LABORATORY BIOSAFETY AND BIOSECURITY GUIDANCE IN CAMEROON

PREFACE

The Laboratory Biosafety and Biosecurity Guidance in Cameroon will serve as a reference for laboratory practitioners on precautions to take when handling, transporting or storing pathogens, toxins and radioactive agents in Cameroon. It allows existing laboratories or those that are being set up to comply with physical standards on containment, operating standards and those relating to verification and performance test.

It should be noted that this is the first document Cameroon has developed to regulate activities involving the handling of pathogens, toxins, and radioactive agents.
This document provides information for all actors involved and researchers, which they certainly need to ensure biosecurity and biosafety in their laboratories and in their immediate and distant environment.

Under the coordination of Professor François-Xavier MBOPI KEOU, this guidance is the result of a close technical multi-sector collaboration involving national experts and development partners, including METABIOTA-JOHNS HOPKINS Cameroon with financial support from the *Global Health Security Agenda.* Therefore, on behalf of the Government, we express our sincere congratulations to them for their determination and commitment to produce a document of quality. It is unquestionable that, for all national and external stakeholders, this guidance is the only reference for all biosafety and biosecurity interventions in laboratories in Cameroon.

THE MINISTER OF PUBLIC HEALTH

Dr MALACHIE MANAOUDA

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ACRONYMS AND ABBREVIATIONS

BSC : Biological Safety Cabinet
BSL : Biosafety Level
CDC : Centers for Disease Control and Prevention
CPC : Centre Pasteur of Cameroon
CRESAR : (Centre de Recherche pour la Santé des Armées) Centre for Health Research for the Army
DNA : Deoxyribonucleic Acid
DGH : Douala General Hospital
EGPAF : Elizabeth Glaser Pediatric AIDS Foundation
HGOPED : Douala Gynaeco-Obstetric and Pediatric Hospital
E. coli : *Escherichia coli*
GHSA : Global Health Security Agenda
GHSS : Global Health System Solutions
GMO : Genetically Modified Organism
HEPA : High Efficiency Particulate Air
HIV : Human Immunodeficiency Virus
IAEA : International Atomic Energy Agency
IATA : International Air Transport Association
IHR : International Health Regulations
ISO : International Standards Organization
LANAVET : National Veterinary Laboratory
MINADER : Ministry of Agriculture and Rural Development
MINDEF : Ministry of Defense
MINEPDED : Ministry of the Environment, Nature Protection and Sustainable Development
MOH : Ministry of Public Health
MSS : Microbiological Security Station
NRPA : National Radio Protection Agency
NIRS : National Institute of Research and Security
NLPH : National Public Health Laboratory
OIE : World Animal Health Organization (International Office of Epizootics)
ONSP : National Public Health Observatory
ORSEC : Contingency/Emergency Plan
PEP : Post Exposure Prophylaxis
PPE : Personal Protective Equipment
RG : Risk Group
SARS : Severe Acute Respiratory Syndrome
SLMTA : Strengthening Laboratory Management Towards Accreditation
The-IDA : The Institute for the Development of Africa
WHO : World Health Organization.

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1. GENERAL
INTRODUCTION

The laboratory is a sensitive and complex environment whose services are essential for the identification and confirmation of the causes of common diseases as well as an epidemic [1]. Indeed, it is an important link in research. It can be the starting point of an outbreak and the personnel is exposed to biological risk. A biological risk is present when people may be exposed to infectious biological agents notably bacteria, viruses, fungi, parasites; and unconventional transmissible agents. These agents may cause infection, allergy or intoxication.

It is necessary for Cameroon to have technical documents which provide practical guidelines to laboratory staff for the application of biosafety and biosecurity rules in the laboratory. The application of these rules is aimed at reducing the risk it presents to its users and to prevent the spread of pathogens into the environment during transportation and storage of specimen, handling of germs and during analyses. Ultimately, the aim is to protect laboratory personnel, the community at large, the animal population and the environment from the consequences of exposure to infectious materials, infected animals or chemicals/radioactive materials and toxins handled in the laboratories' environment.

Biological security in the laboratory is dependent on a proper microbiological technique and the judicious use of equipment by well-trained personnel. Weaknesses were identified following the external joint assessment of the implementation of the 2005 International Health Regulations (IHR) conducted in 2017 [2] and the situation analysis of laboratories during the elaboration of the National Strategic Plan for the Development of Laboratories (NSPDL) in 2018[3]. Priority measures were recommended to improve biosafety and biosecurity in the laboratory. In addition, the development of laboratory biosafety and biosecurity guidance responds to the need for a code of best practices to regulate the handling of potentially infectious biological materials under optimal safety conditions. It therefore imposes an improvement of the techniques currently used in laboratories.

The recommendations in this guide are based on a risk assessment of the different analytical techniques used in various types of laboratories. The basic requirements for laboratory facilities and practices may, however, be adapted to changes in regulations or following a risk assessment. This assessment requires discernment and circumspection, given that an underestimation of this risk exposes personnel, while an overestimation gives them extra work and leads to higher infrastructure, maintenance and laboratory operating costs.

This guidance is intended for use by all actors in the laboratory system.
The objectives are:

- To conform laboratory practices with the WHO and IOE standards as well as new biosafety guidelines,
- To provide information on the safe handling, transportation, and disposal of equipment and organisms presenting with biological

hazards,

- To harmonize current laboratory practices at the national level.

2. DEFINITION OF KEY WORDS

Biosafety: These are measures to prevent and reduce the dangers of handling and using biological materials in diagnostic, teaching, industrial and research laboratories.

Biosecurity: A set of containment principles, technologies and operational practices that are implemented to prevent the unintentional exposure to pathogens and toxins, or their accidental release. Biosecurity therefore, refers to safety measures aimed at preventing the loss, theft, misuse, misappropriation and intentional release of infectious substances or toxins. In the agricultural field, biosecurity refers to preventive measures that aim at minimizing the risk of introducing disease to an animal or plant population and the risk of spreading a pathogen to an animal or plant population within an already infected place.

The "biosafety" and "biosecurity" concepts are essentially complementary; indeed, the use of biosafety best practices enables to strengthen biosecurity programmes and vice versa.

Danger: Intrinsic ability or capacity of equipment, a substance, a method of work, to cause damage to the health of workers.

Risk: A combination of the probability and the consequence(s) of the occurrence of a specified hazardous event.

Infectious agent: An organism capable of causing diseases in humans, animals or plants.

Biological risk: It is related to the presence of pathogenic biological agents in the workplace.

Dangerous situation: Situation in which a person is exposed to one or more phenomena that could lead to damage.

Exposure: A situation in which a person is subjected to one or more chemical or biological agents, or to a physical phenomenon (noise, radiation, dust, etc.) that may cause damage in the long or short term.

Primary prevention: These are measures to prevent the occurrence of risk by eliminating the causes. These measures act on the risk factors before the accident.

Secondary prevention: Measures that prevent damage.

Tertiary prevention: Measures that limit the damage. Avoiding the occurrence of complications, sequelae, recurrences, occupational disabilities and promote reintegration.

Hazardous substance: Material presenting a physical or health hazard. This includes both chemicals and biological agents.

Anti-infective: Agent that kills micro-organisms or inhibits their growth and multiplication.

Antimicrobial: Agent that kills microorganisms or inhibits their growth and multiplication.

Antiseptic: A substance that inhibits the growth and development of microorganisms without necessarily killing them. Generally, antiseptics are applied to the skin.

Biocide: A general term for any agent capable of killing microorganisms.

Decontamination: Any process intended to eliminate or kill micro-organisms. This term also refers to the elimination or neutralization of hazardous chemicals or radioactive materials.

Disinfectant: A chemical substance or mixture of chemicals used to kill microorganisms, but not necessarily spores. They are usually

applied to surfaces or inanimate objects.

Disinfection: Destruction, by physical or chemical means, of germs but not necessarily of their spores.

Germicide: A chemical substance or mixture of substances used to kill microorganisms.

Microbicide: A chemical substance or mixture of chemicals intended to kill micro-organisms. This term is often used instead of "biocide", "germicide" or "anti-infective", which are synonymous.

Sporicide: A chemical substance or mixture of chemicals intended to kill micro-organisms and their spores.

Sterilization: The process by which microorganisms and spores are killed or eliminated.

3. LABORATORY BIOSAFETY AND BIOSECURITY

3.1. RISK ASSESSMENT

3.1.1. . CLASSIFICATION OF MICRO-ORGANISMS BY RISK GROUP

IThere is a great diversity of microorganisms, pathogenic or not. The establishment of risk groups for different microbial agents is one of the most important tools for microbiological risk assessment. This classification takes into account several parameters, particularly:

- Pathogenicity;
- Transmission mode and the range of hosts which may depend on the immune status of the local population, the density and mobility of hosts, the presence of vectors and the level of environmental hygiene ;
- The possibility of taking effective preventive measures locally, which may include prophylaxis by vaccination or administration of immune sera (passive immunization), sanitary measures with regards to food and water hygiene, elimination of animal reservoirs or arthropod vectors;
- Possibility to have a local effective treatment, passive immunization, post-exposure vaccination, use of anti-infection agents and chemotherapeutic or antiviral agents, without neglecting the risk of the appearance of pharmaco-resistant strains.

Biological agents are classified into four groups according to the importance of the risk of infection [4, 5]:

Risk Group 1 (low or no risk for individuals or the community): A micro-organism that, in all probability, cannot cause human or animal disease.

Risk Group 2 (moderate risk for individuals, low for the community): A pathogenic germ that can cause a human or animal disease but is unlikely to pose a serious threat to laboratory personnel, the community, livestock or the environment. Laboratory exposure is likely to result in a serious infection, but it can be effectively treated or prevented, and the risk of spreading the infection is limited.

Risk Group 3 (high risk for individuals, low for the community): Pathogenic germ that usually causes a serious human or animal disease, but is not usually transmitted from one individual to another. There is an effective treatment and preventive measures.

Risk Group 4 (significant risk for individuals and the community): Pathogenic germ that usually causes a serious human or animal disease and can be easily transmitted from one individual to another, either directly or indirectly. There is usually no treatment or effective preventive measures.

Table 1: Classification of microorganisms by risk groups [6].

Groups	*Pathogenicity in humans*	*Danger for the personnel*	*Spread in the community*	*Existence of a prophylaxis or effective treatment*
1	*No*	-	-	-
2	*Yes*	*Yes*	*Unlikely*	*Yes*
3	*Yes*	*Yes*	*Possible*	*Yes*
4	*Yes*	*Yes*	*High risk*	*No*

A classification of the best known biological agents was developed by the National Institute of Research and Security in June 2018.

3.1.2. **RISK ASSESSMENT PROCESS**

Laboratory activities involve pathogenic microorganisms or toxins presenting potentially significant risks for humans and their environment. Biosecurity is essentially based on a risk assessment. Several tools can be used in this assessment, but the most important factor is professional discernment. Risk assessment should be done by those who master most of the factors to be analyzed, notably:

- Characteristics of the micro-organisms on which to work ;
- Equipment and operating procedures to be implemented ;
- Animal models that could be used ;
- Available containment systems and facilities.

Risk assessment requires consideration of biosafety and biosecurity elements, the main ones are presented in Table 2 below.

Table 2: Elements to consider during laboratory risk assessment

Biosecurity	*Biosafety*
• Transport procedures • Disinfection and decontamination • Equipment, maintenance, calibration and certification • Infrastructure requirements (buildings, facilities) • Management of incidents or accidents • Emergency and contingency plans • Healthcare	• Nature of biological agents handled • Inventory and information on pathogens and toxins • General safety • Human Resources and Competence • Good microbiological techniques • Clothing and Personal Protective Equipment (PPE)

It is the responsibility of the laboratory head or main researcher to ensure that appropriate risk assessment is conducted periodically. They must work closely with the institution's safety committee and the biosecurity personnel to ensure that the equipment and facilities required for the proposed work are provided to the laboratory. Once the risk is assessed, it is necessary to periodically re-examine the situation and reassess if necessary taking into account the new data.

The establishment of risk groups for different microbial agents is one of the most important tools for microbiological risk assessment. Nevertheless, knowing the risk group to which a particular pathogen belongs is not enough to evaluate the actual risk. Other considerations must be taken into account, including:

- The pathogenicity of the germ and the infectious dose ;
- The possible outcome of exposure to the germ ;
- The natural mode of transmission;
- Other routes or modes of transmission resulting from laboratory manipulations (parenteral route, airborne particles, digestive tract) ;
- Germ stability in the environment ;
- The concentration of the germ and the volume of concentrated biological material to handle ;
- The presence of an appropriate host (human or animal) ;
- Information from animal testing, reports of laboratory infections or medical reports ;
- The type of operations envisaged (ultrasonic treatment, aerosol production, centrifugation, etc.);
- Any genetic manipulation of the micro-organism likely to extend its range of hosts or to modify its virulence or sensitivity to treatments known to be effective ;
- The possibility of intervening locally as prophylactic or curative.

The information from risk assessment makes it possible to determine the level of safety required for the work to be done, to choose personal protective equipment and to establish standard operating procedures incorporating additional measures to ensure maximum safety during the works.

Samples for which information is limited.

If sufficient data is not available to properly assess the risk (clinical or epidemiological samples collected in the field), it is better to handle them carefully :

- The usual precaution must always be taken and mechanical protection devices (gloves, gowns, glasses) used when collecting samples from patients.
- The practices and procedures for minimum biological safety level 2 should be applied for the handling of samples.
- The transportation of samples shall be in accordance with national or international regulations.

Some data may provide additional information useful for assessing the risk of handling these samples, notably:

- The patient's medical file ;
- Epidemiological data (morbidity and mortality statistics, alleged mode of transmission, other data from the study of the outbreak) ;
- Data on the geographical origin of the sample.

In the case of outbreaks of a disease of unknown etiology, special guidelines are developed and disseminated to indicate how to prepare samples for transportation and specification of the biosecurity level for testing.

3.2. CLASSIFICATION OF LABORATORIES

The laboratory classification approach takes into account three types of structures, depending on their nature of activity; human

and animal health laboratories (L), animal facilities (A) and greenhouses (G). Human and animal health laboratories are structures that collect and analyze various fluids and biological tissues of human or animal origin. Animal facilities are areas of a laboratory where animals are used for experimental or diagnostic purposes. They can be located in the laboratory or in a side room. Greenhouses are closed or semi-open translucent structures made of glass or plastic, supported by a metal or wooden structure, for the cultivation of plants used for experimental purposes.

To protect individuals and communities from the potentially serious hazards of handling pathogens or infected animals and plants, laboratories develop strategies to prevent the risk of contamination and propagation. Laboratories are thus classified according to Biosafety Level (BSL). The biosafety level is a composite index that takes into account the type of organization, the construction method, the means of containment, the equipment of the laboratory as well as the practices and procedures to be observed to work on agents belonging to the various risk groups. There are four levels of biosafety grouped into three classes of laboratories (Table 3); basic security (BSL1 and BSL 2), containment (BSL 3) and high-security containment (BSL4).

To determine what level of laboratory biosecurity applies to a given agent, a risk assessment is necessary. For this, one must take into account not only the risk group but also a number of other factors. For example, an agent in risk group 2 will generally require facilities, equipment, practices, and procedures that correspond to biosecurity level 2 if the work is to be done with minimal risk. However, if certain manipulations involve the production of highly concentrated aerosols, it will be better to go to biosecurity level 3 so that the safety conditions are met because, at this level, better confinement of the aerosols will be ensured in the laboratory.

The determination of the biosecurity level required for a given manipulation therefore, consists of assessing the risk "on a professional level" rather than automatically adopting the level of safety corresponding to the risk group to which the pathogen belongs.

Table 3: Classification of laboratories [5].

Biosafety level	Description of the security	Laboratory type	Type of biological agents	Laboratory examples
BSL1 or P1	*Basic security*	*Basic Facility*	*Biological agents with no disease risk for humans*	*L1 laboratories, A1 animal facilities and G1 greenhouses*
BSL2 or P2	*Basic security*	*Primary healthcare facilities; analysis or research laboratories*	*Biological agents that may present a risk of disease in humans, but whose spread is unlikely. Treatments exist to fight against this type of disease*	*L2 laboratories, A2 animal facilities and G2 greenhouses*
BSL3 or P3	*Containment*	*Laboratory conducting diagnosis and specialized research*	*Pathogenic biological agents for humans with the possibility of propagation. Treatments exist, generally, to fight against this type of disease.*	*Les laboratoires L3, les animaleries A3 et les serres S3*
BSL4 or P4	*High security containment*	*Laboratory handling dangerous pathogens*	*Biological agents that may constitute a significant risk of disease for humans and lead to serious diseases for which treatments are non-existent or ineffective.*	*L4 labs, A4 animal facilities and G4 greenhouses*

N.B : *BSL1 or P1: Biosafety Level 1 : BSL2 or P2: Biosafety Level 2 : BL3 or P3: Biosafety Level 3 : BSL4 or P4: Biosafety Level 4.*

3.3. BIOSAFETY AND BIOSECURITY MEASURES

Biosecurity measures include the appropriate design of facilities, the availability and appropriate use of PPE, safety equipment and safe work practices. All hazards must be identified and risk assessment conducted regularly.

3.3.1. LAYOUT OF FACILITIES

Safety in the design of facilities should be taken into account in the initial planning and establishment of a laboratory, and on-

going assessments are necessary to ensure that the work being done is adequate. Some of the elements to be taken into account are:

- The location and layout of the laboratory;
- The requirements of air circulation and ventilation;
- The materials of the work surfaces, depending on the type of work and the disinfection considered;
- Furniture made of suitable material and the ergonomic design;
- Sanitary facilities and hand washing.

3.3.2. LABORATORY BIOSAFETY MEASURES

All personnel must adopt the following security practices:

- Adopt good microbiological techniques.
- Maintain personal hygiene.
- Appropriate precautions during microbiological handling, especially when implementing procedures generating aerosols.
- Proper storage of samples and microorganism isolates with the corresponding level of access control and inventory maintenance.
- Adequate decontamination and proper disposal of infectious materials and wastes.

3.4. BASIC LABORATORY (Biosafety levels 1 and 2)

The most important principles to apply are listed below.

3.4.1. ACCESS

i. The international pictogram of biohazard (figure1) must be pasted on the doors of rooms where microorganisms belonging to risk group 2 or higher groups are handled.

ii. No stranger including children should be allowed to access the laboratory working areas.

iii. Laboratory doors must remain closed.

iv. Access to the animal facility must be subject to authorization.

v. The presence of animals which are not used for experiments in the laboratory should be prohibited.

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Figure 1 : *International pictogram of biological risk [5].*

3.4.2. INDIVIDUAL PROTECTION

Personal Protective Equipment (PPE) and safety equipment provide a barrier to minimize the risk of exposure to aerosols, splashes, and accidental inoculation. The safety equipment chosen should be based on the nature of the work performed. PPE includes protective clothing, gloves, and goggles. They must be used, maintained, disinfected and stored properly. Inventories and maintenance records of this equipment should be kept.

i. The wearing of overalls, gowns, lab coats or uniforms is mandatory for laboratory work.

ii. Proper gloves are required whenever there is a risk of direct contact with blood or other body fluids, potentially infectious material or infected animals. After use, remove them aseptically and wash your hands.

iii. Personnel should wash their hands after handling infectious material or animals and before leaving the laboratory.

iv. The wearing of safety glasses, a face shield (visor) or other protective device is mandatory to ensure the protection of the eyes or face against splashing liquids or the impact of objects or ultraviolet radiation.

v. Wearing protective clothing (overalls, gowns, lab coats or uniforms) is prohibited outside the laboratory, e.g. in the canteen, cafeteria, offices, library, staff room or washroom.

vi. Wearing open toe shoes (slippers, samaras, "sandals", etc.) in the laboratory is prohibited.

vii. Eating, drinking, smoking, putting on makeup or handling contact lenses in laboratory work areas is prohibited.

viii. Storing food or drinks at any point is prohibited in laboratory work areas.

ix. All PPE must be removed in case of contamination or when its use is no longer necessary, with proper decontamination before reuse or disposal.

x. Protective clothing that has been worn in the laboratory should not be stored in the same locker room or wardrobes as work clothes.

3.4.3. OPERATIONAL MODES

i. Mouth pipetting is strictly prohibited.

ii. No object or material should be brought to the mouth; labels should not be moistened with the tongue.

iii. All techniques used must minimize the formation of aerosols and droplets.

iv. The use of hypodermic needles and syringes should be limited. They should not be used as a substitute for pipetting devices or for other purposes than parenteral injections or collection of laboratory fluids.

v. In the case of exposure to infectious liquids or materials, the laboratory head must always be informed immediately. Accidents and incidents must be recorded and the report archived.

vi. It is necessary to establish in writing a procedure for the cleaning of products of all kinds that would be disseminated.

vii. Contaminated liquids must be decontaminated (physically or chemically) before disposal into the sanitary sewer system. Depending on the result of the risk assessment of the agent(s) handled, it may be necessary to have an effluent treatment system.

viii. If documents must leave the laboratory, they must be protected from contamination.

3.4.4. LABORATORY WORK AREAS

i. The laboratory must be kept clean, tidy and free from any products or objects not needed for the work.

ii. Work surfaces must be decontaminated at

the beginning and at the end of work. These surfaces must also be decontaminated if they have been contaminated with potentially dangerous products during work.

iii. Any contaminated material, sample and culture must be decontaminated before disposal or cleaned for reuse.

iv. Packaging and transportation of samples are subject to national or international regulations.

v. If the windows can be opened, they must be fenced to prevent entry of arthropods.

3.4.5. BIOSAFETY MANAGEMENT

i. The laboratory head shall ensure the development and adoption of a biosecurity management plan as well as a biosecurity manual.

ii. The laboratory head must ensure that staff receives regular training on laboratory safety.

iii. The staff should be aware of the specific risks associated with laboratory activities and read the Biosecurity Manual. They should also respect standard instructions and protocols. The laboratory head should ensure the good comprehension and implementation of this manual. The laboratory must have a copy of the manual.

iv. There must be a programme for the control of arthropods and rodents.

v. If necessary, all staff should be examined and followed-up by a doctor, and a medical record should be opened for each.

3.4.6. DESIGN AND LAYOUT OF THE LABORATORY

The design of a laboratory and the definition of the tasks assigned to it must take into account known situations that may cause problems, notably:

i. Aerosol formation

ii. Work on large volumes or high concentrations of microorganisms

iii. Too many staff or devices compared to space available

iv. Infestation with rodents or arthropods

v. Entry or access to the laboratory

vi. Task scheduling: use of specific samples and reagents.

Figures 2 and 3 give examples of the layout of laboratories of Biosecurity Levels 1 and 2. In its design, the laboratory must meet the following requirements.

i. The laboratory must be spacious enough for safe work, easy to clean and maintain.

ii. Walls, ceilings, and floors should be smooth, easy to clean, impervious to liquids and resistant to chemicals and disinfectants normally used in the laboratory. Floor coverings must be slip-resistant.

iii. Work surfaces must be impervious to water, resistant to disinfectants, acids, alkalis, and organic solvents and be able to withstand moderate heat.

iv. Lighting should be sufficient for all types of work. Avoid disturbing reflections and bright lights.

v. Laboratory furniture must be solid. Ensure that free spaces between and under work surfaces, enclosures, and various appliances are accessible for cleaning.

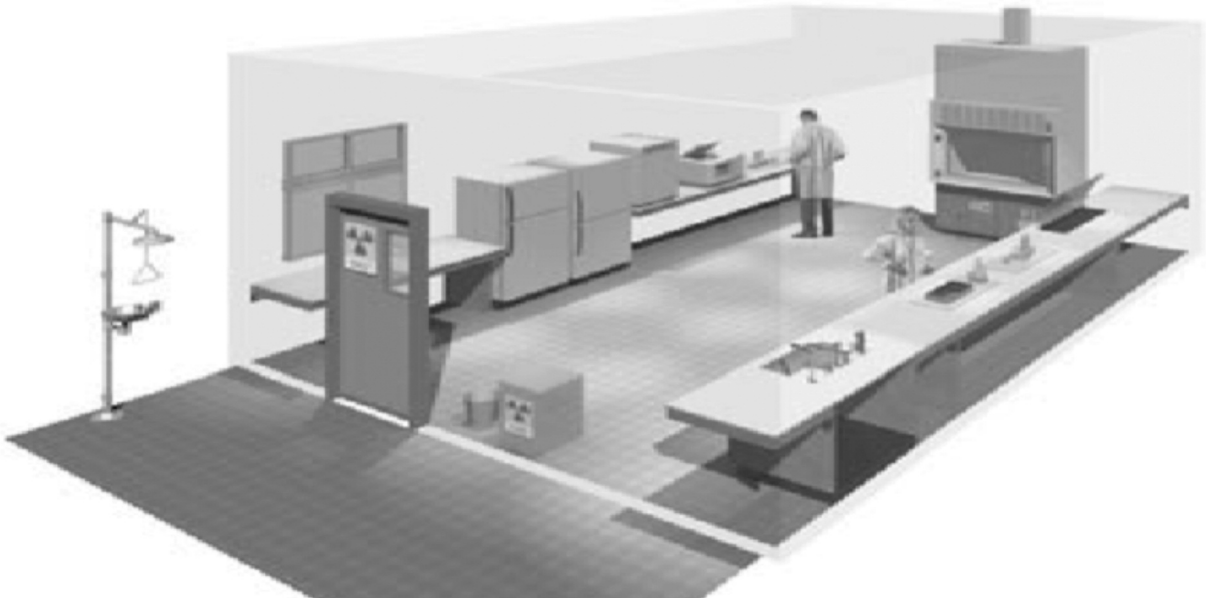


Figure 2: Standard Laboratory of Safety Level 1 [5] .

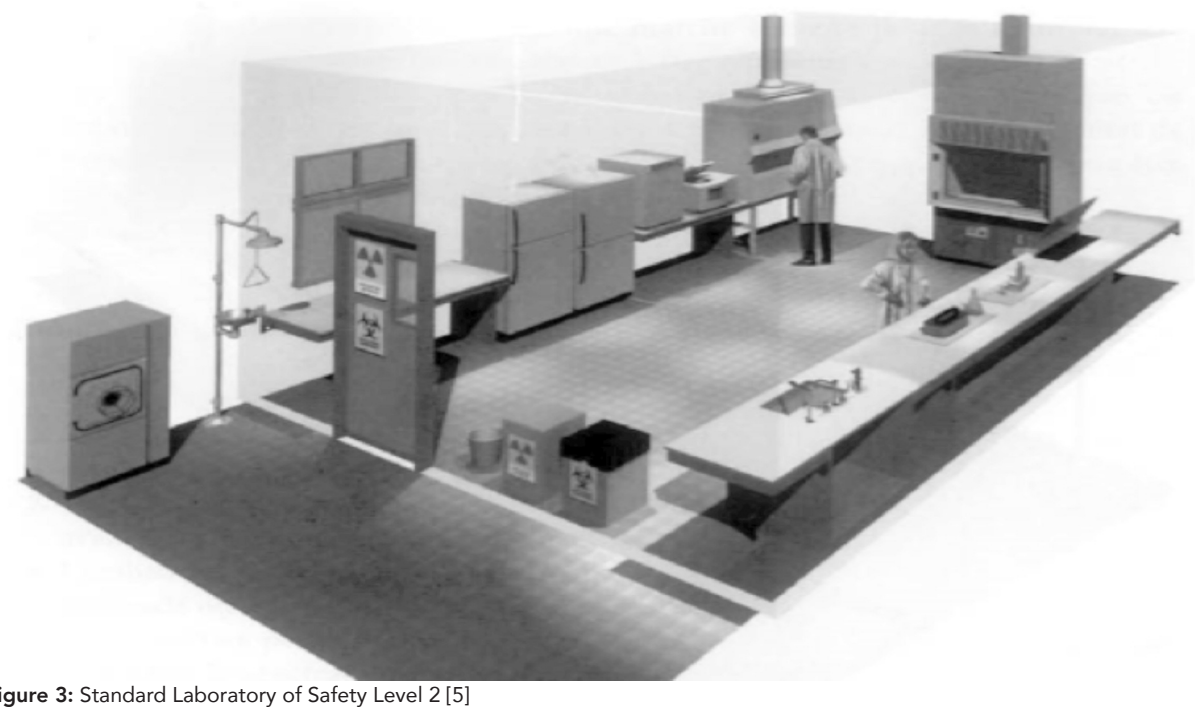


Figure 3: Standard Laboratory of Safety Level 2 [5]

vi. Storage spaces must be able to receive common material, to avoid the congestion of work surfaces and passage areas. Also, provide spaces for long-term storage, which should be conveniently located outside the work areas.
vii. Provide space and equipment to safely handle and store solvents, radioactive substances as well as compressed and liquefied gases.
viii. Locker-room for clothes and personal items must be outside work areas.
ix. Areas intended for eating, drinking or resting must also be outside work areas.
x. Install washbasins, if possible with running water, in each room of the laboratory, preferably near the door.
xi. The doors should have transparent panels; have adequate fire resistance and preferably an automatic closing system.
xii. At biosafety level 2, there must be an autoclave or other means of remote decontamination sufficiently close to the laboratory,
xiii. Safety systems must cover the risk of fire, electrical accidents and include a safety shower as well as an eyewash.
xiv. Provide areas or first aid rooms, suitably equipped and easily accessible.
xv. In the design of any new facility, a mechanical ventilation system must be provided to ensure the inward flow of air without recycling. Otherwise, the possibility of opening the windows and being equipped with an anti-arthropod net.
xvi. It is essential that the water supply is reliable and of good quality. There must be no interconnection between the laboratory service connections and the drinking water system. The public supply network must be protected by a non-return device.
xvii. Power supply must be reliable and of sufficient power; emergency lighting must be provided for an exit if need be. The laboratory must have a generator or other alternative energy source for the supply of essential equipment.
xviii. Gas supply must be reliable and sufficient. It is imperative to ensure the proper maintenance of this installation.
xix. Sometimes laboratories and animal facilities are targeted by vandals. The installation of physical protection and fire safety systems should be considered. It is essential to reinforce the doors, to equip the windows with nets and to limit the number of keys. If necessary, study and implement any other measures that may improve safety.

3.4.7. LABORATORY EQUIPMENT AND DEVICES

The laboratory head must ensure that the devices and equipment are adequate and properly used. These must be chosen based on a number of general principles :

i. Be designed to prevent or limit contact between the operator and the infectious material.
ii. Should be made of liquid impermeable materials, resistant to corrosion and in accordance with solidity standards.
iii. Be free from rough edges, sharp edges, and unprotected moving parts.
iv. Be designed, constructed and installed to ease use, inspection, cleaning, decontamination, and submitted to compliance testing. Whenever possible, avoid using glassware and other fragile materials.

Detailed manufacturing and operation specifications are required to ensure that the devices comply with safety standards.

3.4.8. ESSENTIAL BIOSAFETY DEVICES AND EQUIPMENT

i. Pipetting devices to replace mouth pipetting.

ii. Biosafety cabinets, to be used systematically in the following situations :
    - Handling of infectious material.
    - The existence of an increased risk of airborne infection.
    - Techniques involving a high risk of aerosol formation: e.g. centrifugation, grinding, mixing, agitation or energetic mixing, ultrasonic disintegration, the opening of containers containing infectious material when the internal pressure may be different from ambient pressure, intranasal inoculation of animals and harvest of infected tissue from animals or eggs.

iii. Disposable plastic transfer cans or electric incinerators for transfer cans placed in a biosafety cabinet to reduce aerosol formation.

iv. Tubes and vials with screw caps.

v. Autoclaves or other appropriate devices to decontaminate infectious material.

vi. Disposable Pasteur pipettes, plastic if possible, rather than glass.

Verify, by appropriate tests, that the various equipment or apparatus such as autoclaves or biological safety cabinets conform to the specifications, in accordance with the manufacturer's instructions.

3.4.9. MEDICAL AND HEALTH SURVEILLANCE IN LABORATORIES OF BIOSAFETY LEVEL 1 and 2

It is the responsibility of the employer, through the laboratory head, to ensure that the health of staff is satisfactorily followed-up. This follow-up aims to detect occupational diseases. To achieve this, the following should be done:

i. Ensure passive immunization (vaccination) of staff where appropriate;

ii. Facilitate the early detection of infections contracted in the laboratory;

iii. Do not confine high-risk manipulations to particularly vulnerable persons (e.g. pregnant women or immunosuppressed persons);

iv. Take adequate protective measures and ensure the effectiveness of protective devices

Guidelines for the follow-up of workers handling microorganisms of Biosafety Level 1

i. All candidates for a position in a laboratory must do a medical check-up to know their medical history.

ii. Any pathology or laboratory accident must be reported without delay.

iii. All staff members need to understand how important it is to maintain the quality of microbiological techniques.

Guidelines for the follow-up of workers handling microorganisms of Biosafety Level 2

i. A medical check-up is required prior to assignment to a position in a laboratory. This check-up will include an anamnesis to know the medical history and a specific medical check-up of the professional aptitude will be carried out.

ii. The laboratory management will have to keep a record of absences and illnesses of the staff.

iii. Women of childbearing age should be informed of the danger to the unborn child from occupational exposure to certain microorganisms, such as the rubella virus. The specific measures to be taken to protect the fetus vary according to the nature of the germ to which the future mother may be exposed.

3.5. CONTAINMENT LABORATORY (Biosafety Level 3)

The Containment Laboratory - Biosafety Level 3- is designed and planned for work involving micro-organisms of risk group 3 and large volumes or high concentrations of risk group 2 microorganisms whose handling may provoke the diffusion of aerosols.

Biological agents recommended to be handled in Level 3 laboratories include but are not limited to:

Les bactéries

- Bacillus anthracis;
- Burkholderia pseudomallei;
- Brucella spp . (except B. ovis);
- Clostridium botulinum;
- Francisella tularensis;
- Mycobacterium tuberculosis complex;
- Yersinia pestis.

Viruses

- Dengue virus;
- Hanta virus;
- Influenza virus type A (subtypes H2, H5 and H7 ...);
- Japanese encephalitis virus (pre-exposure vaccination recommended);
- Monkey pox virus;
- Rabies virus or rabies related virus (pre-exposure vaccination recommended);
- Rift Valley fever virus;
- Severe Acute Respiratory Syndrome (SARS) Coronavirus;
- West Nile Virus;
- ellow fever virus (pre-exposure vaccination recommended).

Fungi

- Blastomyces dermatitidis;
- Coccidioides spp.;
- Histoplasma capsulatum;
- Paracoccidioides brasiliensis;

The degree of containment involved for safety level 3 requires the strengthening of work and safety programmes compared to those of the basic laboratories - Biosafety Levels 1 and 2. The recommendations in this section add to those relating to basic laboratories - Biosafety Levels 1 and 2, which must therefore, be applied before specific recommendations to containment laboratories - Biosafety level 3.

The most important additions and modifications are:

- The design and layout of the laboratory;
- The code of best practice;
- Medical and health surveillance.

Laboratories in this category must be approved and listed by the relevant national or other health authorities.

The code of best practice, defined for basic laboratories - Biosafety Levels 1 and 2, apply with the following changes:

i. i. The biohazard sign (see figure 1) on the laboratory door shall indicate the level of biosafety and the name of the laboratory head responsible for access to the premises and shall also specify the special conditions of entry into the zone, vaccination, for example.

ii. Protective clothing to be worn in the laboratory must be the following type: aprons, gowns, lab coats, cleaning suits, overalls, headdresses and, where appropriate, overshoes and special shoes. Ordinary laboratory coats that button in front is not suitable, as well as sleeves that do not fully cover the forearms. Laboratory clothing must not be worn outside and should be decontaminated before laundering. It may be justified to remove work clothes to put on appropriate laboratory clothing when working on certain pathogens (pests or zoonotic agents, for example).

iii. Any potentially infectious material should normally be handled in a biosafety cabinet or other primary containment device.

iv. Wearing a respirator may be necessary when handling or when working on animals carrying certain pathogens.

3.5.1. DESIGN AND LAYOUT OF THE LABORATORY

The recommendations for basic laboratory design and layout - Biosafety Levels 1 and 2 apply in addition to those listed below:

i. i. The laboratory must be separated

from unregulated passage areas inside the building. Isolation can be completed by placing the laboratory at the end of a corridor without opening on the outside, by constructing a partition with a door or by opening access only through a vestibule (for example an airlock double entry or the basic laboratory - biosafety level 2) defining a zone specially designed to maintain a pressure difference between the laboratory and the contiguous areas. The vestibule must be arranged for the separation of dirty and clean protective clothing and have a shower if necessary.

ii. The vestibule doors must be self-closing and interlocked so that only one door can be opened at a time. A sign to break in case of emergency must be provided.

iii. The surface of walls, floors, and ceilings must be water resistant and easy to clean. Openings in these surfaces (e.g. piping) must be sealed to facilitate room decontamination.

iv. The laboratory must be able to be hermetically closed to be decontaminated. Ducts will be installed to allow gas disinfection (fumigation).

v. Windows must be tightly closed and shock resistant.

vi. A washbasin that can be controlled without the help of the hands will be placed near each exit door.

vii. The ventilation system must create a directed air flow from the access area to the interior of the room. A visual control device, whether or not equipped with an alarm, should be installed so that personnel can ensure that airflow is always properly directed.

viii. The ventilation system must be constructed in such a way that air leaving the containment laboratory (biosafety level 3) is not recycled in other areas of the building. The air can be filtered using a high-efficiency particulate filter (HEPA) [7], reconditioned and recycled inside the laboratory. The evacuated air from the laboratory (other than the one coming from the biosafety cabinet) will be vented directly outside the building so that it is dispersed far from occupied buildings and air intakes. Depending on the agents used, this air can be vented by first passing it through HEPA filters. A heating, ventilation and air conditioning control system is installed that avoids any permanent overpressure in the laboratory. Consider the installation of a perfectly distinct acoustic or visual alarm device to warn personnel in the event of a failure of the control system.

ix. HEPA filters must be installed to allow gas decontamination or operational testing.

x. Biological safety cabinets must be located outside the passageways and drafts between doors and ventilation systems.

xi. Air flowing out of Class I and II safety cabinets, after passing through the HEPA filters, must be vented without disturbing the flow of air, either in the cabinet or in the building ventilation system.

xii. In the laboratory room, an autoclave must be provided for the decontamination of waste. If infectious waste is to be transported outside the containment laboratory for decontamination and disposal, transportation must be in unbreakable, hermetically sealed and leak-proof containers in accordance with national or international regulations, as appropriate.

xiii. Water supply should be equipped with anti-return devices. Suction lines (vacuum circuit) should be protected by disinfectant liquid traps, HEPA filters or equivalent devices. Vacuum pumps should also be protected by traps and HEPA filters.

xiv. The design of a containment laboratory and the techniques used in this type of

laboratory must be supported by appropriate documentation (Figure 4 gives an example of how to set up a biosafety level 3 laboratory).

3.5.2. LABORATORY EQUIPMENT AND DEVICES

The choice of equipment, devices, laboratory devices, and biosafety cabinets is based on the same principles as for basic laboratories (Biosafety Level 2). However, in a laboratory of biosafety level 3, handling of all potentially infectious material (sample or soiled object) must be carried out in a biosafety cabinet or any other primary containment device. The use of some apparatuses such as centrifuges requires additional containment devices such as buckets/safety pods or containment of the rotor. Some centrifuges or other devices such as cell sorters that are intended to work on infected cells may require the installation of additional ventilation with HEPA filters for effective containment.

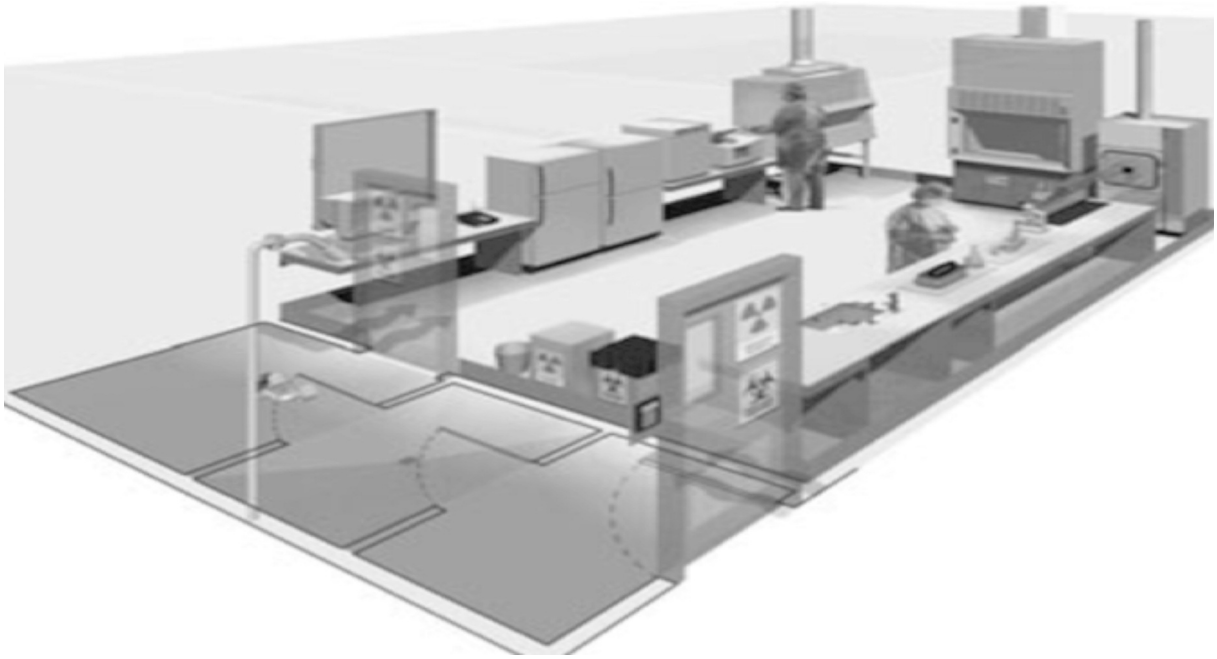
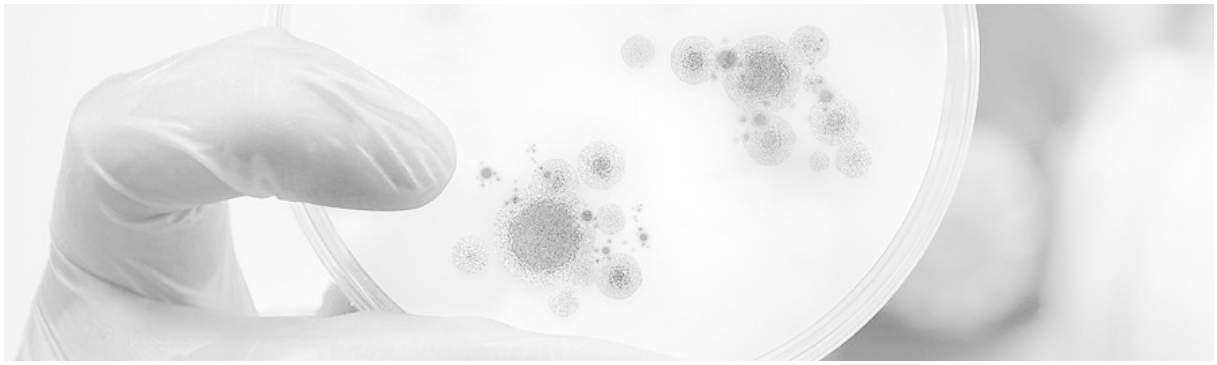


Figure 4 : *Standard Laboratory of Biosafety Level 3*
(Laboratory separated from the general passage and accessible by a hall which can be either a double-door entry, or the basic laboratory -BSL2, or by an airlock. The laboratory is equipped with an autoclave for the decontamination of waste before disposal as well as a "hands-free" sink. Air flows from the outside to the inside and all manipulations on infectious biological material are performed in a biosafety cabinet (BSC) [5]

3.5.3. MEDICAL AND HEALTH SURVEILLANCE IN LABORATORIES OF BIOSAFETY LEVEL 3

i. A medical examination is obligatory for all personnel working in the containment laboratory. It should include an anamnesis for medical history and a physical examination to check whether the person is medically fit to perform this type of professional activity.
ii. If the medical check-up is satisfactory, the person concerned receives a medical card (figure 5) attesting that they are employed in an establishment where a containment laboratory is located - Biosafety level 3. This card, which the holder must always carry on them, bears the picture of the holder and must be stored in a wallet or card holder. It should also indicate the name of the person(s) to contact in case of problems. These persons are designated from the structure but could be the laboratory head, the medical advisor or the biosafety officer.



A-Front Page

MEDICAL SURVEILLANCE

Name _____

_____

Picture

AT THE ATTENTION OF EMPLOYERS

Keep this card on you. In case of unexplained febrile state, present this card to your Physician and indicate persons to contact following this order on the list.

Dr _____ Professional Phone no _____

_____ Personal Phone no _____

Dr _____ Professional Phone no _____

_____ Personal Phone no _____

B-Back Page

AT THE ATTENTION OF PHYSICIANS

The holder of this card is an employee of: _____

Found in an area where viruses, rickettsias, bacteria protozoa and helthminths are present. In case of unexplained febrile state, please contact his employer to know what are the pathogens to which this worker would have been exposed to.

Laboratory' Name: _____

Personal Address: _____

_____

_____

Phone no: _____

Figure 5 : Medical Card Template used for health and medical surveillance of staff [4].

3.6. HIGH-SECURITY CONTAINMENT LABORATORY (Biosafety Level 4)

The high-security containment laboratory - Biosafety level 4 is designed for work on microorganisms of risk group 4.

Agents recommended to be handled in Level 4 laboratories among others include:

- Crimean-Congo hemorrhagic fever virus;
- Ebola virus;
- Guanarito virus;
- Hendra virus;
- Herpes simiae virus (B virus);
- Junin virus;
- Kyasanur Forest Disease virus;
- Lassa virus;
- Machupo virus;
- Marburg virus ;
- Nipah virus;
- Omsk hemorrhagic fever virus;
- Sabia virus;
- Tick encephalitis virus;
- Smallpox virus.

Before building and commissioning such a laboratory, extensive consultation with institutions with expertise and experience in the operation of this type of facility is required. Operational high-security containment laboratories - Biosafety level 4 should be under the control of competent national or other health authorities. The following information is a simple introduction. Any person or institution wishing to establish a high-security biosafety laboratory 4 is invited to contact the WHO or OIE Biosafety Programme for further information.

3.6.1. CODE OF BEST PRACTICES

The provisions of the Code of Best Practice on Biosafety level 3 remain valid, in addition to those listed below:

i. No one should work alone in the lab at any given time; the rule of working in at least two pairs must be strictly applied. This rule is important in a laboratory - Biosafety Level 4, where the wearing of pressurized personal protection overalls is mandatory.
ii. Staff must change clothing and shoes completely before entering the laboratory and before going out. A shower is obligatory before the exit.
iii. Staff should train in the conduct of emergency evacuation of injured or unwell persons.
iv. A communication system must be established between staff members working in a high-security biosafety laboratory level 4 and external personnel, whether for routine contacts or in emergency situations.

There is currently no BSL-4 laboratory in Cameroon. Live organisms in risk group 4 (GR4) should not be handled. Any material suspected of containing GR4 agents requiring laboratory confirmation testing must be packaged in accordance with the United Nations Recommendations [7-11] and the International Air Transport Association (IATA) guidelines [8], and sent to laboratories with adequate security facilities

3.7. SAFETY RULES FOR ANIMAL FACILITIES

Animals are often used for experimental or diagnostic purposes. The user has the moral obligation to take all necessary measures to avoid causing unnecessary suffering (ensuring animal welfare). Animals must be kept comfortable, hygienic, and receive good quality water and food in sufficient quantity. For safety reasons, an animal facility must be independent and separate from the laboratory. Otherwise, it must be designed so that it can be isolated from public areas of the laboratory and easily decontaminated and disinfected.

Animal facilities must be designed according to the risk group to which the germs studied on the animals belong. Their design must also take into account the risk assessment they represent.

The following factors should be considered in the case of pathogens used in an animal testing laboratory:

- The normal route of transmission;
- Volumes and concentrations of inoculums that will be used;
- The route of inoculation;
- The possible route of excretion.

As for experimental animals used in the laboratory, the following factors must be taken into account:

- The sensitivity of the animal to the studied germ;
- The age and sex of the animal;
- The nature of animals, namely their aggressiveness and tendency to bite or scratch;
- The nature of their ecto or endoparasites;
- Zoonoses to which they are sensitive;
- The possible spread of pathogenic allergens and germs.

3.7.1. **3.7.1.SAFETY RULES**

As in the case of laboratories, the requirements for the design, equipment, and precautions are all the more stringent as the biosafety level is higher. They are summarized in Table 4 below.

Tableau 4: Containment levels in animal facilities: safety practices and equipment, adapted from [4].

Risk group	Containment level	Laboratory Practices and Safety Equipment
I	ABSL-1	Limited access protective clothing and gloves.
II	ABSL-2	In addition to the NSBA-1 recommendations, include biohazard panels: Class I or II ESB for aerosol generating activities. Decontaminate waste and cages before washing.
III	ABSL-3	In addition to the ABSL-2 recommendations, note that access is regulated. BSC and special protective clothing recommended for all activities.
IV	ABSL-4	In addition to the ABSL-3 recommendations, note that access is strictly limited. Change clothes before entering. Use Class III BSC or pressurized suits. Take a shower before going out. Decontaminate all waste before leaving.

Biosecurity guidelines are cumulative, that is, at each level of safety apply all the guidelines that are valid for the lower levels.

3.7.1.1. ANIMAL FACILITY – BIOSAFETY LEVEL 1

This is the appropriate level for keeping most farm animals after quarantine (except for primates, for which competent authorities should be consulted) and animals deliberately inoculated with risk group agents 1. At this level the following conditions must be met:

- A good microbiological technique is essential;
- The manager of the animal facility must determine the general course of action;
- Procedures and protocols applicable to all operations and access to the vivarium must be available;
- Appropriate medical supervision of the staff must be instituted;
- A health and safety guide or a practical safety manual must be drafted and staff must comply with it.

3.7.1.2. ANIMAL FACILITY – BIOSAFETY LEVEL 2

This is the appropriate level to work on animals voluntarily inoculated with agents belonging to risk group 2. The following safety measures should apply:

i. Requirements related to all animal facilities - Biosafety Level 1, must be met.
ii. Biohazard signs (see Figure 1) will be on doors and other appropriate locations.
iii. The animal facility must be designed in a way to be easily cleaned and maintained.
iv. Doors must open inwards and close automatically.
v. The premises must be adequately heated, ventilated and lit.
vi. If the ventilation is mechanical, airflow must be directed inwards. Stale air is exhausted outside and must never be recycled anywhere in the building.

vii. Access must be restricted to authorized persons.

viii. Apart from the animals intended for the experiment, no other animal must be introduced in the premises.

ix. An arthropod and rodent control programme needs to be put in place.

x. If there are windows, they must be secure, withstand shocks and if they are likely to be opened, they must have wire screen to prevent the passage of arthropods.

xi. Worktops should be decontaminated with effective disinfectants after use.

xii. Biosafety cabinets (class I or II) or isolators with special air supply and evacuation of stale air after HEPA filter filtration may be used for activities likely to result in the formation of aerosols.

xiii. An autoclave must be installed either on site or nearby.

xiv. When removing litter from animals, aerosols and dust should be avoided as much as possible.

xv. All waste and litter must be decontaminated before disposal.

xvi. The use of sharp or pointed instruments should be limited, whenever possible.

xvii. These instruments should always be collected in resistant containers with a lid (anti-piercing boxes) and treated as infectious material.

xviii. Equipment for autoclaving or incineration must be transported safely in closed containers.

xix. Animal cages should be decontaminated after use.

xx. Bodies of dead animals should be cremated.

xxi. Wearing protective clothing and equipment is mandatory in the animal facility. They should be removed when going out.

xxii. A sink must be installed. Staff should wash their hands before leaving the facility.

xxiii. Any injury, even minor, must be treated appropriately. It must be reported and recorded.

xxiv. It is forbidden to eat, drink, smoke and makeup in the animal facility.

xxv. All staff members must receive appropriate training.

3.7.1.3. ANIMAL FACILITY – BIOSAFETY LEVEL 3

This is the appropriate level for working with animals voluntarily inoculated with micro-organisms in risk group 3, or if a risk assessment indicates this for another reason. All systems, practices, and procedures must be reviewed and checked for conformity every year. The following security rules should apply:

i. Requirements related to all animal facilities - Biosafety Level 1 and 2 must be met.

ii. Access should be strictly regulated.

iii. The facility must be separated from the other laboratories and animal facilities by a room forming hall with a double door.

iv. A sink must be installed in this hall.

v. The hall must also include a shower.

vi. The premises must have mechanical ventilation ensuring a continuous circulation of air in all the rooms. Stale air must be evacuated through the HEPA filters before being recycled to the air outside. The system must be designed in a way to prevent a reversal of the direction of air circulation and any overpressure in the premises of the animal facility.

vii. An autoclave must be installed in a convenient place in the animal facility where the containment equipment is located. Infectious waste must be autoclaved before being transported to other

areas of the facility.

viii. There must be an on-site incinerator or other arrangements made in consultation with the relevant authorities.

ix. Cages of animals carrying micro-organisms belonging to risk group 3 shall be placed in insulators or placed in front of extraction fans.

x. It must be ensured that the litter is dusted as much as possible.

xi. All protective clothing should be decontaminated before laundering.

xii. Windows must be tightly closed and shock resistant.

xiii. Vaccination is recommended to the staff, where appropriate.

3.7.1.4. NIMAL FACILITY – BIOSAFETY LEVEL 4

Work in this animal facility will normally be associated with the handling of the high-security containment laboratory - Biosafety Level 4, and national and local regulatory requirements will need to be harmonized to be applicable to both. If work is to be done in a laboratory where wearing of pressure suits is mandatory, a number of other practices and procedures must be followed in addition to those described here:

i. Requirements related to all animal facilities - Biosafety Level 1, 2, and 3 must be met.

ii. Access should be strictly regulated. Only qualified personnel designated by the facility manager must be allowed access;

iii. Nobody must work alone. The rule of working in pairs must be applied;

iv. The staff should have received the possible most advanced microbiologist training and be familiar with the risks associated with their work and the precautions to be observed;

v. Areas where animals carrying risk group 4 pathogens are housed must at all times meet the containment criteria for high-security containment laboratories – level 4 biological security;

vi. The entrance to the animal facility must be through a hall forming an airlock, the clean side of which must be separated from the access side regulated by a locker room and showers;

vii. Staff should remove their clothes when entering and put on special protective clothing. After work, they must remove the protective clothing so that it is autoclaved and then have a shower before leaving;

viii. The animal facility must be ventilated by means of an air evacuation system equipped with HEPA filters designed to create a depression (inward flow of air).

ix. The ventilation system should be designed to prevent reversal of airflow and overpressure in the premises of the animal facility;

x. A two-door autoclave is required for the exchange of equipment, the clean side opening into a room outside the containment rooms;

xi. The exchange of non-autoclavable material must be done through an airlock, the clean side of which must open in a room outside the containment rooms;

xii. All handling of pathogen-carrying animals in risk group 4 must be carried out under safety conditions corresponding to those of a high-security containment laboratory - Biosafety level 4;

xiii. All animals must be housed in isolators;

xiv. All litter and waste must be autoclaved before leaving the animal facility;

xv. Staff must be under medical supervision;

xvi. The certification label for Biosafety Cabinets (BSCs) must be pasted on the front of the hood.

3.8. SAFETY RULES APPLICABLE TO INVERTEBRATES

CAs for vertebrates, the safety level is determined by the risk group to which the pathogens studied belong, however, a risk assessment may lead to a different decision.

Additional precautions are needed with some arthropods, including flying insects:

i. Infected and non-infected invertebrates should be housed in separate rooms.
ii. Rooms must be hermetically closed for fumigation;
iii. Insecticide sprays must be made available;
iv. Cooling systems should be provided to reduce the activity of invertebrates, if necessary;
v. Access should be through a hall with insect traps and screened doors to prevent the passage of arthropods;
vi. All ventilation outlet ducts and windows that can be opened will be closed by a wire screen preventing the passage of arthropods;
vii. The siphon of sinks and sewers must always be wet;
viii. All wastes should be decontaminated by autoclaving because some invertebrates are resistant to all disinfectants;
ix. The number of larval and adult forms of flying arthropods, crawlers and jumpers should be monitored;
x. Cages of ticks and mites should be placed on trays containing oil.
xi. Infected or potentially infected flying insects should be contained in double-screen cages;
xii. Infected arthropods or that could be infected should be handled in biosafety cabinets or isolators;
xiii. Insects that are infected or that may be infected can also be handled on cooled trays.

3.9. HUMAN RESOURCES

Cameroon laboratories must have a competent workforce in biosecurity and biosafety. To this end:

i. Each laboratory must formally appoint a biosecurity/biosafety officer;
ii. Standard biosecurity and biosafety training modules should be developed. The modules should include: occupational health and safety, responsibility of employees and structure; causes and prevention of fires; the use of fire extinguishers; emergency evacuation; first aid; what to do in case of splashing and spills; the various hazards and risks associated with their practice; use of PPE; proper use of hosts;
iii. In addition to initial training, laboratory personnel must undergo further training to update their biosafety knowledge and skills;
iv. Competency assessment programmes covering biosafety/biosecurity should be conducted periodically;
v. Staff job description should include biosafety responsibilities;
vi. Checks on health history must be done prior to hiring staff for specific laboratories (such as BSL-3 laboratory).

3.10. INFRASTRUCTURE

Cameroon laboratory infrastructure must be safe and secure. To this end:

i. Infrastructure must meet laboratory construction standards;
ii. The design of the laboratory must take into account the basic requirements of laboratory work, personnel safety, secure access, appropriate work space, equipment storage, management flow of samples, waste disposal;
iii. A structural plan for the laboratory organization must be available in all laboratories;

iv. Infrastructure should be designed and maintained based on biological risks and threats;
v. The laboratory must be modified in the light of the recommendations of the competent body;
vi. Alternative measures must be put in place to deal with power cuts and lack of water;
vii. An emergency plan must be available to respond to fires, natural disasters, and secure evacuation;
viii. Security measures must be taken to prevent the theft of samples and equipment.

3.11. BIOSAFETY AND BIOSECURITY EQUIPMENT AND DEVICES

Equipment related to the prevention of biological risks (see Table 5) must be available in the installations as well as an insurance of technical advice and spare parts:

i. There must be a well-defined equipment acquisition procedure at the institutional level in accordance with the specifications;
ii. Regular and documented maintenance of all the equipment must be ensured;
iii. The equipment must be certified according to the manufacturer's requirements by competent bodies;
iv. Each laboratory must have standard operating procedures for decontamination;
v. The laboratory must systematically have at its disposal personal protective equipment according to the risk level (see Table 6).

3.12. BIOSAFETY CABINETS (BSCs)

Biosafety Cabinets (BSCs), also known as Microbiological Safety Cabinets (MSCs), are designed to prevent the operator, laboratory room and equipment from being exposed to infectious aerosols or splashes that may occur during the handling of biological materials containing pathogens, such as primary cultures, strains for cultures and diagnostic specimens.
Depending on the type of protection sought, laboratories should use the biosafety cabinets whose specifications are described in Table 5 below.

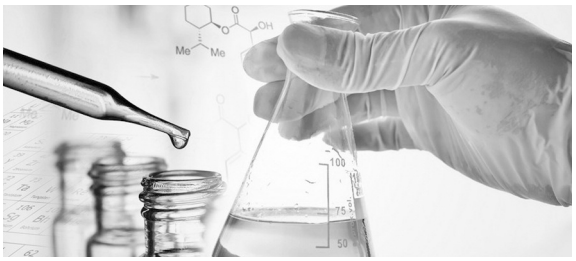


Table 5: Biosafety equipment and instruments [5]

Equipment and instruments	Risks	SECURITY FEATURES
-	-	Good filtration of evacuated air No product protection
BSC-Class I	Aerosols and splashes	Minimum inflow (face velocity) at the front opening.

BSC-Class II	Aerosols and splashes	Minimum inflow (face velocity). Good filtration of evacuated air. Ensures product protection
BSC-Class III	Aerosols and splashes	High security containment Ensures product protection if laminar flow
Flexible plastic sheet vacuum isolator Splash shields	Aerosols and splashes	High security containment
Splash shields	Chemical product splashes	Constitutes a shield between the operator and the handling
Pipette fillers	Risks from pipetting with the mouth: ingestion of pathogenic germs, inhalation of aerosols produced by suction on the pipette, expulsion of liquid or falling drops, contamination of the end of the pipette used to suck up	• Ease of use • No end contamination for suction, protection of pipette filler of the user and vacuum circuit (suction lines) • Possible sterilization • Not leak by the pipette tip
Micro-incinerator handles, Disposable handles	Splashes from transfer handles	• Protection by a tube closed at an end in glass or in ceramic, heated with gas or electricity • Disposable, useless heating
Leak-proof containers for collecting and transporting infectious material for sterilization in an appropriate facility	aerosols, products spread as a result of spills or leaks	• Leak-proof construction with a lid • Wear resistance • Autoclavable
Containers for pointed or sharp objects	Bites and cuts	• Autoclavable • Anti-bites, robust
Transport containers from one laboratory or facility to another	Release of microorganisms in the environment	• Robust • Waterproof primary and secondary containers (leak-proof) • Absorbent material retaining liquids
Autoclaves, manual or automatic	Contaminated objects and equipment (secured for disposal or reuse)	• Approved models • Efficiency of heat sterilization
Screw cap bottles	Aerosols and widespread products	• Effective containment
Vacuum circuit Protection or suction lines	Contamination of vacuum circuit or suction lines by aerosols or overflow of liquids	• Cartridge filter stops aerosols (particle diameter 0.45mm) • The overflow vial contains a suitable disinfectant. A rubber float can be used to automatically shut off depression when the vial is full • The system can be fully autoclaved

Table 6: Personal protective equipment [5]

Equipment	Risk avoided	Security specificity
Laboratory smocks and coats	Contamination of clothes	* Back buttoning * covers city clothes
Plastic apron	Contamination of clothes	* Waterproof * Closed toe
Shoes	Shocks and splashes	* Anti-shock lenses (must be corrective or worn over the glasses)
Goggles	Shocks	* Anti-shock lenses (must be corrective
Safety glasses	Shocks and splashes	* Fully protect the face * Easily removed in case of accident
Respiratory Devices and masks	aerosol inhalation	* Different models: Disposable single-use; with full mask or half- mask and air purification cartridge; with intermittent positive pressure filtered air supply; with air supply
Gloves	Direct contact with microorganisms Cuts	* Disposable, certified microbiological Quality. In latex or polyacrylonitrile PVC * Hand protection * In stitches

Table 7: Choosing a Biosafety Cabinet (BSC) according to the type of protection sought [5]

TYPE OF PROTECTION	BSC TO USE
Protection of staff, micro-organisms of risk groups 1 to 3	Class I, Class II, Class III
Protection of staff, micro-organisms of risk group 4, laboratory with gloves box	Class III
Protection of staff, risk group 4 micro-organisms, compulsory wearing of pressurized suits	Class II
Product protection	Class II, Class III only if laminar flow
Protection against volatile radionuclides/ chemical protection, minimal quantities	Class IIB1, Class IIA2 with external exhaust
Protection against volatile radionuclides/chemical protection	Chemical hood, Class IIB2, Class III

4. BEST PRACTICES IN THE LABORATORY

If best practices in the laboratory are not observed during the pre-analytical, analytical and post-analytical phases, there is a risk of infection for staff and the environment. Best practices in the laboratory should be defined in a disseminated handbook of procedures. These practices include:

i. Sample collection and transportation within the facility: use of sample containers;
ii. Triple packaging;
iii. Sample Receipt: laboratories that receive a large number of samples must reserve a specific room or area for this purpose;
iv. Package opening: the personnel who receive and unpack sample packaging must be aware of the risks they face and must be taught to follow standard precautions;
v. Use of pipettes and pipetting devices;
vi. Precautions to prevent ingestion of infectious material and contact with the skin and eyes;
vii. Precautions to prevent accidental inoculation of infectious material;
viii. Separating serum: proper use of centrifuges;
ix. Use of homogenizers, shakers, mixers, and ultrasonic generators;
x. Use of tissue crushers;
xi. Opening of vials containing freeze-dried infectious material;
xii. Storage of vials containing infectious material;
xiii. Precautions observed in handling blood and other body fluids, tissues and stools;
xiv. Sample collection, labelling, and transportation;
xv. Opening of sample tubes and sampling;
xvi. Handling glass and sharp or pointed objects
xvii. Preparation of thick smears/drops;
xviii. Fabric preparation: fixation and cutting;
xix. Use of PPE;
xx. Decontamination and disinfection techniques;
xxi. Keeping of records
xxii. Compliance with health and safety rules.

5. EMERGENCY PLANS AND RESPONSE

The risk of contracting laboratory-associated infections; the risk of accident, fire, flood, etc. is real, always present and is an integral part of the workplace in diagnostic laboratories in general and in the clinical microbiology laboratory in particular. Security measures when handling germs and animals should be taken in all laboratories. The laboratory or animal facility that handles and stores microorganisms must write an emergency plan to deal with any accidents that may occur. This emergency plan must provide for actions to be taken in different situations:

i. Natural or other types of catastrophes: fire, flood, earthquake or explosion, for example;
ii. Biorisk;
iii. Accidental exposure and contamination;
iv. Exposure of staff and animals.

The following points should be taken into account when developing this plan:

i. Identification of high-risk microorganisms;
ii. Location of high-risk areas such as laboratories, storage areas, animal facilities;
iii. Identification of staff and populations at risk;
iv. Identification of managers and their responsibilities: biosecurity delegate, security team, local health authorities, clinicians, microbiologists, veterinarians, epidemiologists, fire-fighters and police, among others;
v. List of available means to ensure the treatment and isolation of exposed or infected persons;
vi. Transportation of exposed or contaminated persons;
vii. List of sources of immunoserum, vaccines, drugs, equipment, and specialized supplies;
viii. Sources of supply of emergency equipment and material: protective clothing, disinfectants, equipment and supplies for decontamination, for example.

Regular simulation exercises should be organized to familiarize staff with emergency procedures.

Alarm and information system

In the event of a fire or natural disaster, local or national rescue services should be informed of potential hazards in or around buildings. They will be able to enter only accompanied by an experienced staff member. Infectious material should be collected in leak-proof containers or disposable bags made of resistant material. It is up to the security team to determine, according to local regulations, what can be recovered and what must be destroyed.

Concerning rescue services, the following telephone numbers and addresses will be prominently displayed on the premises of the facility:

- Name, address and access plan of the facility or laboratory (not necessarily known by the person calling or the called service);
- Facility manager;
- Laboratory head;
- Biosecurity officer;
- Fire department/fire-fighters;
- Hospitals, ambulances, medical staff (name of various health centres, clinics, medical staff services, if possible);
- Police;
- Medical doctor;
- Technician;
- Water, gas and electricity services.

6. **DISINFECTION** AND STERILIZATION

Knowledge and respect of basic principles of disinfection and sterilization are of crucial importance of laboratory biosecurity. It is equally important to know the basic elements of cleaning prior to disinfection (pre-cleaning).

The contact time required with a given disinfectant is specific to each substance and manufacturer. This is the reason why all recommendations concerning the use of disinfectants must comply with the specifications stated by the manufacturer. Protocols, as well as sterilization schedules must be respected.

7. **MANAGEMENT OF WASTE** AND ANIMAL CARCASSES

7.1. WASTE MANAGEMENT

Waste management aims at handling, safe and reliable disposal of biological waste produced in the laboratory. Good waste management ensures the safety of patients and staff, limits the impact on the environment and helps to control the waste disposal budget. All facilities handling biological material must have an effective waste management plan that includes:

- The identification and classification of waste;
- Compliance with sorting and packaging rules according to the regulations in force;
- Securing storage sites prior to transportation for destruction according to regulations in force;
- Documentation of all stages of waste management;
- Reduction of waste production;
- Waste disposal and traceability of disposed materials;
- Adequate training the personnel dealing with waste by the employer institutes/laboratories;
- Providing personnel with appropriate personal protective equipment for the treatment of waste.

The laboratory manager must ensure the credibility and competence of service providers required for the treatment of waste generated in the laboratory. Accreditation and the contract binding the laboratory to the

waste disposal service provider must be documented in the laboratory.

7.2. MANAGEMENT OF ANIMAL CARCASSES

The adopted method of disposing of carcasses must take into account the causes of death of these animals, the existing devices for the disposal of these carcasses, their capacities, and their performance. It also depends on the conditions required for pathogen inactivation.

For some of them, pre-treatment is likely to be required in the facility before considering the transportation of animal carcasses to central facilities for discarding or incineration.

Pre-treatment may consist of shredding animal carcasses that can then be transported in sealed containers or subjected to fermentation, composting or freezing process. The different treatment methods [8] are:

- Incineration in an open air or air curtain special facility
- Composting
- Discarding
- Burying
- Methanization
- Alkaline hydrolysis
- Biorefining
- Dumping dead animals into the sea.

8. MANAGEMENT OF SAMPLES

Biological material (microorganisms, spores, toxins, and derivatives) must be stored and secured to avoid being used for bioterrorism purposes. The safe and secure preparation, packaging, storage and transportation of samples within the facilities, throughout the country and abroad must be ensured. To this end:

- The staff involved must be trained;
- The regulations in force in the country regarding sample transportation or shipping must be respected;
- The cold chain must be maintained during transportation;
- Transportation documents must be duly completed;
- Packaging procedures must be respected;
- Structures must put in place measures for safe handling (storage, packaging, and transportation) including accidents such as leaks and spills of biological material;
- Appropriate documentation of the samples and their traceability must be available;
- National and international regulations must be respected for international shipments.

9. **OCCUPATIONAL** HEALTH

An occupational health programme contributes to the well-being (physical, mental and social health) of laboratory personnel and ensures a healthy environment. To this end:

- Medical records of the personnel must be available and an annual medical checkup must be carried out for each of the employees;
- The personnel must have access to an occupational doctor;
- An appropriate immunization policy must be established while ensuring access to the required vaccines according to the identified risks (Hepatitis, Yellow Fever, Tuberculosis, Ebola, etc.);
- Post-exposure prophylaxis (PEP) plan should be available based on the degree of risk;
- In the event of exposure, the personnel should have access to post-exposure prophylaxis (PEP) 24 hours a day, 7 days a week;
- Personal protective equipment must be available based on the risk;
- A system must be in place and documented to report incidents and take corrective actions;
- Any case of illness or death attributable to exposure to a biological agent during the service must be notified in writing to the competent authority;
- Designated personnel must be trained on the provision of first aid and emergency care and the use of first aid kits made available;
- Every laboratory should subscribe to an insurance policy covering the laboratory as well as the staff;
- Clear guidelines and specific measures must be put in place to address the prevention of biohazards;
- Problems related to pregnancy, staff with compromised immune status or disability should be taken into account;
- Ergonomics conducive to biosecurity practices must be duly taken into account..

10. **DATA** SECURITY

Access to data must be secured and restricted to authorized persons only.

To this end:

- Data security measures must be taken and available;
- Data confidentiality measures must be rigorous;
- Data backup must be regular and access managed by passwords;
- Archiving must comply with the national policy;
- It is mandatory to secure data and to develop a data management policy at the facility level;
- Facilities with a centralized computer system must ensure data confidentiality and protection.

11. **MANAGEMENT** OF INCIDENTS AND ACCIDENTS

Procedures must be in place to deal with any incident or accident that occurs during handling in a laboratory.

For this purpose:

- All accidents and incidents occurring in the laboratory must be reported immediately and documented;
- An analysis of the causes must be conducted for any incident or accident that occurred in the laboratory;
- Corrective actions must be documented and reviewed periodically;
- A continuous improvement process must be put in place to review and improve the security programme;
- In the event of a potential public health threat, the administration should take appropriate measure and immediately inform the supervising Ministry and the laboratory network.

12. **CHEMICAL** SAFETY

Laboratory personnel are exposed to dangerous chemicals as well as to pathogens [5]. To this end:

- Personnel should be trained on the toxic effects of these products, their routes of exposure and the hazards of handling and storage, as well as the management of chemical fluids.
- Laboratory personnel where such products are used should have access to documentation related to the management of chemicals.
- Only the quantity of products needed for daily use should be kept in the laboratory. - Stocks must be stored in a reserve consisting of a room or a building designed for this purpose.
- Chemicals must be sorted by compatibility.

To prevent any risk of fire or explosion, products listed in the left-hand column of Table 8 must be stored and handled in such a way as to prevent contact with the substances placed opposite each other in the right-hand column.

Tableau 8: General rules of chemical incompatibility [5].

Substance types	Incompatible substances
Alkaline metals, such as sodium, potassium, cesium, or lithium	Carbon dioxide, chlorinated hydrocarbon, water
Halogens	Ammonia, acetylene, hydrocarbons
Acetic acid, hydrogen sulphide, aniline, hydrocarbons, sulphuric acid	Oxidants, such as chromic acid, nitric acid, peroxides or permanganates

13. SAFETY AND DNA RECOMBINATION TECHNOLOGIES

13.1. DNA RECOMBINATION TECHNOLOGIES AND BIORISKS

DNA Recombination technologies (genetic engineering technology) involve combining genetic material from different origins to create genetically modified organisms (GMOs) that have probably never existed in nature. Owing to the potential risks involved in these operations, genetic engineering work must be carried out safely. This requires a proper risk assessment and sufficient safety measures.

The usual techniques of genetic engineering can be safely used on the *E. coli*/pUC18 system at biosafety level 1, as long as the products expressed by the foreign DNA inserted in the bacteria do not require passage to a higher level. Nevertheless, a biosafety high level is needed when:

i. The expression of DNA sequences from pathogenic germs is likely to increase the virulence of the GMO;
ii. The inserted sequences are not perfectly characterized;
iii. Gene products may have a pharmacological activity;
iv. Gene products code for toxins.

When viral vectors are used for gene transfer into other cells, they must lack genes that control replication. These viral vectors are cultured in cell lines capable of compensating for this defect. However, there is a risk of spontaneous recombination following contamination by viruses able to replicate themselves or a lack of purification of the viral strain. These vectors must therefore, be handled at the same biosafety level as the viruses from which they are derived.

13.2. TRANSGENIC ANIMALS AND KNOCK OUT ANIMALS

Animals carrying foreign genes (transgenic animals) must be handled at a confinement level corresponding to the characteristics of the products of these genes. Animals in which specific genes have been deleted (knock out animals) generally do not present a biohazard. Among these transgenic animals are those that express virus receptors normally unable to infect the species in question. If such animals were to escape from a laboratory and transmit their foreign genes to their wild conspecifics, it could theoretically form within the animal population a reservoir for these viruses. Thus, for each new line of transgenic animals, careful studies are required to determine how these animals can be infected, how much of the inoculum is needed for infection, and how many infected animals excrete virus. In addition, all necessary measures must be taken to ensure strict containment.

13.3. TRANSGENIC PLANTS

Transgenic plants expressing genes of human or animal origin are used to obtain products of medical or nutritional interest. A risk assessment should be carried out to determine the biosafety level for these plants to be produced. In the case of work on GMOs, the risk assessment should take into account the characteristics of the donor and recipient organisms

13.3.1. **HAZARDS DIRECTLY ASSOCIATED WITH INSERTED GENE (DONOR ORGANISM)**

A risk assessment is necessary in the case where the product of the inserted gene has a recognized biological or pharmacological activity that could be harmful. Examples that may be mentioned include toxins, cytokines, hormones, gene expression regulators, virulence or virulence enhancement factors, oncogenic sequences, antibio-resistance factors or allergens. In each case, it is necessary to evaluate the expression level necessary for biological or pharmacological activity to occur.

13.3.2. **HAZARDS ASSOCIATED WITH THE RECEIVER OR THE HOST**

The risk assessment will be based on the following elements:

i. The sensitivity of the host;
ii. The pathogenicity of the host strain, including its virulence, infectiousness and toxin production;
iii. The modification of the host range;
iv. The immune status of the recipient;
v. The consequences of exposure.

Some modifications that do not involve genes whose products are inherently harmful may nevertheless lead to adverse effects as a result of modification of existing pathogenic or non-pathogenic factors. To recognize these potential hazards, the following questions must be asked:

i. Is there an increase in infectiousness or pathogenicity?
ii. Can insertion of the foreign gene compensate for an incapacitating mutation in the recipient?
iii. Does the foreign gene code for a pathogenicity factor belonging to another organism?
iv. If foreign DNA contains such a pathogenicity factor, can this be considered to have consequences for the pathogenicity of the GMO?
v. Is there a treatment?
vi. Will genetic modification have consequences on the sensitivity of GMOs to antibiotics or other therapeutic types?
vii. Is eradication of the GMO possible?

The use of animals or whole plants for experimental purposes also requires careful consideration. Researchers must comply with the regulations, restrictions and requirements for working on GMOs in Cameroon.

14. **OTHER** RISKS

14.1. FIRE HAZARD

Fire presents a risk of loss of life and property, injury that must be taken into account, possibly to decide whether it is better to extinguish the fire or circumscribe it. It is important to have fire prevention and fire management measures.

To this end:

- Staff members must be trained on fire prevention and fire management measures;
- A fire safety plan must be available in the laboratory;
- The contact list (standard telephone numbers) of fire and emergency services, the number of the biosafety officer and that of the laboratory manager must be available;
- Fire management gear such as fire extinguishers, masks, an alarm system, etc. must be available;
- Emergency exits must be present and not congested;
- A laboratory plan with visible exits must be available;
- The meeting point must be well materialized;
- A simulation programme must be documented and available;
- Signs, judiciously placed prominently in each room, in corridors and halls, should warn personnel and indicate the proper action to be taken as well as emergency exits to use.
- Fire-fighting gear should be placed near room doors and at various strategic points in corridors and halls;
- The personnel must be trained in the use of fire extinguishers;
- Fire extinguishers should be regularly checked and maintained and made sure they are not expired.

14.2. ELECTRICAL HAZARDS

- All electrical installations and appliances must be checked and controlled regularly, including ground connection;
- All electrical equipment in the laboratory must be earthed, preferably by means of ground connections;
- Circuit breakers and especially differential circuit breakers must be installed on the electrical circuits of the laboratories;
- All electrical equipment and circuits in the laboratory must comply with national electrical safety standards;
- The position of the circuit breakers must be known by all laboratory staff;
- The laboratory must avoid contact of water or chemicals with electrical cables.

NB : *Circuit breakers do not protect people; their role is to protect the circuits from being overloaded and therefore avoid fires. Differential circuit breakers are designed to protect people from electric shock.*

14.3. NOISE HAZARDS

The effects of lasting exposure to excessive noise are insidious. Some laboratory equipment, such as some types of lasers, or facilities that host animals, can cause significant exposure of this kind. Acoustic measurements can be used to determine the risk of exposure to noise. If data obtained justify it, technical measures such

as encasing noisy equipment or the installation of noise barriers or screens around such equipment or between noisy areas and other work areas may be considered. If the noise level cannot be reduced and staffs are permanently exposed to excessive noise, it will be necessary to set up a hearing protection programme providing the wearing of protective earpieces for work in a noisy environment, as well as medical examination of staffs to determine the effects of noise [5]. The use of radios and music devices in the laboratory must be controlled. The use of cell phones is not appropriate in a laboratory.

14.4. RADIOLOGICAL SAFETY AND SECURITY

Radiological safety and security are two key terms in radiation protection that are defined as the set of measures taken to protect human beings, the environment, and property from the harmful effects of ionizing radiation [11]. In the laboratory, radiological safety is the protection of technicians against exposure to ionizing radiation. Security refers to the protection of radioactive substances or other sources of radiation against theft, destruction or use for malicious purposes.

Ionizing radiation originates from natural or artificial radioactivity; it is odourless, colourless, and invisible to the naked eye, yet it is endowed with a very great capacity to harm. In Cameroon, ionizing radiation is used in medicine, industry and research laboratories.

The effects of ionizing radiation are of two types:

- Immediate or deterministic effects, which are radiological burns (serious injuries very difficult to treat), and death when the radiation dose is high;
- Long-term effects are somatic and hereditary.

In the laboratory, the probability of occurrence of long-term effects is higher, especially when radiological safety measures are not respected.

- Somatic effects are, in particular, radiation-induced cancers, for example, leukaemia or even bone, lung or skin cancers, which may appear only several years after irradiation. Other less serious effects may be small skin lesions, alopecia, blood abnormalities, gastrointestinal tract lesions or cataracts.
- Hereditary effects are symptoms that occur in the offspring of exposed subjects. For example, the hereditary effects of gonad irradiation consist of chromosomal abnormalities or gene mutations. High dose irradiation of germ cells in the gonads can also lead to cell death, resulting in impaired fertility in both sexes. Exposure of the fetus during its development, particularly between the eighth and fifteenth week of pregnancy, may increase the risk of birth defects, mental retardation or radiation-induced cancers later

To limit the harmful effects of ionizing radiation, the following four principles of radiation protection should be regulated and applied:

i. Minimize the duration of exposure;
ii. Stay away from the radiation source;
iii. Put a shield around the radiation source;
iv. Substitute radionuclides for other non-radiometric techniques

14.4.1. 14.4.1PROTECTIVE MEASURES IN THE LABORATORY

Protective measures in the laboratory are as follows:

Reduction of exposure time

The exposure time during handling of radioactive substances can be reduced by:

- Practising new and unfamiliar techniques without using a radionuclide until they are perfectly controlled,
- Using radionuclides in a timely manner, with care, and without haste,

- Ensuring that once used, all radioactive sources are immediately stored in their storage place,
- Frequently eliminating radioactive waste from the laboratory,
- Spending as little time as possible in an area of the laboratory where there is a risk of irradiation,
- Practising good management and planning of the handling of radioactive substances and their duration.

"The less time spent in the irradiation field, the smaller the dose received individually", as shown by the following equation:

Dose = Dose rate x time

Increasing distance from the source

A small increase in distance may result in a significant reduction in dose rate.

Dose rate = $Constant \times 1/distance^2$

For most radiation, the dose rate is proportional to the inverse of the square of the distance to a point source: It can therefore, be seen that if the distance between the radiation source and the manipulator is doubled, the exposure will be divided by four over the same duration. Long-sleeve clamps and distance pipetting devices are sometimes used to increase the distance between the manipulator and the source.

Using a shield or a screen

By installing screens capable of absorbing or diminishing the energy radiated by the source between the source and the manipulator or between other laboratory staff, the exposure of these individuals may be limited. The choice of the type of screen and its thickness depends on the penetration capacity of the radiation emitted (i.e., its nature and energy). Screens in acrylic resin, wood or light metal, 1.3 to 1.5 cm thick protect against the less energetic beta particle; but to protect against gamma radiation or high-energy X-rays, it is necessary to use high-density lead screens.

Substitution

Radionuclides should not be used if there are other alternative techniques that can achieve the same goal.

And in case there is no alternative technique, it will be necessary to use the radionuclide whose radiation is the least penetrating or the least energetic when a choice is offered.

14.4.2. RULES FOR HANDLING RADIOACTIVE SUBSTANCES

There are four rules for handling radioactive substances, namely those concerning

- Irradiation zone;
- The working area where the handling takes place;
- Waste management;
- Action to be taken in an emergency situation.

Rules concerning the irradiation zone

- Use radioactive substances in areas specially designed for this purpose;
- Only the necessary staff should be present during handling;
- Wear personal protective equipment, including appropriate laboratory clothing, safety goggles, and disposable gloves;
- Wear a personal dosimeter for dosimetric monitoring of professionals;
- Use radio dosimeters/flow meters for control of work areas, protective clothing and hands after work are completed;
- Use properly shielded transport containers.

Laboratories where radionuclides are handled, should be designed so that containment, cleaning, and decontamination are easy and simplified. The handling area should be located in an adjoining room of the main laboratory away from other work areas. Signs

bearing the international radiation hazard symbol (figure 6) shall be affixed at the entrance to the irradiation or handling area.

Rules concerning the working area where the handling is done.

Figure 6: *International Radiation Hazard Symbol*

- Use trays containing disposable absorbent materials to collect spilled liquids;
- Limit the amount of radionuclide used;
- Have a protective screen separating the radiation sources on the working area and the areas where the radioactive waste is;
- Label the containers of radioactive products, specifying the nature of the radionuclide, its activity and the date of the measurement.

Rules concerning the management of radioactive waste.

- Frequently dispose of radioactive waste from the work area,
- Provide a safe and secure place for the storage of radioactive waste.

Rules concerning action to be taken in an emergency.

- Maintain an accurate record of the use and disposal of radioactive products;
- Develop an emergency response plan and conduct regular simulation exercises;
- In an emergency, take care of the victims first,
- Thoroughly clean the contaminated areas;
- If necessary, seek the assistance of the public security services;
- Write a report following an incident/accident and archive it.

15. **BIOSAFETY, BIOETHICS,** AND RESEARCH

Laboratory staffs are expected to

- Act responsibly and not expose the community to biohazard;
- bide by the safe work practices associated with the practices that will enable to store their samples appropriately and safely (biosafety) and to follow a code of ethics (bioethics).

IIt is the technical and moral responsibility of the laboratory manager and his staff with the support of the competent authorities to inform and reassure the public of the interest of the study on the population.
To this end:

- Research ethical rules must be respected;
- Research involving laboratory analysis and the use of animal and plant models must meet biosafety and biosecurity standards;
- The protocol must include in the methodology an update on the biosafety and biosecurity measures that will be applied in the study, according to the planned manipulations;
- For work using new experiments, in-depth analysis on the benefits for the scientific community, for the general population, the potential risks and the quality of the mitigation measures proposed in the protocol will determine whether or not an ethical clearance is required. The risk analysis will be based on criteria developed in previous paragraphs;
- This element is usually an essential point in the ethics committee's assessment of the protocols, which should emphasize the relevance of the planned measures and their effective application. These measures are designed to protect participants, members of the research team and the personnel involved in the biohazard projects and to ensure their safety. Some essential measures to be planned are
  i. The systematic wearing of personal protective equipment for the manipulations that require it;
  ii. Waste disposal according to standards, including sharp, cutting, piercing and blunt objects;
  iii. The incident and accident management protocol, including exposure to blood and secretions that may contain germs;
  iv. Taking vaccines or prior prophylactic treatment when available

16. MANAGEMENT AND RESPONSIBILITY

16.1. 16.1. MANAGEMENT OF LABORATORY BIOSAFETY AND BIOSECURITY

Every laboratory must have a detailed safety regulation, a biosafety and biosecurity guidance and a plan for continuous improvement of biosafety and biosecurity. The responsibility normally lies with the director or head of the facility, who may, however, delegate some tasks to the safety officer (biosafety officer) or other competent personnel.

Laboratory safety is everyone's responsibility, be it managers or employees, and every staff member is responsible for their safety and that of their colleagues. Everyone (including cleaning and maintenance staff) is required to work in accordance with safety rules and is accountable to the supervisor for any action or situation that would contravene them and for any incident.

An audit of laboratory safety conditions should be conducted periodically preferably by persons outside of the laboratory. The conclusions and recommendations of these audits are used for the development of biosafety and biosecurity improvement programmes.

16.2 . ROLE OF THE BIOSAFETY MANAGER

They are responsible for biosafety. In light of this, they are responsible for ensuring that the safety regulations and the biosafety and biosecurity improvement plan are systematically respected throughout the laboratory. They fulfil these obligations on behalf of the director of the facility or the laboratory. In small units, the biosafety officer may be a microbiologist or a technical staff member who performs these functions. The person so designated must have the professional qualifications required to propose, review or approve the measures to be taken in the extension of containment operations or biosafety.

The biosafety officer is responsible for enforcing national and international biosafety regulations and guidelines and assisting the laboratory in establishing standard work practices. He must have a technical background in microbiology and biochemistry with basic knowledge in physics, chemistry, and biology. It is also desirable that the biosafety officer be familiar with safety practices and rules in the laboratory and in the clinical field, particularly with regard to the containment of biological material, waste management and the technical principles relating to the operation and maintenance of the facilities. He or She must also be able to communicate effectively with administrative and technical staff, as well as with maintenance and cleaning staff.

The duties of the biosafety officer will consist of:

i. Consulting on compliance with biosafety and biosecurity rules and technical requirements;
ii. Ensuring the display and compliance of pictograms and other warning signs at various points in the laboratory;
iii. Organizing periodic internal biosafety audits, techniques, procedures and protocols, biological agents, materials and equipment;

iv. Interacting with those concerned about violations of biosafety guidelines and protocols;
v. Verifying with all staff that they have received appropriate biosafety training and identifying training needs;
vi. Providing further training on biosafety;
vii. Investigating any incident due to the possible release of potentially infectious or toxic material, reporting the results to the Laboratory Director and the Biosafety Committee with appropriate recommendations (investigation and documentation of incidents and accidents);
viii. Cooperating with the medical service regarding the possibility of infections contracted by the laboratory staff performing their activities;
ix. Ensuring that decontamination is properly performed after accidental spilling of liquids or other incidents involving infectious material;
x. Ensuring proper waste management;
xi. Ensuring that any appliance or equipment is properly decontaminated before repair or inspection;
xii. Raising staff awareness on community attitudes to health and environmental issues;
xiii. Establishing the appropriate procedure for the import and export by the laboratory of pathogenic biological material in accordance with national regulations;
xiv. Analysing, from a security perspective, all plans, protocols, and procedures used in research work;
xv. Setting up a system to deal with emergencies.

16.3 . BIOSAFETY COMMITTEE

There is a need for a Biosafety Committee whose role will be to define the biosafety policy of the facility and develop a code of best practices. The Committee must equally review research protocols involving the handling of infectious agents, the use of animals, the implementation of DNA recombination techniques or the use of genetically modified organisms.

The Committee may also be responsible for assessing risks, developing new biosafety regulations and arbitrating conflicts on biosafety issues.

The composition of the Biosafety Committee depends on the technical platform of the laboratory. It must be representative of the various professional branches of the facility as well as its scientific specialties

The following staff may be members of this Committee:
i. One or more biosafety officers
ii. Scientists;
iii. Medical staff;
iv. One or more veterinarians (in case of animal experimentation);
v. Representatives of the technical staff;
vi. Representatives of the laboratory administration.

The Biosafety Committee should equally consult with safety experts of the various departments (radiation protection, industrial hygiene and safety, fire fighting, etc.) and may occasionally call on outside specialists from different related fields, local authorities and national regulatory bodies. When a particularly sensitive or contentious protocol is under discussion, it may also be useful to have the opinion of members from the community.

16.4. THE CENTRAL LEVEL

All biosecurity reports prepared by the laboratories in the country are sent to the Biosafety Unit. It makes an annual update of biosafety of the country, sets biosafety and biosecurity guidelines in laboratories, publishes the biosafety monitoring and audit programme in laboratories; identifies training needs and publishes the training plan for the staff

17 . MONITORING AND EVALUATION OF LABORATORY BIOSAFETY AND BIOSECURITY

It is important to document all activities performed in the laboratory, including:

- Training;
- Inventory and maintenance of security equipment;
- Updated inventory of stored samples and isolates;
- Accidents and incidents;
- The health of staffs, including immunization and illnesses;
- Safety inspection and audit;
- Improvement actions;
- Annual report.

These elements will serve as background documents for the monitoring and evaluation activities of the laboratory. A monitoring and evaluation plan for biosafety and biosecurity activities must be developed, available and implemented in the laboratory.

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19 . APPENDICES: DRAFTING TEAM AND LIST OF CONTRIBUTORS

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