and record environmental conditions, were there designated, secure storage areas for hazardous materials and biological waste and whether were fume hoods or bio-safety cabinets provided and correctly ventilated for handling chemical or biological agents and no responses were, 12(38.71%). This was then followed, yes, 11(35.48%), 7(22.58%), which was from question one, whether there were secure access and egress mechanisms in place to control entry to the laboratory, and two, if there were HVAC systems designed to manage air quality, pressure cascades. Last but not least, 3(9.68%) were responses given to the question whether eye wash stations, emergency showers, fire extinguishers, and spill kits were appropriately located and accessible.

Still on the issue of lab design and workflow, the question with the highest number of yes responses was the question on whether there was availability of running tap water, whereby public LWs responded with the highest yes 69(97.18%) and no the lowest 2(2.83%) while the private followed closely with yes responses 25(80.65%) and no responses 25(80.65). This is one of the BB implementation elements that scored

above 80%, indicating the LWs' perceived handwashing and the major practice in BB implementation. Another element that scored higher than the running tap water, with yes responses at 31 (100%) among private LWs and 69 (91.18%) among the public. The question was on whether the surfaces (benches, walls, floors) are non-porous, resistant to disinfectants, and easy to clean, particularly in high-risk areas. This means that the LWS adore easy-to-clean benches in BB implementation. Conformance in laboratory design and work flow was high in public hospital LWs at 40.58 % than private LWs who had conformance at 37.67%

On constraints on workload and staffing using the KMLTTB and WHO WISN. The LWs' responses on whether they were registered with KMLTTB were at 100% (N=102)

Of 71 public LWs who had trained on formal BB, 21(29.52%) responded yes; of 6 private LWs who had also trained on the same, 6 (19.35%) responded yes.

There were questions about whether they worked 8 hours a day or less. Their responses were 27 (38.03%) yes and 0 (00%) among public LWs. In contrast, among private LWs, 11 (35.48%) worked for 8 hours, and 0 (0%) never worked less than 8 hours. On the issue of LWs going on leave yearly, 35(49.30%) said yes, indicating they go on leave on a yearly basis, while 36(50.70%) responded with no answer, indicating their workload was too much, which kept them on the job. On the other hand, private LWs: 22 (70.97%) went on leave yearly, while 9 (29.03%) did not want to miss a month's salary and so opted to continue working.

There was a question about whether the laboratory worker had been absent from work due to fatigue or work burnout. The public hospital laboratory workers expressed the highest absenteeism of 78.87% by saying yes responses, and on the contrary, in the

private sector, only 1 laboratory worker said yes, with (2'23%), which would be due to fear of losing a job in the private hospitals. Unlike the public hospital counterparts, they were aware that their job was permanent and pensionable. Even though their absenteeism was not explained, in the focus group interviews, participants commented that 'even if you work throughout, nobody recognises you,' another one said that if she died, they would look for somebody to replace him.

LWs in public had a high workload, analysing more than 75 tests per WISN by the WHO. Those who responded yes, whether they analysed less than 75 tests, were 21(29.52%), while those who tested more than 75 a day were 50 (70.48%), and this was established by their non-responses. 11(35.48%) among private LWs responded yes; on the other hand, 20 (64.52%) responded that they do more than 75 tests a day. In general, private hospital LWs had 52.26 % in workload, which was higher than public LWs at 41.67 %.

The issues of laboratory-acquired infection and work place exposures were also a matter of concern, as the results were analysed. The participants were to answer no or yes to the above. The participants' responses on whether they were aware of any reporting procedure of needle stick injury/any exposure to infectious biological agents, the LWs in the public sector reported 100% of being aware. In contrast, in the private sector, 9(29.03%) were not aware, but only 22(70.97%) out of 31 LWs were aware. Another question that followed was if they had ever documented any exposure they had incurred to a suspected infectious agent. 21(29.56%) out of 71 LWs in public hospitals reported to have documented, and in private, 19 (61.29%) out of 31 also agreed that they had documented. Still, the research was not able to access the book. The element of whether they were aware of aerosols generating procedures in the laboratory; interestingly, 100% of public LWs were aware, but only 28(90.22%) in

private were aware. However, the matter of concern is the 3(9.78%) who are not aware. Finally, the question of whether there is a post-exposure prophylaxis available for HIV was worrying because only in the private sector, 6(29.5%) said it was not available in their facilities. We had 3(4.23%) in the public sector who reported that it was not available. The LAIs and knowledge of pathogens in the laboratory were higher in private than in public hospitals.

In the focus group interviews, some of these issues were confirmed, where some LWs in this study cited work overload and stress. They blamed the county government for employing non- LWs and posting them to laboratory LWs, and this is the main reason for the LWs shortage. Focus group interviews again on the issue of infrastructure are due to diverting priorities and resolving on cheap labour and not involving LWs for technical advice. One LW said ‘I once received a very negative reaction from the non-professional in the hospital while complaining of LW who contracted yellow fever from a needle stick and another tuberculosis because of a lack of PPE, and said they were responsible for their illnesses.’

4.6 Objective four

This objective was “Appraise the level of compliance on bio-safety and bio-security during their implementation” This objective was meant to answer objective 4 of the study, which states that “Appraise the level of compliance on bio-safety and bio-security during their implementation with recommended standards among laboratory workers” To achieve this objective, the (appendix 9) tool was used.

Compliance was assessed using items aligned with recommended biosafety and biosecurity standards. An overall compliance score was computed and categorised into low, moderate, and high levels.

Table 4.16: Level of Compliance with Biosafety and Biosecurity Standards (N = 102)

Compliance level	n	%
Low	31	30.4
Moderate	44	43.1
High	27	26.5

From table 4.16 above, generally showing the level of compliance of the respondents, 27 (26.5%) had high compliance. In comparison, 44 (43.1%) had moderate compliance, and 31 (30.4%) had low compliance, calling for the essence of policymakers visiting facilities more often to enforce compliance.

Table 4.17: Physical facility observation N=70 laboratories

Description of the observation	N	Public	Private	Total Percentage (%)
Level of Bio-safety BSL1	39	32 (45.71%)	7 (10.00%)	55.71
BSL2	31	25(35.72%)	6(8.57%)	44.29
Separate specimen collection room, analytical and administration rooms	29	20(28.57%)	9(12.86%)	41.43
Safe and Running tap water	68	57(81.41%)	11(15.73%)	97.14
Operational eye wash stations	11	5(7.14%)	6(8.57%)	15.71
Proper ventilation	62	33(47.14%)	29(41.43%)	88.57
Uninterrupted power (electricity)	63	34(48.57%)	29(41.43%)	90.00
Bio-safety cabinet	14	5(7.14%)	9(12.86%)	20.00
Proper working incinerator	14	6(8.57%)	8(11.43%)	20.00
Assess LWs before employment	50	27(38.57%)	23(32.86%)	71.43
Mental	0	0(0.00%)	(0.00%)	0.00
Occurrence book	21	9(12.86%)	12(17.14%)	30.00
LWs personal files	4	1(1.43%)	3(4.29%)	5.71
Designated area for waste disposal	68	37(52.86%)	31(44.21%)	97.14
Fire extinguishers	39	18(25.71%)	21(30.00%)	55.71
Proper record keeping and maintenance	23	10(14.29%)	13(18.57%)	32.86
Areas of staff wellbeing, handwashing facilities and privacy in specimen collection	39	17(24.29%)	22(31.43%)	55.70

Table 4.17 provides a detailed evaluation of physical facility biosafety and biosecurity measures across 70 laboratory facilities in Narok County, disaggregated into public and private sectors. The public were 51 and 19 were private hospital laboratories. The

table captures both structural and operational indicators essential for safe laboratory practice, with findings expressed as frequencies and corresponding percentages to facilitate comparative interpretation.

The distribution of laboratories by biosafety level (BSL) indicates that 55.71% of facilities operated at BSL-1, while 44.29% operated at BSL-2. This pattern suggests that the majority of laboratories are engaged in handling low-risk biological agents, although a substantial proportion are equipped to manage moderate-risk pathogens. Public facilities constituted a larger proportion of BSL-1 laboratories (45.71%), whereas private facilities contributed a smaller but notable share (10.00%). For BSL-2, public facilities accounted for 35.72% while private facilities contributed 8.57%, indicating relatively similar but slightly lower representation of higher-level biosafety infrastructure in the private sector.

Assessment of spatial organisation within laboratory settings revealed that only 41.43% of facilities had proper separation of specimen collection areas, analytical workspaces, and administrative sections. This implies that 58.57% of laboratories lack adequate physical partitioning, increasing the likelihood of contamination, workflow interference, and compromised infection prevention and control (IPC) practices. This structural limitation is particularly critical in laboratories processing infectious specimens, where zoning is a fundamental biosafety requirement.

Basic infrastructure for hygiene was largely adequate, with 97.14% of facilities reporting access to safe and running tap water (public: 81.41%, private: 15.73%). This high level of compliance supports effective hand hygiene and routine decontamination procedures. Similarly, designated waste disposal areas were present in 97.14% of

facilities (public: 52.86%, private: 44.21%), indicating strong adherence to waste segregation protocols at the point of generation.

Despite these strengths, emergency preparedness infrastructure remains markedly inadequate. Only 15.71% of facilities had functional eye wash stations (public: 7.14%, private: 8.57%), highlighting a critical gap in immediate response mechanisms for chemical splashes or biological exposures. Additionally, fire safety measures were present in just 55.71% of laboratories (public: 25.71%, private: 30.00%), leaving nearly half of the facilities vulnerable to fire-related incidents.

Environmental control systems demonstrated relatively strong performance. Proper ventilation was observed in 88.57% of facilities (public: 47.14%, private: 41.43%), which is essential for maintaining air quality and reducing airborne transmission risks. Likewise, 90.00% of laboratories reported uninterrupted power supply (public: 48.57%, private: 41.43%), ensuring consistent operation of critical laboratory equipment such as refrigeration units and diagnostic instruments.

However, the availability of specialized biosafety equipment was notably limited. Only 20.00% of facilities had biosafety cabinets (public: 7.14%, private: 12.86%), indicating restricted capacity for handling hazardous biological materials under controlled conditions. Similarly, functional incinerators were available in only 20.00% of laboratories (public: 8.57%, private: 11.43%), suggesting inadequate infrastructure for the safe disposal of infectious waste, which may increase environmental and public health risks.

From a workforce preparedness perspective, 71.43% of laboratory workers had received professional training in biosafety and biosecurity prior to employment (public: 38.57%, private: 32.86%). While this reflects a moderate level of

competency, a significant proportion (28.57%) of personnel may lack formal training, potentially affecting adherence to standard operating procedures (SOPs). Notably, mental health assessments for laboratory workers were completely absent (0.00%) across all facilities, indicating a critical oversight in occupational health frameworks, particularly given the psychological demands associated with laboratory work involving infectious materials.

Administrative and monitoring systems were also found to be weak. Only 30.00% of facilities-maintained occurrence or incident logbooks (public: 12.86%, private: 17.14%), limiting the ability to document, track, and mitigate laboratory accidents or near-miss events. Furthermore, proper record keeping and maintenance systems were present in just 32.86% of facilities (public: 14.29%, private: 18.57%), which may undermine quality assurance, regulatory compliance, and audit readiness.

Personnel documentation was particularly deficient, with only 5.71% of facilities maintaining laboratory workers' personal files (public: 1.43%, private: 4.29%). This indicates weak human resource management systems and limited traceability of staff qualifications, training history, and occupational health records.

Consideration of staff welfare and patient-centered infrastructure showed moderate performance. Only 55.70% of facilities had designated areas for staff wellbeing, adequate handwashing facilities, and ensured privacy during specimen collection (public: 24.29%, private: 31.43%). This suggests that nearly half of the facilities do not fully meet standards for worker comfort and patient dignity, which are essential components of quality healthcare delivery.

Overall, the findings reveal a mixed landscape of biosafety implementation across laboratory facilities in Narok County. While core infrastructure such as water supply,

waste management areas, ventilation, and power reliability demonstrates strong compliance, critical gaps persist in engineering controls, emergency preparedness systems, specialised equipment availability, documentation practices, and occupational health measures. Although private facilities show slightly stronger performance in selected areas such as equipment availability and welfare provisions, deficiencies are evident across both sectors.

These observations highlight the need for systematic strengthening of biosafety and biosecurity frameworks, including investment in infrastructure, enforcement of regulatory standards, expansion of training programs, and integration of comprehensive monitoring and evaluation systems. Addressing these gaps is essential to ensure safe laboratory operations, protect healthcare workers, and minimise risks to the broader community.

Table 4.18: LWs observations N=102

Aspect observed	Public - 71 LWs		Private - 31 LWs		Summary	Total percent
	Yes	No	Yes	No	n	%
Wearing of PPE	71(100%)	0%	31 (100%)	0%	102	100%
Changing gloves within procedures	47 (66.20%)	24(33.80%)	27 (87.10%)	4 (12.90%)	74	72.86%
Donning and doffing of gloves well done	36 (50.70%)	35 (49.30%)	22 (70.97%)	9 (29.03%)	58	57.14%
Adherence to SOPs	26 (36.62%)	45 (63.38%)	18 (58.06%)	13 (41.94%)	44	42.86%
Proper handling of specimen/equipment	50 (70.42%)	21 (29.58%)	26 (83.87%)	5 (16.13%)	76	74.29%
Stress and fatigue	47 (66.20%)	24 (33.80%)	24 (77.42%)	7 (22.58%)	71	70.00%
Proper separation of wastes	49 (69.01%)	22 (30.99%)	27 (87.10%)	4 (12.90%)	76	77.14%
Identifies well all Laboratory hazards	58 (81.69%)	13 (18.31%)	29 (93.55%)	2 (93.55%)	87	85.71
Eating, drinking and applying cosmetics in the laboratory	3 (4.23%)	68 (95.77%)	4 (12.90%)	27 (87.10%)	7	7.1%
Proper use of equipment	67 (94.37%)	4 (5.63%)	22 (70.97%)	9 (29.03%)	89	87.14%

Table 4.18 presents observational data on the implementation of biosafety and biosecurity practices among 102 laboratory workers (LWs) across public (n=71) and private (n=31) health facilities in Narok County. The observations were conducted during routine laboratory procedures, with compliance assessed across key behavioral and procedural indicators. The findings are summarized using frequencies and percentages to allow comparison between the public and private sectors.

The results indicate generally high compliance with certain fundamental biosafety practices, alongside notable gaps in adherence to critical procedures. Use of personal protective equipment (PPE) was universal (100%) across both public and private facilities, demonstrating strong baseline awareness of protective measures among laboratory personnel. This suggests that PPE availability and enforcement are well established across the facilities assessed.

However, compliance declines when examining more specific procedural practices. For instance, only 72.86% of laboratory workers reported changing gloves between procedures (public: 66.20%; private: 87.10%), indicating that 27.14% failed to perform this essential infection prevention step consistently. This lapse poses a significant risk for cross-contamination between samples and patients.

Similarly, proper donning and doffing of gloves was observed in only 57.14% of workers (public: 50.70%, private: 70.97%), leaving 42.86% of personnel performing this procedure incorrectly. This gap highlights deficiencies in practical skills despite general awareness of PPE use. The higher compliance observed in private facilities suggests better enforcement or stronger training reinforcement than in public institutions.

Adherence to standard operating procedures (SOPs) was notably low at 42.86% overall, with public facilities showing significantly lower compliance (36.62%) compared to private facilities (58.06%). Consequently, 63.38% of public sector workers and 41.94% of private sector workers failed to consistently follow SOPs, raising concerns about procedural standardisation and the reliability of laboratory results.

In contrast, proper handling of specimens and equipment was relatively high at 74.29% (public: 70.42%, private: 83.87%). Nonetheless, 25.71% of laboratory workers were observed handling specimens improperly, which may increase the risk of contamination, exposure, and compromised diagnostic accuracy.

Workforce wellbeing indicators revealed that 70.00% of laboratory workers reported experiencing stress and fatigue (public: 66.20%, private: 77.42%). This high prevalence suggests systemic issues, such as staff shortages, excessive workload, or inadequate support systems, that may negatively affect adherence to biosafety protocols and increase the likelihood of human error.

Waste management practices showed relatively strong compliance, with 77.14% of workers properly segregating waste (public: 69.01%, private: 87.10%). However, 22.86% of laboratory workers failed to follow appropriate waste segregation procedures, often mixing infectious and non-infectious waste, thereby increasing environmental and occupational health risks.

Hazard awareness among laboratory personnel was notably high, with 85.71% of workers correctly identifying laboratory hazards (public: 81.69%; private: 93.55%). Despite this, 14.29% lacked adequate hazard recognition, which may be attributed to

insufficient training or limited experience. The higher performance in private facilities again suggests better emphasis on safety education.

Concerningly, unsafe behaviours were still observed. 7.10% of laboratory workers reported eating, drinking, or applying cosmetics within laboratory spaces (public: 4.23%, private: 12.90%). Although this represents a minority, such practices pose serious biosafety risks due to the potential ingestion of hazardous biological agents.

Encouragingly, proper use of laboratory equipment was observed in 87.14% of workers (public: 94.37%, private: 70.97%), indicating a generally strong level of technical competence. However, 12.86% of personnel were observed using equipment incorrectly, which could compromise both safety and diagnostic outcomes.

Overall, a consistent pattern emerges across the findings: private facilities demonstrate higher compliance with most behavioral and procedural indicators than public facilities. This disparity may be attributed to differences in resource availability, staff-to-workload ratios, supervision, or institutional enforcement of biosafety policies.

Despite high compliance in fundamental areas such as PPE usage, the data reveal critical gaps in procedural consistency, particularly in SOP adherence, glove handling, and waste management practices. These gaps are significant because they directly influence laboratory safety, infection control, and the reliability of diagnostic processes.

The findings underscore the need for targeted interventions to strengthen biosafety implementation, including continuous professional training, stricter enforcement of SOPs, supportive supervision, and addressing systemic challenges such as staff fatigue and resource limitations. Emphasis should also be placed on translating

knowledge into practice, as evidenced by the discrepancy between high PPE use and lower compliance with related procedures.

In conclusion, while laboratory workers in Narok County demonstrate a foundational understanding of biosafety principles, the inconsistent application of these practices highlights the need for a more integrated and enforced biosafety framework to ensure optimal safety standards across both public and private health facilities.

4.7 Focus Group Discussions

Presents the results of the focus group discussion (FGD) conducted to assess implementation practices of BB as recommended by the BB training. FGD included participants' perceptions, content, assessments, and practical components, as well as institutional bio-safety measures. The chapter reports findings derived directly from participants' responses without interpretation, in line with qualitative research reporting standards.

A total of eight participants took part in the focus group discussion, divided into two groups of four. Two participants reported prior training in biosafety and biosecurity through Training of Trainers (TOTs) programs, while the remaining participants had no formal BB training experience. All participants were involved in laboratory-related or institutional environments where biosafety and biosecurity practices were relevant.

The FGD revealed several recurring patterns across training delivery, assessment practices, participant engagement, theoretical grounding, institutional support, physical security, and biological hazard management.

Participants who had undergone formal biosafety and biosecurity training reported that the program was delivered primarily through face-to-face sessions. These sessions incorporated structured course outlines, clearly articulated learning

objectives, and visual instructional materials. Practical demonstrations within laboratory settings were identified as central components of the training approach. Participants indicated that visual aids and real-life examples facilitated comprehension of complex biosafety principles.

Assessment methods reportedly included multiple-choice questions (MCQs), short-answer questions (SAQs), and practical evaluations. Trained participants indicated that pre-test and post-test assessments were administered to evaluate knowledge acquisition and measure learning outcomes. These assessments were described as aligned with course content and reflective of practical laboratory realities. Participants without formal training reported the absence of structured assessments and indicated that their understanding of bio-safety procedures was largely experiential or informally acquired.

The data further indicated that practical engagement was a defining feature of the formal training experience. Trained participants described interactive sessions in which facilitators encouraged questions, discussions, and hands-on participation. Feedback mechanisms were reportedly incorporated during practical sessions, with facilitators providing corrective guidance and clarification where necessary. Feedback was described as constructive and aimed at reinforcing compliance with bio-safety standards.

Regarding the theoretical foundations of biosafety and biosecurity, participants reported that the objectives and scope of the training were clearly communicated at the outset. The course purpose, institutional responsibilities, and expected laboratory practices were outlined during the sessions. Participants further noted visible

management endorsement of biosafety initiatives, which was perceived as reinforcing institutional commitment to safety and compliance.

The discussion also revealed disparities in awareness concerning physical security measures. Participants who had received training demonstrated familiarity with biosafety level classifications, access control policies, and the presence of intrusion-detection mechanisms in laboratory facilities. Some participants indicated that biosafety level standards were being implemented in certain units, suggesting variability in institutional compliance. References were made to efforts to align laboratory practices with recognised regulatory and quality assurance frameworks. In contrast, untrained participants demonstrated comparatively limited knowledge of formal physical security systems.

Regarding biological hazard management, trained participants reported awareness of procedures governing the procurement, handling, storage, documentation, and transfer of valuable biological materials (VBMs). The existence of standard operating procedures (SOPs) was acknowledged in facilities where training had been conducted. Biohazard signage was reported to be present in laboratory environments and recognised as an important component of hazard communication. Participants without formal training indicated reliance on peer guidance and routine practices rather than documented procedures.

Across the discussion, differences in knowledge levels between trained and untrained participants were evident. Trained participants consistently demonstrated greater familiarity.

With regulatory requirements, structured safety systems, and documentation processes. Untrained participants expressed limited exposure to a formalised biosafety framework.

4.7.1 Focus Group Discussions

Presents the results of the focus group discussion (FGD) conducted to assess implementation practices of BB as recommended by the BB training. FGD included participants' perceptions, content, assessments, and practical components, at the same time institutional bio-safety measures. The chapter reports findings derived directly from participants' responses without

Below are steps involved in FGDs:

Phase 1: Setup & Consent: the research tested the audio equipment in the actual room before participants arrived. Once gathered, read the consent form aloud, explicitly state that the session is being recorded, and obtain verbal or written signatures.

Phase 2: Live Recording: Started the recorders *before* the icebreaker. The note-taker should focused heavily on capturing **group dynamics**, contextual shifts, and any silent consensus or disagreements that an audio recorder cannot pick up.

Phase 3: Immediate Post-Session Debrief: As soon as the participants left, the moderator and note-taker spent 20 minutes compiling their thoughts. Captured immediate impressions, dominant themes, and any adjustments needed for the next FGD.

Phase 4: Transcription: the research converted the audio into written text. This was the raw material for which was used for analysis.

Verbatim Transcription: Captured every word, "um," "ah," pause, and emotional expression. The researcher used **intelligent Verbatim which** which cleaned up repetitive fillers to make the text easier to read for thematic coding and interpretation, in line with qualitative research reporting standards.

A total of eight participants took part in the focus group discussion who were divided into two discussion groups, each comprising four members. Two participants reported prior training in biosafety and biosecurity through Training of Trainers (TOTs) programs, while the remaining participants had no formal BB training experience. All participants were involved in laboratory-related or institutional environments where biosafety and biosecurity practices were relevant.

The FGD revealed several recurrent patterns relating to training delivery, assessment practices, participant engagement, theoretical grounding, institutional support, physical security, and biological hazard management.

Participants who had undergone formal biosafety and biosecurity training reported that the program was delivered primarily through face-to-face sessions. These sessions incorporated structured course outlines, clearly articulated learning objectives, and visual instructional materials. Practical demonstrations within laboratory settings were identified as central components of the training approach. Participants indicated that visual aids and real-life examples facilitated comprehension of complex biosafety principles.

Assessment methods were reported to include multiple-choice questions (MCQs), short-answer questions (SAQs), and practical evaluations. Trained participants indicated that pre-test and post-test assessments were administered to evaluate knowledge acquisition and measure learning outcomes. These assessments were

described as aligned with course content and reflective of practical laboratory realities. Participants without formal training reported the absence of structured assessments and indicated that their understanding of bio-safety procedures was largely experiential or informally acquired.

The data further indicated that practical engagement was a defining feature of the formal training experience. Trained participants described interactive sessions in which facilitators encouraged questions, discussions, and hands-on participation. Feedback mechanisms were reportedly incorporated during practical sessions, with facilitators providing corrective guidance and clarification where necessary. Feedback was described as constructive and aimed at reinforcing compliance with bio-safety standards.

With respect to the theoretical foundation of biosafety and biosecurity, trained participants reported that the objectives and scope of the training were clearly communicated at the outset. The purpose of the course, institutional responsibilities, and expected laboratory practices were outlined during the sessions. Participants further noted visible management endorsement of biosafety initiatives, which was perceived as reinforcing institutional commitment to safety and compliance.

The discussion also revealed disparities in awareness concerning physical security measures. Participants who had received training demonstrated familiarity with biosafety level classifications, access control policies, and the presence of intrusion detection mechanisms within laboratory facilities. Some participants indicated that implementation of biosafety level standards was ongoing in certain units, suggesting variability in institutional compliance. References were made to efforts aimed at aligning laboratory practices with recognized regulatory and quality assurance

frameworks. In contrast, untrained participants demonstrated comparatively limited knowledge of formal physical security systems.

Regarding biological hazard management, trained participants reported awareness of procedures governing the procurement, handling, storage, documentation, and transfer of valuable biological materials (VBMs). The existence of standard operating procedures (SOPs) was acknowledged in facilities where training had been conducted. Biohazard signage was reported to be present in laboratory environments and recognized as an important component of hazard communication. Participants without formal training indicated reliance on peer guidance and routine practices rather than documented procedures.

Across the discussion, differences in knowledge levels between trained and untrained participants were evident. Trained participants consistently demonstrated greater familiarity.

With regulatory requirements, structured safety systems, and documentation processes. Untrained participants expressed limited exposure to formalized biosafety framework;

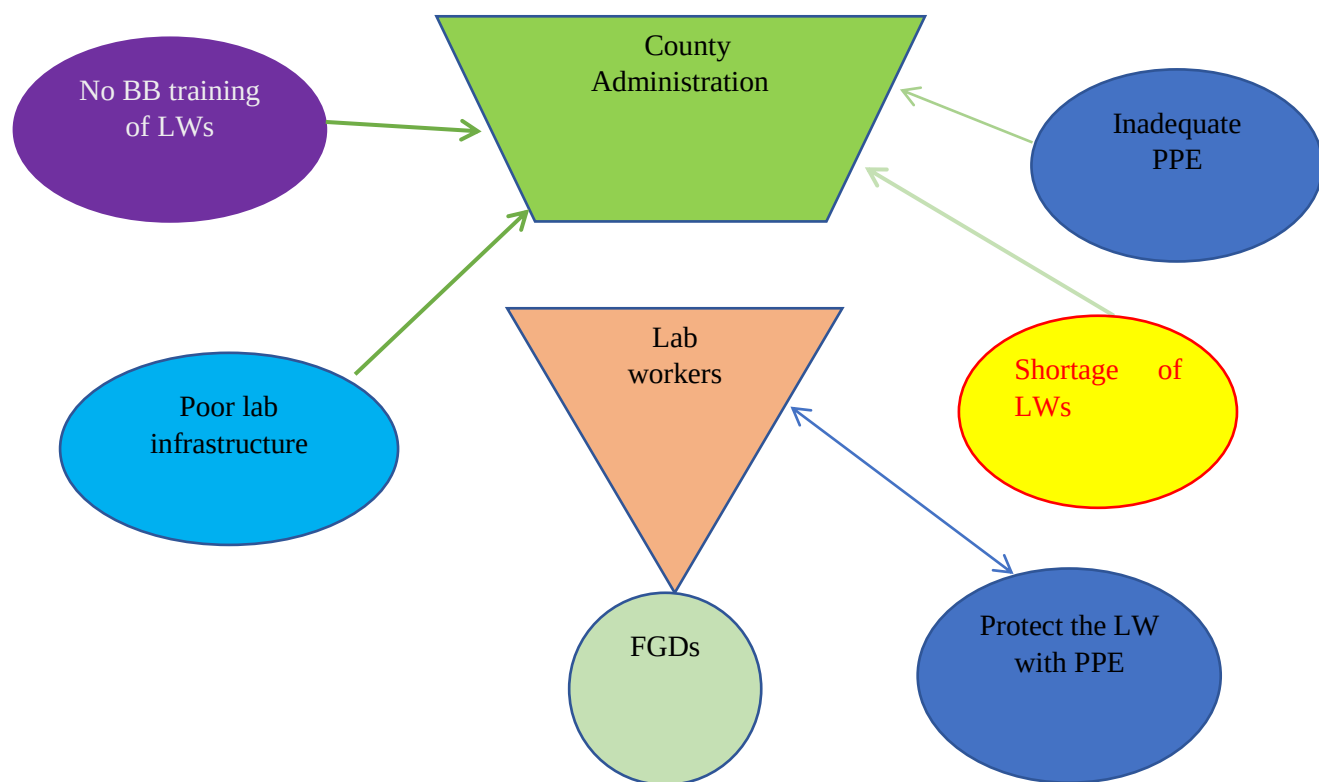


FIGURE 7: SUMMARY OF LAB CONSTRAINTS IN BB IMPLEMENTATION

CHAPTER FIVE

5.0 Summary of Findings, Conclusions and Recommendations

5.1 Introduction

The study's findings have been interpreted and compared with those of related studies. This has been followed by conclusions based on the findings of this study, and the researcher has finally made recommendations for various stakeholders, including hospital medical laboratory workers. A total of 102 participants completed the self-administered study questionnaire; overall, 35 (34.3%) had adequate knowledge, 39 (38.2%) had moderate knowledge, and 28 (27.5%) had poor knowledge. Only 27 (26.5%) had participated in prior formal biosafety training courses. The level of knowledge did not differ significantly with gender, but it increased with increasing work experience in years, level of professional training and training on BB. Age group did not affect knowledge level. The level of compliance for respondents was divided into 3; only 27(26.5%) had high compliance, 44(43.1%) had moderate compliance, and 31(30.4%) had low compliance, explaining why only 44(42.86%) lab workers were observed to have followed SOPs while the rest preferred shortcuts. Multiple constraints were stated and observed, including inadequate resources, mentioned by 61/102 (59.8%) respondents, which explained why only 74 (72.86%) lab workers were observed changing gloves during procedures. At the same time, the rest used the same gloves, handling multiple specimens. Inadequate training was reported in 75 (73.5%) cases, which was associated with the low percentage of LWs who had received formal BB training (27, 26.5%). Poor infrastructure was mentioned in 63 (61.76%) cases, and a large number of field observations were made. Of the 70 laboratories observed, only 29 (41.43%) had separate rooms for analytical work from specimen collection and the administration room, while the rest operated from a

single room. Then, staff shortage was mentioned 76(74.5%), which was evidenced (30%) of the workers reporting stress and fatigue. Only 39(55.71%) of the laboratories had fire extinguishers, leaving the others vulnerable to fire accidents. 68(97.14%) of the facilities had a designated waste-disposal system. 0% of the facilities performed mental status examinations for their lab employees, and only 11 (15.71%) laboratories had eye-wash stations. Only 14 (20%) laboratories had biosafety cabinets, posing a high risk of infectious disease spread, compared with the other 56 (80%) laboratories; similarly, only 14 (20%) facilities had operational incinerators, with most of the other 56 (80%) relying on the county referral hospital. This research should answer the question of the level of implementation of biosafety and biosecurity measures in laboratories in Narok County, coupled with knowledge of BB among the laboratory staff.

5.2 The relationship between LWs demographics and level of knowledge on BB (objective 1)

Objective one was to appraise the relationship between laboratory workers' biosafety knowledge and social demographic characteristics.

According to Monroon's rating of biosafety levels (MRBL), knowledge of biosafety was the same among laboratory workers across Narok County. Every biosafety has a classification of the type of microorganisms to be handled and the PPE to be used (Cornish et al., 2021). The use of gloves and a dust coat is basic personal protective equipment commonly used in BSL1 for microorganisms such as the common flu and urine specimens (Pen et al., 2018). The MRBL served as a baseline, establishing the association between socio-demographic characteristics and knowledge of biosafety and biosecurity implementation among laboratory workers in Narok hospitals. The study found that the F-statistic was 0.84, indicating no statistically significant difference in the means of laboratory workers across sub-counties. The P-value

($p=0.541$), meaning statistical significance; a p -value < 0.05 was significant for the study. They revealed that there was no statistically significant difference in MRBL and BB knowledge. Therefore, we accept the null hypothesis.

This means that the laboratory workers know the type of biosafety level of the laboratory they are working in.

BB training attainment, level of education, and years of experience were significantly associated with laboratory workers' knowledge of BB practices ($p < 0.001$, $p = 0.020$, and $p = 0.033$, respectively). This implied that level of professional education ($p=0.02$), BB training ($p < 0.001$) and more years of experience ($p=0.033$). This implies that the higher the professional level, the more BB training as additional training, and the more years of experience, the more likely one is to have greater knowledge of biosafety and biosecurity. Hence, a more theoretical and practical foundation leads to greater knowledge. A study on the assessment of LWs' knowledge suggests that a higher level of education influences Biosafety and biosecurity practices (Razali et al., 2025); however, it disagrees with years of experience, which was significant for this study. A Togo study generalised demographic data, whereas this study broadened the scope by clearly highlighting BB knowledge by demographic (Halatoko et al., 2024). Age did not influence knowledge ($p=0.081$), indicating that knowledge was evenly distributed across all age groups. A study on biosafety assessment and biosecurity among workers in research laboratories found that BB training influenced BB implementation as practice [$F(5, 266) = 5.43$, $p < 0.05$]. As well as years of experience (OLU et al., 2022). Also, other studies agree with this study, finding that those with more years of experience and a higher educational level (doctorate) were more knowledgeable about BB than those with less experience and a lower educational level (Tran, 2025).

In contrast, a Chinese study found that age and knowledge were more strongly associated with the implementation of biosafety measures (Santome-Pariona et al., 2023); however, they did not examine years of experience or gender. To differ with this study, it is conventional that being older in a field means having practiced for quite some time, leading to a higher probability that they have also received additional training on BB, as reported by other researchers in Morocco (Bajjou et al., 2019). The study in Morocco did not explicitly report statistical comparisons, such as the use of P-values specifically for the effect of age on BB practices, nor did it present a formal age-group comparison solely for practice behaviors' in bio-safety, which this study addressed.

Compared between males and females, there was no statistical difference in BB knowledge. The means difference was too small to reach statistical significance, $t(2) = 0.868$, $p = 0.388$. Shamsol Kamal, Shaharuddin, and Ahmad Yusof investigated KAP regarding laboratory bio-safety at a Malaysian public university and reported no statistically significant difference in laboratory bio-safety scores between male and female respondents (p -value = 0.05; Shamsol Kamal et al., 2025). In contrast, a study in Nigeria on biosafety practices found that gender was statistically significant (OLU *et al.*, 2022). In Togo, the assessment of KAP among LWs concluded that men had a higher level of knowledge compared to women (Halatoko *et al.*, 2021).

Beyond individual sociodemographic determinants, the implementation of biosafety and biosecurity practices among laboratory workers (LWs) in Narok County hospitals can also be interpreted within the broader framework of global biosafety standards and health system preparedness. The World Health Organization emphasizes in its Laboratory Biosafety Manual that knowledge alone is insufficient unless supported by institutional infrastructure, standard operating procedures (SOPs), continuous risk

assessment, and supervisory enforcement (World Health Organization (WHO, 2020). Similarly, the Centers for Disease Control and Prevention underscores that biosafety implementation depends on layered controls, including administrative policies, engineering controls, and personal protective practices rather than demographic characteristics alone (CDC, 2020). In this context, the statistically significant association observed between BB training, education level, and years of experience with biosafety knowledge in this study may reflect cumulative exposure to structured systems, mentorship, and institutional culture rather than education level alone. More experienced and highly educated personnel are more likely to have undergone formal certification, participated in audits, or been exposed to international biosafety frameworks, thereby strengthening compliance behaviors. Evidence from low- and middle-income countries indicates that laboratories operating within structured quality management systems demonstrate better adherence to biosafety measures regardless of individual worker characteristics (Oladipo et al., 2022; WHO, 2020).

Furthermore, the global emphasis on compliance with the International Health Regulations (2005) reinforces the view that laboratory biosafety capacity is both an individual competency and a system-level obligation (WHO, 2016). Therefore, while the present findings demonstrate demographic predictors of knowledge, they simultaneously highlight the need for institutional reinforcement mechanisms to translate knowledge into sustained biosafety practice. In resource-constrained county hospital settings such as Narok, infrastructural limitations, inconsistent PPE supply, and absence of routine biosafety audits may moderate the strength of the knowledge–practice relationship. Studies have shown that even knowledgeable laboratory professionals may demonstrate suboptimal compliance where organizational safety climate is weak (Auta *et al.*, 2018). Sustained implementation requires embedding

biosafety culture within hospital governance structures, continuous professional development, and supportive supervision. The integration of competency-based refresher training, periodic drills, and monitoring indicators aligned with WHO laboratory biosafety guidelines would strengthen practice implementation beyond demographic advantages. Ultimately, these findings reinforce the multidimensional nature of biosafety and biosecurity implementation—where education, experience, and BB training serve as facilitators. However, institutional systems remain the critical determinants of long-term compliance and resilience against laboratory-associated infections.

5.3 Objective Two Discussions

Objective 2 aimed to evaluate laboratory staff's skills and knowledge in biosafety and biosecurity for BB implementation using standardized questionnaires. 102 respondents completed the questionnaires, representing the total number of LWS in Narok County.

The results discussed here are based on LWS's years of work experience, age group, and educational level.

Generally, the respondents registered high scores in this section, which was self-administered, standard questionnaires. Therefore, the respondents could have rated themselves higher than they really are. (Alen & der Velden, 2005) suggest that respondents intentionally alter their responses when taking a self-assessment in order to appear 'normal'. They note that even with assurances of confidentiality and specific instructions about the tool's purposes, some may still feel emotional pressure to answer a certain way.

Secondly, the LWs could have scored high because LWs are considered to be doing those tasks daily and therefore good at doing their duties.

In the LW knowledge section, the LWs scored highly; only 27.5% had poor knowledge, with 72.5% getting above a moderate knowledge pass mark. This finding suggested that some LWs still needed training on BB. In this profession, even 1 person counts; one mistake can lead to an outbreak or a pandemic of infectious disease that brings more damage. The lab workers' knowledge finding in this study agrees with a study done to assess KAP in laboratories among health workers, which concluded that 72.5% of the respondents scored high on knowledge, while 26.7% scored at a medium level on the knowledge questionnaire (Alzahrani et al., 2022)

The level of professional training did not influence management among LWs, $F(2, 98) = 1.51$, $p = 0.20303$. Age also had no statistical significance on individual LW knowledge and skills in management. In both instances, the means were too close, suggesting no meaningful difference and an even distribution of knowledge and skill. Years of experience influenced LWs' managerial capability, $F(3,98)=2.61$, $p=0.039$, with those with 10-14 years of experience being the best managers, while the rest had almost equal levels of management knowledge, with slight variation. It was concluded that managerial ability was influenced by the level of professional training, not age, but by years of experience.

In contrast, a study conducted in Zambia aimed at improving laboratory quality and capacity through leadership and managerial training concluded that formal leadership/management training can significantly enhance laboratory management knowledge and competencies (Gopolang *et al.*, 2021). A cross-sectional assessment of biosafety and biosecurity knowledge, attitudes, and practices conducted at CPU

University, Philippines, among employees who handle biological agents and materials found that age did not significantly influence BB knowledge. In statistical analysis, there were no significant differences in knowledge by age groups. Regardless of age, participants showed similar levels of understanding of hazards, risks and safe handling practices; age also did not affect related attitudes or practices in this study (Saladar, 2024). Other studies found that years of experience influenced LWs' managerial capability.

Age and level of professional training did not differ significantly in biosecurity among LWs ($p\text{-values} > 0.05$). In contrast, years of experience showed strong statistical significance, $F(3, 98) = 5.04$, $P = 0.001$. Whereas LWs' knowledge and skills on matters of biosecurity were evenly distributed among LWs regardless of age and level of professional training, LWs with 10-14 years of experience had the highest level of knowledge compared with the rest. This difference in knowledge indicates that the most senior staff members practice proper biosecurity practices in the laboratories. This can best be explained by the hands-on experience gained over the years and by possible BB training over time. Despite this outcome, the trend in knowledge per year of experience did not show a clear pattern: those with <4 years' experience ranked second, possibly because of their recent history of leaving training institutions, and those with >15 years' experience ranked last. This deduction was made with a limited number of LWs, only 3 of them. This finding agrees with a study done in Lesotho analysing healthcare waste management knowledge versus practice, which reported that even where knowledge and attitudes were present, unsafe practices continued, showing that knowledge did not fully translate into compliance or safe practice, while years of experience had a great impact on BB measures (Siimane & Nts'ihlele, 2024)

In the remaining 5 domains, both years of experience and level of professional training were statistically significant ($p < 0.05$), whereas age did not influence the results ($p \geq 0.05$). These domains included accountability of lab materials, physical facilities, personal reliability, BB training and practice, and involvement with clinical mentors. These findings also revealed that LWs with bachelor's qualifications had the best across all domains, followed by those with diploma qualifications, regardless of age. LWs with 10-14 years of experience performed best compared to those who were senior or junior to them, underscoring the importance of assigning roles and forming teams with such considerations in mind. The LWs with >15 years of experience performed poorly due to role reassignments and a lack of continuous hands-on experience, as they were assigned managerial roles in the laboratory. This can be because years of work experience for LWs reshape how people think about risk, responsibility, and consequences in a real clinical environment. In short, experience shapes risk perceptions, which in turn determine behavior among LWs, where they act right not because they are expected to, but because they understand the consequences. Another explanation is that repetition creates habitual compliance. While inexperienced workers rely on reminders, experienced ones rely on self-monitoring. This finding agrees with ISO 15189-based training studies, which concluded that professional training enhanced competency and accountability. (Xu *et al.*, 2024). Consequently, a study in Cambodia seeking to find mentoring impact in lab quality improvement concludes that higher levels of professional training correlate with more effective clinical mentorship engagement and practice (Wang Y, *et al.*, 2024) but it disagrees with study done on mentorship in African health and clinical research: addressing barriers and building research capacity which stated that professional training alone may not overcome contextual, structural, or organizational barriers that

actually determine mentor involvement, use of physical facilities and predict personal reliability. (Shaibu, Ojo, & Chigozie, 2025)

These findings show the essence of continuous education among LWs: it enhances their performance and, most importantly, their reliability, because to work as a team, everyone must be reliable. These findings agree with a study that was done in Piura, Peru to determine factors in the implementation of bio-security measures which concluded that higher level training and professional preparation correlate with stronger implementation of BB measures and enhanced reliability (Agurto Cordova et al., 2024) However this study disagrees with, study done in Morocco that concluded that reliability and BB training and practice was not linked to level of professional training, it instead argues that the two depended on years of work experience (Bajjou et al., 2018). The finding disagrees with a study done in Uganda seeking to find adherence in bio-safety practice among medical laboratory workers, which concluded that bio-safety practices were not significantly associated with training level or bio-safety level of the laboratory they work in (Uganda lab student bio-safety practice study, 2022)

The strong statistical association between prior formal training and biosafety knowledge ($\chi^2(2) = 18.7, p < 0.001$) further underscores the centrality of structured capacity-building in strengthening biosafety and biosecurity implementation among laboratory workers in Narok County hospitals. Training functions not merely as an information-delivery mechanism but as a behavioural reinforcement strategy that shapes risk perception, compliance attitudes, and procedural consistency. According to the World Health Organisation, competency-based biosafety training should be continuous, context-specific, and integrated into institutional policy frameworks to ensure sustained adherence to safe laboratory practices (WHO, 2020). This aligns

with evidence showing that laboratories with periodic refresher courses and formal certification systems report significantly higher compliance with infection prevention and control standards than facilities lacking structured training programs (Oladejo et al., 2021). The Food and Agriculture Organization of the United Nations and the World Organization for Animal Health further emphasize that biosecurity awareness training is critical for mitigating risks associated with the accidental or intentional release of pathogens, particularly in decentralized health systems where oversight may be limited (FAO & WOA, 2019). In the Kenyan context, strengthening biosafety training directly supports national health security priorities and compliance with the International Health Regulations' core capacities. Empirical evidence from sub-Saharan Africa shows that laboratory personnel who undergo formal biosafety instruction demonstrate improved adherence to PPE use, waste segregation protocols, and incident reporting systems (Ngwa et al., 2020). These findings reinforce the present study's observation that participants with prior biosafety and biosecurity training achieved higher MRBL ratings than untrained counterparts. Importantly, training also reduces variability in practice across age groups and experience levels by standardizing procedural knowledge. While more experienced laboratory workers may accumulate knowledge over time, structured training ensures harmonization of practices across cadres, minimizing generational gaps in safety behaviors. Moreover, adult learning theory suggests that experiential and scenario-based training enhances retention and practical application, which may explain the strong effect size observed in this study. However, literature cautions that one-off workshops without monitoring mechanisms often fail to produce sustained behavioral change (WHO, 2020). Therefore, institutionalising mandatory refresher courses, mentorship programs, and performance-linked biosafety evaluations could enhance long-term implementation.

Investment in simulation exercises, biosafety drills, and supervisory audits would also translate knowledge into observable compliance. Given the high MRBL scores reported among respondents, Narok County hospitals possess a strong cognitive foundation upon which structured institutional policies can build. Consequently, formal training emerges not only as a predictor of knowledge but as a strategic intervention point for strengthening laboratory resilience, preventing occupational exposure, and enhancing overall biosecurity governance within county-level healthcare systems.

An additional dimension that Cato considers in interpreting these findings is the role of the institutional environment and organizational support systems in shaping laboratory workers' knowledge and skills. While individual-level factors such as education, training, and experience have been shown to influence performance, the broader institutional context within which laboratory workers operate plays a critical role in determining how knowledge is applied in practice. Studies in health systems research emphasize that even highly trained personnel may underperform in environments characterized by inadequate supervision, limited resources, and weak enforcement of standard operating procedures (SOPs) (Peters et al., 2013) & (Freeman *et al.*, 2021) . In the context of this study, the variation observed across domains such as accountability, personal reliability, and BB training and practice may therefore reflect not only individual competencies but also differences in facility-level support, leadership, and monitoring mechanisms.

Furthermore, the concept of the knowledge-practice gap provides additional insight into the findings observed in this study. Although respondents demonstrated generally high knowledge scores, this does not necessarily imply equivalent levels of compliance or safe practice. Research in infection prevention and control has

consistently shown that knowledge alone is insufficient to ensure adherence to safety protocols (Allegranzi *et al.*, 2011) & (Roy, S., Mandal, B., & Das, 2025). Behaviorist, including attitudes, perceived risk, and workplace norms, often mediate the translation of knowledge into practice (RAHIM, R. A., 2018). This is particularly relevant in laboratory settings, where routine tasks may lead to normalizations from standard procedures. The findings from Narok County, where high knowledge coexists with variability across domains, align with this broader evidence base.

Another important aspect is the influence of continuing professional development (CPD) in sustaining and enhancing laboratory workers' competencies over time. While initial professional training provides foundational knowledge, continuous learning is essential to keep pace with evolving biosafety guidelines, emerging pathogens, and technological advancements. Studies have demonstrated that laboratory workers who engage in regular CPD activities exhibit higher levels of competency, improved adherence to safety protocols, and better overall performance (Rowe *et al.*, 2018). In this study, the observed variation in performance across years of experience, particularly the strong performance among those with 10–14 years of experience, may reflect a balance between accumulated experience and relatively recent exposure to updated training.

The findings also highlight the importance of mentorship and peer learning in laboratory settings. Although not directly measured in all domains, the influence of experience suggests that informal learning mechanisms, such as on-the-job training, supervision, and peer interaction, may play a significant role in shaping knowledge and skills. Evidence from laboratory strengthening programs in low- and middle-income countries indicates that mentorship-based approaches significantly improve laboratory quality management systems and biosafety compliance (Yao *et al.*, 2014).

Such approaches facilitate knowledge transfer, reinforce correct practices, and provide continuous feedback, thereby complementing formal training programs.

In addition, the role of resource availability and infrastructure cannot be overlooked when interpreting the findings. Adequate access to essential supplies, equipment, and functional laboratory spaces is a prerequisite for effective implementation of biosafety and biosecurity measures. Studies have shown that resource constraints often limit workers' ability to adopt recommended practices, even when they possess adequate knowledge (Oleribe et al., 2019). In the Narok County context, variations in performance across domains such as physical facility and accountability may partly reflect differences in resource distribution across facilities.

The influence of behavioral and psychological factors is another critical consideration. Laboratory work involves repetitive tasks, exposure to potential hazards, and high levels of responsibility, all of which can influence workers' behavior. Theories from occupational psychology suggest that factors such as motivation, job satisfaction, and perceived organizational support significantly affect adherence to safety practices (Maslach & Leiter, 2016). In this study, the relatively high scores in personal reliability may indicate a strong sense of professional responsibility among laboratory workers, although. However, ability across groups suggests that these factors may not be uniformly distributed.

Moreover, the findings can be viewed within the framework of health system resilience, which emphasizes the capacity of health systems to absorb, adapt, and respond to challenges. Laboratories are a critical component of health systems, particularly in disease surveillance and outbreak response. Strengthening biosafety and biosecurity practices among laboratory workers is therefore essential for

enhancing overall health system resilience. Evidence from global health literature indicates that robust laboratory systems with well-trained personnel and strong biosafety practices are better equipped to detect and respond to emerging health threats (Kruk *et al.*, 2015). The generally high knowledge levels observed in this study suggest a strong foundation upon which improvements in practice can be made. The lack of influence of age on knowledge and skills also aligns with findings from other studies, suggesting that competency in biosafety is more closely related to training and experience than to demographic factors. This reinforces the importance of focusing interventions on capacity building rather than demographic targeting. Standardized programs, regular assessments, and supportive supervision ensure that all laboratory workers, regardless of age, achieve and maintain the required competency levels.

Another relevant consideration is the role of policy and regulatory frameworks in shaping laboratory practices. National and international guidelines, such as those from the World Health Organization and ISO standards, establish minimum requirements for biosafety and biosecurity. However, the effectiveness of these guidelines depends on their implementation at the facility level. Studies have shown that strong regulatory oversight, accreditation systems, and quality assurance mechanisms are associated with improved compliance and performance in laboratory settings (ISO, 2019). The findings from this study highlight the need to continue enhancing such frameworks to support laboratory workers in effectively implementing biosafety measures. The findings underscore the importance of integrating multiple strategies to improve biosafety and biosecurity practices. While training and experience are critical, they must be complemented by supportive institutional environments, adequate resources, effective supervision, and strong safety culture. A multi-faceted

approach that addresses both individual and system-level factors is likely to yield the most sustainable improvements in laboratory performance.

In summary, the additional analysis reinforces that a complex interplay of factors, including training, experience, institutional support, and resource availability, influences laboratory workers' knowledge and skills in biosafety and biosecurity. The study demonstrates generally high levels of knowledge; the variability observed across domains highlights the need for targeted interventions to strengthen the translation of knowledge into practice. Strengthening continuous professional development, mentorship programs, and institutional support systems will be essential in enhancing biosafety implementation and ensuring the safety of laboratory workers, patients, and the wider community.

5.4 Objective Three Discussions.

This objective was to establish the laboratory workers' constraints among LWs in NCHs on the implementation of BB."

The objective of this study is to determine the constraints faced by laboratory workers in implementing biosafety and biosecurity practices. The findings indicate that the PPE, in particular the dust coat, scored 100% among both public and private laboratory workers, whereas using a single pair across multiple procedures scored 78.88% among public laboratory workers and 16.13% among private laboratory workers. This suggests that pathogen transfer between laboratory workers and patients is very high and results in environmental contamination. Still a recommendable number of laboratory workers in public: 50 (70.48%) out of 71 change gloves if they contain spills and torn only. This calls for urgent refresh training to compact LAIs through BB training for proper BB implementation. A study on aerosol measurement

in a clinical laboratory (Lee, B. U., 2024) recommended that laboratory dust coats help prevent aerosol particles.

Other PPEs like dust coat, gloves, glass goggles and face masks were assessed on their availability and proper use, and this study found out that (21.12%) and 16.13 % was scored in public laboratory works and private, respectively. WHO (2020) emphasises the proper and consistent use of all PPE in the clinical laboratory to prevent LAIs and contain microorganisms. The study involved both public and private laboratory workers for the BB implementation assessment to support disease control and prevention. This study was conducted in Kenya (Ogaro et al., 2018). This study of Ogaro concluded that without involvement of private hospitals and worker control of these infectious diseases, like *Mycobacterium tuberculosis* and HIV, the spread will continue. Hence, incidence rates and prevalence will rise. Constraints impede the implementation of biosafety and biosecurity practices. This was done subjectively (based solely on respondents' interpretations, feelings, or judgments) rather than on universally verifiable facts about the constraints that matter.

Constraints encountered by laboratory workers hinder the implementation of BB practices. Among LWs in Narok County, only 26.50% trained in BB practice. This can be interpreted as inadequate BB training opportunities (as additional training in their profession. Laboratory workers, especially those in the public sector in this study, faced these difficulties. Forcing them to use a single pair of gloves while handling different specimens and patients, for instance, during phlebotomy, is a major predisposing factor for the acquisition and transfer of infectious agents to patients or for the contamination of specimens, thereby leading to false-positive results. Whose consequences are dire to the patient, as it leads to mismanagement and abuse of

medication. Ideally, the World Health Organization emphasizes 100% adherence to PPE when working in the lab to protect yourself (WHO, 2020). This was also echoed by Cornish et al. (2021) in their report on previous outbreaks. In a study at an Ethiopian public hospital, adherence to protective barrier use was 61.7%, indicating insufficient PPE supply. In this study, public hospitals had 38.58% compliance with PPE, while according to the WHO/MOH, it is supposed to be 100%. This is because they did not have sufficient PPE for their protection, whereas in the private sector, LWs had 60% still not compliant; however, they were much better than their counterparts in public hospitals because there was an adequate supply. A study conducted in both Public and Private Facilities amongst LWs in western Kenya showed that about 71.6% adhered to BB measures. There was a section of participants with a bad attitude towards PPE. The inadequacy of BB materials in public hospitals rose significantly due to the devolution of Health services to the 47 counties in Kenya, one participant commented. This came up strongly during the focus group discussions.

The issue of inadequate supply of BB materials can be addressed by adopting a holistic approach to address inefficiencies in the health sector (Zeng et al., 2022; Masaba et al., 2020). The approach reduces the stress posed by such inadequacy, promoting the implementation of BB measures to the set standards. A study conducted on biosafety gaps in clinical laboratories emphasized the use of PPE, among other measures, to combat disease outbreaks (Cornish *et al.*, 2021). Nevertheless, this study is in concordance with these studies.

Additional BB training to properly implement safety measures indicates better LAI prevention. This study found that only 27 (26.47%) of the 102 LWs were trained in

the entire county. According to the World Health Organization, 100% of LWs should undergo this training before starting work in the laboratory. During the COVID-19 outbreak, training in BB was emphasized (Cornish et al., 2022) to reduce the spread of infectious diseases and protect lab workers and the environment. In this study, in the public sector, 21 (29.52%) of the 71 LWs had been trained, while in private facilities, only 6 (19.35%) of the 31 LWs had been trained. Training of BB involves financial resources, making it difficult for participants to sponsor themselves. This agrees with a study that reported that there was a lot of challenges in training of LWs in BB (Huang et al., 2020). Another study adds that as BB training is compulsory for every lab worker it has challenges, due to inadequate staffing which makes it difficult for LWs to leave the facility and attain the training (Bayot, M. L., & Limaïem, F., 2019). The solution to these Challenges will only be achieved by involving the county governments to collaborate with private facilities and other parties to support their LWs. This aligns with a study conducted in low- and middle-income countries to harmonize their biosafety and biosecurity policies, particularly for collaborations in resource-limited settings (Maehira & Spencer, 2019). Online training will also play a greater role here—adequate utilisation of clinical mentors in all of this will boost good outcomes. The online training saves time and money while also facilitating knowledge. This concurs with the training conducted to increase BB knowledge and standards and practices (Qasmi et al., 2022). Qasmi highlights the issue of risk assessment and control measures in the context of the COVID-19 pandemic, specifically targeting this context.

Training is not merely informational but very transformative; it shapes safety culture, risk perception, and behavioral consistency (Santamato, Marengo, & Aversano, 2026) in the study of biosafety protocols and strategies. The improper placement of printed

laboratory results on contaminated work surfaces, as observed in this study, reflects lapses in procedural awareness that structured training programs are designed to correct. During COVID-19, the issues of polishable benches and clean laboratory services helped prevent the virus (Małecka et al., 2020). Similar deficiencies were identified in biomedical laboratories in Athens, where gaps in biosafety training programs were associated with weak biological risk management systems (Vourtsis *et al.*, 2025). Evidence from outbreak-prone settings further demonstrates that insufficient training contributes to improper specimen handling, inadequate disinfection practices, and increased likelihood of laboratory-acquired infections (Cornish et al., 2024).

Good laboratory design and workflow are paramount for implementing biosafety measures in any laboratory. Bio-safety indicators such as proper ventilation for good airflow, separate rooms for phlebotomy and analytical work to manage traffic, and an office for files or tea for the officers. Lack of strengthening can undermine the success of BB implementation, so laboratories should work to promote handwashing hygiene (Cornish et al., 2021). This study established that running tap water or improvised taps was impressive at 97.18% for Private LWs and 80.65% for both. Studies done on waste segregation and a well-designed area must be in place for the success of BB implementation (Pande et al., 2024). The laboratory estimated the place for hazard was 61.29% private LWs, and (21.13%), much lower than indicated. The back-up power system laboratory responded with availability of 84.51% and 61.29% in public, respectively, to sustain equipment like refrigerators to keep reagents and specimens safe. Cold rooms and refrigerators need backup power to support power outages, which in turn support risk assessment in the laboratory (Cornish et al., 2021) and in hospital cleaner work tops, among other things (WHO, 2020). Laboratory design

instability underscores laboratory performance in any clinical laboratory (Vernooij, 2021). If the laboratory design and workflow are inadequate, coupled with limited access to clean water and electricity, this affects the accuracy and precision of laboratory operations (Al-Worafi, Y. M., 2024). The respondents in this study were from both public and private facilities, as all play key roles in disease control and prevention. The findings are: 40.58% of public facilities reported that it was adequate in terms of workflow, signage, and ventilation.

Regarding power availability and backups, the scores were 91% and 80%, respectively. Although they performed poorly in areas like designated, secure storage areas for hazardous materials, only 15 (21.13%) responded to their availability. It is good that BB does not need the WHO list approach. 61.29% of private-sector participants responded 'yes' to good laboratory design and workflow. It agrees with (Vernooij, 2021; Al-Worafi, Y. M., 2024) and (Nkengasong, Yao, & Onyebujoh, 2018). Nkengasong, Yao, and Onyebujoh, in their study on Laboratory medicine in low- and middle-income countries, found that basic laboratory services could be improved across all aspects if infrastructure design were taken into account. Poor physical facility security, inadequate storage of laboratory materials, and a poor curriculum for BB have compromised BB practice and implementation. The World Health Organisation has rolled out guidelines and regulations for the implementation of biosafety and biosecurity (WHO, 2020). The fact that private hospitals were doing well in terms of infrastructure is associated with the absence of bureaucracies in private institutions, especially in procurement. Overall, private conformance was 37.65%, which was much lower than public conformance (40.48%) in both lab design and workflow. In addition, the lack of laboratory personnel involvement in their

designs is an issue in public institutions. During the study, a researcher encountered many residential houses and one store that had been converted into laboratories.

On issues of staff working in the laboratory: Workload elements for clinical laboratory staff include: main activities; additional categorical activities each staff member performs; and any other individual activities performed only by specific staff members (Thomas et al., 2025). Thomas goes on to say that workload in clinical laboratory staff is measured using the Workload Indicators of Staffing Need (WISN) method, which is mostly used by human resources, and will help LW avoid being overwhelmed by work. Unfortunately, Narok County has not used this WISN; as a result, it ends up employing non-LWs to work in the lab, only to find out they cannot work. LWs are properly trained and licensed by KMLTTB. This course involves quality checks, as it deals with biological materials, which require proper implementation of BB (Rao et al., 2023). Therefore, to realise proper BB implementation, LWs must work as stipulated in WISN (Thomas et al, 2025). During this study, a researcher found that one LW at a sub-county hospital handling 200 specimens a day looked fatigued and stressed, hence compromising BB implementation.

In another sub - county hospital, there was an outbreak of cholera, and only one worker and a student were present in the laboratory. Specimens were scattered, and fatigue was evident among the laboratory workers. Still, this facility lacks proper storage for these infectious specimens, and you would assume pathogen exposure was unavoidable. The focus interview indicated that two of the LWs acquired the disease. On the contrary, the adjacent private facility staff were idle with few workloads. There were questions about whether they worked 8 hours a day or less. Their

responses were 27 (38.03%) yes and 0 (00%) among public LWs, whereas among private LWs, 11 (35.48%) worked for 8 hours and 0 (00%) never worked less than 8 hours. Regarding LWS going on leave yearly, 35 (49.30%) said yes, indicating they go on leave annually.

In comparison, 36 (50.70%) responded with no answer, indicating that their workload was high and that no one was available to relieve. Studies have indicated that overworking can lead to stress and burnout among laboratory workers (He et al., 2023). On the other hand, private LWs: 22 (70.97%) went on leave yearly, while 9 (29.03%) did not want to miss a month's salary and opted to continue working. Low staffing affected the quality of work during COVID-19 (Huq Ronny et al., 2023). Duty shifts and overtime are causing a staffing shortage among laboratory workers, thereby compromising the BB practice (Halstead & Sautter, 2023).

The findings indicate that LWs in public had a high workload, analyzing more than 75 tests (50, 70.48% of 71), which led to fatigue and stress. Among private workers, 20 (64.52%) reported performing more than 75 tests a day. According to the WHO working standards, laboratory workload is calculated using WISN, which estimates that a laboratory worker should perform approximately 75 tests per day, constituting a normal workload. However, due to a small number of staff, this leads to performing above 75 tests and denying LWs access to leave, among other LWs, 36(50.70%) in public not going on leave. However, for private, this can be ignored (9; 29.03%), because not going on leave can be translated as getting overtime money.

This study aligns with a study on Ebola virus outbreaks and biosafety in malaria laboratories (Cornish *et al.*, 2021). Work overload among laboratory staff led to low biosafety scores (67 %) (Tadesse *et al.*, 2025). Laboratory staffing was inadequate

according to WISN; hence, the importance of information technology (IT) in biosafety management was emphasized, along with recommendations for medical laboratory institutions (Tang et al., 2024). However, this study by Tang does not suggest that IT should replace the workforce.

There was an issue of absenteeism, where the laboratory in the public sector recorded the highest (78.87%), but the public was only 1 out of 31, translating to 2.23%. A study on shifts and heavy workload found increased absenteeism, mostly in public hospitals (Rajan, D., 2023). A laboratory worker under a heavy workload can become physically disabled (Kumareswaran et al., 2023). A study in South Africa reported that a heavy workload can cause emotional stress, leading to absenteeism (Shikulo, S. P., 2022). Shikulo continues to say that this can cause errors at work and violations of biosafety practices. This study, therefore, examines heavy workload, stress, and burnout.

The issue of laboratory-acquired infection occurred in 31 (43.68%) of public lab hospital workers and in 61.29% of private laboratory workers. This creates anxiety and concern, as the County does not screen its LWs for infectious transmissible agents before employment, nor does it provide any vaccination for them. This study found that 43.66% of LWs in public hospitals have LAIs, either through needlestick injuries or inhalation and spread of aerosols caused by processing specimens in the lab. This agrees with a study done on forensic laboratories where LW were exposed to chemical inhalation, such as formaldehyde (Chaiklieng et al., 2021). This is caused by the scarcity of Personal Protective Equipment, mostly in public hospitals. Research laboratories reported 276 infections and eight fatalities, whereas clinical laboratories accounted for 227 infections and five deaths in one year (Dhaw et al., 2025) in his

systematic review. Also, in a study done in Kajiado, Kenya, on factors affecting biosafety, it was stated that about 80% LWs contract LAIs (Kung'u, M. M., 2021).

The LAIs were almost similar across all sectors, were by 61.99% of the private laboratory workers having encountered an exposure to infectious biological materials and had documented it. Also, 90.32% were working with specimens producing aerosols, hence enhancing exposure to biological agents. Obogo *et al.*, (2025 confirm these findings, whereby they indicated laboratory-created aerosols increase the risk of LAIs. Surprisingly, 70.97% Private hospital laboratory workers were not aware of reporting procedures in case of needle stick injury or pathogen exposure. A surveillance on laboratory exposures with pathogens indicated that the process of reporting exposure has not been covered well. In the year 2018, laboratory exposure and laboratory-acquired infections occurred in 89 people out of 235, which was twice than the 2017 of the previous year. (Choucraallah et al., 2019). All these surveillances were conducted in Canada; this study has created a reference for Kenya and, more so, Narok County.

BB implementation is affecting LWs across the board. This is because they are all working with biological specimens of unknown sources, which would vary from highly infectious to less infectious. One of the clinical biosafety gaps is working with biological specimens from patients (Cornish et al., 2021).

5.5 Objective four, compliance of laboratory workers and facilities on BB implementation

This is meant to answer objective 4 of the study, which states that “Appraise the level of compliance on bio-safety and bio-security during their implementation with recommended standards among laboratory workers” This was purely observation; no active interview was done. The BB implementation process has set standards to

ensure safety for both the LW and the patient, the environment. More importantly, clinical laboratories work with biological specimens that can be highly infectious; careless handling and storage can lead to unintentional escape. Hence, it can be used as a biological weapon.

Generally, private facilities performed better than public facilities, probably due to the sufficient supply of resources.

The laboratories were observed, and the events during the study were recorded based on the above. Various standards were seen to have been implemented across the facilities. Only wearing of PPEs by LWs got a 100%. Implying that 70(100%) of the laboratories observed provided LWs with PPEs. This was quite amazing, stressing the fact that LWs were protected against laboratory-acquired infections. This can also be due to trauma from experience, or lessons learnt from colleagues on the probability of contracting diseases. The excellent use of PPEs in all laboratories was also a similar finding in Ndu *et al.*, (2017) which was a mixed-methods systematic review of infection prevention and control among LWs. It was concluded that laboratory staff had very high PPE usage, with LWs reporting 100% use of certain PPEs (gloves/coveralls), specifically greater PPE use among Lab staff compared to doctors (Ndu *et al.*, 2017, as cited in Aldhamy *et al.*, 2023)

In the group discussion, one of the respondents said that it is better to use the same pair of gloves over multiple specimens instead of taking chances. This act of 100% wearing of PPE is a sign of improvement from the previous retrospective study that was done to identify clinical laboratory biosafety gaps, identify areas of future improvement, and identify the need to improve the use of PPEs (Cornish *et al.*, 2024)

Despite the fact that the PPEs were used by all LWs, only 58(57.14%) were able to don and remove gloves – a basic component of PPEs- appropriately, while the rest were seen not observing the set standard. This finding showed inconsistencies in the practice and skills in performing basic procedures. This finding is similar to a survey done in Karachi, Pakistan, on bio-safety practices in lab personnel. They concluded that a high percentage of laboratory technicians, lacked awareness of proper lab practices and biosafety measures, with many not using PPE, frequently recapping used syringes, or continuing mouth pipetting (Ahmad et al., 2019) The only difference between these 2 studies is coverage, that of Pakistan had a small coverage, 12 selected facilities while this one did 70 facilities but the outcome was consistent in both.

Poor adherence to SOPs was observed in 58 (57.14%) of the laboratory workers; these were the LWs who could not follow the set protocol in the bio-safety and bio-security line of operation. This would be attributed to high workload, as noted both in the FGD and on-site visit. Failure to do things with precision and accuracy leads to the commission of errors that may bring down facilities and individual LWs. This is in agreement with the biosafety standards, which state that laboratory workers need to be updated on BB procedures at all times (Manjengwa, J., 2022). The observation done on LWs was consistent with a study evaluating the capability of clinical laboratories, including those in hospitals, to manage biosafety risks and safely test patient specimens, highlighting the challenges faced by laboratory professionals. It identified retrospective bio-safety gaps in SOPs such as specimen collection, storage and processing, equipment safety, waste management, personnel training/competency assessment, and accreditation processes. This study also agreed with another study that implementing these standards was difficult because the guidelines are only applicable in research laboratories (Cornish et al., 2021). Nevertheless, this

prospective study also agrees with Cornish and others on the issues of inadequate PPE and infrastructure. All the other findings were consistent with the earlier-mentioned studies.

Proper handling of equipment/specimen was observed in 76(74.29%) of the LWs. This clearly shows that we still have inappropriate handling of specimens in 26(25.71%) of LWs, which is a point of concern. For instance, in one of the areas where there was a cholera outbreak, it happened that there was no refrigerator to hold the specimens separate (from blood and reagents) waiting to be taken to KEMRI. The specimen samples were displayed in the open air, on tables as if they were very friendly bacteria. This also can refer to the mysterious tales surrounding the start of the unforgettable Coved 19 that claimed thousands of lives. Apart from this revelation, there were 7(7.1%) LWs observed to be eating in the laboratory. A similar observation was made in a study done to assess bio-safety and bio-security among LWs, a qualitative and risk assessment study. Concluded on listing the basic reasons for personnel infection, including neglect of immune prevention, late disease diagnosis, human factors (e.g., inexperience, inattention), and violations of sanitary rules, which act as constraints and challenges (Burtseva *et al.*, 2022). It was then concluded that the LWs were not implementing the policies in totality, errors were committed and this risks lives, careers and reputation of the facility. Measures ought to have been put in place to ensure compliance at the personal level, if it means purely involving the administration for closer monitoring of LWs.

Apart from personal LWs compliance, the study extended the scope to observing the layout, structure and flow of events in the Laboratories. Out of 70 laboratories observed, 39(55.71%) were BSL1 level while 31(44.29%) were BSL2 level. There was no other above the 2 levels. To add to that, only 1 lab was ISO certified, Narok

County Referral Hospital. While 2 were still in process to be certified, the Lolgorian level 4 hospital and the Transmara West Sub-County Hospital were still in process. The remaining 67 did not have the accreditation, nor did they have a plan to obtain it. This statistic explains why there were inconsistencies in competence and compliance all over.

On the layout of the laboratories, only 29 (41.43%) were partitioned into 3 rooms: analytical room, specimen collection room and administration. This finding revealed that more than half of the facilities did not have the standard implemented. They were operating from a single room, which could also act as a store. Some rooms were congested increasing the risk for injury to LWs. On infrastructure, it was noted that only 14(20%) of the facilities had a bio-safety cabinet. The rest, 56(80%), lacked this feature which is quite a big number. The facilities also had an issue with areas for staff welfare; only 39(55.70%) had an area for staff wellbeing.

Implying that in the remaining 31(44.7%), the staff did not have privacy whenever they needed the Lab services, no separate area for hand washing, risking acquisition of laboratory-acquired infections. This finding puts LWs and the hundreds of dependents at risk. These LWs have families they go back to, so an infection that could have been prevented by implementation of safety guidelines enters an innocent family, changing the family dynamic for good. Ventilation got a good compliance outcome; 62(88.57%) had proper ventilation. It was only 8(11.43%) facilities that had an issue with this, but to be honest, 8% is not 0% and thus, 8% means something. 8 facilities have poor ventilation; that is, more than 15 laboratory workers' lives are at risk, while even one life matters. Poor ventilation in most of these facilities that do sputum culture for TB test means a possible acquisition, and thus, 8 facilities are too big to be ignored. Generally, the outcome in compliance, as far as infrastructure is

concerned, was inconsistent compliance across the 70 laboratories. Every laboratory became a statistic in one or more of the components in this study. This is a special calling on the bodies that regulate Labs to step up and do their job and ensure the laboratories are built to the set standard for efficient operation. This finding goes hand in hand with the previous research in this field. Especially the study that reviews the laboratory workers' perception of biological risks and evaluates how they manage biological materials in Biomedical laboratories of Public Hospitals in Athens, Greece. This study highlighted specific deficiencies, such as the lack of restricted access, controlled ventilation, use of biological safety cabinets, and bio-risk management systems (Vourtsis *et al.*, 2024)

Bio-safety features had moderate to poor implementation. 39(55.71%) facilities had fire extinguishers in place. The other 31(44.29%) were lacking this basic requirement; labs have flammable reagents, electronic machines that can easily start a fire outbreak. 44.29% of the facilities lacking this feature is a red flag, a big risk of losing all the equipment to fire. More so, the loss of records and disease surveillance books was a major risk they dared to take. These fire outbreaks can spread to the rest of the hospital, causing irreparable damage and threatening the lives of immobilized patients. Incineration, being the center of destroying infectious wastes, did not stand the test either; 56(80%) of laboratories lacked a functional incinerator. The 80% relied on 1 facility, NCRH. This raised a question about how safe it was to transport infectious material from one place to another. That movement act showed the possibility of spreading infections unintentionally. There was a high compliance record on the designated area for waste disposal, as it was implemented in 68(97.14%) of the facilities.

The occurrence book was another missing feature in the laboratories, where 49(70%) laboratories lacked the book. Some laboratories improvised a maternal and child health (MCH) book as the occurrence book. This brings a huge concern about the accountability and reporting as it is supposed to be. This study agrees with a cross-sectional study done in Pakistan assessing the implementation of biosafety and biosecurity measures among clinical diagnostic laboratories during the Covid 19 pandemic. It concluded that there was poor biosafety implementation in clinical diagnostic labs (Sarwar *et al.*, 2022). Another, similar agreement was made in a semi-quantitative study in Indonesia, which evaluated gap analysis of biosafety/bio risk management implementation in 8 referral hospital labs. Key deficiencies included: none of the labs had fully implemented a formal biosafety management system according to ISO 350001 standards (Handayani *et al.*, 2024). In a study done in Khartoum state, diagnostic labs found low biosafety precautions, whereby there was a very low number of essential biosafety elements. Coincidentally, there were only 2 functional incinerators across all labs, very low awareness among lab personnel toward biosafety principles, indicating poor biosafety implementation overall (Khartoum state study, 2022)

The LWs' welfare was another area of concern, the lack of a designated area for their specimen collection, and the lack of eyewash stations in 59(84.29%) of the facilities. They only had access to taps that were used for lab operations. Risking the loss of sight was another very evident thing. Eye irritation by chemicals and then conjunctivitis could lead to unwanted collateral damage to LWs. The most uncommon finding of this study was that 0% of the facilities did a mental health assessment of their LWs. Negligence to the LW's mental well-being is a quick way to say that do whatever it takes in whichever way to get us the results. In the end, we end up with

omission and commission. Only 4(5.71%) facilities had LWs files, a rare feature as the statistic suggests.

In conclusion, these findings are that the LWs have been neglected and the administration needs to act and ensure their well-being and comfort, and this will definitely enhance their reliability. This finding is consistent with other researchers quoted in this section earlier. For instance, Vourtsis reviewed the laboratory workers' perception of biological risks and evaluated their management of biological materials in biomedical laboratories of public hospitals. He identified marked deficiencies in containment and administrative controls; restricted access (48.9%), use of Biological Safety Cabinets (31.8%), and assigned biosafety officers (10.8%). He went on and emphasized the urgency of addressing critical gaps in biosafety and emergency preparedness, noting a lack of risk assessments, biosafety manuals, and staff training programs.

The findings of this study can also be interpreted through the lens of systems-based biosafety implementation, which emphasizes that compliance is not solely dependent on individual laboratory workers but is strongly influenced by institutional structures, leadership, and resource allocation. The variability observed across facilities in Narok County reflects what is described in global health systems literature as “fragmented implementation environments,” where policies exist but are unevenly operationalized due to contextual constraints (Peters **et al.**, 2013). In such environments, laboratory workers often operate within limitations that shape their behavior, including inadequate infrastructure, limited supervision, and inconsistent enforcement of standards. This reinforces the need to view non-compliance not purely as individual failure but as an outcome of broader systemic inefficiencies.

A critical dimension that emerges from this study is the role of organizational safety culture in shaping biosafety practices. Safety culture refers to the shared values, beliefs, and norms that influence how safety is prioritized within an organization. Studies have shown that institutions with strong safety cultures demonstrate higher compliance with infection prevention measures, reduced incidence of laboratory-acquired infections, and improved reporting of near-miss events (Singer et al., 2009). The observed lack of occurrence books in 70% of facilities suggests weak safety culture maturity, as incident reporting is a key indicator of an organization's commitment to learning and continuous improvement. Without structured reporting systems, unsafe practices may become normalized, reinforcing cycles of non-compliance.

The issue of workload and human factors is another critical determinant of biosafety adherence highlighted in this study. The high prevalence of stress and fatigue among laboratory workers (70%) aligns with findings from occupational health research, which indicate that fatigue significantly impairs cognitive function, decision-making, and adherence to safety protocols (Caruso *et al.*, 2004). In high-pressure laboratory environments, workers may prioritize task completion over procedural accuracy, leading to shortcuts such as failure to change gloves or improper specimen handling. This phenomenon is consistent with the human factors theory, which posits that errors often arise from system design flaws rather than individual negligence (Reason, 2000). Addressing these issues requires interventions such as adequate staffing, workload redistribution, and supportive supervision to reduce cognitive overload.

Another important perspective is the concept of risk perception and behavioral compliance. Although 85.71% of laboratory workers were able to identify hazards, this did not fully translate into safe practices, as evidenced by improper glove use and

SOP non-adherence. This disconnect between knowledge and behavior is widely documented in public health research, where risk awareness does not always lead to risk-averse actions (Slovic, 1987). Behavioral change theories, such as the Health Belief Model, suggest that individuals are more likely to adhere to safety practices when they perceive a high level of personal susceptibility and severity, combined with clear cues to action and minimal barriers (Rosenstock, 1974). In this context, the persistence of unsafe practices such as eating in the laboratory (7.1%) indicates that perceived risk may be underestimated or overshadowed by convenience and habit.

The infrastructural gaps identified in this study, particularly the low availability of biosafety cabinets (20%) and incinerators (20%), can be analyzed within the framework of health system capacity strengthening. According to the Global Health Security Agenda (GHSA), laboratory systems must be equipped with essential biosafety infrastructure to effectively detect, respond to, and contain biological threats (GHSA, 2018). The reliance on a single facility (NCRH) for incineration services introduces logistical risks associated with the transportation of infectious waste, including accidental spills and environmental contamination. This centralized model may be efficient in resource-limited settings but requires strict regulatory oversight to ensure safe handling and transport.

The absence of mental health assessment programs (0%) among laboratory workers represents a critical gap in occupational health policy. Emerging evidence highlights the importance of psychological well-being in maintaining workplace safety, particularly in high-risk environments such as laboratories handling infectious materials. Chronic stress, burnout, and emotional fatigue have been linked to increased error rates and reduced compliance with safety protocols (Shanafelt et al., 2015). The neglect of mental health in this context suggests a narrow focus on

physical safety measures, overlooking the broader determinants of worker performance and safety.

From a governance perspective, the low level of laboratory accreditation and certification observed in this study has significant implications for compliance. Accreditation frameworks such as ISO 15189 and ISO 35001 provide structured guidelines for quality management and biosafety implementation, including requirements for documentation, training, risk assessment, and continuous improvement. Studies have shown that accredited laboratories demonstrate higher compliance with biosafety standards and better overall performance compared to non-accredited facilities (Yao *et al.*, 2014). The fact that only one laboratory in this study was ISO-certified indicates limited adoption of these frameworks, which may contribute to the observed inconsistencies in practice.

The findings of this study also resonate with the concept of “latent failures” in safety systems, where underlying system weaknesses create conditions for active errors to occur (Reason, 2000). Examples from this study include a lack of infrastructure, inadequate training, and the absence of monitoring systems, all of which create an environment where unsafe practices can emerge. Addressing these latent failures requires a proactive approach that focuses on system redesign rather than reactive responses to incidents.

Furthermore, the observed differences between public and private facilities highlight issues related to resource distribution and health sector inequalities. Private facilities demonstrated relatively higher compliance across several indicators, likely due to better funding, lower patient loads, and more efficient management structures. This disparity is consistent with findings from other low- and middle-income countries,

where public health facilities often face resource constraints that limit their ability to fully implement biosafety standards (Oleribe *et al.*, 2019). Bridging this gap will require targeted investments in public sector laboratories, including infrastructure development, training programs, and policy enforcement.

In addition, the concept of continuous quality improvement (CQI) is essential in addressing the gaps identified in this study. CQI involves iterative processes of monitoring, evaluation, and improvement to enhance performance over time. The absence of proper record-keeping systems (32.86%) and occurrence logs (30% compliance) indicates limited capacity for internal quality assessment. Implementing CQI frameworks, including regular audits, feedback mechanisms, and performance benchmarking, can significantly improve compliance and safety outcomes (Deming, 1986).

Finally, the findings underscore the importance of integrating biosafety into broader health system resilience strategies. Laboratories play a critical role in disease surveillance, outbreak response, and public health decision-making. Weak biosafety systems not only endanger laboratory workers but also compromise the integrity of health systems and community safety. The COVID-19 pandemic has highlighted the global consequences of inadequate biosafety practices, reinforcing the need for robust and standardized implementation across all laboratory settings (WHO, 2021).

In conclusion on this objective, Individual competence was determined and grouped into 3, as low, moderate and high. The majority (44/102 respondents) had moderate compliance.

Compliance level	n	%
Low	31	30.4
Moderate	44	43.1
High	27	26.5

With that simulation, only 27 (26.5%) LWs had high compliance, which is of great concern. Adherence to biosafety principles is the basis upon which LWs should operate at all times. This shows that most incidents in laboratories are due to human error and obvious ignorance. Berche (2025) and colleagues analyzed published reports of laboratory-associated infections worldwide and found that approximately 70% of laboratory exposure incidents were due to human error (Berche et al., 2025). This conclusion aligns with broader findings in biosafety literature that avoidable human behavior and procedural mistakes, including ignorance of standard protocols, are the dominant causes of lab accident events (Ross & Harper, 2023)

The observed pattern of compliance—characterized by universal PPE availability but inconsistent procedural adherence—illustrates a critical distinction between symbolic compliance and functional biosafety performance. While 100% PPE usage suggests institutional acknowledgment of occupational risk, the improper donning and doffing practices observed among 44(42.86%) of laboratory workers indicate gaps in procedural fidelity. Implementation science literature emphasizes that the availability of protective equipment does not automatically translate into safe behavior; instead, sustained compliance depends on behavioral reinforcement systems, supervisory accountability, and embedded safety culture (Fixsen et al., 2005). The concept of “work-as-imagined” versus “work-as-done,” widely discussed in safety systems theory, explains how frontline workers often adapt protocols under real-world pressures, sometimes normalizing deviations from standards (Hollnagel, 2017). In laboratory settings, such normalization may include glove reuse or partial adherence to SOPs, especially when workload or supply pressures exist. The International Organization for Standardization, through ISO 35001:2019, outlines that biosafety management systems require documented procedures, competency verification,

internal audits, and corrective action cycles to ensure continuous improvement rather than episodic compliance (ISO, 2019). The finding that only one laboratory was ISO-certified, with the majority lacking structured accreditation pathways, likely contributes to the observed variability in compliance levels. Accreditation processes create external accountability mechanisms that standardize performance indicators and reduce procedural drift. Moreover, biosafety level distribution (39(55.71%) BSL-1 and 31(44.29%) BSL-2) without facilities exceeding BSL-2 suggests limited capacity for handling higher-risk pathogens locally, reinforcing dependency on specimen referral systems. The World Health Organization underscores that biosafety level designation alone is insufficient unless accompanied by engineering controls such as certified biological safety cabinets, airflow verification, and waste decontamination systems (WHO, 2020). The low availability of biosafety cabinets in 14(20%) facilities indicates partial implementation of containment principles, potentially increasing aerosol transmission risk during specimen manipulation.

Additionally, the lack of occurrence books in 49(70%) of laboratories signals a weak incident documentation culture, undermining learning from near-misses and exposure events. High-reliability organizations emphasize structured incident reporting as a cornerstone of risk mitigation (Reason, 2000). Without systematic documentation, laboratories lose opportunities for corrective learning and trend analysis. Therefore, the moderate overall compliance rate of 44(43.1%) respondents observed in this study reflects systemic implementation gaps rather than isolated worker negligence. Strengthening compliance will require integration of formal biosafety management systems, periodic competency assessments, structured supervision, and movement toward incremental accreditation. Embedding continuous quality improvement cycles within laboratory governance structures may bridge the gap between policy presence

and practical execution, ensuring that PPE usage translates into comprehensive biosafety adherence across all procedural domains.



FIGURE 8: DIAGRAMMATIC REPRESENTATION OF FINDING INTER-CONNECTIONS

5.6 Limitations During the Study

Despite the success of the study, there were some limitations encountered and how they were solved.

5.6.1 Limitation to objective one on demographic

1. Self- reporting bias was a great limitation. However, this was solved by the use of trained interviewers and improvement of data accuracy through an anonymous survey, ensuring participant confidentiality, and using neutral, non-leading questions.
2. False responses on the socio- demographic information, this was resolved by counter-checking personal files after obtaining informed consent.

5.6.2 Limitation on objective two on use BB standards

1. Participants hesitated before responding to questions concerning management support on BB. The interviewers reminded and assured their bosses that anonymity and confidentiality were maintained
2. Time was limited for LWs to cover the huge workload during working hours and still attend the interview. This was addressed by allowing them to attend to their patients and reschedule the visit. Those on night duty were reached through scheduled online interviews.

5.6.3 Limitation on objective three on BB constraints

1. Denial of consent in some of the private facilities, which was later resolved by a summons from the county director of health.
2. Poor lab design and work (Inadequate space) and poor ventilation: Many laboratories, especially the public ones had one room for reception, analysis and office. This was handled by getting a convenient place for the interview.

3. Few PPE, especially during the ENT, NG observation of the interviewer and even the interviewee. This was resolved by the researcher providing the PPE that we had procured for the research.

5.6.4 Limitation to objective four on compliance

1. The researcher was unable to find all the LWs during one visit. Therefore, the researcher made a return visit to the facility.
2. Scarcity of PPE: Many public hospitals had inadequate PPE, so as the researchers went out some carried basic PPE which the investigator had procured for demonstrations.

In summary, biosafety and biosecurity are primarily driven by institutional support, training, and the enforcement of protocols. While demographic factors may show marginal relationships, they are not reliable predictors of compliance compared to the structural environment 56.9% of the respondents reported staff shortage as a major constraint, while 70% reported fatigue/stress. From that finding, the county government should increase the number of laboratory personnel in all facilities to prevent overworking and fatigue. Policies should be established to maintain adequate staffing ratios, rotate shifts, and provide rest periods, reducing human errors associated with stress and fatigue (Crayon *et al.*, 2020). Promote the mental health and Well-being of LWs by conducting an assessment of the same before any employment to avoid unnecessary court cases. At the point of the study, none of the LWs had a mental assessment. Complementary support services, such as counseling or stress management programs, should also be made available. By implementing these measures, the County Government can strengthen laboratory safety, improve compliance with BB standards, reduce occupational hazards, and protect public health while fostering a professional and resilient workforce.

Staff shortage can cause fatigue and non-adherence to SOPs. Only 42.86% of the lab workers adhered to SOPs. Regular self-audits and peer checks can reinforce procedural compliance and enhance laboratory safety (Sarwar *et al.*, 2022; Cornish *et al.*, 2024).

Each laboratory worker should actively contribute to a culture of safety by reporting hazards, participating in audits, and adhering to BB standards even under resource constraints. Taking individual responsibility for safety helps protect colleagues, patients, and the wider community from avoidable risks (WHO, 2020; & Crayon *et al.*, 2020).

By adopting these measures, laboratory workers will improve their competency, reduce occupational risk, enhance diagnostic accuracy, and contribute to a safer, more reliable laboratory environment.

CHAPTER: SIX

6.0 Conclusion and recommendations

6.1 Conclusion

The study sought to investigate the implementation of biosafety and biosecurity measures in Narok County among medical laboratory workers. The conclusion made here was based on objective one, which addressed the knowledge relationships with socio-demographic characteristics in the implementation. The second objective was based on the knowledge, skills, and values using the WHO/MOH standardized questions; the third objective was on establishing constraints faced by LWs; and the fourth objective was based on the compliance level of biosafety and biosecurity. All these objectives;

6.1.1 Objective one conclusion

In particular, the study sought to appraise the level of knowledge of LWs based on demographic characteristics. Their conclusion is

Education level, BB training attainment, and years of experience significantly influenced knowledge on BB. Age and gender do not significantly affect knowledge levels.

Years of work experience, professional educational level, and BB training as additional training in the profession were statistically significant, where $p < 0.05$; hence, reject the Null hypothesis. That is to say that there is a statistically significant difference in knowledge between years of experience, professional level and additional BB training among LWS in Narok County hospitals, which agrees with (Chan et al., 2020) on their cross-sectional study on the association between training experience and readiness for advance care planning among healthcare professionals:

Whereas on BB, knowledge-based gender and age did not have statistical significance in BB implementation and therefore accept the null hypothesis that there is no statistically significant difference between age and gender in pertaining BB knowledge among Narok LWs.

Targeted BB training should prioritize less educated and less experienced workers, while age and gender need not be differentiating factors in training design.

6.1.2 Objective two conclusion

This objective was meant to appraise the knowledge, skills and attitudes of laboratory workers using standardized questionnaires of the WHO/MOH guidelines.

Personal reliability, accountability of lab materials, and physical facility were statistically significant in matters of level of professional training ($p < 0.05$). Alongside personal reliability and BB training, both had ($p < 0.001$) and involved clinical mentors ($p = 0.02$), which were statistically significant, suggesting that we reject the null hypothesis that states that there is no significant difference between professional level training and the BB knowledge, skills and attitudes.

The domain of age groups we accept the null hypothesis because there is no statistically significant difference between the means (f- statistic was less than 1 and p-value ($p > 0.005$)). So, we conclude that there is no statistically significant difference between age groups.

Years of experience showed a difference between the group means, F-statistics > 1 and the P-value in all domains was ($p < 0.05$). We therefore reject the null hypothesis.

Overall: Continuous professional development and on-the-job experience are critical for building comprehensive BB competence, but management and biosecurity require additional specialized training beyond general professional education.

6.1.3 Objective three conclusion

The objective was about the constraints encountered during the BB implementation. Non-conformity of PPE availability was a major issue of non-adherence, with about 21.12% adhering to PPE in public, while private adherence was 83.87%. The issue of proper use of dust coats was at 100% for both public and private laboratory workers, implying that they valued the dust coat and it was an acquisition before getting a job in the hospitals. This agrees with a study done on a clinical laboratory workers' training program on biosafety, which found that dust was at 100% while laboratory workers worked in the laboratories (Mahmoud & Sabry ,2019). Therefore, not only dust coats but also all PPE must be made mandatory for LWS for BB implementation and practice. In this study, it was found that, on average, PPEs had major non-conformity (inadequate) as per WHO/MOH standards. For example, findings of changing gloves only if they are torn came out strongly at 70.48% and 16.13% on public and private LWs, respectively, thus indicating transfer of microorganisms from one individual to another. Nevertheless, more effort is needed with LWs to ensure adherence to avoid the need for prick injuries and LAIs.

Based on BB training, only 26.50% are trained in BB in the entire county; hence, there is a need to enroll more LWs or provide BB training to facilitate BB implementation.

Lab design and workflow are wanting in Narok County except for the three laboratories, one of which is ISO-certified, and two are undergoing the same. The private is better than the public, whereby the public is at 44.29%, meaning they are working to meet the expectation of BB. Laboratory workers are overwhelmed by a high workload. The majority, over 75%, had a workload above 75% in public, and they appeared stressed and fatigued.

Overall: Systemic resource gaps and staffing inefficiencies are the primary barriers to BB implementation. The WISN (Workload Indicator of Staffing Need) tool should be adopted for accurate staffing audits, particularly in public facilities

6.4.4 Objective four conclusions

This was about the compliance of BB implementation by observation using the WHO/MOH checklist. This study observed that the individual lab workers needed to improve on compliance, especially in the strict following of SOPs. Waste segregation is vital in BB measures. There was an inadequate number of color-coded bins for waste segregation. Some facilities still mix highly infectious waste with the less infectious, posing a risk to both the lab worker and the environment. Not all the laboratories were 100% compliant with the set standard per WHO/MOH in one way or another. Although one facility met the ISO standards, that is the Narok County referral laboratory, which is a BSL2. There are also two other Kilgoris and Lorigorians who are right now undergoing accreditation, but they are at the tier 2 level towards implementation of BB. Incineration was functional at only four facilities. Otherwise, other facilities, including private ones, were burning waste, which is a biohazard to both the burner and the environment. Generally, waste management was poor against the recommended standards and BB implementation.

Overall: The demonstrated that compliance was superficial. 100% reported PPE use does not translate to consistent safe practices. Strengthened monitoring, enforcement of SOPs, and infrastructure rehabilitation are essential to bridge the gap between knowledge and practice.

6.2 Recommendations

This study reveals that laboratory workers in Narok County demonstrate foundational biosafety awareness (100% PPE use), despite systemic constraints—particularly inadequate resources (74.5%), insufficient training (67.6%), and poor infrastructure (59.8%)—that prevent translation of knowledge into consistent practice, with only 26.5% achieving high compliance. The recommendations given here will facilitate the biosafety and biosecurity implementation in terms of the knowledge gap. It will also inform the laboratory workers to adhere to the WHO/MOH guidelines and standards based on skill levels. Also, the issue of constraints for laboratory workers and compliance will be addressed. These recommendations are given as per the objectives of the research study as directed below.

6.2.1 Objective one

The national and county governments should strengthen employment opportunities for LWs based on the level of professional training, years of experience, and BB training as additional training to promote BB implementation effectively. Also, they recommend the BB training be included in training institutions like universities and the Kenya medical training to minimize retraining since it leads to absenteeism at the workplace.

6.2.2 Recommendation on objective two

The national and county governments should one strengthen continuous professional development (CPD) programs to sustain knowledge across all domains. Two, introduce specialized training modules on management and BB which are areas not sufficiently covered by general professional training. Three, should institutionalize regular competency assessments to monitor knowledge retention and skill application.

6.2.3 Recommendation to objective three on constraints

The county government of Narok should:

- 1. Increase BB training frequency and ensure all LWs are trained because currently only 26.5% trained, through online learning and other digital platforms like simulations.
- 2. Improve infrastructure—upgrade laboratory facilities, ensure adequate PPE supply, and rehabilitate physical structures.
- 3. Conduct WISN-based staffing audits to accurately determine staffing needs and address shortages and hence will address workload
- 4. Perform free mental Health assessment for LWs before and within work, and to vaccinate all staff against highly infectious agents.
- 5. Invest in simulation exercises, bio-safety drills, and supervisory audits to translate knowledge into observable compliance. LWs should be given study leaves to upgrade in their profession.

6.2.4 Recommendation on objective four on compliance

The county government should :

1. Facilitate all laboratories being ISO certified so that we can operate under the set standards.
2. Enforce SOP compliance through regular audits and spot checks—especially on glove-changing and specimen handling.
3. Strengthen waste management protocols—ensure proper lining, segregation, and disposal of infectious waste and invest in infrastructure rehabilitation and promote BSL 1 to BSL2 & BSL3 respectively.

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APPENDICES

Appendix 1: Timeframe (Workplan)

[illegible]

Appendix 2: Research Budget

Category/item	Unit cost	Multiply factor	Total cost
Training of research assistants			
Meals for 1 principal & 7 RAs	@2000 X 8 people	16000 X 2 days	Ksh.32,0000
Transport cost (public vehicle)	@300X 8 people	2400X2days	Ksh. 4800
Pilot study			
Pilot study at Maasai Mara University-Narok (2 TOT researcher& 6 Ras) Transport costs	300x 8 people	4800(to and fro)X2	Ksh. 9600
Teas and lunches	@2000 X 8	16000X1	Ksh. 16000
During actual study			
Transport costs (Public transport) & accommodation (for 1 principal researcher & 1 RA, to and fro)			
Route 1 (Narok north hospitals	@6000 X4 people @14000	48000X2days 14000X2days	Ksh. 96000 Ksh 28000
Route 2 (narok east hospitals)	@6000X4 @14000	4800X2days @14000X2days	Ksh. 96000 Ksh. 28000
Route 3 (Narok South Hospitals)	6000X4 @14000	4800X2days @14000X2days	Ksh. 96000 Ksh. 28000
Route 4 (Narok south)	6000X4 @14000	4800X2days @14000X2days	Ksh. 96000 Ksh. 28000
Route 5 (Emurwa Dikir)	6000X4 @14000	4800X2days @14000X2days	Ksh. 96000 Ksh. 28000
Route 6 (Transmara west)	6000X4people @14000	4800X2days @14000X2days	Ksh. 96000 Ksh. 28000
Route 7 (Transmara east)	6000X4people @14000	4800X2days @14000X2days	Ksh. 96000 Ksh. 28000
Stationery			
Printing papers	@800 X6 bundles	4800	Ksh. 4800
Services (printing &photocoping)	@10x1000	10000	Ksh. 10000
Pens	@20 X40 pieces	800	Ksh. 800
Pencils	1 dozen @400	400	Ksh.400
Erasers	@ 50 x 10 piece	500	Ksh. 500
Binding final research services	@600X 10 copies	6000	Ksh. 6000
Airtime			Ksh 5000
internet			Ksh. 10000
Hiring a biostatistician for data analysis by SPSS			Ksh. 50000
Research approvals			Ksh. 20000
Bags for carrying documents	@1000 X8 people		Ksh 8000
Dust coats	@800 x8	6400	Ksh 6400
Total			Ksh.1,002,300
10% Contingency			Ksh. 100,230
Grand total			Ksh. 1,102,530



Appendix 3: Informed Consent



MOI TEACHING & REFERRAL HOSPITAL / MOI UNIVERSITY
COLLEGE OF
HEALTH SCIENCES -INSTITUTIONAL RESEARCH AND
ETHICS COMMITTEE(MTRH/MU-IREC)
INFORMED CONSENT FORM

Study Title: ASSESSING THE IMPLEMENTATION OF BIOSAFETY AND BIOSECURITY PRACTICES AMONG LABORATORY WORKERS IN NAROK COUNTY HOSPITALS, KENYA.

Name of Principal Investigator(s): ORINA GRACE MORAA

Co-investigator(s):

Name of Organization: Moi University

Address: graceorina@gmail.com

Telephone Number: 0722 637 321

Name of Sponsor/Funding Agency:

Informed Consent Form for: implementation of biosafety and biosecurity practices among laboratory workers in Narok County hospitals

This Informed Consent Form has two parts:

- Part I: Information Sheet [to share information about the study with you]
- Part II: Certificate of Consent [for signatures if you choose to participate]

PART I: INFORMATION SHEET

Introduction: You are being asked to take part in a research study. This information is provided to tell you about the study. Please read this form carefully. You will be given a chance to ask questions.

Taking part in this research study is voluntary. Saying no will not affect your rights to health care or any other services. Your treatment/payment or enrollment in any health plans or eligibility for benefits will not be affected if you decide not to take part. You are also free to withdraw from this study at any time. If, after data collection, you choose to quit, you can request that the information provided by you be destroyed under supervision. This would be before data is de-identified and aggregated. You will be notified if new

information becomes available about the risks or benefits of this research. You will receive a copy of this form after it is signed.

Purpose of the study: To evaluate the implementation of biosafety and biosecurity practices among laboratory workers in Narok County hospitals and identify strategies for improvement.

Study site: The study will be conducted in Narok County

Study population: The study population for this research includes laboratory workers in the selected healthcare facilities in Narok County.

Study procedures: The participants, based on the knowledge in surveys, will respond and give information based on their experience that will directly relate to the issues of interest to the research (Young, 2010). Fink (2002) was cited by Ayiro (2010) and identified four types of data collection procedures used in surveys: self-administered questionnaires, interviews, structured document reviews to collect financial data, medical or school information, and structured observations. This study adopted a survey design. Those questionnaires, observations, focus group discussions, and document analyses will be used to generate data that will explain existing factors pertaining to training needs, constraints, and perceived competence of diploma medical laboratory students.

If you agree, you will do the following: Except for the survey, respond and give information based on their experience that will directly align with the issues of interest to the research. Also, give permission for a phone call to be made in case you are unable to make it. This phone call will be to inquire about your condition at that point.

Benefits: There will be no direct benefits of participating in this study, but your involvement will assist us in gaining information that will impact the management of patients needing gastrointestinal anastomosis. Study subjects will be accorded the same quality of management as non-study subjects.

Risks/Discomforts: There are no anticipated risks to the participants attributable to this study.

Payments and Reimbursements: There will not be any payments or reimbursements for the participant.

Confidentiality: All reasonable efforts will be made to keep your protected information private and confidential. Using or sharing (“disclosure”) of such information will follow national privacy guidelines. By signing the consent document for this study, you are giving permission (“authorization”) for the use and disclosure of your study information. We may need to share your protected information with the community advisory board, MTRH//MU-IREC, NACOSTI, or the healthcare team. We will retain your/your patient’s research records for at least six years after the study is completed. At that time, the research information is destroyed.

If you decide to withdraw your permission for use of your/your patient’s personal data, contact the primary investigator in writing and let them know your decision. At that time, we will stop further collection of any information about you. However, the health information collected before this withdrawal may continue to be used for the purposes of reporting and research quality. Your information will be added to your medical record, and any research information entered into your medical record will be kept indefinitely. You have the right to see and copy your personal information related to the research study for as long as the study team holds this information.

Compensation for injury: There is no anticipated injury in this study, but in the event of an injury resulting from participating in this study, medical expenses will be covered for treatment of that injury by the principal investigator for the duration of the treatment

PART II: CONSENT OF PARTICIPANT I have read or have had someone read to me the description of the research study. The investigator or his/her representative has

explained the study to me and has answered all the questions I have at this time. I have been told of the potential risks, discomfort, and possible benefits (if any) of the study. I freely volunteer to take part in this study.

[This section must be written in the first person. If the participant is illiterate, or for some reason is unable to write, they should provide a thumbprint, and a competent witness must be engaged during the consent process]

Name of Participant

Signature of participant/Thumbprint

Date & Time

Printed name of the investigator

Signature of Investigator

Date

Appendix 4: Biographical Form

Date-----

Answer the following questions by ticking the appropriate choice for you and kindly give a supporting explanation as per your choice of answer

The interviewer explains the below statement to the interviewee

Please respond to all the items in this form by putting a tick in the boxes and by filling the spaces provided as appropriate:

1. Gender ☐ Male ☐ female

2. Age in years ☐ 20-29 ☐ 30-39 ☐ 40-59 ☐ >

3. Level professional training ☐ < diploma ☐ diploma ☐ Bachelor ☐ > bachelor

4. How long have you been working in this hospital laboratory(years)?

☐ < 4 ☐ 5-9 ☐ 10-14 ☐ >15

5. Have you had additional training on laboratory acquired infections prevention skills specifically in biosafety? Yes ☐ No

a) If yes, what is the name of the course which you undertook the additional training biosafety skills?

b) How long was the training on biosafety skills? ☐ 1 day ☐ 1 week ☐ 2 weeks

c) On your own word explain how the training has befitted you -----

Appendix 5: Laboratory worker knowledge

Date-----

Designation of the respondent-----

Number of years served in that position-----

The interviewer explains the below statement to the interviewee

Below are statements designed to assess your infection prevention in performing laboratory procedures in the biosafety and biosecurity training. Carefully listen these statements and on the scale provided, please respond how you feel about your ability to perform these tasks, by rating to the appropriate number 1 to 5, where; 1= Strongly agree; 2= Agree; 3= Indifferent; 4= Disagree 5= Strongly disagree

The following questions can help determine how well you know your standard biosafety procedures in!

Questions	1	2	3	4	5
PPE is personal protective equipment					
Persons working in the laboratory should be properly trained on PPE					
Biological materials that need to be transported from the lab to another location should be shield in secondary, shatter proof container					
Hands are washed before or after working in a biological safety cabinet					
Every lab is required to have both a First Aid kit and a Spill kit					
When working with infectious biological material, the best place to perform the work would be a fume hood					
If you have a spill in the laboratory, you should clean it up and not tell anyone					
Infectious agent and biological material must be disinfected chemically or by autoclave before final disposal					
A Biohazard sign must be posted on lab entry door(s) in order to meet Biosafety Level 2 containment requirements					
☐					

Total maximum scores: 115 normed scores: not available

Appendix 6. Biosafety training techniques and practice (BTTP)

Date-----

Designation of the respondent-----

Number of years served in that position-----

The interviewer explains the below statement to the interviewee Below are statements designed to assess your understanding on your ability to perform biosafety and biosecurity tasks.

Please respond how you feel about your ability to perform these tasks, by rating the appropriate number 1 to 5, where; 1= Strongly agree; 2= Agree; 3= Indifferent; 4= Disagree 5= Strongly disagree

Management	1	2	3	4	5
Does the facility management assign responsibilities and specific roles to LWs					
You are provided with all biosafety instruments all the time					
The facility has biosafety biosecurity policy					
The facility has implemented the policy BB.					
The facility has policy and procedures on individual access to confidential information.					
The facility has biosafety officer.					
The facility has a back-up system for sensitive and confidential information					
There available standard operating procedures (SOPs) regarding transfer of VBM					
The facility has up to date policy and guidelines on visiting persons (eg doctors, contractors, students) that gained access to this facility					
Biosecurity					
Are you aware about biosafety/ biosecurity training/seminars?					
You are formally trained on BB					
Is BB implemented in this facility?					
You were done entry -level orientation on biosecurity before starting work in this laboratory					
There is continues training on LWs implementing BB					
You practice biosafety in your facility at all times (e.g. in obtaining a blood specimen from a patient)					
Reporting mechanisms in place in case of biosecurity breach in this facility.					
About physical facility					
There different levels of security					
There is enforcement of access control policy by management.					
The facility has closed-circuit televisions (CCTs) and					

strategically placed					
The facility has intrusion detection system to detect unauthorized entry to facility and biological agents.					
Identification for both LWs and visitors available					
The facility has self-closing lockable doors.					
Accountability for laboratory materials					
The facility has inventory management policy for valuable biological materials (VBM).					
The facility maintains update inventory for VBM					
The facility has biosafety procedures to prevent intentional escape of biological agents					
The facility has records of periodic reviews of biological agents.					
The facility has biohazard signage in the laboratory and in stores of VBM					
You are comfortable about BB in terms accountability on VBM					
About personal reliability					
Formal background screening processes including credentials, skills, and personnel trait based on risk assessment is done this place.					
Health assessments including psychological and mental done before employment.					
Risk assessment procedures can exclude inappropriate personnel from accessing facility or VBM					
Handling VBM is the most difficult task.					
The facility takes all personnel through BB (example the purpose of PPEs) procedures and SOPs					
Telling patients the purpose of PPE is difficult.					
It must be on PPE while handling procedures.					
Had specific teaching or training for biosafety.					
Have all the knowledge and ability to practice BBP.					
BB training and practice					
It is difficult to practice BB in this facility.					
Time schedule for the training is inadequate.					
I was trained on BB but trainers have little knowledge					
The laboratory clinical instructors / mentors take up their role continuously					
Involving clinical mentors in clinical practice.					
I can work comfortably in any BSL laboratory.					
Curriculum structure involves theory then practical or integrated (practical and theory combined)					
Theoretical basis of biosafety skills covered well.					
Biosafety training using practical approach was done.					
Challenging situations in biosafety were addressed					
Realistic approach in reporting laboratory incidences/accidents while working in the laboratory.					

Appendix 7: Site Visits (Observation)

Date -----

The researcher to observe and tick yes or no on the statements and finally write general comment on the components of the research study during the site visits

Area/ Item

1. Physical facilities (level) -----

A) Laboratory space, Separated:

i. Specimen collection room **yes () no ()**

ii. Analytical work **yes () no ()**

Iii. Administration room **yes () no ()**

B) Essential utilities

I. Uninterrupted power; yes () no ()

ii. Clean water supply ; **yes () no ()**

Iii. Proper ventilation; **yes () no ()**

2. Safety features

i. Eyewash stations : **yes () no ()**

ii. Fire extinguishers ; **yes () no ()**

Iii. Designated waste disposal systems; **yes () no ()**

3. Separate areas for staff well-being;

i. Hand washing facilities available; **yes () no ()**

ii. Privacy for sample collection available; **Yes () no ()**.

4. Staff personal protection

- i. Availability of tap running water for hand washing ; **yes (0**
- ii. Proper use of lab coats, gloves, and eye protection, and whether it fits correctly. ; **yes () no ()**
- iii. Eating, drinking, or applying cosmetics in the lab;; **yes () no ()**

1. Behavioral Factors:

I. Responsible conduct vs. Horseplay; **yes () no ()**

I. Fatigue; yes () no ()

II. Stress; yes () no ()

III. The probability of an incident or exposure occurring; yes () no ()

2. Competency on LWs:

I. Understanding of procedures; **yes () no ()**

II. Proper equipment use; **yes () no ()**

III. Able recognition of hazards; Yes () no ()

3. Communication systems in the facility:

- i. Proper warning signs for hazardous materials or conditions; **yes () no ()**
- ii. list of staffs and phone numbers; **yes () no ()**
- iii. reference forms ; **yes () no ()**
- iv. disease surveillance forms ; **yes () no ()**

4. Specialized equipment available :

- i. Refrigerators; **yes () no ()**
- ii. Autoclaves; **yes () no ()**

iii. Calibrated instruments; **yes** () **no** ()

9. Waste Categorization and Segregation

Waste segregated as

I. Availability of sharp containers

II. Biohazards containers yes () no ()

III. chemical waste into marked containers; yes () no ()

IV. maintaining detailed record-keeping.; yes () no ()

V. Operational incinerator ; yes () no ()

Any other comments -----

Appendix 8: Focus Group Discussion

Welcome, everybody, to these FGDs. In this FGD, everybody has an equal chance to participate, and nobody will be penalized. This was meant to improve the BB training in the future.

You are expected to register on the form provided.

1. Discussions about biosafety and biosecurity in the following areas:
 - a. About trainers
 - i. Content delivery
 - ii. Assessment delivery as multiple-choice questions (MCQs), short-answer questions (SAQs) and any other
 - b. Discuss the practical and feedback from the TOTs
 - Practical delivery
 - ii. Trainees' involvement
 - iii. Feed and correction action
2. Discuss whether a theoretical basis of biosafety was taught, such as:
 - a. Course purpose
 - I. Management involvement
 - ii. Explain what the course is all about
 - b. How are the communication skills presented
3. Discuss physical security
 - a. about security level
 - b. access control policy
 - c. intrusion detection system
 - d. General BB training in physical
4. Discussions about biological hazards
 - a. Purchase of valuable biological materials (VBMs)
 - b. management of valuable biological materials in the laboratory
 - c. transfer of valuable biological agents
 - d. Biohazard signage
5. Discussions about security
 - a. policy on BB
 - b. protection of information
 - c. about personnel
6. Discussion about understanding or comprehension of some of the biosafety procedures, especially PPE.
 - a. Any opportunity to apply what you have learned in real patients and work?
 - b. Did you receive any feedback during your training?
 - c. Did you have any discussion on biosafety beyond the training?
 - d. Did you have any discussion on follow-ups of biosafety in areas of practice?
 - e. What are the common constraints you come across when performing the biosafety procedures?
 - f. In general, what can you comment on the BB training and practice?

Appendix 9 A :Assessment on the laboratory constraints and bio risk

Site visit date:-----

Researcher to explain the objectives of the research study and seek views on the following:

General information

Designation of the respondent-----

Number of years served in that position-----

For the following interview, the interviewer is to say **(yes or no)** appropriately against the statements listed below based on the interviewee responses

On daily work, how do you get your PPE and use (eg gloves)		
	Yes	No
Do you wear a dust coat while at work?		
Are PPE always available		
Do you use one pair glove for many procedures?		
Only change gloves when torn/spills?		
Do you use face masks/glass when working with infectious specimens?		
About BB formal training and on job training		
Are you formally trained in BB		
Have you been mentored on BB at work-place?		
About laboratory design and work flow(according to ISO 15189:2022 clause 6,3 (facilities and environment)		
Is there effective separation between neighboring areas within the lab?		
Does the layout promote a logical flow from sample receipt, to pre-analytical handling, analysis, and post-analytical storage?		
Are patient sample collection areas separate from the main laboratory ?		
Is there sufficient space allocated for staff to perform tasks without compromising quality or safety?		
Does the design include systems to monitor, control, and record environmental conditions		
Are HVAC systems designed to manage air quality, pressure cascades?		
Are surfaces (benches, walls, floors)		

non-porous, resistant to disinfectants, and easy to clean, particularly in high-risk areas?		
Are there secure access and egress mechanisms in place to control entry to the laboratory?		
Are eye wash stations, emergency showers, fire extinguishers, and spill kits appropriately located and accessible?		
Are there designated, secure storage areas for hazardous materials and biological waste?		
Is there adequate power supply and a backup generator system for critical equipment		
Is there availability of running tap-water		
About work-load and staffing (Kenyan clinical laboratory requires aligning laboratory workers with work load)WHO-workload indicator of staffing Need(20,000 tests for LW per 1 month)1667 per a month, 75 test per day		
Are registered by KMLTTB?		
Are you aware of WISN?		
Do you work for 8 Hrs. a day?		
Do you work less than 8 Hrs. a day		
Do perform less than 75 tests a day		
Do you go for leave yearly ?		
What are some of the LAIs and work place exposures ?		
Are you aware of any reporting procedure of needle stick/or injury /any exposure of infectious specimen?		
Have ever documented any exposure of infectious specimens?		
Are there aerosol-generating procedures?		
"Is post-exposure prophylaxis (PEP) available for HIV?		

Appendix 9 Bs: In depth interview guide with the trainers

Site visit date:-----

Researcher to explain the objectives of the research study and seek views on the following:

General information

Designation of the respondent-----

Number of years served in that position-----

For the following interview, the interviewer is to say **(yes or no) appropriately** to the items listed below based on the interviewee's responses.

1. Relating to the laboratory worker on the biosafety training curriculum
 - a. Is it divided into theory, background information, concepts and complex information on biosafety and Complex communication skills **(yes or no)**
 - b. Teaching of biosafety practical is examined more than once a week **(yes/no)**
2. What was the approach in the training of biosafety practices?
 - a. biosafety taught as a procedure **(yes/no)**
 - b. Biosafety taught as a practical **(yes/no)**
3. Were specific challenging situations addressed during your training?
 - a. putting on and removing PPE **(yes/no)**
 - b. Handling infectious specimens **(yes/no)**
 - c. laboratory behavior **(yes/no)**
 - d. Dealing with accidents **(yes/no)**
 - e. proper hand washing **(yes/no)**
4. A biosafety procedure beyond the laboratory worker (where they were taught how to do it)
 - a. Communicate with colleague **(yes/no)**

b. Communicate with a patient (yes/no)

c. Communicate with biosecurity officer **(yes/no)**

5. Do you have any specific plan to demonstrate after teaching in class (yes or no)

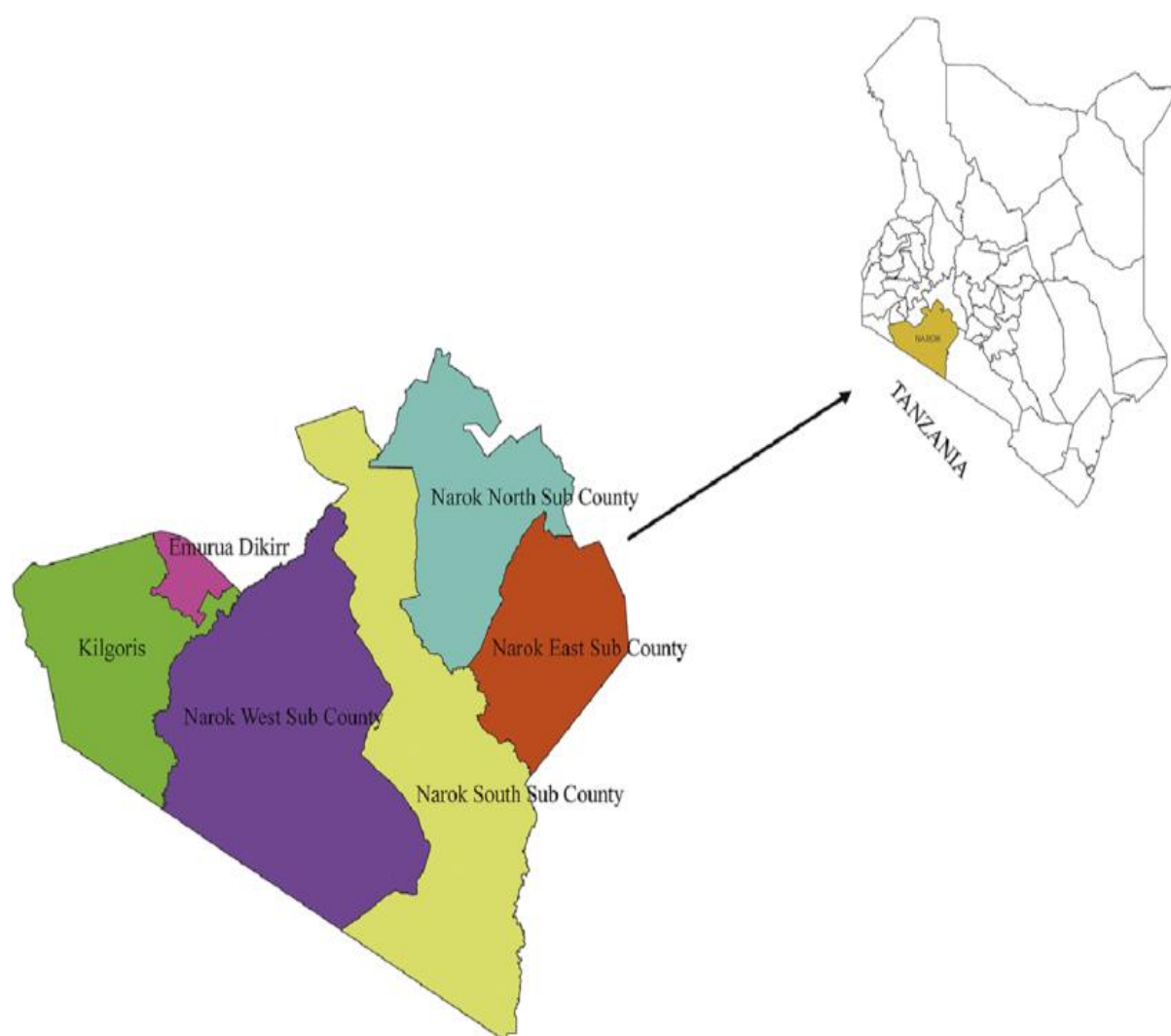
6. Do you demonstrate and leave there (yes/no)?

7. Do you demonstrate, and give participants the opportunity to practice the same (yes or no)

8. Do you demonstrate, give participants the opportunity to practice, or take them to a hospital visit to observe? (yes or no)

Overall do you think the course offered in biosafety biosecurity training is adequate in preparing you in biosafety and biosecurity (yes/no)

Thank you for offering to participate in this research.

Appendix 10: A Map of Narok County divided into Sub- Counties

Appendix 11: NACOSTI Research License

 REPUBLIC OF KENYA	
Ref No: 347628	Date of Issue: 15/October/2025
RESEARCH LICENSE	
	
This is to Certify that Dr.. GRACE MORAA ORINA of Moi University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Narok County Hospital on the topic: TO ASSESS THE IMPLEMENTATION OF BIOSAFETY for the period ending : 15/October/2026.	
License No: NACOSTI/P/25/4180493	
347628	
Applicant Identification Number	Ag. Director General NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION
Verification QR Code	
	
NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.	
See overleaf for conditions	

Appendix 12: Approval by Narok County Government



NAROK COUNTY GOVERNMENT
DEPARTMENT OF HEALTH AND SANITATION

Telegrams: "HEALTH", Narok
Telephone: Narok 22300 and 22308
Fax: (050) 22394
Email: countyhealthdirectornarok@gmail.com

COUNTY DIRECTOR OF HEALTH
NAROK COUNTY
P.O. BOX 11- 20500
NAROK

When replying please quote our Ref and date

OUR REF: DIR/NRK CNTY/MOH/60/VOL.VIII/224

21st October, 2025

Dr. Grace Moraa Orina
Maasai Mara University
P. o Box 861-20500
Narok.

RE: APPROVAL FOR DATA COLLECTION ON IMPLEMENTATION OF BIOSAFETY AND BIOSECURITY AMONG HOSPITAL LABORATORY WORKERS IN NAROK COUNTY, LICENCE NO: NACOSTI/P/25/4180493.

Reference is made to your request regarding the permission to collect data on implementation of Biosafety and Biosecurity among hospital laboratory workers in Narok County.

Authority is hereby granted to you to carry out research in Narok County on the topic "*To assess the implementation of Biosafety*" for the period ending 15th October, 2026.

The researcher will be expected to strictly adhere to the conditions that are stated in the NACOSTI and ESRC approvals.

By copy of this letter, the Sub County Medical Officers of Health and the Medical Superintendents are requested to support the study team.



Dr. Francis K. Kiio
County Director of Health
NAROK COUNTY GOVERNMENT
CC.



CECM- Health and Sanitation, Narok County Government

Chief Officer - Clinical Services, Narok County Government

Chief Officer Preventive and Promotive Health Services, Narok County Government

Sub County Medical Officers of Health, Narok County Government.

Medical Superintendents, Narok County Government.

Appendix 13: ISERC Formal Approval



MTRH/MU-INSTITUTIONAL SCIENTIFIC & ETHICAL REVIEW COMMITTEE (ISERC)

MOI TEACHING AND REFERRAL HOSPITAL
P.O. BOX 3
ELDORET
Tel: 33471/2/3



MOI UNIVERSITY
COLLEGE OF HEALTH SCIENCES
P.O. BOX 4606
ELDORET
Tel: 33471/2/3
16th October, 2025

Reference: IREC/1234/2025

Approval Number: 0005188

Dr. Grace Moraa Orina,
Moi University,
School of Medicine,
P.O. Box 4606-30100,
ELDORET- KENYA.

Dear Dr. Orina,

FORMAL APPROVAL:- TO ASSESS THE IMPLEMENTATION OF BIOSAFETY & BIOSECURITY PRACTICES AMONG LABORATORY WORKERS IN NAROK COUNTY HOSPITAL

This is to inform you that **MTRH/MU- ISERC** has reviewed and approved the above referenced research proposal. Your application approval number is **FAN: 5188**. The approval period is **16th October, 2025 – 15th October, 2026**. This approval is subject to compliance with the following requirements;

- i. Only approved documents including (informed consents, study instruments, Material Transfer Agreements (MTA) will be used.
- ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by **MTRH/MU- ISERC**.
- iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to **MTRH/MU- ISERC** within 72 hours of notification.
- iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to **MTRH/MU- ISERC** within 72 hours.
- v. Clearance for export of biological specimens must be obtained from **MOH at the recommendation of NACOSTI** for each batch of shipment.
- vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
- vii. Submission of an executive summary report within 90 days upon completion of the study to **MTRH/ MU- ISERC**.

Prior to commencing your study; you will be required to obtain a research license from the National Commission for Science, Technology and Innovation (NACOSTI) <https://oris.nacosti.go.ke> and other relevant clearances from study sites including a written approval from the CEO-MTRH which is mandatory for studies to be undertaken within the jurisdiction of Moi Teaching & Referral Hospital (MTRH) and its satellites sites.

Sincerely,

DR. PETER SAULA
CHAIRMAN

MTRH/MU-INSTITUTIONAL SCIENTIFIC & ETHICAL REVIEW COMMITTEE



cc	CEO	-	MTRH	Dean	-	SOP	Dean	-	SOM
	Principal	-	CHS	Dean	-	SON	Dean	-	SOD

Appendix 14: Plagiarism Certificate

SR1225



ISO 9001:2019 Certified Institution

THESIS WRITING COURSE

PLAGIARISM AWARENESS CERTIFICATE

This certificate is awarded to

GRACE MORAA

PhD/ME/4952/23

In recognition for passing the University's plagiarism

Awareness test for Thesis **entitled: ASSESSMENT OF THE IMPLEMENTATION OF BIOSAFETY & BIOSECURITY PRACTICES AMONG LABORATORY WORKERS IN NAROK COUNTY HOSPITALS**, with similarity index of 5% and striving to maintain academic integrity.

Word count:52671

Awarded by

Prof. Anne Syomwene Kisilu

CERM-ESA Project Leader Date: 28/04/2026