CHAPTER 8

ENERGY SUPPLY

8.1 General

It is essential that a reliable energy supply is available to ensure continuity of the work in an emergency laboratory. Energy may be provided by the following sources:

- combustion-powered generators
- solar energy supply systems
- energy modules.

8.2 Combustion powered generators

Electrical energy can be provided by a fuel generator. The generator may be the combustion engine of a motor car or a separate generator. A separate generator, producing an alternating current of 110 V or 220 V, can usually generate more energy than a car engine, which provides a direct current of 12 V or 24 V. The electricity can be fed into rechargeable batteries (see **8.3.3**). The type of current available will limit the selection of laboratory equipment; for example, an instrument that requires direct current can be supplied with energy from:

- batteries
- a direct current network
- an alternating current network with converter[1].

The installation of a direct current electrical network is simple and biohazards do not occur during operation. For instruments working with low voltage direct current, the high voltage from the direct current network has to be converted by means of a transformer. Alternatively, for instruments running on alternating current, the direct current must be converted into alternating current by means of a converter. Converters are heavy and expensive instruments and significant losses of electrical energy occur in the conversion process. Therefore, it is preferable to use direct current appliances to avoid the need for a converter.

enerators may not always be available. Even when a main power supply is accessible, lectric current may fluctuate or be subject to frequent breakdown. This can cause derable problems for analytical equipment used in a laboratory.

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[1] :onverter changes the type of current

8.3 Solar energy supply systems (photovoltaic systems)

8.3.1 Cost effectiveness

An emergency laboratory with a small number of low energy consuming instruments can work with a small energy supply. For such a laboratory, a solar energy supply system meets the requirements better than a generator system. Moreover, the installation of a photovoltaic system eliminates fuel supply problems. Manufacturers of photovoltaic equipment are listed in Annex 9.

At present, the investment cost of a photovoltaic system far exceeds that of a suitable generator system. Therefore, the installation of a generator system may be more cost effective in countries where a well developed oil supply network exists. In other countries, the installation of a photovoltaic system will provide a more reliable source of energy and one which requires less maintenance. Moreover, the running costs of a photovoltaic system are almost nil, counterbalancing the initial investment cost. A solar energy supply system, (**Figure 8.1**), consists of three components:

- solar panel
- electronic charge regulator
- batteries.

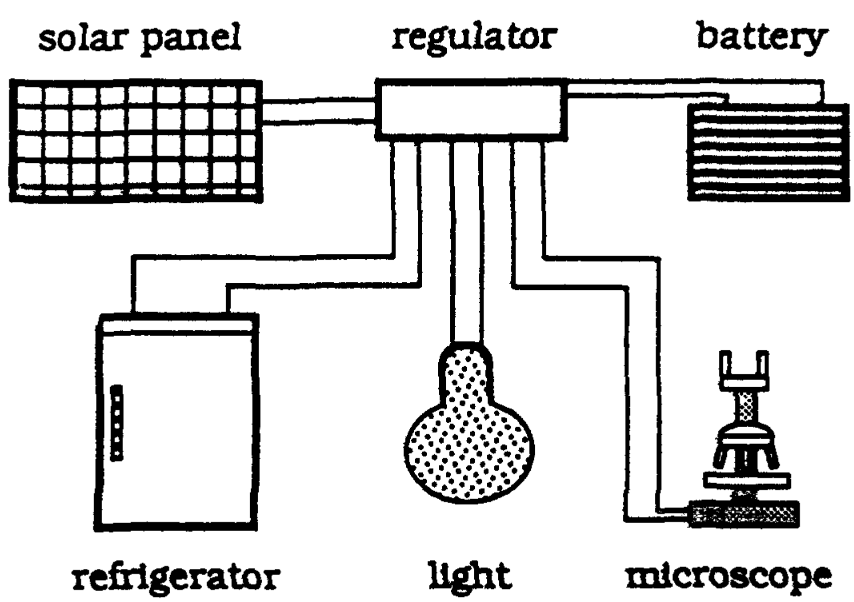

Figure 8.1 Solar energy supply scheme

8.3.2 Solar panels

TYPES

There are two different kinds of solar panel commercially available: crystalline silicon and amorphous silicon. The panels differ in their physical properties and cost. Amorphous silicon panels are less expensive but are also less effective in producing electricity than crystalline silicon panels. However, it is expected that further development will improve the quality of the amorphous silicon panels. Some important differences in the properties of the panels are shown in **Table 8.1**

TABLE 8.1 **Properties of commercially available solar panels**

Properties of commercially available solar panels	Panel with cells of crystalline silicon	Panel with cells of amorphous silicon
Power of largest available panel	70 W	20 W
Expected lifespan (years)	25	10
Guaranteed lifespan (years)	10	5
Mechanical stability	Good	Good
Reliability	Good	Variable
State of development	Finalized	In progress
Power supply from 1 m2	130 W	60 W

Installation

The power output of a solar panel is dependent on solar radiation and temperature of the solar cells The output current of the panel will increase as the solar radiation increases. Conversely, the voltage will significantly decrease, resulting in a decrease of power, as the cell temperature decreases. The power output is maximal when the operating conditions for the panel are chosen at their optimum. The maximal power output is also called the peak power (Wp) of a panel.

Solar panels must be installed so that they are exposed to light. Shadow will not obscure the panel. The panel should be positioned at an angle as close as possible to the degree of latitude of the site location, for example, if the panel is to be used in a country near or on the equator, the panel should be at an angle of at least 15°. However, if it is to be used at a latitude of 25°, the panel will need to be tilted to 25°. Place the panel on the sunny side of the building. The panel must face north if it is used in the southern hemisphere and south if it is used in northern hemisphere. The back of the panel must be freely ventilated. The minimum distance between the back of the panel and the surface of the supporting construction should be 5 cm to avoid overheating the panel, which will reduce the efficiency of the energy production. Solar panels are wired for 12 V direct current.

8.3.3 Electronic charge regulators

A charge regulator is an essential part of the solar energy supply system (**Figure 8.2**). It controls the charging and discharging of the batteries automatically. When the battery voltage falls below the threshold during discharge, the instrument will be disconnected from the battery. On the other hand, if the voltage increases above a threshold when recharging the battery, the panel is disconnected from the battery. A good charge regulator adapts the maximum voltage of the battery to the change in temperature of the battery environment. This adaptation prevents loss of water in the battery from evaporation. It is important to keep a spare charge regulator in stock in case of breakdown.

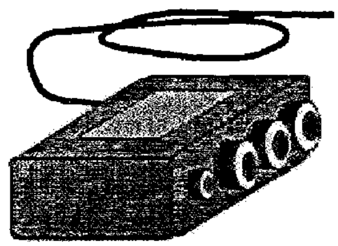

Figure 8.2 Electronic charge regulator

Attention must be paid to the stability of the charge regulator under tropical conditions. It is advisable to choose a charge regulator with an integrated digital display indicating the battery voltage.

8.3.4 Batteries

Lead Batteries

Solar energy systems require rechargeable batteries. These may be lead batteries or nickel-cadmium (NiCd) batteries. High efficiency lead batteries are preferred. A great variety of lead batteries are commercially available (see **Table 8.2**). Batteries with high efficiency have practical advantages, although they are more expensive than normal batteries.

When purchasing batteries, 12 V batteries with the highest capacity (100 Ah) should be chosen. Maintenance-free lead batteries are commercially available, but are expensive. The development of this type of battery is still in progress, and it has not been thoroughly tested in tropical climates For the time being, caution is advised in the use of maintenance-free batteries.

Transportation

It is important to remember that, in accordance with the regulations of the International Air

Transport Association (IATA) [2], lead batteries for transportation by air must be empty of electrolytes. For safety reasons the same precaution should also be taken during any other form of transportation.

Maintenance

The daily discharge of lead solar batteries should not exceeed 20 % of the total capacity of the batteries, otherwise the lifespan of the batteries, normally about 1100 cycles, will be shortened. If the batteries are repeatedly discharged up to 40 % of their capacity they will only last for about 600 cycles, although there are certain kinds of lead battery that can be discharged to 40 % of capacity, while lasting for about 3000 recharge cycles. For maintenance, the fluid level should be checked regularly and refilled with distilled water, as for car batteries, when necessary.

High efficiency batteries cannot simply be replaced by normal car batteries in case of breakdown. When only car batteries are available to replace a defective high efficiency battery, the batteries of the energy storage system must all be replaced together with the same type of battery.

TABLE 8.2 **Specifications of batteries used for solar power supply**

Plate type	Lead calcium	Lead calcium antimony (6%)	Lead calcium antimony (2%)	Nickel cadmium
Electrolyte type	Liquid	Liquid	Liquid	Liquid
Maximum discharge	50%	80%	80%	100%
Discharge during normal operation	20%	20%	20%	20%
Voltage/ cell	2 V	2 V	2 V	1 V,2 V
Self discharge rate	Low	Medium	Low	High
Topping-up required	Infrequent	Frequent	Infrequent	Minimal
Capital costs	Low	Mid-range	Mid-range	Very high
Suitability for photovoltaic use	Not recommended	Recommended	Highly recommended	Highly recommended

Nickel-cadmium (NiCd) batteries

NiCd batteries can be recharged by a solar panel. There are NiCd batteries that are the same size but have different capacities. The AA size NiCd battery is available from 500 mAh up to 700 mAh capacity. Batteries with the highest capacity should be chosen. Small NiCd batteries, type AAA to D, for use in instruments should be recharged in advance for continuous operation of a laboratory. The lifespan of NiCd batteries may be up to 1000 recharging cycles.

Maintenance

NiCd batteries do not always work reliably in tropical countries, causing problems to arise. The reason for this apparent unreliability is an increased rate of discharge, rather than less efficient recharging of the battery at higher ambient temperatures. This may be partially circumvented by taking the following precautions:

a) NiCd batteries should be recharged just before being used and at low ambient temperatures (e.g. in a refrigerator or in a specially constructed recharging box). For example, only 62 % of the potential energy is made available from a NiCd battery that is charged at 40°C
b) Recharged NiCd batteries should be stored at low temperature as they have a high degree of self-discharge when stored at elevated temperatures. For example, a NiCd battery stored under dry conditions for two weeks at 40°C will have a residual capacity of 32 %. High humidity will accelerate the self-discharge of a NiCd battery.

NiCd batteries have a 'memory' and are therefore less efficient if they are not fully charged and then completely discharged. A battery should not be put on the charger for a few hours only. It is better to carry a spare NiCd battery which can be put on the charger when the other battery is being used.

8.4 Energy modules

8.4.1 Basic energy modules

A basic energy module can provide an independent small electricity supply. All batteries of types AAA to D can be recharged with the equipment of the basic energy module (**Figure 8.3**). In the field, the NiCd batteries can be recharged either by a car battery or by solar energy. The equipment for recharging batteries is listed in Module 2: Energy (Chapter 7).

8.4.2 Portable solar energy supply systems

Various portable solar energy supply systems are commercially available (**Table 8.3**). The portable solar power station has a foldable solar panel and a charge regulator assembled in a medium-sized suitcase.

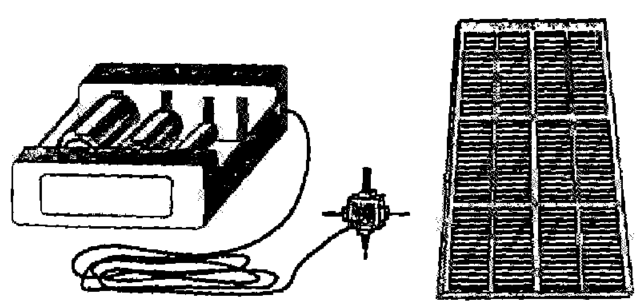

Figure 8.3 Basic energy module equipment

TABLE 8.3 **Portable solar energy supply systems**

Item	Size	Costs	Batteries to be used	Power supply
Small solar battery charger	Very small	Inexpensive	4 AA batteries only	Integrated solar panel
Advanced solar battery charger (prevents over charging)	Small	Less expensive	All types of NiCd battery	Separate solar panels
Battery charger	Small	Less expensive	All types of NiCd battery	11-32 V d.c. car battery
Small solar power station	Brief case	Expensive	6 V d.c. 12 V d.c.	Foldable solar panel delivers 140 Wh/day

8.5 Calculation of the energy requirements of an emergency laboratory

The energy demand of a laboratory is determined by the number of electrical instruments. Solar energy is recommended as a source of energy for a low energy demand. On the other hand, fuel-powered generators should be considered if the power demand for a laboratory is more than 500 W. The flowchart in **Figure 8.4** can be used to decide what kind of energy supply should be used.

The investment cost of a solar energy supply system is high. Therefore, the calculations for energy requirements should be made carefully in order to ensure that the power produced meets the energy demand. The daily energy demand is calculated from the average daily energy consumption of each item of electrical equipment. This figure is used to calculate the size of the solar energy supply system, including the number of solar panels and the battery capacity (see **Table 8.4**).

An emergency laboratory will normally have the following electrical items:

- light
- refrigerator
- microscope
- centrifuge
- colorimeters
- incubator

The calculation of the daily energy demand for a laboratory equipped with these items is explained below.

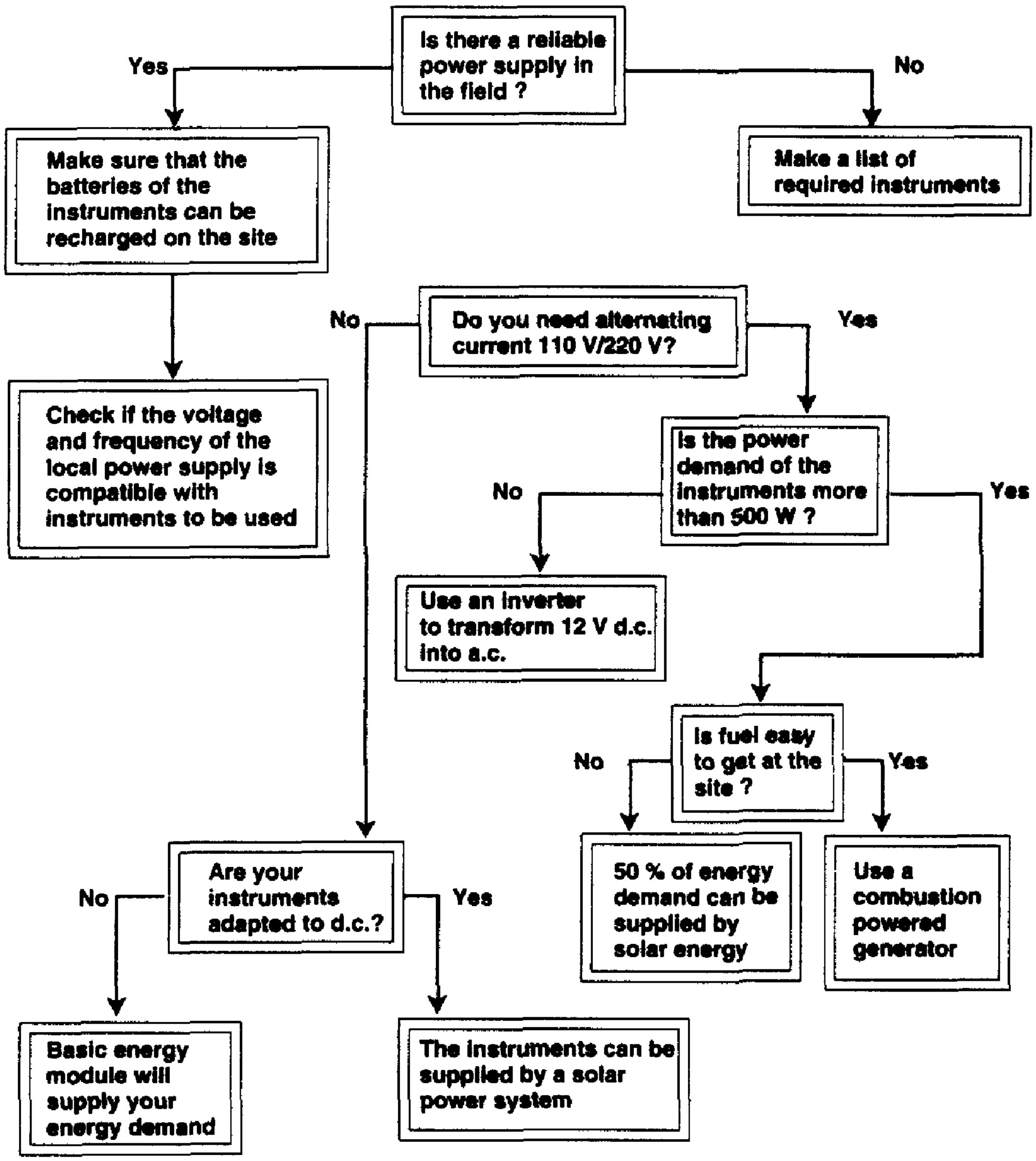

Figure 8.4 Energy supply flowchart for laboratory equipment

TABLE 8.4 Calculation of energy demands and size of a solar energy supply system

Equipment	Power demand (W)	Daily operating hours of equipment	Daily energy demand (Wh)	Number of photovoltaic standard modules	Battery capacity (Kwh)
Light (4 bulbs)	11	12	528	3.8	2.6
Refrigerator (110 L)	50	24	600	4.3	3.0
Microscope	20	8	80	0.6	0.40
HCT-centrifuge	10	3	30	0.2	0.15
Blood centrifuge	30	3	90	0.6	0.45
Colorimeter	4	4	16	0.11	0.08
Incubator	30	24	360	2.6	1.80
Total			1704 Wh	13.2	8.48 KWh

Notes to Table 8.4.

1 Low energy consumption light bulbs should be used. These bulbs emit about 4 to 6 times more light intensity for a given energy consumption than conventional bulbs For example, a low energy 11 w bulb emits as much light as a conventional 75 w bulb. Although low energy consumption bulbs are more expensive than conventional bulbs, their lifespan is far longer. For solar powered systems, ordinary car headlight bulbs can be used if no low energy consumption bulbs are available
Note Spare bulbs should be kept in stock, one for each lamp .

2 The calculation for a refrigerator is based on the use of a compressor refrigerator. The energy supply is based on a maximum of 12 hours per day. This is an arbitrary assumption, which may vary according to the local temperature conditions (see also Chapter 9)

3 The number of solar panels required is calculated from the daily energy requirement and the energy that can be provided by a standard solar panel The standard solar panel provides 140 Wh during a day. This panel has a maximum peak power (*Wp*) of 50 W. The number of panels with *Wp* differing from the standard panel must be calculated accordingly

4 In calculating the battery capacity, it must be remembered that only 20 % of the total energy capacity of the lead battery should be made available for daily use

5. The purchase cost of a solar energy supply system comprises the costs of the solar panels, charge regulator, batteries, and installation material

If the expected daily operating hours of an instrument are different from those listed in the table, or if instruments with a different power consumption are used, the daily energy demand can be calculated using the following formula:

Daily energy demand = number of instruments x power demand x daily operating hours

Example: three lights and a microscope are used in a laboratory.

Light (3 lamps)	3 x 11 W x 8 h =	264 Wh
Microscope	1 x 20 W x 4 h =	80 Wh
Total daily energy demand	=	344 Wh

To set up a solar power system for the laboratory the solar peak power required and battery capacity have to be determined.

Required solar peak power

$$= \frac{\text{daily energy demand}}{\text{energy output of standard panel (Wh/day)}} \times \text{peak power of standard panel}$$

$$= \frac{344\text{Wh}}{140\text{Wh}} \times 50\text{Wp} = 123\text{Wp}$$

Total storage capacity of the batteries

= Daily energy demand x 5*
= 344Wh x 5 = 1720Wh

Battery capacity required of a 12V battery system

$$= \frac{\text{total storage capacity}}{12\text{ V}}$$

$$= \frac{1720\text{Wh}}{12\text{V}} = 143\text{Ah}$$

The energy requirement of a solar power system for the example described would be therefore as follows.

Solar panels	123Wp
12V battery	143Ah
Solar charge regulator	12V, 123Wp

* The coefficient 5 results from the fact that the battery can only be discharged by 20% (1/5), if appropriately used.

CHAPTER 9

LABORATORY EQUIPMENT

9.1 General

The requirements of laboratory instruments used in an emergency laboratory are different from those used in a routine laboratory. Fully automated equipment is too sophisticated. The instruments must be reliable and maintenance must be easy. In this chapter the following laboratory equipment is discussed:

- microscope
- centrifuge
- colorimeter and haemoglobinometer
- incubator
- refrigerator
- water purification systems.

Annexes 8 to 16 list suppliers and manufacturers of laboratory equipment.

9.2 Microscopes

In many emergency situations the microscope is the instrument which is used most in the laboratory. The procurement of a microscope is a long-term investment. Therefore, price should not be the primary consideration. Reliable, medium-priced microscopes are commercially available. When purchasing a microscope, attention should be paid not only to the magnification but also to the resolution and curvature of the field, which are important criteria. These are not satisfactory in less expensive microscopes, which may also have mechanical problems. Microscopes should be supplied with a socket in the base where a plug from a 12 volt battery can be connected. The microscope should be supplied with a stable light source connected to a battery which can be charged by a solar panel or local power supply. The case should be made out of strong plastic with an interior that is moulded and foam-lined. The microscope base should be held firmly in place with a screw.

The advantages and disadvantages of different microscopes and their accessories are outlined in **Table 9.1**. The addresses of suppliers are listed in Annex 10.

Work conditions should be taken into consideration when choosing a microscope. A standard binocular microscope is recommended for a mobile or stationary laboratory, but a monocular model can also be used if resources are limited. A small and compact microscope(e.g. McArthur microscope) can be used for a portable laboratory. **Table 9.2** lists some properties of commercially available microscopes.

TABLE 9.1 Advantages and disadvantages of portable light microscope types and accessories

Type/Accessory	Advantages	Disadvantages
Monocular	Less expensive	Tiring over longer periods of use
Binocular	Easy to use	Higher investment cost More light needed
Mirror lamp	Allows the microscope to be used in the absence of electricity supply; inexpensive	In poor sunlight an external light source may be required
Built-in base lamp	Gives good,constant and even field of light Controllable light intensity	More expensive than a mirror Bulbs may be difficult to obtain Requires an external power source
Built-in base socket for 6 V/12 V for battery connection	Usable in the field without alternate current supply	

TABLE 9.2 Some properties of commercially available microscopes

Microscope	Optics	Light and energy sources
Gillet and Sibert	Very good	All power sources
Olympus CH2	Very good	Mirror, 110V, 220V
Zeiss, KF2	Excellent	All power sources
Nikon LSK	Excellent	All power sources
McArthur	Very good	AA batteries, mirror

9.3 Centrifuges

Centrifuges are needed to:

- measure haematocrit (PCV)
- separate blood cells from plasma
- concentrate casts and cells in urine
- concentrate cells in CSF.

Centrifuges can be driven mechanically, by batteries or by a main source of electricity. While the separation of cells or casts from body fluids requires only a low speed centrifuge, haematocrit centrifuges are used for quantitative measurement and must have good stability to maintain a high and constant rotor speed. Determination of haematocrit is a useful method for diagnosis of anaemia and obviates the need for haemoglobin determination.

Battery-operated portable and bench centrifuges are available that can also be supplied with solar energy. Some of these instruments can also operate at 110 V/220 V a.c. The energy required to run a centrifuge increases proportionally to the weight of the specimen to be centrifuged. Therefore, haematocrit centrifuges require less energy than other centrifuges.

Electrically driven centrifuges have practical advantages for routine work. However, they are more expensive and require a continuous supply of electricity. Portable mechanical centrifuges have also been developed. Some properties of portable centrifuges are listed in **Table 9.3**. The addresses of suppliers are listed in Annex 7.

TABLE 9.3 **List and specifications of commercially available mechanical and battery-driven haematocrit and multipurpose centrifuges**

Name	Type[1]	Voltage	Specimen capacity	Company
Ames microspin	1100	6 V d.c.	6	Bayer Diagnostics
Hettich EBA11	-	12 V d.c/ 110-220 V a.c.	4 - 8	Hettich
Hemata Stat C-70B	H	12 V d.c./ 110-220 V a.c.	6	Separation Technology Inc.
Multipurpose centrifuge	M	12 V d.c./ 110-220 V a.c.		Technical Research Association
Saturn	-	12 V d.c./ 220 V a.c.	20	Roy Rickman
Multipurpose centrifuge	M	6 V d.c.	2	Dr Kendall Smith
Spectrum	-	Mechanical	10	Roy Rickman
JabusRickman	-	Mechanical	20	Roy Rickman
Multipurpose centrifuge	M	Mechanical	4	Solmedia Tropical Laboratory Supplies

H haematocrit
M multipurpose

9.4 Colorimeters and haemoglobinometers

Colorimeters are used for the quantitative determination of haemoglobin, serum glucose and sometimes other analytes in an emergency laboratory. Haemoglobinometers are designed to measure only haemoglobin.

Haemoglobin can be measured by a variety of means including:

- comparative estimation of the transmission of daylight through a thin capillary blood film;
- comparative estimation of light transmission of haemolysed undiluted blood by means of a portable battery-driven haemoglobinometer;
- determination of haemoglobin in diluted blood after chemical reaction.

The accuracy of haemoglobin determination is highest with methods using chemical reactions such as the conversion of haemoglobin to cyanhaemoglobin, and is lowest in the comparative procedures. However, in emergency situations the accuracy in haemoglobin determination of some comparative methods may still be acceptable. For example, the Lovibond method using undiluted blood has been found suitable. Comparative estimation of haemoglobin after conversion of haemoglobin into acid haematin has an unacceptably low accuracy and precision (e.g. the Sahli method).

Table 9.4 outlines some of the available techniques for detecting anaemia in the field, together with their advantages and disadvantages.

Measurement of haemoglobin after chemical reaction requires additional disposables and pipetting steps that can introduce error. **Table 9.5** lists some features of commercially available portable, battery-operated colorimeters and haemoglobinometers. The addresses of manufacturers are listed in Annex 12.

TABLE 9.4 **Advantages and disadvantages of some techniques used for anaemia detection**

Technique	Advantages	Disadvantages
Cyanmethamoglobin	Standardized, good for large-scale screening, accurate	Difficult to make reagents, solutions require refrigeration, expensive, labour intensive, requires colorimeter
Oxyhaemoglobin	Accurate, simple reagents	No international standards, requires colorimeter
Sahli	Quick, simple, inexpensive	Inaccurate, subjective, unreliable,difficult to use
Haematocrit	Fast, accurate, simple, well-standardized	Requires haematocrit, centrifuge and capillaries
Copper sulfate	Accurate, inexpensive easy to use	Difficult to make solutions
Talquist	Inexpensive, easy to use	Inaccurate, unreliable
Filter paper	Inexpensive, easy to use	Inaccurate
Clinical examination	Inexpensive, reliable	Sensitive to severe anaemia, inaccurate, not quantitative
Lovibond[1] Undiluted	Accurate[2], no reagents required, simple, reliable, no battery, no disposables	Moderately expensive

[1] This method, without dilution, is extensively used by Médecins sans Frontières, with a glass wedge-slide
[2] In contrast to the normal Lovibond method, using ammonia as a diluent, which is inaccurate

TABLE 9.5 **List of battery-operated portable haemoglobinometers**

Name	Digital display	Light source	Wavelength	Manufacturer
Biotron	Yes	LED	564 nm	Biotron
Delphi	Yes	LED	555 nm	True Test Ltd.
HemoCue	Yes	LED	546 nm	HemoCue
Miniphotometer MPA	Yes	LED	546 nm	Karl Hecht
Miniphotometer XJY 1	Yes	LED	560 nm	Beijing FilmMachinery Industry
WPA CO 700 D	Yes	Tungsten	10 wave-lengths	Walden Precision Apparatus
Primechem, Nutrichem	Yes	LED	580 nm	Primecare
Minilab PC	Yes	LED	546 nm	Bayer Diagnostics
Miniphotometer	Yes	Halogen	Filter	Dr Lange
Chematests	Yes	Tungsten	505 nm	S.E.R.O.A SA

LED Light-emitting diode

9.5 Portable incubators

The field applications of incubators include diagnostic bacteria culture, parasite culture in human body fluids and bacteriological water analysis. A variety of field incubators have been developed that meet these requirements. Four field incubation systems are discussed here.

a) *WHO portable incubator*

The WHO incubator is supplied with the accessories necessary for water testing and a 12 V d c. battery It can also be operated from a.c. mains (via rectifier) or from a solar panel system. It is approximately 50 cm x 35 cm x 30 cm in size and lightweight. It can be used for any incubation from ambient to 50°C. (See Annex 13 for supply.)

b) *GQF Portable laboratory incubator*

The GQF incubator can operate with 110 V or 220 V a c. or with 12 V d.c. Maximum energy requirement is 30 W. Its external dimensions are 43 cm x 36 cm x 43 cm and those of the chamber 35 cm x 27 cm x 26 cm. It can be operated from ambient to 45°C, but the most efficient operating range is 35-37°C. It comes with a dial thermometer . It is made of thermal plastic with an outer shell of high impact styrene and weighs approximately 3 kg. (See Annex 13 for supply.)

c) *Millipore portable incubator*

This incubator was developed for water sanitation bacteriology using membrane filter technology. It can be adapted for other uses, especially enrichment broth culture, but it has limited capacity. It operates on 6 V, 12 V and 24 V d.c. or 110 V/220 V a.c. The chamber is approximately 15 cm x 15 cm x 15 cm. It has a sturdy case and weighs approximately 4 kg. Incubation temperature ranges from ambient to 45°C.

d) *Portable waterbath incubator*

This instrument is 30 cm x 13 cm x 13 cm in size and weighs 1 kg. It operates on one of two interchangeable heaters, on 12 V d.c. or 110 V/ 220 V d.c. The heaters can be easily exchanged to accommodate a local power source. The instrument was specifically designed to incubate tubes of selective enrichment broth, 16 at a time. The holding holes in the lid adapt automatically to test tubes of various diameters. It comes with a dial thermometer and temperatures can be adjusted from ambient to 45°C.

e) *Other incubators*

There are other instruments available which can be used either as a refrigerator or as an incubator. Their energy demand is very high and they should be used only where the energy supply is inexpensive.

9.6 Refrigerators

9.6.1 General

Electric refrigerators have high energy consumption. They are available in 110 V/220 V a.c versions and 12 V/24 V d.c. versions. Refrigerators working on the absorption principle cool without making noise. However, they require much more energy than refrigerators working on the compressor principle. Refrigerators operating on 12 V/24 V d.c. usually have no freezing compartment and so consume considerably less energy. Refrigerators operating on 110 V/220 V a.c. may have an integrated freezing compartment and if so, consume considerably more energy. Refrigerators with a top opening preserve their temperature better than refrigerators with a front opening, and therefore consume less energy. There are also small refrigerators (18 litres) available which can be used for incubation to keep things warm. They are powered by 12 V d.c. or 110 V/220 V a.c. As their energy consumption is very high, they are only recommended where cheap electricity is available.

A suitable refrigerator for a field laboratory has a cooling chamber of 120 litres or less. The size of the refrigerator should not be larger than necessary, because the dead volume in the cooling chamber must also be kept at low temperature, which requires additional energy. If blood for transfusion is to be stored in the refrigerator, it must maintain a temperature range of +2°C to +8°C and have a temperature monitoring system.

Manufacturers of refrigerators, including solar powered refrigerators, are listed in Annexes 14 and 15.

9.6.2 Installation and use

The correct installation and use of a refrigerator can reduce energy consumption considerably. When installing a refrigerator, it should placed in a position that allows maximum air circulation at the condenser. It should be placed at least 10 cm away from the wall behind it and should not be covered. The air convection behind the refrigerator can be improved by providing a suitable small ventilator fan.

The energy-consumption of a refrigerator depends mainly on the frequency of use. The degree of heat exchange is proportional to the number of times the door is opened and for how long. These facts are important to remember in daily use, particularly if the refrigerator runs on photovoltaic energy.

9.7 Water purification systems

Pure water is a basic requirement for laboratory services. Pure water is needed to prepare stains and other reagents, for equipment and general cleaning, and for sterilization. Good sources of clean water are rain, collected from a roof, or springs. Make sure that the container used for collection and storage of water is protected by a cover or lid at all times. A list of manufactureres of water purification systems is give in Annex 16.

number of simple methods can be used to treat water for laboratory use.

Removal of suspended solids

1. Place the water in a container such as a tank or bucket, and leave it to stand overnight. Slowly pour off the clearer supernatant water, and discard the muddy part at the bottom
2. Add aluminum sulfate (alum cake) to the supernatant water at a rate of 5 g to 1 bucket (10 litres) of water. Leave it to stand for 20 minutes, then carefully pour off the clear supernatant water.

b) *Adjustment of pH*

1. Test clear water with a pH paper strip.
2 If the pH is above 8.0, add dilute hydrochloric acid (0.1 molar) while continuously stirring to lower the pH to 7.0. If the pH is low, add dilute sodium hydroxide (NaOH) solution while continuously stirring until the pH is 7.0.

c) *Sterilization of contaminated water*

The pores of ceramic filters quickly become clogged by muddy water. The water should be treated first for excess suspended solids. Add 500 mg alum, or alum sulfate, to one litre of water, mix, allow to settle and then pour off the supernatant water into the filter.
Filter the clear water through a filter with a pore size greater than 0.22 m, e.g. a gravity ceramic filter such as the Doulton A1 or LP Model. This removes all sediment, ova, cysts,

protozoa, and bacteria (but not viruses). The filter does not remove inorganic and low molecular organic solutes.

d) *Distillation*

In water stills, water is purified by evaporation and steam or water vapour condensation. The condensed steam is collected as distilled water.

Water stills remove non-volatile and all inorganic material. Stills with a water flask and heating device are costly to maintain. They require a source of cool water and a reliable energy source. Water with a high salt content cannot be distilled with this method.

A simple solar-powered water still can be built using local materials to overcome pure water supply problems in sunny remote areas (**Figure 9.1**). A glass sheet covers a clean plastic container with a large surface area (1 m x 1 m) at an angle of about 30°. Water in the container is evaporated by the sun, condenses on the glass cover, and drops into a water collector placed at the lower end. From there the distilled water drops into a flask. In hot climates, 2-7 litres of distilled water with a conductivity of 30-60 S can be produced daily from a solar still with a surface area of 1 m.

e) *Demineralization*

Demineralizers contain ion-absorbing resins, which remove inorganic and organic ions from water. Demineralizers operate without an energy input, but they do not produce sterile water and do not remove all organic impurities. They may be subject to bacterial contamination, particularly in a warm environment. Their capacity for demineralization of water is limited, and they require routine control and maintenance. Portable demineralizers are commercially available.

Good quality water can also be obtained by means of carbon filters and reverse osmosis. Carbon filters have a limited capacity and the filters, resins or membranes have to be replaced.

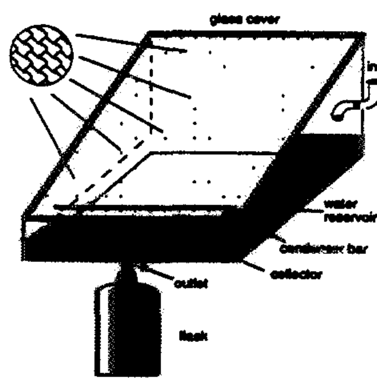

Figure 9.1 Solar still

Note The Doulton and British Berkfeld sterasyl candle (ceramic element) filters are self-sterilizing and last for 6-12 months They require weekly cleaning with a stiff-bristled brush and clear water (with no detergent).

CHAPTER 10

SUPPLY OF BLOOD FOR TRANSFUSION IN EMERGENCIES

10.1 General

The first decision to make in any emergency is whether blood for transfusion is required. This will depend upon factors such as:

- the type of patient involved (e.g. epidemics or natural disasters such as floods are not likely to result in conditions requiring urgent blood transfusions);
- the availability and accessibility of blood from existing blood transfusion services;
- the availability of plasma substitutes, or volume expanders, such as crystalloid or colloid solutions.

These factors should be considered during preliminary assessment of the emergency situation.

10.2 Situations involving patients with acute blood loss

10.2.1 Basic equipment and consumables for blood transfusion in emergency situations

Crystalloids and colloids must always be available in situations involving patients with acute blood loss. The decision to provide such supplies should be based on the preliminary assessment and they should be included in emergency surgery/pharmaceutical kits.

For details of equipment and consumables for blood transfusion needed in emergency situations, see Modules 22a and 22b: Blood transfusion (Chapter 7).

The management of patients with acute blood loss may involve any or a combination of the following:

- plasma substitutes
- blood supplied from existing transfusion services
- blood from selected donors on site
- blood salvage.

10.2.2 Plasma substitutes

The infusion of plasma substitutes (crystalloid or colloid solutions) must always be the first choice for volume replacement therapy in patients with acute hypovolaemia due to haemorrhage.

The administration of such solutions will not normally involve the laboratory service. Guidelines on the indications for use of crystalloids and colloids and on the general management of acute haemorrhage can be found in Plasma and Plasma Substitutes in Developing Countries [3].

10.2.3 Blood supply from existing transfusion services

If plasma substitutes are not available or have been used and blood is still required, the patient must be transferred to a health facility where safe blood is available. Alternatively, the blood must be transported to the site depending upon the number of patients involved. In most emergency situations involving large numbers of patients, blood should be transported from existing transfusion services, but certain prerequisites are necessary:

- an adequate supply of blood
- adequate communications
- adequate transport facilities whether by road, rail, river or air
- adequate cold chain for transport and storage of blood
- power supply for storage (see equipment list of Module 2: Energy)
- materials for rapid blood typing (see Module 22a: Blood transfusion).

10.2.4 Blood from selected donors on site

In emergency situations where blood from existing transfusion services is not available, it may be necessary to take blood from selected donors on site, but this should not be done without the basic materials necessary to collect, test and transfuse blood safely. Donors should be selected, as far as possible, to comply with standard selection criteria (see **10.4**) and must be grouped and tested for human immunodeficiency virus (HIV), Hepatitis B surface antigen (HBsAg) and syphilis, using simple, rapid tests (see equipment and consumables of Module 22a: Blood transfusion).

10.2.5 Blood salvage

In emergency situations where plasma substitutes are not available and there is no access to a blood supply of any kind, autologous transfusions using blood salvage techniques may be employed with basic equipment and training These procedures would not usually involve the laboratory services. Guidelines on blood salvage can be found in the publication *Autologous Transfusion in Developing Countries* [4].

10.3 Blood transfusion in refugee camps

Blood from existing transfusion services should be the first choice for emergency transfusion in refugee camps. Where such blood is not available, it may be necessary to collect blood from 'walking donors

A 'walking donor' system involves the selection, grouping and screening of voluntary potential donors who can provide blood in an emergency. The prerequisites involved in setting up such a system are:

- access to testing facilities for initial grouping, screening for relevant transmissible agents such as HIV, HBsAg, syphilis etc., and regular monitoring of donors;
- basic equipment and consumables for collecting and transfusing blood;
- basic laboratory services on site for simple grouping and compatibility testing and rapid, simple testing for HIV, HBsAg and syphilis where relevant;
- adequate on-site record system.

10.4 Bleeding donors on site

10.4.1 Selection of donors

International criteria (for example those of WHO) should be applied as far as possible.

- Weight: local standard
- Haemoglobin (Hb) local standard
- Health status: donor should be interviewed; haemoglobin and temperature should be checked

Exclude or avoid as far as possible:

- younger sexually active males and females
- women of childbearing age.

Include and prefer:

- older children
- men over 50
- women past the menopause.

10.4.2 Testing blood donors

Donors are tested for ABO and Rh blood groups. They are also tested for transfusion transmissible agents, including HIV, HBsAg, syphilis and malaria (where appropriate).

Transfusion recipients are also tested for their ABO and Rh blood groups.

10.4.3 Crossmatching

Saline room temperature immediate spin method should be done, followed up by an anti-human globulin test, if possible.

10.4.4 Blood collection volume

The local standard should be applied, based on 8% of blood volume.

10.5 Summary

The first choice of therapy for volume replacement in emergencies must always be plasma substitutes and, if necessary, blood from existing transfusion services. Blood from other sources should only be used when absolutely necessary.

Blood transfusion must always be used appropriately and should always be the therapy of last resort, never the first.