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INTEGRATED DEVELOPMENT FOR WATER SUPPLY AND SANITATION

Equipping water testing laboratories

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WHEN PLANNING TO establish water testing laboratories, Government authorities often require handy information with regard to suitable space, equipment, chemicals, capital and recurrent costs, etc. in relation to the intended number of samples to be analysed and type of tests to be carried out. This paper is intended to facilitate the search for relevant advice and gives practical guidelines on the procurement of spare parts as well as main equipment hardware.

Categories

There are two main categories of laboratories:

a) Fixed site laboratories
b) Portable laboratories

Fixed site laboratories

Within the fixed site category there are three sub-categories:

Basic laboratories

This is the lowest level of laboratory which could also be described as peripheral. These laboratories will usually be located in smaller provincial towns or smaller water works and should be equipped only with indispensable, low cost apparatus. However, they should be capable of carrying out all the essential water quality tests and perhaps simple waste water analysis. In addition to the basic physico-chemical parameters (pH, temperature, turbidity, conductivity/TDS, chlorine, smell and colour) the laboratory should be equipped to perform the analysis of total and faecal coliforms. The membrane filtration method is proposed for undertaking these tests due to its simplicity, reliability and the speed with which results of both total and faecal coliforms can be obtained. The basic laboratory may be staffed by only one technician who should be able to analyse six to eight samples per day and carry out all supporting work such as preparing media, sterilising equipment and recording results. The technician(s) should be supervised by regular visits from a microbiologist posted at a laboratory of the next higher category. An inventory of spare parts should be procured at the time of order and normally at 10 per cent of the actual equipment value.

For bacteriological testing a small room of about 20m^2 is sufficient. It should have adequate lighting, proper ventilation and should be reasonably dust proof. Laboratory benches of a total length of 5m (in one or more sections) are the minimum required working space for one technician and for the equipment. The benches should be 90cm high, 60cm deep with drawers and cupboards underneath. For the bench tops, smooth resistant light duty melamine plastic would be adequate.

A sink with 3 taps and ample adjacent draining area is required. Five or six electrical sockets are necessary for the

Table 1A. Basic test variables

Variable	*Method*
Alkalinity	Titrimetric
BOD	Dilution method
Chloride	Titrimetric
Chlorine	DPD colour comparator
Conductivity	Electrometric
Colour	Comparison with glass colour standards
Fluoride	Colour comparator, ion selective/ photometric
Hardness, total	Titrimetric
Jar test	Coagulation / flocculation
Nitrogen, ammonia	Colour comparator / photometric
Nitrogen, nitrate + nitrate	Colour comparator / photometric
Oxygen, dissolved	Winkler method, electrometric
pH	Electrometric / colour comparator
Solids, suspended	Electrometric
Solids, total dissolved	Electrometric
Turbidity	Nephelometric / turbidity tube
Faecal + total coliforms	Membrane filtration method

Table 1B. Major equipment for basic laboratory bacteriological testing

Description
Autoclave, portable
Steriliser
Balance
Hotplate
Incubator
Membrane filter holder
Refrigerator, general purpose
Water bath
Water still
Portable test kit (optional)
Set of miscellaneous glassware
Set of miscellaneous lab ware
Set of bacteriological expendable materials
Set of Spare Parts

Table 1C. Major equipment for basic laboratory chemical testing

Description
Balance, analytical
Balance, rough, sliding mass
Comparator (colorimeter)
Conductivity meter
Hot Plate
Nesslerizer
Oven for heating and drying
pH meter, portable
Refrigerator, general purpose
Stirring device for jar tests, 6 places
Temperature regulator
Turbiditimeter, portable
Water or steam bath
Water still
Portable test kit (optional)
Glassware, chemicals + laboratory sundries
Set of Spare Parts

benches. Gas fittings are not essential. Other recommended furniture includes a small wall mounted lockable cupboard for chemicals and other materials and a small desk with chair and stool. For chemical testing a room of about 25m^2 is required. If a bacteriological laboratory is being set up as well, the two laboratories should be near to each other to facilitate the joint use of certain equipment. They should not be in the same room because chemical fumes may affect bacteriological work.

Table 2A. Expanded list of variables and methods

Variable	*Method*
Alkalinity	Titrimetric
BOD	Dilution or manometric method
Calcium	Titrimetric
$CaCO_3$ stability test	Titrimetric
Chloride	Titrimetric with mercuric nitrate
Chlorine	DPD colour comparator / photometric
COD	Dichromate reflux method
Conductivity / TDS	Electrometric
Colour	Comparison with colour standards
Fluoride	Photometric/ion selective
Hardness, total	Titrimetric
Iron	Photometric/ion selective
Manganese	Photometric/ion selective
Nitrogen, ammonia	Photometric/ion selective
Nitrogen, nitrate	Photometric/ion selective
Nitrogen, nitrate	Photometric/ion selective
Oxygen, dissolved	Electrometric
pH	Electrometric
Phosphate	Photometric
Sodium	Ion selective / photometric
Solids, suspended	Gravimetric
Solids, total dissolved	Gravimetric / electrometric
Sulphate	Turbidimetric
Turbidity	Nephelometric
Faecal + total coliforms	Membrane filtration
Other possible bacteriological parameters	Membrane filtration

Intermediate laboratories

These laboratories are located in provincial capitals or other major municipalities. Size, staff and equipment of these laboratories will be more extensive to cope with a higher work load and there should also be the capability to determine more variables than basic laboratories. This requires some advanced equipment which need not, however, be too sophisticated or costly. The intermediate laboratory should be staffed with one chemist (at least BSc level or equivalent) and one well trained technician, and in addition one or two laboratory attendants are needed. For bacteriological testing a room of about 30m^2 is needed. It should be dust proof and have adequate lighting and ventilation. In addition to the benches there should be a gas supply with gas taps on the smaller type benches. For chemical testing it is recommended to accommodate the laboratory, if possible, in two rooms. The smaller room should house the analytical balance and the electrometric instruments such as the spectrophotometer, turbidity meter, specific ion meter, pH and conductivity meters, etc. As with basic laboratories, intermediate laboratories should always include an inventory of spare parts.

Advanced/central laboratories

At the highest level there should be a central or reference laboratory. It will usually suffice if there is one of this kind in a country, located in the capital. Such a laboratory should be well staffed and equipped and should also possess some sophisticated instruments. Its size and level of performance however, will largely depend on the size and

Table 2B. Major equipment for intermediate laboratory bacteriological testing

Description
Air / filter pump
Autoclave, portable
Balances
Colony counter
Hotplate
Incubator
Membrane filter holders
pH meter, portable
Refrigerator, general purpose
Steriliser, hot air
Water bath
Water still
Water test kit, portable, for field determinations of total and faecal coliforms
Glassware set
Labware set
Bacteriological consumables
Spare parts set

Table 2C. Major equipment for intermediate laboratory chemical testing

Description
Balance, analytical
Balance, rough, sliding mass
Comparator (colorimeter)
Conductivity meter, bench top
Dissolved oxygen meter
Hot plate
Heating bench, 6 places
Oven for heating and drying
pH meter, portable
pH meter, mains operated
Photometer
Refrigerator, general
Specific-ion meter, mains operated with various electrodes
Spectrophotometer, wavelength 325-900nm
Stirrers, magnetic
Stopwatches
Temperature regulator
Turbidimeter
Vacuum / pressure pump
Water or steam bath
Water deioniser
Water still
Portable chemical water analysis kit, complete with chemical
Glassware set
Chemicals set
Spare parts set

needs of the country; economic conditions, availability of trained man power etc. As a reference laboratory the main duty of the central laboratory is to provide guidance for all other water laboratories in the country. Such guidance should include the following:

- Assisting the government in setting national standards for water quality.
- Determining the variables and tests to be performed on routine bacteriological and chemical water samples analysed by the other water laboratories.
- Selecting analytical methods for other water laboratories and to evaluate new ones prior to their application at other laboratories.
- Selecting laboratory equipment, chemicals, consumables and other materials to be purchased for all water laboratories in the country.
- Checking the results and performance of the laboratories through occasional or regular inter-laboratory quality control exercises.
- Offering, whenever needed, in-service training and staff development programmes to the other water laboratories.

The central laboratory should be able to examine water and waste water samples for pollution indicator organisms other than members of the coliform group (i.e. faecal streptococci, clostridium perfringens staphylococci, pseudomonas aeruginosa. It should also be in a position to detect certain pathogenic bacteria (cholera and salmonella) in water, and also viruses.

To be able to fulfil its duties the central water laboratory should have ample space. At least 3 rooms are recommended for bacteriological testing:

1 for routine work;
2 for reference activities;
3 a small one for media preparation.

The laboratory should be headed by a fully qualified and experienced microbiologist and the staff should consist of another microbiologist and a number of well trained technicians according to the work load. For a virological section a specially trained virologist is needed. The chemical testing area also requires ample space. It is recommended that there be 4 rooms for the following purposes:

1 chemical routine analysis of water samples;
2 analysis of organic constituents;
3 applied research, surveys etc.;
4 sensitive electronic instruments and balances.

Rooms 1 and 2 should each have a gas supply and a fume hood. The laboratory should be headed by a fully trained chemist specialising in water chemistry and the staff should consist of another chemist and several well trained technicians depending on the work load.

Reconsidering the equipment for an intermediate laboratory in Tables 2.B and 2.C, the central laboratory should also have some items of a larger size amongst its inventory of autoclaves, hot air steriliser, incubators, water deionisers/ stills, membrane filtration apparatus and refrigerators/ freezers. In addition, a range of microscopes will be required alongside extra glassware, chemicals and laboratory sundries. Other items needed are additional analytical balances, vacuum pumps, jar testing equipment, centrifuges, muffle furnaces, water samplers and electric heating mantles. Two further significant additions are the inclusion of an atomic absorption spectrophotometer (AAS) and a gas chromatograph (GC).

The central laboratory should be able to test water and waste water samples for all physico-chemical variables listed in Table 2.A. It should also have the equipment and expertise for the determination of heavy metals and other inorganic substances of health significance as well as health related organic compounds. As well as a substantial spare parts inventory, the central laboratory should also consider taking out a maintenance contract with the equipment supplier.

Portable laboratories

Portable kits for bacteriological and chemical analysis are widespread in developing countries. These kits are used

whenever certain basic information on water quality is needed that cannot be easily obtained otherwise. This may be the case for surveys in remote areas or the exploration of new water sources far from any laboratory. Such kits can also be employed in fixed site laboratories, since they are usually easier for untrained staff to handle than standard laboratory equipment.

For ease of use the membrane filtration technique is recommended for bacteriological testing since the sample preparation process is simpler and the analysis time is shorter. Media may be in the form of dehydrated powder or prepared ampoules. The advantage of dehydrated media is that it has a longer shelf life and is of a lower cost. Pre-prepared ampoules are however easier to use and this may justify their higher cost. It is important that the portable incubators within the kits have a multi-power facility to be able to run off AC mains electricity, internal rechargeable battery, vehicle dash board and external DC battery. Solar power packs should be available for recharging the internal battery. The incubators should be accurate to plus or minus 0.5°C and should operate at 37°C for total coliforms and 44°C for faecal coliforms. Other parameters may be monitored such as faecal streptococci, pseudomonas etc.

Physico-chemical testing is carried out by the use of simple colour comparators and hand held instruments. The most important tests are pH, temperature, conductivity/TDS and turbidity and free chlorine. In addition the colour and taste of the sample is of importance to the consumer. Other tests may be carried out depending on the local significance i.e. fluorides, nitrates, nitrites, ammonia, etc. A photometer or spectrophotometer housed within the carrying case of the portable water testing kit should allow up to 40 such parameters to be analysed.

Depending on the sophistication of the monitoring programme heavy and trace metals can be analysed in the field, since many heavy metals with health significance have been found in waters used for public supply, especially in countries with increasing industrialisation. Portable heavy metals analysers are also ideal for use within the fixed laboratory. Guideline values have been set by WHO for arsenic, cadmium, chromium, lead, mercury and selenium. Aluminium, copper and zinc have a much lower toxicity and are therefore not of primary health significance but their concentration is sometimes of interest.

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