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Aspects of field testing of water

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This paper describes some field techniques available for water testing in developing countries. It concentrates on the bacteriological testing of water for faecal coliform organisms and possible ways of reducing costs. Short descriptions of chemical and physical tests follow a discussion of water quality guidelines.

1. Water Quality Guidelines

Basic requirements for drinking water quality are:

1) Absence of pathogenic (disease causing) organisms
2) Absence of compounds that have an adverse effect, acute or in the long term, on human health.
3) Clarity (i.e. low turbidity, little colour)
4) Total dissolved solids below 3000 mg/l
5) Absence of compounds that cause an offensive smell or taste.
6) Freedom from tainting of food cooked in it, staining of clothes washed in it, or corrosion or encrustation of the water supply system.

The World Health Organisation recently published their Guidelines for Drinking Water Quality which outlines in great detail their latest advice and recommendations for water quality criteria. (WHO, 1982).

This paper is not the place to discuss the validity or values of water quality criteria, but if progress in improving quality is to be made, a pragmatic approach to the latest recommendations is essential. It should be determined by each country and each district based on routine survey data e.g. at least 5-10 consecutive weekly samples.

Table 1 gives some suggestions on bacteriological criteria.*

1. Chlorinated samples post treatment collected from distribution system.

A) at least 80% of samples taken over a 12 month period should have a zero *E. Coli* count per 100 ml.

and b) The *E. coli* should never exceed 10 per 100 ml.

If guidelines are not met, a sanitary survey should investigate and rectify the cause of contamination.

B) Unchlorinated water sources eg hand pumps, wells, springs, gravity flow systems, etc.

Mean Count** *E. Coli*	Comment
0	Excellent
1-10	ACCEPTABLE but regular sanitary and O & M checks needed.
10-100	UNACCEPTABLE Corrective action needed quickly, repair, rectify and disinfect.
More than 100	More than 100 GROSS POLLUTION. Look for better source or disinfect.

**E. Coli* detected by incubation at 44°C by membrane filtration with appropriate media.
** At least 10 consecutive weekly samples.

2. Bacteriological Testing

Pathogens are not normally looked for when examining water samples for pollution because it is not practically possible. The testing procedure for pathogens is complex and takes several days. The pathogens themselves may only be present occasionally in the water although pollution by faecal material might be occurring continuously. So the normal procedures determine if the water is polluted by faecal material. This means the determination of the presence or absence of types of bacteria which are ALWAYS present in the excreta and intestines of man and other warm blooded mammals (such as sheep, cows, pigs, poultry etc) and whose presence therefore INDICATES faecal pollution.

FAECAL INDICATOR ORGANISMS	
ABSENT	PRESENT
⇩	⇩
PATHOGENS PROBABLY ABSENT	PATHOGENS MAY BE PRESENT

Fig.1. Rationale for use of indicator organisms.

The most commonly used indicator organism for

field surveillance of the bacterial quality of water is Escherichia Coli (or E. Coli for short) which have the ability to ferment lactose at 44°C. Other organisms in the coliform group able to ferment lactose at 37°C but not at 44°C occur in faeces but also in the soil naturally and are not definite for faecal pollution. Small numbers of the coliform group of organisms 1-10 per 100 ml may not be necessarily of sanitary significance.

Incubation at 44°C provides the most direct route to detecting faecal coliform in drinking water.

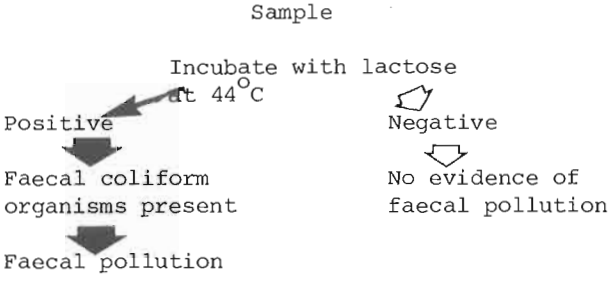

Fig.2 Faecal coliform organism determination

2.2 Aseptic procedures

In many cases we are looking for very low levels of indicator bacteria perhaps only 1 or 2 per 100 ml of sample, it is important that the sample or testing apparatus must not be contaminated by careless handling.

At this point a timely reminder of the numbers of organisms excreted into the environment from various sources will not be amiss.

Table 2 (based on Mara, 1974)

Animal	Average wet wt. faeces g/day	Estimated no. faecal coliform organism per capita per day
Man	150	2000×10^6
Sheep	1130	18000×10^6
Cow	23600	5400×10^6
Pig	2700	8900×10^6

So before we analyse our water sample we need:

1. Clean the dust and draught free working area
2. Wash our hands
3. Use only media, diluting fluids and equipment known to be sterile
4. Avoid touching any part of a container, petri dish, pipette etc which will come in contact with our sample.
5. Only open sterile packs or petri dishes for as short a time as possible.
6. Use disinfecting cloths with self indicating strips for both preparing the working area and cleaning hands before and after testing.
7. Use a small gas torch or burner for sterilizing taps, forceps and stainless steel apparatus.

2.3 Sampling

Sampling for representativeness is an art. A saying among analysts is "the analysis is only as good as the sample". It is extremely difficult to obtain representative samples and it is very easy to contaminate samples during sampling.

Where several samples are being taken for water quality testing at the same location, the sample for bacteriological examination must be collected first to avoid danger of contamination of the sampling point.

Samples for bacteriological analysis must only be collected in sterile containers.

In tropical areas where schistosomiasis (bilharziasis) is endemic the sampler should be aware of the dangers of exposing himself to the water.

The reader is referred to standard texts such as APHA (1980) and WHO (1976) for details on sampling frequency and methods.

2.4 Methods

There are two main procedures for the detection and counting of indicator organisms:

A. The membrane filtration technique
B. The multiple tube fermentation technique (MPN method)

For field work only the membrane filtration method will be discussed.

Several researchers are investigating various ways of making bacteriological testing cheaper and hence more widely available; a listing of new developments may be helpful. Most equipment has to be sterilizable in an autoclave or pressure cooker.

A. Filtration units

Stainless steel types from Millipore, Sartorius or Gallenkamp cost £30 to £210. Millipore plastic (disposable) type cost £25.

B. 2-way Vacuum Pump Plastic

Millipore £12. Mitivac £23.

C. Resterilizable plastic, glass or metal petri dishes

Glass Pyrex £20 for 10
Metal Oxoid Co £2.50 for 10

Plastic disposable* Millipore £11 for 100
+ absorbent pads Millipore £14 for 100

* but can be re-used, see Mara (1974)

D. Selective Growth Media

Sterile ampoules (Millipore) MFC broth 24 x 2 ml £15 store in refrigerator

Prepared dehydrated McConkey MFC membrane broth is available from Oxoid or Millipore for making your own media. £15 for 100 g.

E. Membrane filters

Often the most costly item. Individually wrapped and made with cellulose acetate esters with grid markings and controlled pose size of 0.45 µm are manufactured by Millipore, NEERI, Sartorius, Oxoid, Nuclepore and Gelman. Prices are around £25 for 100. Oxoid Nuflow filters are possibly reusable (Cheesbrough, 1984) but I prefer to open a new one especially under field conditions

F. Diluted water

Now easily prepared by using Millex filters and large syringes.

G. Incubators

The most costly item for bacteriology is the incubator. In most developing countries the electrical power supply is unreliable with frequent cuts and fluctuations in voltage and frequency. This unreliability is often the cause of early failure of water works and pumping equipment. For proper incubation of faecal coliform organisms at 44°C it is preferable to use a laboratory incubator.

Laboratory incubators can be bought for around £140. For field work a battery powered portable incubator is recommended. However the price of these is high, £1300 for a Milli-pore battery/mains portable incubator. Although this instrument is an excellent performer its cost is prohibitive for most situations.

At Loughborough we are experimenting with the production of a battery-powered incubator capable of incubating 12 petri dishes at 44°C or 37°C. The material costs are less than £100. The most expensive items are the Plati-num wire contact thermometers at £18 each and the 12V motor and fan at £10. The latest results of this device will be presented in Singapore.

H. Transport Media

In most parts of the world it is possible to bring samples to a laboratory in an ice box within 24 hours. However in remote locations it may be advisable to filter the sample as normal and place the filter onto an absorbent pad saturated with "transport media" and sealed in a petri dish. The filter is transferred to a pad saturated with the MFC broth on arrival at the base laboratory and incubated for the normal times at 44°C.

The algorithm (Fig. 3) shows the possible choice of procedures (from Hutton, 1983).

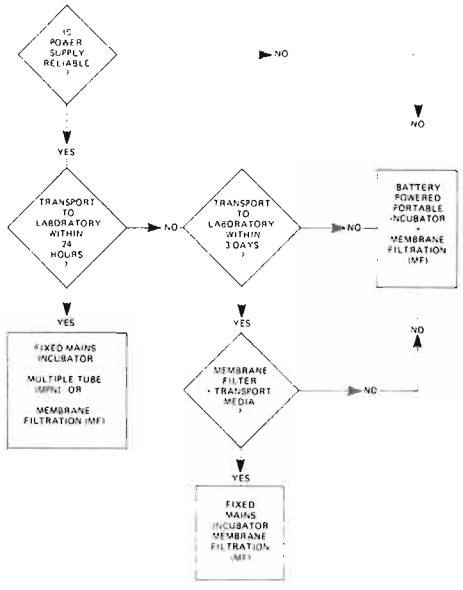

Fig. 3 Algorithm for choice of procedures for bacteriological testing of water in developing countries

2.5 Negative bacteria testing = positive chlorine testing

When chlorination is carried out the most important parameter to be determined is the free residual chlorine content. If we find free residual chlorine in a sample we can assume that, provided sufficient contact time between chlorine and the water has passe passed, the water will be bacteriologically SAFE, at the point when and where the sample is taken. This is no guarantee that contamination is not occurring elsewhere in the distribution system. A small amount of free residual chlorine 0.2-0.5 mg/l is unlikely to be strong enough to kill any bacteria invading via leaks or cross connection.

The method used currently employs the property of D.P.D. (Diethy-para-phenylene diamine) to turn pink in the presence of free chlorine. (See Figure 4)

Chlorinated water sample	+ DPD
Pink colour	no colour change
Chlorine present and	no free chlorine
Bacteria probably	possible pollution
absent	possible pathogens

Fig. 4. Positive chlorine = negative bacteria

2.6 Summary

The costs of bacteriological testing can be reduced by appropriate selection of materials and techniques but are still often prohibitive.

3. Chemical Analysis

Chemical analysis of water samples is rapid compared with bacteriological analysis and also detects pollution not caused or reflected by organisms. Many parameters of water quality such as nitrates, nitrites, dissolved oxygen, chlorine, iron, carbon dioxide, alkalinity and acidity change on transportation to a laboratory and field tests can overcome the need for preservation of samples prior to laboratory analysis. A comparison of field and laboratory determinations is made in Table 3.

FIELD	LABORATORY
Requires less skilled personnel	Requires skilled personnel
More immediate results and possible action	Loses immediacy - urgency and can be lost
Not always as accurate	Can be highly accurate
Portable	Not always portable
Equipment can be used in field and laboratory	Usually only laboratory
Cheaper to operate	Overheads can be high
No need for preservation	Sophisticated preservation often necessary.
Limits of detection sometimes above guideline values	Low limits of detection
Easily repeated	Costly to repeat
Simple sampling	Often requires multiple samples

There are several techniques used in field chemical analysis based on colour reactions, titrations and electrodes. Hutton, (1983) describes these field tests in detail.

Most notable developments include:

1. Merckoquant test strips for nitrate, nitrite and sulphate
2. Hach and Lovibond colorimetric tests using comparators for many parameters
3. The Hach digital titrator for field titrations of alkalinity, HCO_3^-, CO_3^{--}, CO_2, O_2, Cl^-, Ca^{++}, Mg^{++}
4. Specific ion electrodes for Fluoride and dissolved oxygen.
5. Field atomic absorption spectrophotometer for trace metals (The cost £26,000).

4. Physical Analysis

A visual and nasal examination of a sample in a clean glass can indicate purity, clarity, colour, smell, and iron and manganese.

pH can be measured with paper strips, colour reagents or dipstick probes.

There are now portable instruments for turbidity, pH, eH, conductivity, dissolved oxygen and several other parameters.

5. Concluding Remarks

There is a very wide choice of techniques and equipment for field testing of water and the field worker needs to check what is available to do the tests to the accuracy described. More are being developed and the user should choose equipment which can be used for more than one application.

References

APHA, 1980 Standard methods for the examination of Water and Wastewater, 15th Ed., New York, APHA/AWWA/WPCF

Cheesbrough, M 1984 Medical Laboratory Manual for Tropical Countries, Vol II, Bacteriology Tropical Health Technology Ltd., Doddington, UK

Hutton, L.G. 1983 Field Testing of Water in Developing Countries, Water Research Centre, Medmenham, UK.

Mara, D.D. 1974 Bacteriology for Sanitary Engineers Churchill Livingstone, London.

WHO, 1976 Surveillance of Drinking Water, WHO Monograph No. 63, Geneva.

WHO, 1982 WHO Guidelines for Drinking Water Quality, Volumes 1-3, EPF/8239 WHO, Geneva.