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Guide of Best Practices

Environmental Management in Labs

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1. Background

ECVET-Lab is a European project funded by the ERASMUS+ programme of the European Commission. The Project will contribute to the implementation and validation of non-formal training on environmentally sustainable practices for environmental testing laboratory technicians.

Environmental Testing Laboratory operations may have significant environmental impacts, ranging from energy and resource consumption to chemical and equipment usage and waste disposal.

Experience shows in many cases that this impact could be reduced or avoided in cost-effective ways without compromising safety.

Collecting ***Best Practices*** that laboratories are already following is an essential stage for fostering the ***best practices*** in other laboratories, which is one of the ECVET-Lab project's goals.

The exchange of knowledge and practical experience among laboratories from different European countries can be considered of outmost importance for defining the ***best practices*** applicable to the sector, as well as for promoting their implementation.

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2. The aim of the guide

The aim of this guide is to present examples of ***best practices*** through the use of real-life environmental testing laboratory study-cases around Europe. These ***best practices*** can be utilised in other laboratories, either as given in this guide or through their customization to suit the needs of the respective laboratory and of the individual technician.

The priorities set in this guide focus on the achievement of:

1. Better knowledge and understanding of environmental sustainability issues in the workplace.
2. Better readiness of the knowledge on the available environmentally sustainable laboratory methods.

More specifically, the guide intends to work on the improvement of these key areas by raising awareness of laboratory staff so that they can implement the ***best practices*** in their respective laboratories with regards to:

- Conserving natural resources: water, energy, raw materials, which are consumed during laboratory activities.
- Applying measures for improving the material and energy resource efficiency of equipment and lighting, as well as utilizing renewable energy sources.
- Protecting people and the external to the laboratory environment, from chemical or biological risks, by means of the suitable noise, hazardous substance and wastewater pollution prevention and safe overall waste management.

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3. Target audience

The main target audience group of this guide includes technicians employed in environmental testing laboratories, but the ***best practices*** described in the guide can be useful for any other laboratory type with similar impacts, such as testing or R&D chemical laboratories.

Using this guide, the technicians will benefit by increasing their knowledge and generating a behavioural change in relation to environmental issues.

Another target audience group includes stakeholders who can have influence on laboratory behaviour. Those, among others, can be:

- *Educational providers, initial vocational education training (I-VET) and continued vocational education and training (C-VET) providers* as well as colleges and universities.
- *Public bodies*, in charge of policy making in the field of education and environment, thus integrating the ***best practices*** in public strategies and regulations.
- *Technological institutes*, having the capacity to develop further the innovation towards the establishment of ***best practices***.
- *Certification bodies, auditors and quality controllers*, having a role in laboratory assessment.
- *Customers and civic society organisations* as motors of change.

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4. Elaboration phases

Two tools were key for the ***best practice*** identification during the creation of this guide: on one hand, a checklist was prepared of potential ***best practices*** so that laboratories could mark what practices they implemented. On the other hand, three focus groups were held to collect and debate on ***best practices***.

- **Invitation of laboratories and other stakeholders**

The project consortium identified a large number of laboratories Europe-wide, which were contacted and invited to participate in the project in order to identify the best practices that could be applied in laboratories, in the framework of environmental sustainability.

Other stakeholders, like authorities and institutions dealing with professional training, were also invited to participate in the activities with the laboratory personnel, in particular during the development of this guide.

- **Conduction of questionnaire surveys**

All environmental testing laboratories invited to participate in the project were asked to fill in a checklist prepared as a tool to identify and collect their environmental ***best practices***, with the intention of selecting the most relevant ones to be included in this guide. This checklist included a list of possible best practices so that participant laboratories could mark those ***best practices*** they've been implementing.

- **Conduction of focus groups**

Partners in three European countries (Spain, Cyprus and Poland) organised a focus group each, where local stakeholders and laboratory representatives were invited, to discuss about their current ***best practices***.

Environmental experts were also invited, including researchers and scientists that could contribute to the discussions regarding the ***best practice*** evaluation, and that were able to provide additional information

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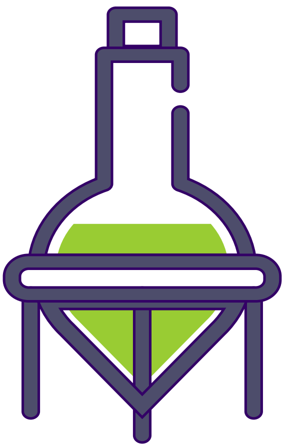
regarding innovative ***best practices*** to be considered in the preparation of this guide.

- **Selection of best practices**

Through the completion of the checklists and the conduction of the focus groups, a total of 60 ***best practices*** were collected to be further analysed by partners.

During the workshop organised by Nireas-IWRC in June 2017 at the University of Cyprus, the partners identified and selected 42 best practices from the 60 collected, considering in the decision process important criteria such as environmental improvement, technical and financial feasibility and innovation. Besides, a wide representation of different organizations (laboratories and other stakeholders), in different countries was taken into account.

In total, 44 organisations from 14 countries, participated in the project providing their ***best practices***.



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5. Best Laboratory Practices

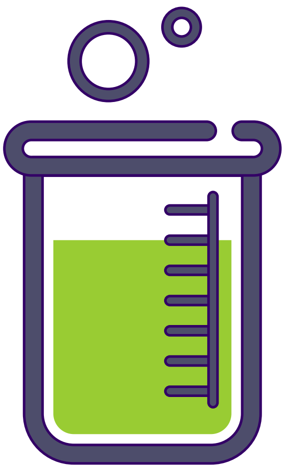
The best practices were organised according to the environmental issues that laboratory technicians should manage in their workplace. Each practice was then categorised according to its application frame (lab/ universities/ educational/ VET schools, etc.).

Two levels of environmental practices were considered:

A) Good practices: related to the minimum/basic level of compliance, which give the desired functional result.

B) Best practices: related to giving an added value by exceeding expectations, indicating an optimum level of compliance.

The topics are described in detail below and examples are given for all best practices.



USE OF CHEMICALS

Laboratory staff must be trained to work safely during the handling of chemicals.

The following actions should be considered as ***good practices*** to be taken into account in relation to the use of chemicals:

A) Chemical Identification & Information:

- Labelling.
- Use of chemicals according to their Material Safety Data Sheet (MSDS), which must be available and readily accessible by the laboratory staff.
- Information related to handling, usage and risks of these chemicals must be available.
- Control of the chemicals from their arrival at the laboratory until their collection and final disposal.

B) Regarding Storage:

- Chemicals must be separated according to their incompatibilities.
- Chemicals must be stored in a separate, secure and proper room well ventilated with restricted entry.
- No storage of chemicals under sinks.
- Storage of large / heavy breakable containers, particularly of liquids, below shoulder height.
- No overloading of shelves.
- Storage of gas bottles outside the laboratory area (closed and protected).
- Isolation or confinement of certain products (security cabinets).
- Arrangement of cold rooms and freezers for products that require it.
- Maintenance of good housekeeping.
- Minimization of quantities: Stock reduction to the minimum needed, avoiding accumulation.

Apart from these ***good practices***, some ***best practices*** can be considered when using chemicals in the laboratory activities:

Best Practice

Substitution of toxic chemicals for less toxic ones

Substitution of toxic materials with less hazardous materials is one of the most effective ways of eliminating or reducing exposure to materials that are toxic or pose other hazards, along with the protection of the natural environment.

This practice interrupts the path of exposure between the hazardous material and the worker or natural environment, resulting in the reduction of risk or elimination of injury or harm, as well as protecting the environment from hazardous waste and wastewater and/or helping to reduce contaminant emissions. Although chemical substitution removes the hazard at the source, the selection of a substitute can be a very complex process.

Some of the major considerations regarding any chemical substitution should include the substitute effectiveness, its chemical compatibility, existing control measures, waste disposal and environmental hazard assessment.

Examples given by laboratories are shown in Table 1.

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Original Material	Substitute material	When it can be used
Acetamide	Stearic Acid	In phase change and freezing point depression
Acetonitrile	Methanol	In some liquid-mass applications (HPLC-SPE on line-MS / MS) for determination of some compounds[(1)]
Benzene	Cyclohexane; sodium chloride solution	Freezing point lowering
Benzoyl Peroxide	Lauryl Peroxide	When used as a polymer catalyst
Carbon Tetrachloride	Cyclohexane	In test for halide ions
Carbon Tetrachloride	Tetrachlorethylene	Tests of oils/fats
Chloroform	DNA extraction kits	DNA extraction
Chromic Acid cleaning solutions	Alconox, Micro, Pierce RBS-35, or similar detergents	In glassware cleaning. i.e. for the analysis of compounds of butyltin, phenyltin and phthalates (analytical technique: microextraction L-L-CG-MS)
Chromic mixture (Lower consume $K_2Cr_2O_7$)	Thermodesinfector for cleaning	

Table 1. Some examples of the material substitutions in environmental testing laboratories (Source: http://ehs.yale.edu/sites/default/files/files/chemical-substitution-tips.pdf)

Original Material	Substitute material	When it can be used
Formaldehyde, Formalin	'Formalternate' or Ethanol	For storage of biological specimens
Halogenated Solvents	Non-halogenated Solvents	In parts washers and other solvent processes
Mercuric Chloride Reagent	Amitrole (Kepro Circuit Systems)	Circuit Board Etching
Mercury Salts	Mercury-free catalysts (Copper Sulfate, Potassium Sulfate, Titanium Dioxide)	Kjeldahl digests
Mercury Thermometers	Mineral Spirit, stainless steel, bimetal, digital	Measuring temperature
Mercuric Chloride (biocide)	5-10% Methylene Chloride, 1% Formalin, 1 N Hydrochloric acid, Sodium Hypochlorite	Biocide use
N-Hexane	Cyclohexane	Analytical technique: Microextraction L-L-CG-MS. Determination of phthalates (Di (2-ethylhexyl) phthalate, Dimethyl phthalate, Diethyl phthalate, Dibutyl phthalate, benzyl butyl phthalate and Di-n-octyl phthalate)

Original Material	Substitute material	When it can be used
Sodium Dichromate	Sodium Hypochlorite	Metal treatment, corrosion inhibitor
Sulfide Ion	Hydroxide Ion	In analysis of Heavy Metals
Wood's Metal	Onion's Fusible Alloy	High-temperature coupling fluid in heat baths
Xylene or Toluene	Simple Alcohols and Ketones	Cell staining
Xylene or Toluene	Non-Hazardous Proprietary Liquid scintillation	In radioactive tracer studies

(1) Determination of compounds such as:

- Organophosphates.
- Triacins.
- Organonitrogenates.
- Ureas.
- Carbamates.
- Other substances.

For more information, see Appendix 1.

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Best Practice

Application of methods requiring smaller quantities of chemicals

Any proposed and selected method by a laboratory must be based on sound scientific principles and must be demonstrated to produce repeatable results under a variety of sample variations.

Each step of the method should be evaluated and tested by a qualified expert before it is applied in real samples. Some examples of good analytical tests with fewer quantities of chemicals are:

1. In chemical oxygen demand (COD) analysis, the sample size and the chemical consumption during analysis can been reduced after validation studies
2. Application of ion chromatography since it uses less chemicals instead of titrimetric and spectrophotometric methods.
3. In oxygen measurements, the probe method is being used instead of the titration method
4. Replacement of the traditional liquid - liquid extraction with the Liquid-Liquid (L-L) microextraction : In liquid-liquid microextraction only 1 to 1,5 mL of solvent per sample is used (Fig. 1). The traditional liquid-liquid extraction uses between 30 and 90 mL. The analytical technique used is the L-L-GC-MS microextraction in all of the methods described below, except for the hydrocarbon determination, which is L-L-GC-FID microextraction(2).

(2) Methods in which it is applied:

- Determination of Phenolic compounds (Phenol, o-Cresol, m, p-Cresol, 2-Chlorophenol, Dichlorophenols, Trichlorophenols, Tetrachlorophenol and Pentachlorophenol.

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- Determination of Orthophenylphenol, 4-Tert-Octylphenol, 4-n-Octylnonylphenol, 4-Nonylphenol and Bisphenol-A.
- Determination of Technical Nonylphenol.
- Determination of Butyltin compounds (Monobutyltin, Dibutyltin and Tributyltin).
- Determination of Phenyltin compounds (Monophenyltin, Diphenyltin and Triphenyltin).
- Determination of phthalates (Di (2-ethylhexyl) phthalate, Dimethyl phthalate, Diethyl phthalate, Dibutyl phthalate, benzyl butylphthalate, Di-n-octyl phthalate.
- Determination of C10-C40 hydrocarbons.

5. In Liquid chromatography–mass spectrometry (LC-MS) the Online Solid Phase Extraction (SPE) is used instead of the Offline SPE(3).

(3) This substitution can be carried out in the determination of the following compounds:

- Determination of Organophosphates: Omethoate, Dimethoate, Diazinon, Malation, Methyl-Pirimiphos, Trichlorfon.
- Determination of Triacins: Metribucine, Metthopucine, Simethrin, Cyanazine, Ametrine, Atrazine, Simacine, Terbutilacin, Terbutryn, Trietazine, Propazine, Desisopropyl-Atrazine, Desethyl-Atrazine, Prometrine, Destil-Terbuthylazine, Destil-.
- Determination of Organonitrogenates: Propizamide, Molinate.
- Determination of Ureas: Diuron, Linuron, Isoproturon, Diflubenzuron, Flufenoxuron, Lufenuron, Clortoluron.
- Determination of Carbamates: Aldicarb, Carbaryl, Carbofuran, Pirimicarb, Metiocarb, Benfuracarb.
- Other: Metomyl, Oxamyl, Metamitron, Bromacil, Imazalil, Thiabendazole, 3,4-Dichloroaniline, 4-Isopropylaniline, Carbendazima, Quinoxifene,, Metalaxyl, Miclobutanil, Dichlorvos, Cibutrina, Imidacloprid, Tiacloprid, Ciprodinil, Triadimenol, Oxadiazon, Triallat, Thiamethoxam, Clotianidin, Acetamiprid, Spinosin A and D and Fosmet.

6. Setup of a procedure to reuse already used or recovered solvents for the initial rinse of glassware in order to reduce the needs of pure solvents, that should only be used during the final rinse of glassware.

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7. Use of the bar extraction technique with thermal desorption (twister) in substitution of SPE for determination of pesticides in waters to avoid the use of solvents (Fig. 2).

Fig. 1. Thermal desorption (twister) (Source: Provided by a participant laboratory)

Fig. 2. L-L Microextration (Source: Provided by a participant laboratory)

Resizing purchases of chemicals (Mostly used in educational organisations)

This practice is mostly applied at Universities and/or Vocational & Educational Training Institutes for educational purposes. Where possible, procedures and purchases should be scaled down to minimize chemical usage and waste generation. Fortunately, modern laboratory instrumentation requires smaller quantities of chemicals than were used in the past to achieve satisfactory analytical results. For the conduction of teaching laboratories, instructors should plan experiments based on the smallest scale possible. Examples concerning the resizing of chemical purchases gathered were:

1. Purchases of kits of chemical reagents for laboratory training practices instead of big containers of products (Fig. 3).
2. Adjusting quantities of chemicals to be bought only to the basic necessities required by the educational practices (different from those needed by standards used in accredited laboratories).
3. Centralizing purchases and management of laboratory chemicals: one person responsible for providing/distributing specific quantities required by the chemists.
4. Students may also work in teams in order to reduce the number of chemicals bought that are be used for training purposes.

Fig. 3. Example of kits of chemical reagents (a) ammonium determination reagent test kit and (b) DNA extraction kit (Source: Provided by a particpant laboratory)

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Best Practice

Micro-scale testing methods (Mostly used in educational organisations)

Micro-scale procedures and equipment use smaller quantities of reagents therefore are safer and consequently produce less quantities of waste. Efforts at developing micro-scale experiments for general, organic, inorganic, and physical chemistry courses have been and continue to be successful.

An inexpensive way to achieve an initial level of micro-scale procedure application would be:

1. To use flexible, small diameter polyethylene tubing instead of bent glass tubing to transfer gases.
2. Using micro pipettes.
3. Using micro-burettes.
4. Hirsch filtration funnels rather than the traditional larger size equivalents.

An example of an applied micro-scale experiment is the redox titration of manganese. Moreover, the conical reaction vial may be used for the conduction of micro-scale experiments for extraction of chemicals such as dichloromethane (Fig. 4, 5).

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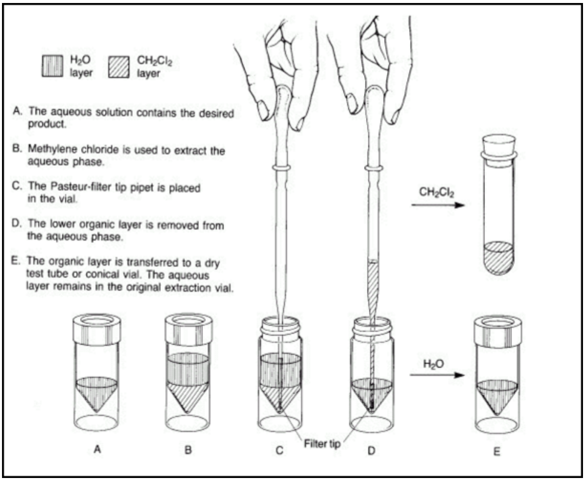

Fig. 4. A microscale extraction procedure, where extraction involves a heavy solvent such as dichloromethane (Source: http://www.chemistry.mcmaster.ca/~chem2o6/labmanual/microscale/complete.html)

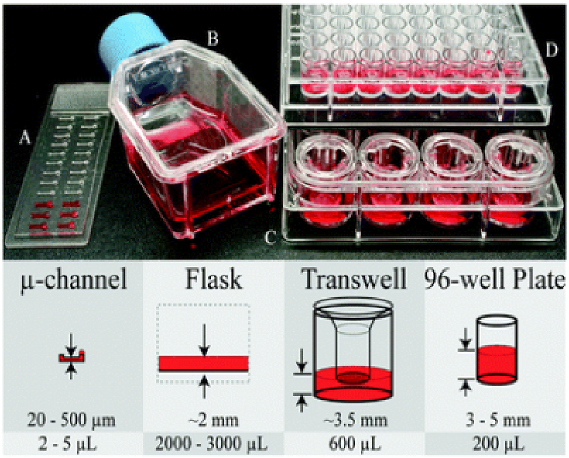

Fig. 5. Volumes used in biological experiment microdilution methods, involving small volumes of reagents (Source: http://pubs.rsc.org/en/Content/ArticleHtml/2009/IB/b823059e)

Best Practice

Control of chemicals: Chemical management lists

Accurate, up-to-date and easy back-tracking of records of chemicals and of chemical management activities is essential to minimize liabilities of compliance with regulations, to reduce cleaning and inspection costs and be able to provide information to the customers. Managing chemical inventories effectively can prevent many other problems such as excessive inventory stocks and poor use of materials, which can lead to adverse environmental impacts (i.e. hazardous spillages) and/or occupational safety hazards.

Thus, by managing chemical inventories in a simple and effective way, it is possible to avoid many of the aforementioned problems. The system of record-keeping must be such that all documents are filed, making it easy for anyone who needs information to be able to retrieve them immediately.

Moreover, all the chemicals arriving in the laboratory must be identified and all the necessary information must be added into a database (Fig. 6).

Some examples of Chemical Management lists are:

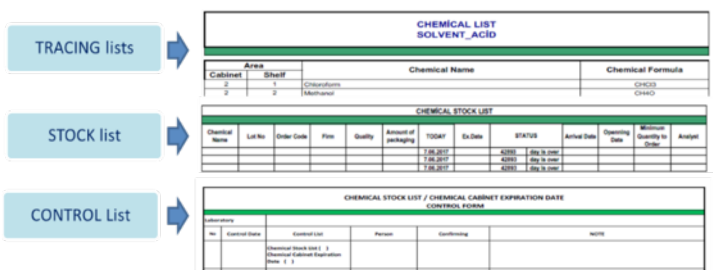

Fig. 6. An example of a Chemical Management List
(Source: Provided by a participant laboratory)

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Best Practice

Storage of liquids: Use of anti-spill buckets/trays

The handling of hazardous liquids which are flammable, combustible, environmentally toxic or even explosive, is addressed to laboratory employees, who have the basic knowledge of the health and safety regulations. It is important that in order to achieve effective spill control, products must be stored in places where it's possible to apply a rapid spill response action. An example of the safe storage of liquids in laboratories is the use of different type (size or colour) of containers to carry and collect possible spills of chemicals (Fig. 7).

Fig. 7. Examples of anti-spill containers (Source: Provided by a participant laboratory and https://www.calpaclab.com/storage-totes-and-trays/)

This practice can also prevent the contamination of soil or water and the generation of hazardous waste by cleaning leaks.

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Best Practice

Conditioning of the storage shelving area

Some examples of ***good practices*** regarding chemical storage on shelves include:

- Barriers in front of the shelves for preventing falls (Fig. 8).
- Trays under shelves in the storage cabinets resistant to solvents.
- Sticky or non-slippery materials on each shelf to keep bottles from rolling over.

Fig. 8. Example of storage shelving area for chemicals at laboratories (Source: Provided by a participant laboratory)

Other examples of ***good practices*** that are applied by the participating laboratories regarding the conditioning of the storage shelving area are:

- For items that are stored above shoulder height, workers must ensure that they are light-weight or infrequently used and that there is a safe means of access (e.g. step stool or ladders).
- Central shelving on benches must have raised edges to prevent items being pushed off the other side of the shelf.

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Best Practice

Spill control

Spills of chemicals are difficult to avoid in laboratories but there are ways to achieve their control.

Some ***best practices*** applied to prevent or to control the spills of chemicals in the workplace are:

- The staff uses the necessary equipment such as gloves, glasses etc. for their own and for environmental protection.
- The chemicals are placed in chemical storerooms, including berms, sumps, or even simple plastic containers.
- The storage cabinets are anchored to walls and floors.
- Stored chemicals are inspected periodically for signs of leakage, poor storage practices, or any other problems.
- Existence of a spill kit for spillages control and response (Fig. 9).

Fig. 9. Example of spill kit (Source: Provided by a participant laboratory)

It is important that products that need a spill control are stored in places where it is possible to apply a rapid spill response. The laboratory should keep records of spills and leaks and take notes of why and how the incidents have occurred, in order to be avoided in the future.

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Best Practice

Environmental Emergencies: Emergency Planning

Environmental emergencies in laboratories related to the use of chemicals may include, among others:

- Spillages of hazardous substances, such as chemicals, oil, stored hazardous waste, etc.
- Release of toxic vapours.
- Emissions of hazardous gases.

The technician handling the environmental emergencies, should follow the steps below:

The first step is to learn about the hazards of the chemicals in the laboratory (environmental hazard identification and assessment). Accordingly, a plan should be prepared for preventing or handling emergencies in which all the potential problems will be included, along with the hazard class of all the chemicals that are being used. The following properties of the chemicals are of major concern when preparing for possible emergencies: flammability, reactivity to air or water, corrosion, and toxicity level.

In this first step, the availability of all the required equipment and the training of the personnel should also be considered.

The second step for a technician is to prepare response procedures to address the identified hazards (Fig. 10). Such procedures should detail:

1. The initial steps to take when an environmental emergency occurs.
2. The actions and responsibilities of the staff.
3. The communication methods or instructions during the emergency response.

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4. Reporting and recording of the incident.

5. Definition and planning of corrective measures, if any.

EMERGENCY PLAN		DATE
		EDITION
CHEMICALS SPILLAGE		
What to do	Who	Resources

Fig. 10. Example of emergency response plan for chemicals spills
(Source: Provided by a participant laboratory)

It is also very important to analyse the emergency response, once the planned protocol has been implemented after an emergency incident, to check which improvements can be made to avoid this kind of problem in the future.

Moreover, emergency drills should be planned in order to verify the effectiveness of the emergency response procedures. All laboratory employees should participate in these drills.

WASTE MANAGEMENT

Hazardous waste is any solid, liquid, or gaseous material that displays either a "Hazardous Characteristic" or is specifically "listed" by name as a hazardous waste.

Laboratory staff should be trained to work safely during the handling of hazardous waste.

Good practices that are applied for appropriate waste management are listed below:

- Use of designated containers for each type of waste.
- No waste mixing.
- No discharge of chemicals in sinks.
- Use of hermetically sealed containers for the storage of waste.
- Handling of stored waste with care to avoid damages to the containers and/or spill production.
- Label the waste containers with the content and the relevant hazard details.
- The use of external labels (Fig. 11, 12) for each type of hazardous waste according to local legislation.
- Storage: Specific facility for waste storage outside the lab, with proper conditions for pollution prevention (Fig. 13).
    - Covered space and non-permeable pavement.
    - Containers with liquid waste: use of spillage collection systems.
    - Containers properly closed and labelled.
    - Fire protection equipment

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- Waste must be collected by an external authorised company responsible for their collection, transportation and final treatment.
- It is also recommended that this facility has a restricted access and/or security control (Fig. 14).

Fig. 11. Example of labelling and packaging waste (Source: Provided by a participant laboratory)

Fig. 12. Example of contents for an External hazardous waste label (Source: Environmental Protection Agency (EPA))

Fig. 13. Example of hazardous waste storage outside the lab (Source: Provided by a participant laboratory)

Fig. 14. Example of controlled access of a hazardous waste storage (Source: Provided by a participant laboratory)

Best Practice

Waste containers: Packaging unification

The use of the same type of containers for each type of waste throughout the laboratory, is a practice that can improve the proper separation, collection and facilitate the recycling treatment (Fig. 15).

Fig. 15. Example of packaging unification for waste containers
(Source: Provided by a participant laboratory)

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Best Practice

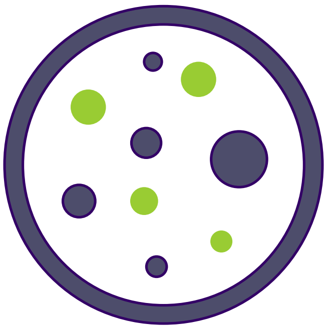
Hazardous waste separation at source

The separation of liquid hazardous waste at the source according to their origin consists a ***good practice***.

Some examples include waste that come mainly from acids and will be hereby considered as acidic liquid waste. Also, waste that comes from basic solutions, are considered as basic liquid waste.

In cases where the origin is not defined by the person who produces it, the pH must be determined.

Finally, hazardous waste produced will be separated according to their nature in bins, drums or boxes intended for this purpose in a dedicated section of the laboratory.



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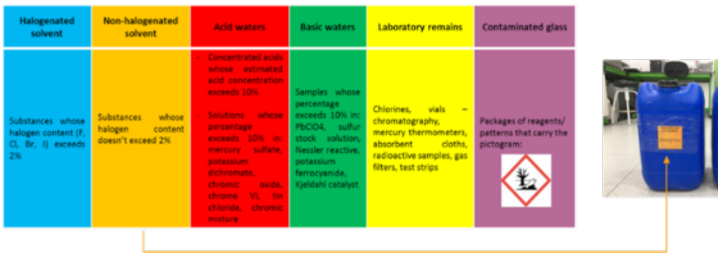
Best Practice

Hazardous waste identification: Internal labelling

Waste are not listed as hazardous specifically by their chemical name but they are regulated as hazardous waste because they exhibit one or more hazardous characteristics. These characteristics include ignitability, corrosivity, reactivity and toxicity. The use of internal labels for each type of hazardous waste produced in the laboratory is an easy way to identify each type of waste (Fig. 16).



Halogenated solvent	Non-halogenated solvent	Acid waters	Basic waters	Laboratory remains	Contaminated glass
Substances whose halogen content (F, Cl, Br, I) exceeds 2%	Substances whose halogen content doesn't exceed 2%	- Concentrated acids whose estimated acid concentration exceeds 10% - Solutions whose percentage exceeds 10% in: mercury sulfate, potassium dichromate, chromic oxide, chrome VI, tin chloride, chromic mixture	Samples whose percentage exceeds 10% in: PbClO4, sulfur stock solution, Nessler reactive, potassium ferrocyanide, Kjeldahl catalyst	Chlorines, vials – chromatography, mercury thermometers, absorbent cloths, radioactive samples, gas filters, test strips	Packages of reagents/ patterns that carry the pictogram:

Fig. 16. Example for internal labelling at laboratory facilities
(Source: Provided by a participant laboratory)

Apart from internal labelling, a short instruction for safe operation should be provided and set next to the hazardous waste containers. This short instruction should include, at least, hazard identification, first aid measures, fire-fighting measures, exposure control/personal protection, stability and reactivity.

Best Practice

Waste reuse and recycling: Returning non-hazardous waste to the product suppliers and other recycling/reuse practices

Effective waste minimisation strategies that can be applied within laboratories are the reuse and recycling of waste. Where possible and safe to do so, the use of washable or reusable lab ware instead of disposable items should be allowed to reduce the volume of waste.

Some products need to be single-use items for the integrity of the project and for safety, but it may be possible to reuse other items after appropriate decontamination and cleaning. Some ***good practices*** mentioned by the participants were:

- Reuse of the storage boxes of pipette tips.
- The recovery of waste generated by giving it back to its supplier, i.e. empty laboratory tubes and vials, toners and ink cartridges, reusable packaging of acetone, methanol and dichloromethane (Fig. 17).

Fig. 17. Examples of recovery of waste by a laboratory (Source: Provided by a participant laboratory)

- Internal reuse practices include the use of leftover chemicals from laboratory companies for educational purposes in schools, vocational training centres, institutes, etc.

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Best Practice

Optimization of external recycling procedures of waste

Recyclable laboratory non-hazardous waste includes materials such as:

- Plastic bottles.
- Corrugated cardboard boxes.
- Light card packaging.
- Paper e.g. white office paper and coloured paper.
- Metals e.g. aluminium cans and containers.
- Green, brown and clear glass bottles.
- Plastic containers e.g. graduated containers and trays.
- Polystyrene packaging.

All of the aforementioned materials may be recycled externally by authorised national or private recycling agents.

Researchers and laboratory workers have the best knowledge on chemical analyses and processes, and for that reason, they are best suited to make determinations on how to minimise waste.

Two ***best practices*** suggested by researchers for recycling hazardous waste are:

- The reuse of microbiological sampling flasks for further chemical sampling.
- The distillation of cleaning or extraction solvents.

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Best Practice

Microbiological waste treatment: Decontamination of biological waste by autoclaving, chlorine or heat treatment

Microbiological waste can be very dangerous for the working environment but also for the workers and the natural environment, due to the possible contamination when they are found in external areas. Thus, it is essential that biological waste should be disposed in a clear autoclave bag or red biohazard bag. Most laboratories apply a 60-minute autoclave cycle (excluding exhaust time) in order to allow enough time for the centre of the load to reach the desired temperature and have sufficient steam penetration (Fig. 18).

Some other good practices used for the decontamination of biological waste are:

- The use of autoclave indicator tape on the external side of the bag indicating that waste has been processed (Fig. 18).

Fig. 18. Autoclave and a biohazard bag used in laboratories for the decontamination of biological waste (Source: Finlab Nigeria Limited)

- Biological waste must be kept in specific containers in a cold storage area which is specifically designed and used for biological waste produced in the laboratory. It is also important that biological waste do not remain in bags for more than 5 days.

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- Ventilation should be available in these rooms and only biological waste must be stored in these areas.
- During the decontamination process, laboratory technicians must be qualified for decontamination tasks and must be aware of the risks.
- Decontamination methods include among others, the use of chlorine and heat.

Best Practice

Waste Database: Computer app for Waste management

A waste database is a very useful tool for laboratories or companies with many waste production points and volumes. Keeping a record has many benefits since it saves valuable time and resources during an incident, allows more efficient and effective waste management decision-making.

The use of waste databases also encourages stakeholders (e.g., state, local, tribal and territorial governments, owners of private storage, treatment and disposal facilities, residents) to work together to prevent chemical-associated incidents. Moreover, it increases community adaptation to the waste-related impacts of climate change as there are exact records of use of chemicals, and boosts the community's resilience and increases preparation levels in the case of chemical-associated incidents.

Finally, a computer app for waste management allows the digital register of all waste management steps (interactive application for all stakeholders) but also can be made to sell and buy these "second hand" products (or to share/ exchange them for free), so they can be reused for other purposes.

The information that a database should include is at least the following information:

- Requests for waste removal by the producing area (quantity, type, etc.).
- Indications of date of removal.
- Requests to external authorized persons for waste collection and transportation.
- Waste management documentation by the waste treatment authorised person.

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- Register of quantities by waste type and their final treatment.

The final output is a very complete and traceable waste production record.

There are various waste management software available for use by laboratories, and these include but are not limited to: EMS, CHEMATIX, LabCup and ADVISE Waste Management Modules which are 'cradle-to-grave' hazardous waste management software tools that include tracking, documentation and compliance reporting.

Best Practice

Information about waste management: Informative 'invoice' of laboratory waste management

Waste management also involves a waste 'invoice', where the producing laboratory receives the following information from the authorised waste collection and treatment company:

- The waste quantities according to their category.
- The treatment cost for the waste produced.
- The final treatment of the waste.

The aim of this informative 'invoice' is to highlight to laboratory technicians, the importance of waste management ***best practices***.

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ENERGY MANAGEMENT

The following ***good practices*** concerning energy management can be implemented inside a laboratory:

- Switching off the laboratory Equipment (GC, ICP, incubator, oven, centrifuge, reactor, distiller, distilled water treatment system, etc.) when not in use for a long period of time.
- Where possible, programming of automatic 'turn off' of the laboratory equipment.
- When not viable, e.g. for chromatograph MS detectors, saving methods should be activated to minimize consumption of gas and energy.
    - Closing the laboratory hood when not in use can save an important amount of energy.
    - Reducing the analysis duration of some test methods can minimize energy consumption.
- Streamlining the use of air conditioners.
- Energy saving techniques in computer equipment.
- Maximum use of natural light; Lighting adaptation to light needs of each area of the lab.

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Best Practice

Energy-efficient equipment: High efficiency lamps

Due to the nature of the work undertaken in laboratories, they are consuming large amounts of energy and that is why the selection of equipment and its energy consumption must be taken into consideration. Although some energy issues are not directly related to the laboratory work, such as energy efficient lamps and sensors, they are also important.

Light-emitting diode (LED) lighting is a promising and one of the most widely applied solutions so far, for the provision of high-efficiency lighting. It was shown to provide reduction in maintenance costs as this type of lamp lasts longer (around 5 years), it reduces labour for fitting lamps and downtime without lighting. Moreover, LED lamps reduce energy consumption by up to 60% compared to conventional lamps, as they have low-wattage use compared to fluorescent and other types of lamp. As a result, the overall carbon footprint of laboratory lighting has the potential to be reduced, while eliminating lamp disposal issues (Fig. 19).

Fig. 19. An example of use of effective LED lighting in a laboratory (Source: https://www.labdesignnews.com/article/2015/06/lighting-path-efficient-lab-design)

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Best Practice

Energy-efficient equipment: Automatic sensors

Another measure not related directly to laboratory activity but one that needs to be taken into account for the reduction of the energy consumption, is the placement of automatic lighting sensors (on/off) in corridors and outside the building. Automatic lighting sensors can save energy and minimize the impact on the environment due to energy efficient technologies and systems. A good placement of automatic lighting sensors instead of manual switches can also save money and time (Fig. 20).

Fig. 20. An example of use of automatic lighting sensors a laboratory (Source: Provided by a participant laboratory)

Best Practice

Selection of energy efficient laboratory equipment

Selection of energy-efficient laboratory electrical equipment (e.g. A, A++, Fig. 21) is a way to save more energy and money. For example, the choice of equipment according to its energy efficiency label can be important for reducing the energy consumption within a laboratory.

Fig. 21. A to G scale for energy efficiency of laboratory appliances (Source: European Union-EP)

More specifically, this practice offers:

- Manageable costs with the use of energy-efficient equipment.
- Minimization of the lab's energy needs by using less energy.

After the selection of energy-efficient equipment, a very important step to achieve and maintain low energy consumption is the preventive maintenance of the equipment, which all laboratories should plan well ahead, in order to allow the longer lifespan of the equipment.

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Best Practice

Renewable energy: Photovoltaic systems

The installation of renewable energy systems has many benefits and it is a good practice that should be applied, to the degree that each laboratory can apply it.

More particularly, photovoltaic systems utilising solar panels produce a renewable type of energy, which is eco-friendly, and are a reliable resource of energy. These systems may also provide a high yield of renewable energy to all facilities that take advantage of them, including laboratories.

Autonomous photovoltaic systems (not connected to an electricity grid) generate electricity which is stored in batteries or can be directly used. These systems are common in remote areas and can be used for the supply of electricity to small premises (Fig. 22).

Large scale photovoltaic systems are installed mostly on roofs of buildings, and the produced electricity may be sent to the electricity grid or may be utilised locally, in the building where it was produced (Fig. 22).

Fig. 22. Two examples of photovoltaic systems that may be utilised by laboratory facilities to produce renewable energy in countries where there is a high yearly amount of solar radiation (Source: http://www.k-energy.com.cy/en/services/photovoltaic-systems/18-k-energy/photovoltaics-and-solar-panels, www.arimec.eu)

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Renewable energy: Water-heating solar panels

Heating water is also very expensive as it requires a huge amount of energy, and due to this fact, solar panels are a great way to reduce energy costs, especially in countries which receive a high yearly amount of solar radiation. In the case of solar thermal panels, the sun's energy is used to heat water which can be used for different purposes within a laboratory (Fig. 23).

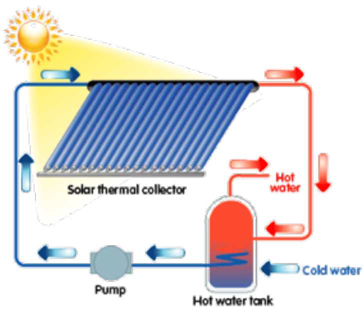

Fig. 23. A visual representation of solar panel water heating system (above) and a picture of a solar panel which heats the water in the connected tank above it, in Cyprus (below) (Source: http://www.3m.co.uk/intl/uk/3Mworldly-wise/primary-bldg-southside-6-solar-panel.htm, http://www.solarthermalworld.org/content/cyprus-system-replacements-increase-efficiency)

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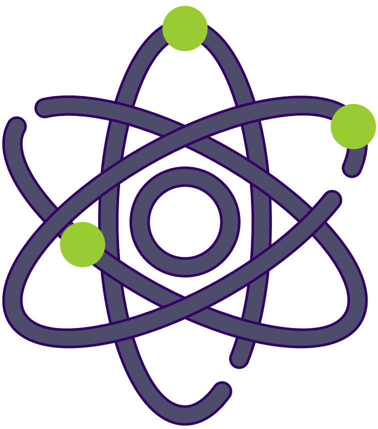
Best Practice

Building energy efficient design

In general, there are many available strategies for designing an energy-efficient building. The two main goals for the creation of such an energy-efficient building are: to minimize the energy losses and maximize the solar energy gains. This double mission means that laboratories must provide levels of safety, space conditioning, and indoor air quality not usually maintained in conventional office buildings. To this end, design of research laboratories typically have minimal energy considerations.

It is essential to design energy-efficient laboratories that offer cost savings and safe working conditions to their research personnel. For example, the energy-efficient design of the building may include many large windows for maximum sunlight and the building materials used during the building may be insulating, to keep a building warm or cool, depending on the climate.



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WATER MANAGEMENT

Concerning water consumption within the laboratory, a ***good practice*** for measuring the levels of consumed water are the establishment of a water meter for each space in the building. In this way, the amount of water consumed each month is determined and the efficiency of the applied water-saving methods is monitored.

In order to saving water, optimization of the applied cleaning processes can be as follows:

- Appropriate cleaning guidelines e.g. no detergents for non-oily products.
- Reuse of cleaning water.
- Avoiding leaving faucets running.

Other ***good practices*** to be taken into account in order to save water are:

- Operation of equipment only when it is fully loaded (washing machines, etc.).
- Leak prevention by inspecting water equipment water use (maintenance is very important to avoid leaks).
- Minimization of the water content used in analyses.
- Where possible, water cooling replaced by chillers.
- Reusing some wastewater streams or collected rain water for watering the plants.

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Best Practice

Installation of of water efficient faucets

Most laboratory buildings use significant amounts of water, primarily to meet their large cooling and process needs.

A laboratory's water efficiency can be improved by making changes in specific types of equipment, such as adaptations to water treatment and sterilizing systems, to use less water.

Also, in order to reduce the water consumption, specialised water-saving faucets can be installed. As a result, intensive cleaning power and time and water savings are achieved.

For example, aerators can be placed on faucets, which aerate the water giving it a higher pressure and faster outflow, thus limiting the use time and thus water consumption (Fig. 24). Another example of water-use efficiency in laboratories is the use of a reduced pressure backflow preventer, which contains two check valves with a relief valve located between them (Fig. 25). A check valve is a one-way valve, which will only open in one direction and will only allow water to flow in that direction.

Fig. 24. High efficiency faucets used in laboratories (Source: https://www.labdesignnews.com/article/2010/04/understanding-laboratory-plumbing-systems-water)

Fig. 25. A reduced-pressure-type backflow preventer contains two check valves with a relief valve located in between them (Source: https://www.labdesignnews.com/article/2010/04/understanding-laboratory-plumbing-systems-water)

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Best Practice

Selection of equipment with low water requirements

In order to reduce water consumption, the integration of water-efficient equipment in day-to-day operations must take place in laboratories, whose operations require large volumes of water. This replacement with water-efficient equipment, also provides laboratories with more opportunities to make further improvements related to water efficiency, thus reducing water use costs. Examples of equipment that have the capacity to utilize less water include cooling towers and glassware washing machines (Fig. 26).

Fig. 26. Glassware washing machine used in laboratories (Source: Provided by participant laboratories)

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Best Practice

Wastewater and rain water reuse

Recycling is a term that is most commonly applied to aluminium cans, glass, plastic bottles, and newspapers, but water can be recycled as well. Water reuse is the repurposing of water used in certain laboratory operations, to other beneficial purposes. Reusing wastewater streams offers resource and financial savings, e.g. a laboratory facility reusing water that has already been used for cooling processes.

Another common type of reusable water is rainwater, which can be used in sonicators and for equipment cooling. Rainwater can be also stored and used for other purposes not directly related to the laboratory activity, such as watering of the plants and lawn around the laboratory buildings.

The laboratory staff can also implement water-saving ways such as washing in plastic containers.

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Best Practice

Recirculation of water streams for reusing

Reusing already used water streams is a practice that can be of great use within a laboratory. This is due to the fact that large amounts of water are already used in the laboratory for washing and for other purposes.

Some examples of recirculation of water are:

- Cooling water used during the analysis of the samples can be diverted to a tank, where it can be reused.
- Wastewater from deionized water production processes can be stored in tanks and used for toilet flushing.
- Bypass hot water from the distiller's wastewater can be used for washing various materials.
- Wastewater may be used in some laboratory tests, depending on its suitability (e.g. packaging tests).

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28 USE OF OTHER RESOURCES

Best Practice

Efficienct use of other resources

In a laboratory, the use of paper is huge. The reason is that paper is a versatile material with many uses, including writing, printing, packaging, cleaning as well as a number of laboratory processes. So, it is important to reduce the paper consumption.

This can be achieved by reducing the use of printers through the digitalization of reports (digitalized test reports sent to the clients), by replacing the use of paper in the calibration processes by preparing them on a computing support, and also by replacing paper towels for individual cloth hand towels.

Concerning the use of transport fuels for the collection of samples from different points, it is of great importance to optimize the sampler's routes in order to save fuel and protect the environment (Fig. 27).

Fig. 27. (Source: Provided by a participant laboratory)

29 NOISE

Best Practice

Isolation of noisy equipment

The overall level of noise in a laboratory depends on a number of factors including the location of the laboratory, the materials used in construction of the building as well as the instrumentation and equipment used to carry out the tasks of the facility. Since high noise levels can lead to a variety of medical issues for laboratory personnel and the surrounding environment, the laboratory technicians must develop strategies in order to reduce the level of noise. A way to reduce noise disturbance is the isolation of noisy equipment. This practice consists of an effective approach to minimizing the noise emitted to the environment and ensures that health and safety of the occupants are optimized.

Some examples:

Noise emitting devices placed in separate spaces:

- Fume hood, ventilation motors, ICP chillers and vacuum pumps, sonication baths, etc. can be placed in separate sections, as far apart as possible so as not to affect each other and the staff, or even outside the building (e.g. nitrogen generators)
- If required, very noisy equipment can be isolated (e.g. located in insulated cupboards).
- In cases where a separation is not possible, noise insulation boxes can be used (e.g. to minimize the noise of vacuum pumps of mass detectors) (Fig. 28).

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Fig. 28. Example of noise insulation box for vacuum pumps (Source: Provided by a participant laboratory)

Best Practice

Selection of equipment with low noise emissions

The goal is to provide the design community with an understanding of sound isolation and noise control issues in buildings, and with tools to address these.

It is important to note that a laboratory has acoustical performance established when the relevant building elements are selected and assembled. An excellent way to reduce the noise levels in the laboratory is to select devices that are designed to generate less noise, but also the frequent preventive maintenance of the equipment.

One such example is the use of LC-MS technologies which come with a provision of nitrogen gas tanks, rather than selecting the in-house production nitrogen generator option for provision of nitrogen to the LC-MS, as it is a noisy option. The selection of such technologies which produce less noise, assists in the reduction of noise levels within and around the laboratory premises. Another example is the use of oil-free air compressors in laboratories, instead of the oil-driven compressors for air purity.

In addition to this, noise tests can be performed to check if noise from certain equipment is within the recommended levels (e.g. fume hoods).

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Best Practice

Noise monitoring

Measuring noise levels and workers' noise exposures is the most important part of a workplace hearing conservation and noise control program. It helps identify work locations where there are noise problems, employees who may be affected, and where additional noise measurements need to be made. For occupational hygiene purposes, the sound pressure level must be measured in order to determine noise exposures. Various instruments and techniques may be used. The choice depends on the workplace noise and the information needed. However, the first step is to determine if there is a noise problem in the workplace. Instruments which may be used to measure noise levels include meters which measure noise, sound and sound pressure levels in dB (Fig. 29).

Fig. 29. Example of a noise, sound and sound pressure meter (Source: https://www.pce-instruments.com/english/measuring-instruments/test-meters/sound-level-meter-noise-level-meter-pce-instruments-sound-level-meter-pce-318-det_61498.htm)

Moreover, acoustic audits should be conducted in order to verify that laboratory activities do not produce noise that could cause an impact on the external environment.

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32 AIR EMISSIONS

Best Practice

Equipment to reduce emissions: Air cleaning systems

A number of factors including the location of the laboratory, the materials used in construction of the building as well as the instrumentation and equipment used to carry out the tasks of the facility, must be taken into account for the air quality within a laboratory. High contaminant levels can lead to a variety of medical issues for laboratory personnel and to the external environment. Consequently, the laboratory technicians must develop strategies in order to reduce air polluting emissions.

More specifically, the installation and the use of safety cabinets or fume extractor hoods fitted with suitable filters depending on the type of chemicals to be emitted, is an example of a way to reduce air emissions (Fig. 30).

Good practices also include the change of the fume extractor hood filters after their use and the monitoring of air flow speed and uniformity in order to verify if air contamination remains within recommended levels.
Other systems for air emissions 'cleaning:

- Scrubber systems to remove acid vapours.
- Bio-safe fume hoods for working on potentially contaminated samples.
- HePA filtered cabinets for any samples where asbestos may be present.

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These practices are effective approaches towards minimizing air emissions and ensuring that health and safety of the occupants are optimized.

Fig. 30. Biosafety cabinets class II with laminar flow technology (Source: Provided by a participant laboratory)

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Reducing emission of harmful vapours

It is critical for every laboratory operator to document the type and quantity of air contaminants emitted to the air from their laboratory activities. This can be achieved by tracking the quantity of chemicals used and the quantity of these chemicals that becomes waste. Using a mass-balance approach, calculations can be conducted to determine air emissions from the laboratory operations. These calculations should be performed for all contaminant emission points in the laboratory.

For instance, to improve air quality within the laboratory, installation of safety caps for mobile phase bottles (eg. VOCs) in LC-MS equipment can be considered. This can prevent the emission of harmful vapours (Fig. 31).

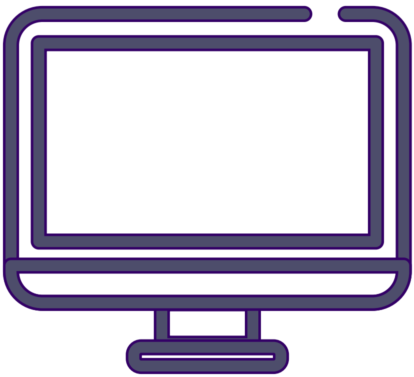
Fig. 31. Example of safety cups for VOCs bottles (Source: Provided by a participant laboratory)

Best Practice

Maintenance of equipment

Maintenance and regular inspection of laboratory equipment are essential parts of a smooth laboratory operation. Many of the accidents that occur in the laboratory can be due to improper use or maintenance of laboratory equipment. Preventive maintenance and inspections can be done to check for:

- Air emissions filtration (fume hoods/ gas cabinets) and equipment producing other air emissions (equipment burning fuel, e.g. boilers).
- Controlling the leakage of greenhouse gases (GHG) by air-conditioning equipment.
- Vehicles used by samplers/inspectors.



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Best Practice

Air pollution monitoring

Air emission sampling and analysis is a particularly difficult aspect of environmental monitoring and specialist equipment may need to be used. Both stages of air emissions monitoring demand a high level of competency and quality control, in order to provide the required level of accuracy, precision and resolution.

The monitoring of air pollution must consider that:

- Measurements outside of the laboratory of possible air contaminants emitted, e.g. HF, HCl, SO2, VOCs and other contaminants from a gas exhaust treatment system, should be done in order to verify compliance with permitted/regulated values to be released into the environment.
- Testing air emissions can provide additional information and warning to users of toxic or flammable gases in laboratories.

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36 WASTEWATER
Best Practice

Separation of wastewater streams

Wastewater must be separated at the source into several streams, according to its physicochemical characteristics, in order to ensure its most suitable final treatment. For instance, wastewater may be separated into acidic, alkaline, aqueous, solvent, cleaning water and nutrient-containing waste streams etc.

Acid or basic water test samples, which were analysed in the laboratory, should be neutralized before discharge.

It is important to note that all wastewater streams should be periodically monitored before discharge, to check if their contaminant concentrations are within authorised levels.

It is also essential to separate hazardous liquid wastes from other kind of wastes.

Moreover, wastewater from washing of equipment or glassware in a laboratory is considered to be "industrial wastewater," and must be properly managed in accordance with all applicable state and local rules.

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ENVIRONMENTAL MANAGEMENT

For a high-quality environmental management system (EMS), a good information and documentation management system is necessary. It should contain the main applicable regulations, guidance documents and other environmental management material. These must specifically include an environmental policy, specific procedures to assure compliance with each regulation, a description of the roles and responsibilities for the implementation and maintenance of the EMS system as well as a requirement tracking system with regular updates to the EMS (Fig. 32).

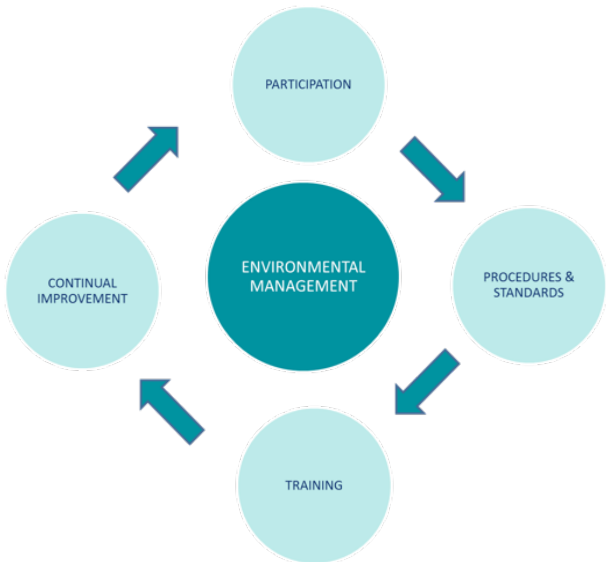

Fig. 32. Key aspects in an EMS to be applied in a lab
(Source: personal database)

It is recommended that an EMS is based on a continuous improvement approach. So, in order to achieve this, it must follow the methodology known as Plan-Do-Check-Act (PDCA), which is a model for continuous improvement that checks regularly whether laboratory EMS regulations and set goals are being implemented (Fig. 33):

Fig. 33. PDCA methodology for EMS (Source: http://iso9001-2008awareness.blogspot.com.cy/2014/04/pdca-cycle.html)

- **Plan:** establish the objectives and processes necessary to deliver results in accordance with the organization's environmental policy.
- **Do:** implement the processes.
- **Check:** monitor and measure processes against environmental policy, objectives, targets, legal and other requirements, and report the results.
- **Act:** take actions to continually improve performance of the environmental management system.

Best Practice

Environmental Policy

Laboratories undertake activities that may cause harm to the environment. An environment policy is a way of acknowledging their environmentally harmful actions or practices and agreeing to address them in the future. It represents a commitment to protect the environment in a responsible manner, to meet all
relevant environmental compliance obligations, and to enhance environmental performance. It can also:

- Identify and rectify wasteful and harmful current practices.
- Highlight cost savings/more efficient environmentally friendly ways of working.

An environmental policy is a great starting point for any group that serious about creating sustainable communities and doing their duty to protect the environment.

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Planning: aspects, objectives

A crucial point for achieving a successful environmental management system is to design a systematic process for the identification, prediction and evaluation of the environmental impacts of proposed laboratory actions and projects. This process is applied prior to major decisions and commitments being made, in order to provide information for decision-making on the environmental consequences of proposed actions, but also to promote environmentally sound and sustainable development through different measures. These goals can be achieved by:

- Setting objectives: For example, a comprehensive plan can be developed with clearly pre-defined objectives. Moreover, in addition to the objectives, for each environmental issue it is easier to separate the objectives into short-term and long-term objectives. This ensures that there is an initial realistic goal established and each activity can be developed towards the achievement of the objectives.
- Identifying tools/resources to achieve these objectives: For example, it is important to identify partners and networks, sources of funding and other planning considerations.

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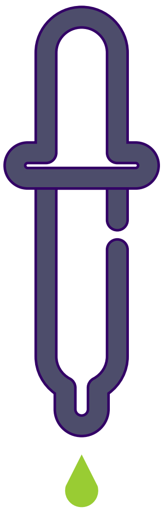
Best Practice

Training and awareness

Raising awareness of environmental issues amongst staff is a key action for the success of the development and implementation of the environmental policy.

It can also be a step for creating positive statements that a laboratory will carry out in the future to minimise damage to the environment. These statements will collectively form the laboratory environmental policy.



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Best Practice

Written procedures

Documenting policies, procedures, and delegations of authority will help the laboratory to organize and prepare for emergencies, but also to figure out and handle the mistakes that could happen during following of the set procedures. The written procedures must have the following characteristics:

- Ease of Access: An up-to-date, on-line system will permit those who use or are directly affected by policies and procedures to have the access they need.
- Cost Effectiveness: Making written policies and procedures readily available can reduce time spent on the telephone and fewer errors.
- Responsiveness: The ability to quickly update and disseminate procedures enables the laboratory to adapt to new environments.
- Accountability: Clearly written policies and procedures with clearly stated responsibilities to specified persons are one of the founding elements of any system.

Some examples of categorisation of environmental procedures/instructions to be developed for controlling the environmental aspects of a laboratory are:

- Chemical management.
- Waste management.
- Wastewater control.
- Natural resource conservation.
- Noise control.

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- Air emissions control.
- Environmental Inspections.
- Emergency preparedness and response.
- Infrastructure and equipment maintenance.

The creation of procedures covering the above should create a path to the implementation of the ***best environmental practices*** in a laboratory.

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Best Practice

Green purchases in laboratories

Green procurements/purchases include processes where laboratories seek to purchase goods and services which have a reduced environmental impact throughout their life cycle. By using their purchasing power to choose goods and services with lower impacts on the environment environmental testing laboratories can make an important contribution to sustainable development.

Also, a green purchase system ensures the creation of direct environmental benefits and reduces the negative environmental impacts with the same or even better quality, functionality or value for money compared to conventional choices.

The use of green purchases can be a powerful practice to provide a strong stimulus for eco-innovation, helping national and international efforts towards a more resource-efficient and sustainable society.

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Best Practice

Performance monitoring

To help a laboratory monitor its performance, environmental performance monitoring of procedures must be conducted to identify current groups of activities or practices that potentially harm the laboratory and external environment. A laboratory must identify activities where the minimisation of harmful actions and practices can be implemented, but also create positive statements that will help protect the environment. Continuous monitoring of correct performance of the complete processes of a laboratory helps to identify potential errors quickly and is one of the most important activities for continuous improvement. This monitoring can be carried out using check lists, interviews, visual inspections, measurements, etc.

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6. Conclusions

In conclusion, ***good and best practices*** towards environmental sustainability in environmental testing laboratories were collected and presented in this guide. These practices were selected through focus group discussions and questionnaire surveys, which were conducted in three separate countries (Spain, Cyprus and Poland). The ***good and best practices*** were concerned with various environmental testing laboratory natural resources and experimental/routine procedures. More specifically, these practices were concerned with the areas of:

1) The use of chemicals.

2) Waste management.

3) Energy management.

4) Water management.

5) Other resources.

6) Noise.

7) Air emissions.

8) Wastewater.

9) Environmental management systems.

The most important ***good/best practice examples*** which aim at protecting the natural resources that are utilised for the smooth operation of the surveyed environmental testing laboratories were included in this guide.

It was concluded that there is a lot of improvement to be achieved in the sustainable development of environmental testing laboratories, as there are many practices in all abovementioned areas, which may be implemented to conserve resources and protect the physical environment, by laboratories all over Europe.

As a result, this guide gives a useful beginning as to the provision of

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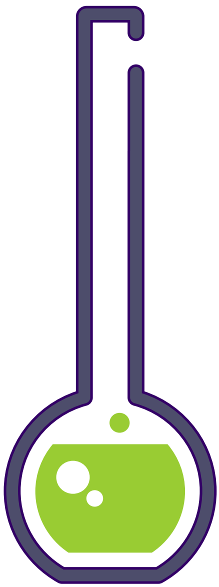
environmental testing laboratories with the tools and the basis for building a framework of practices which aim at environmentally sustainable practices, which will eventually become imperative for their smooth operation.

As this guide is based on experience along with an extended literature review of similar practices available from national/international organisations, it is recommended as a key tool for those laboratories and their staff as to their sustainable development and environmental performance.



7. Laboratories involved

> Aristos Loucaides Chemical Laboratory Ltd.

> Crop Science Lab, Department of Agricultural Sciences, Biotechnology and Food Science, Cyprus University of Technology

> Cyprus University of Technology - Department of Environmental Science and Technology. Oikotoxicologia-Research Group in Environmental Toxicology

> Microbiology Lab, School of Science and School of Medicine, European University Cyprus

> C. P. Foodlab Ltd.

> State General Laboratory, Cyprus

> Geological Survey Department of Cyprus, Chemical Laboratory

> Pankemi Laboratory, Cyprus

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> Gaia Laboratory of Environmental Engineering, University of Cyprus

> Laboratory Institute for Water Quality, Resource and Waste Management (TU Wien)

> IPROMA

> AUDIOTEC Ingeniería Acústica S.A.

> AMBITEC Laboratorios

> ADIMME

> NGI's Environmental Laboratory

> Laboratorios Tecnológicos de Levante

> AGROKONTROLA

> Textile Testing Institute

> AGUAS DO ALGARVE

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> CEVRE

> ECON

> Laboratories of Environmental Biotechnology. Department (Silesian University of Technology)

> Department of Environmental Sciences Jozef Stefan Institute, Ljubljana

> Laboratorio Multidisciplinar, S.L.

> SIGGO

> EXOVA

> CTCV MAS-LMA

> UMA – Unidade de Microbiologia Aplicada do IPVCA

> GEMAR Environmental Measurement and Analysis Laboratory

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> University of Environmental Sciences in Radom

> Microbial Ecology Group (MEG) – CNR-ISE, Verbania

> University of Architecture Civil Engineering and Geodesy

> Institute for Sustainable Technologies, National Research Institute, Environmental Technologies Department

> Institute for Environmental Protection, National Research Inst

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8. Collaborating Universities and VET Centers

- IES Vicent Castell i Domènech
- Universitat Politècnica de València
- Universitat Jaume I
- Universitat de València
- Universidad Miguel Hernández
- CIPFP Canastell
- Laboratories of VET school IES Dr. Peset Aleixandre_FP Laboratorio de Análisis y de Control de Calidad

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9. Project developer partners

> Novotec Consultores S.A

> FEH, Fundación Equipo Humano

> MMC, Management Center Limited

> ITeE-PIB, Instytut Technologii Eksploatacji - PIB

> UCY, University of Cyprus

> 3S, Research Laboratory - Forschungsverein

> EUROLAB, European Federation of National Associations of Measurement, Testing and Analytical Laboratories

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Directive 2004/37/EC - carcinogens or mutagens at work of 29 April 2004 on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (Sixth individual Directive within the meaning of Article 16(1) Directive 89/391/EEC) as last amended by Directive (EU) 2017/2398 of the European Parliament and of the Council of 12 December 2017.

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and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC (Text with EEA relevance)

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11. Appendix 1

[1] Determination of compounds such as:

- Organophosphates: Omethoate, Dimethoate, Diazinon, Malation, Methyl-Pirimiphos, Trichlorfon.
- Triacins: Metribucine, Metthopucine, Simethrin, Cyanazine, Ametrine, Atrazine, Simacine, Terbutilacin, Terbutryn, Trietazine, Propazine, Desisopropyl-Atrazine, Desethyl-Atrazine, Prometrine, Destil-Terbuthylazine.
- Organonitrogenates: Propizamide, Molinate.
- Ureas: Diuron, Linuron, Isoproturon, Diflubenzuron, Flufenoxuron, Lufenuron, Clortoluron.
- Carbamates: Aldicarb, Carbaryl, Carbofuran, Pirimicarb, Metiocarb, Benfuracarb.
- Other substances: Metomyl, Oxamyl, Metamitron, Bromacil, Imazalil, Thiabendazole, 3,4-Dichloroaniline, 4-Isopropylaniline, Carbendazima, Quinoxifene, Metalaxyl, Miclobutanil, Dichlorvos, Cibutrina, Imidacloprid, Tiacloprid, Ciprodinil, Triadimenol, Oxadiazon, Triallat, Thiamethoxam, Clotianidin, Acetamiprid, Spinosin A and D and Fosmet.

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For more information, please contact us:
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ECVET - Lab Environmental Management in Labs Online Training Course will be available on our website very soon.

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