Advice on the structural concept design and layout of the laboratory and to carry out the environmental and social risk assessment of the proposed site on South Tarawa

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INFOPESCA

Summary

1. Background

The proposal for a reference laboratory for fisheries products' analyses is an integral part of the Pacific Islands Regional Oceanscape Program (PROP) project in Kiribati. The reference laboratory would undertake food and water analyses to support the export market of tuna. The laboratory would also analyse reef fish for the domestic market, especially with regard to ciguatera.

Overall, developing a reference laboratory for fishery products represents a significant investment. The following report describes the structural concept design, the designated area for building the structure. It also described in detail the lay/out of the building, and all the structural investments needed, such as Ventilation and Air Conditioning (VAC), water and waste treatment. It also describes the power supply, which in a country like Kiribati is a major concern. The building needs a good working uninterruptible power systems (UPS) system.

Finally the environmental and social aspects of the construction and running of a reference laboratory are illustrated.

2. Structural concept design

2.1. Nature of the facility

The building hosting the laboratory and other offices either could be considered as an integrated facility which actually manages operations for all parties and would offer a single contact point for enquires about analyses and results. It would have an experienced laboratory director in charge of implementing the management system and quality assurance and control disciplines. The staff carrying out a higher number of tests would quickly gain proficiency, and reach a high standard of service.

2.2. Location

The issue of the location of the reference laboratory is significant for the timeframe for having the laboratory built. The MFMRD has already designated an area where the reference laboratory will be built, namely in Ambo. The location seems to be appropriate to the needs of the facility and the overall environment.

3. Layout of the laboratory

3.1. Considerations for layout

The preferred option for a laboratory building is a stand-alone facility. A laboratory environment includes or generates hazardous chemicals and waste, potential noise, vibration, smells and fumes...all presenting risks or inconveniences for the public. Integrating a laboratory in a general use building (hospital, offices...) would incur additional costs e.g. for better protection of environment and safety systems. Finally, a stand-alone facility allows expanding the laboratory building in the future.

The facility should include the following:

- Reference laboratory building;
  - Offices, board & meeting rooms, canteen and break rooms, either a separate unit or integrated to the lab building, possibly as a second floor;
  - Separate technical building (45-50m^2) to host the storage for chemicals and gases; the generator and fuel tanks, the air compressor, the power regulation, the water filtration unit;
  - Hangar or shed (80 m^2) to accommodate the fumigation and incineration activities.

It is possible to design multi-storey labs, or to host laboratory section into a multi-storey building. Nevertheless, there is little economic gain as the reduction of structural costs is almost offset by the additional access (stairs), extra materials used to withstand weight, and the need to extend reticulation, power lines, ducts etc. Furthermore, single-floor labs provide better security (access for rescue teams, evacuation, etc).

Laboratories are usually designed and built so as to minimize potential impact of any external factors on the environment and operations of the laboratory. When variations are kept to a minimum, the laboratory is in good condition to work regularly and produce reliable results. The standard ISO/IEC17025 describes in details which factors should be controlled (or monitored), including:

- Security: access to most areas is restricted by keys or locks. This contributes both tosecurity and to protection of confidentiality.
- Reducing the possibility of air-borne contamination (bacteria, solvents, fumes...) by maintaining a negative pressure in work areas; this is achieved by extraction of the airvolume and replacement by external air.
- Absence of physical contamination in the incoming and circulating air. Contaminants includeinsects, dust, particulates, bacteria, etc. The lab building must be insect-, bird-, rodent- and
  - vermin-proof. Preventing contamination also requires the use of air filtration systems, and determines dispositions to avoid cross-contamination.
- Control of temperature and humidity of the circulating air where these could affect the resultsof operations.
- Environmental protection with control of effluents (test solutions) and waste (sample,matrices)
- Ease of cleaning and sanitation (especially for microbiology), which requires all surfaces tobe smooth, easily washable, and acid- and solvent-resistant.
- Adequate lighting to ensure easy reading of colours and instruments indications.

In addition, it is also recommended to consider

- Reducing the area of windows and using fixed window panes with tinted glass
- Using an external, separate building for storing chemicals
- Restricting access to chemicals and laboratory equipment to trained personnel
- Stabilizing electrical power (voltage and wave when needed)
- Using a pre-filtration and reverse osmosis unit to filter the water supplied to labs.
- Keeping the gas cylinders and pressure equipment in external enclosures with concrete orcinder blocks walls.
- Using a fire protection system with smoke detectors and temperature alarms.

The size of the proposed laboratory is determined by the scope of services, the number of samples and tests, the land space available, and finally by the target budget. Based on the designs and information gathered, it is proposed to consider a building with a footprint of 160 m^2, respectively.

The laboratory would need the following work areas:

- Office & general purpose rooms
  - Offices for administrative staff
  - Toilets (1 for men, 1 for women)
  - Showers (1 for men, 1 for women)
  - Changing room
  - Cleaning and decontamination room with post-rooms for autoclave
  - Small reception area (info counter) to receive queries and samples and sample holding (refrigerators, freezer, shelves etc.)
  - bench for test items preparation
  - One ambient store for generic, dry reagents and miscellaneous supplies
  - One controlled store room for sensitive media
- Microbiology Laboratory
  - media preparation room (including adjacent media storage)
  - room for incubators
  - reference culture storage and maintenance room (could be fitted at later stage)
- Chemical/physical laboratory
  - Digestion/ extraction area
  - A ‘wet’ chemistry area for the methods involving titration, spectrometry, conductivity...
  - Instrument rooms hosting the Atomic Absorption Photometer (AAS), Gas Chromatograph (GC), and high-pressure liquid chromatography (HPLC) instruments

3.2. Construction

A few options may be considered for building the facility premises, depending on the nature and characteristics of the underlying soil. A traditional option consists of a cinder blocks structure built on concrete foundations, pillars and slab; it must be entirely heat-insulated by proper lining.

Alternatively, the laboratory could be built as a metallic structure with insulated sandwich panels walls and ceilings. This would require equipping the lab rooms with mobile benches and cabinets, since the walls would not be fit to bear masonry benches.

All floor surfaces must be covered with materials suitable for laboratory use: PVC tiles, high-grade ceramic tiles, epoxy-resins...and the angles with floor and ceilings must be rounded to allow easy cleaning.

All windows and doorframes should be high quality, durable PVC assembly; windows should be in small dimension with fixed tinted, dual- or triple insulated glass reducing heat and UV transfer.

The construction project for the building should be tendered under one of the two options below.

a. Design-Build tender allowing selecting a consortium of firms offering the best cost-to-valueproject; or
b. Preparation services commissioned to various experts, resulting in the production of theBuilding Plans, Schematic Design, Construction Documents and Specifications; followed by Tendering of the works, building materials and project management services,based on the documents prepared.

3.3. Functional Systems

The definition and set-up of all the functional systems should be part of the construction project (either option a. or b.).

3.3.1. Ventilation and Air Conditioning (VAC)

This represents a crucial system for the laboratory, since it determines the security and stability of the operational environment, as well as well-being of staff. The lab has three kinds of zones requiring different atmospheres:

- Areas/ rooms for generic work, dry stores, and office areas where simple airextraction and air conditioning is sufficient.
- Rooms where temperature and humidity must be maintained within set limits (25±1.5ºC and 55±2 percent HR),
- Rooms with controlled ambiance, and supply of filtered air with very low levels of particulates or bacteria.

The requirements to control humidity and temperature combined with the need to renew the air volumes can lead rapidly to significant power consumption. The VAC system should thus include a combination of individual air conditioners, and a unit for supplying de-humidified and filtered air in replacement of the extracted volumes in controlled rooms.

3.3.2. Power

The importance of high quality power cannot be emphasized enough. Most technical representatives and equipment suppliers fail to understand the extent of power issues in developing countries.

- Voltage typically can vary from 180 to 240 volts.
- Outages are frequent and unpredictable
- Spikes are frequent; they are caused by load variation, network imbalance, start ofnearby generators, lightning...The structure of the alternative current wave may vary in shape and amplitude
- The start-up of certain instruments generate currents five time higher than thenominal (current usage load)

These conditions can generate variations in the instruments, and cause premature aging. Across brands, instruments have very different built-in protection and stabilization features. Certain brands are better than others, but in any case, there is a need for high-quality protection at two levels: a general unit and some units dedicated to the AAS, HPLC, and GC instruments. Cheaper or entry-level uninterruptible power systems (UPS) just turn on below a pre-set voltage, but do not stabilize or redress the power wave. Even the best UPS equipment does not have good surge protection. Hence, the lab's main power board must be fitted with a high-grade surge protector, capable of withstanding lightning and other network spikes. The AVR capability is essential in high precision work, since variable mains load can affect results especially in cheaper instruments with weak internal regulation. Furthermore, the reference laboratory must have either:

- Top-range UPS that transforms incoming AC voltage/current to a battery and then generate astabilized sinusoid AC voltage calibrated at 240 Volts 50 hertz; or
- Basic UPS combined with separate automatic voltage regulator (AVR) to lock in 240 Volts.

Another aspect to take into account is the quality of the realization of the laboratory power lines, which must be well balanced over 3 phases and prevent resonance effects. All electrical works should be professionally designed and validated beforehand, use certified materials, switches, relays...adequate to a lab power grid, and be carried out by certified technicians according to Australian safety and performance standards.

Finally, given the very high cost of electricity, there will be a need to realize an energy diagnostic study, to find the most economical way of powering the lab. It is proposed to equip the reference laboratory with solar panels for supplying part of the power used in the lab during the day for lightning, hot water, small amperage plugs..., and the basic functions used during night time (security, low power ventilation, fridges and freezers). This would require also a set of batteries, aninverter and a controller unit. The investment comes at an extra cost: it should be evaluated as part of the detailed preparation of the investment project. There will be a need of professional advice and design services to define a stable and regular power supply and distribution grid, as well as balancing the use of fossil- and solar-based energy sources.

The infrastructure foresees a set of UPS systems, capable of keeping all machinery working in the laboratory, even during periods of long power cuts.

3.3.3. Water

The laboratory should have a single medium-size unit to filter, de-ionize and purify the water supplied by the Public Utility Board. In first estimation, the unit should process about 100 litres/ day, which means a nominal output capacity of 20 litres/ hour (water 'type 335'). The lab should have input and output buffer tanks of half to one m^3 to store incoming water in a sufficient quantity for feeding the washing machine, sterilizers and water stills or ultra-purifiers for a couple of days.

3.3.4. Waste

The laboratory must have a system to process waste. One option is to store in separate bins biological waste (after decontamination) and physical waste (paper, plastic, glass etc.). The containers would be taken away by the public waste collection service. However, autoclave decontamination is for laboratory waste, but not adequate for quarantine samples. Therefore, there is an opportunity for the new facility to accept waste from various sources and to burn it properly in a medium-sized incinerator. Modern incinerators have dual combustion and gas cleaning system that reduce their environmental impact.

The liquid waste (solvents and acids) should neither be burned nor released in the environment. Instead, it must be stored in ad hoc containers and shipped away to the nearest recycling centre.

The waste resulting from fumigation (spent phosgene pellets and other solids) must be collected, stored securely, and sent away for recycling.

3.3.5. Internet access

Access to a broadband service provider is a necessity for the laboratory. Beyond mundane search and exchange of technical information, the cloud-based transmission and storage of data, access to online database of tests, distributed (cloud-based) Laboratory Information Management Systems (LIMS), and online hook-up for maintenance of equipment...are now of common use in laboratories.

4. Environmental risks through a laboratory

4.1. Considerations on environmental risks

The setting up of a reference laboratory will help to control the environment and minimize health risk associated with consuming fishery products. The reference laboratory will be planned to ensure good working controls which will avoid any unnecessary environmental impact from its operations.

Laboratory buildings, processes, and equipment can be resource and energy intensive as safely carrying out high-quality research can require temperature control, ventilation, or high sterility. Beyond that, laboratory consumables and instruments all have an environmental footprint during their sourcing, manufacturing, and disposal. Life science research frequently relies on high energy use, water consumption, single use plastics, reagents, and solvents

Water use is one of the potential environmental problems. Water is used for cooling reactions and equipment as electron microscopes, gas chromatographers, mass spectrometers. In addition, water is used for flushing, purging and washing laboratory equipment. Water consumption is highest for research-intensive laboratories, since it is used for different purposes, such as cooling or washing. Autoclaves are, for instance, critical pieces of lab equipment, but they are also large consumers of energy and water. An autoclave uses an average of 170 liters of water per cycle and 16,000 kWh of energy per year (nearly 1.5 times the energy use of an entire house).

Chemicals are used as reagents for reactions and as catalysts. In addition, chemicals are important as solvents for washing, flushing, separation and analysis (e.g. chromatographic purification). Laboratories frequently require the use of chemicals and other hazardous materials for experiments. It is critical to follow all storage and use recommendations from Environmental Health & Safety (EHS) when using these substances. Chemicals do not only have a carbon footprint and human health impacts, but can also result in the pollution of air, water, and soil.

Single-use plastic is used in vials, beakers, flasks, bottles, filters, pipette tips, syringes, cell culture plates, and also in packaging of all effects used in the laboratory work. In many research laboratories, single-use plastics constitute a source of material consumption and environmental impact. Single-use plastics are frequently used to conduct cell culture experiments or when sterility is required. According to a study, organizations engaged in biological, medical, or agricultural research globally generate roughly 5.5 million tonnes of plastic trash per year, or about 2 % of the world's total plastic garbage. In addition, a large amount of plastic waste produced by science labs goes straight to landfill every year as most recycling plants do not accept them due to potential health and safety risks or because of missing knowledge about recycling possibilities. Nevertheless, it exists a tendency for researchers and industry to look for alternatives that aim to cut-off or at least considerably reduce single-use plastic material.

Energy is used for basic lighting, air conditioning and ventilation. All equipment has high energy requirements, such as autoclaves, hotplate stirrers, pumps, etc. Microscopes, electron microscopes, HPLC, mass spectrometers, etc. use electricity. In addition, computers including data storage, analysis, modelling are consuming energy. Studies have shown that the median energy usage of laboratories is three times that of an equally sized office. An analysis of London's university buildings found that laboratories and workshops had the highest heating and electricity consumption, approximately double compared to teaching and administration spaces.

4.2. Recommendations for reducing environmental impacts of laboratory

There are several recommendations for the new laboratory on how to reduce environmental impacts. The purchase of an energy efficient freezer is fundamental. It is recommended to buy a new high efficiency (HE) units. They consume up to 50 % less energy than non-HE models and use natural refrigerants that do not contribute to global warming. Increasing the temperature setting of a ULT freezer to -70 °C instead of -80 °C can reduce its energy consumption by 30 – 40 %. Minimizing the amount of time, the freezer door is open, reduces temperature fluctuations within the unit, and saves energy. Defrosting freezers at least once per year, and checking door seals on a regular basis also decreases energy consumption.

Reduce fume hoods opening as much as possible. Many hoods operate on a "variable air volume" (VAV) system, which means the volume of air exhausted will vary depending on the size of the face opening. Thus, the larger the fume hood opening, the larger amount of energy is needed to heat and cool the space. Thus, closing the sashes of a fume hood further down can reduce their energy consumption by 40 % or more. Further, keeping the hood closed is the single most important step you to save energy. In the manual on the proper management of the laboratory this simple rule needs to be highlighted.

There are various approaches to reduce laboratory water consumption, such as aerators on taps, equipment that removes the need for water altogether like waterless condensers, and devices and systems that use closed loops and recirculate water. It is essential to use the lowest appropriate water purity and sterility for the task at hand. For example, use tap water to wash hands and dishes and only use deionized water and filtered water when the task requires it. The manual on management of the laboratory should include these simple recommendations for reduced water usage.

Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and ultimate disposal. They also specify the 12 principles of Green Chemistry which include: the selection of more benign, less hazardous reagents and solvents, more efficient reaction design, including the use of more selective catalysis, and sourcing chemicals from renewable sources instead of being derived from fossil fuels. There are several available online tools, databases, and inventory management tools for keeping track of chemicals, which can assist laboratories in monitoring chemical usage and avoiding over-ordering.

Disposable plastics are preferred over the use of durable products that can be cleaned and reused because of the momentary convenience of throwing something away when no longer needed, plus the believe that only new consumables allow to achieve high-quality results. Recycling of some plastic material utilized in laboratory science could be complex. For example, items used with potentially harmful substances should not be recycled in a form in which they could potentially harm individuals who might be in contact with them. Some of the plastics used in the labs also pose a recycling challenge: they can be structurally and chemically modified to resist heat and degradation. However, there are everyday items in the labs that can be recycled:

shipping boxes, printer cartridges, and styrofoam boxes.

The laboratory will also have a proper resource usage and waste management system.

5. Socio-cultural feasibility

The laboratory will create some marginal employment opportunities with increase Competent Authority (CA) inspector and laboratory technician numbers. The new Lab Technicians are responsible for receiving, testing, analyzing, recording and reporting results of their tests. Their main duties and responsibilities include receiving, labeling and safely storing samples to be tested. Determining and performing tests needed for the analysis and report.

Laboratories can be a dangerous place to work, therefore safety standards need to be designed and implemented. It is fundamental to carry out capacity building course, aiming at reducing health risk coming from working in the laboratory as far as possible.

Annex

Literature

[Torres Benito, L. (2023) Go Green: Sustainability in Laboratories, Bio Science.]

Acronyms

AAS	Atomic Absorption Photometer
CA	Competent Authority
GC	Gas Chromatograph
HPLC	high-pressure liquid chromatography
PROP	Pacific Islands Regional Oceanscape Program
UPS	uninterruptible power systems
VAC	Ventilation and Air Conditioning