Oxfam

Water quality analysis in emergency situations

Water quality analysis is required in emergency situations to determine whether water is safe to drink. People who are traumatised by an emergency event and in poor health are particularly vulnerable to water related diseases including those which are spread through the drinking of poor quality water.

In the initial phases of an emergency it should be assumed that all water sources are contaminated microbiologically and when water is supplied to people in camp situations, chlorination and the testing of chlorine residual should always be undertaken. For water with a low turbidity, chlorination is reasonably simple, but for water with a high turbidity, a pre-treatment process will be required to reduce the turbidity levels to <5TU prior to chlorination. After the initial phase of the emergency is over, investigation can then be undertaken into the microbiological, and where appropriate, the chemical constituents of the water.

This Technical Brief outlines the usual testing regime as recommended for use by OXFAM staff in emergency situations. It focuses on what is realistic during the various stages of an emergency, whilst also ensuring that water is safe for the affected populations. It looks at microbiological, physical and chemical testing parameters. It does not replace the water testing kit instruction materials but is complementary and they should be read together.

The purpose of water quality analysis

Pathogens such as bacteria, virus', ova and cysts, can be ingested through drinking water. Water which looks clear may still be microbiologically contaminated or have chemical contaminants which are dangerous to health, such as arsenic or high levels of nitrates or nitrites.

The biggest risk to life in an emergency situation is microbiological contamination as diarrhoeal diseases can spread rapidly in environments where large numbers of people are living in poor conditions and in close proximity. In the initial stages of an emergency, focus should be on providing an adequate quantity of water and then on good quality water microbiologically. In the initial stages of an emergency, it should be assumed that all water is contaminated and will require chlorination, particularly for piped supplies. After the initial stage is over, it is then appropriate to test the water microbiologically and also to look at other parameters of health significance or which could cause problems due to adverse colour, taste, or staining, if it is felt that they may be a significant problem.

Focus on quantity and microbiological contaminants

WHO (2004, p109) notes that '*Many chemicals in drinking-water are of concern only after extended periods of exposure. Thus, to reduce the risk of outbreaks of waterborne and water-washed e.g. trachoma, scabies, skin infections) disease, it is preferable to supply water in an emergency, even if it significantly exceeds the guideline values for some chemical parameters, rather than restrict access to water, provided water can be treated to kill pathogens and can be supplied rapidly to the affected population*'.

Which parameters need testing in an emergency and when?

	Initial phase of emergency	Post initial emergency phase
Faecal coliform	Not unless there is a diarrhoea outbreak – assume all water is contaminated and chlorinate all supplies provided through a tap. Chlorinate open wells.	Yes, test initially after 1 month. Then test monthly. Only if there are outbreaks of diarrhoeal disease will there be a need to re-test at other times to identify if the water is the problem, or to eliminate water quality as the cause.
Turbidity	Yes if chlorinating – should be <5TU	Yes if chlorinating – should be <5TU
pH	Yes if chlorinating, if pH >8.0 then the retention time for contact before supply should be increased	Yes if chlorinating, if pH >8.0 then the retention time for contact before supply should be increased
Chlorine residual	Yes when chlorinating	Yes when chlorinating

Chemical parameters, such as arsenic, fluoride, chloride, TDS/conductivity, iron, manganese, nitrate, nitrite, aluminium or zinc, would usually only be tested after the initial phase of an emergency and then only when a specific problem is suspected through local knowledge, catchment mapping, or sanitary survey.

Sanitary survey which identifies the contamination risks should be one of the key tools for determining if water quality analysis is required during the intermediary periods.

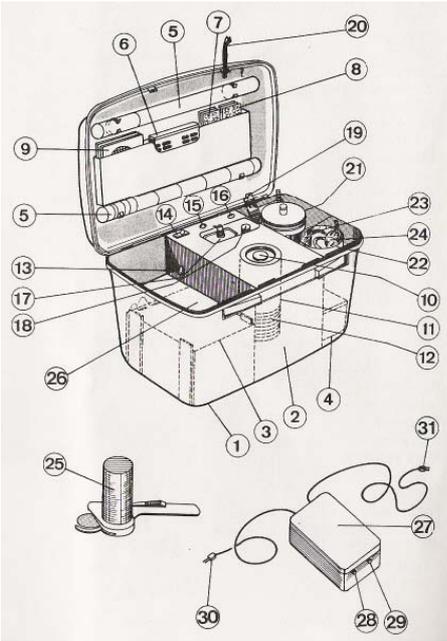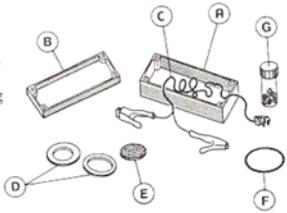| Minimum frequency of sampling and analysis of small community water supplies – under non-epidemic conditions (WHO Fact Sheet 2.29)		
Source / supply	Bateriological	Physical / chemical
Open wells	Once monthly	Once monthly
Covered dug wells tubewells with handpumps	Twice yearly	Twice yearly
Springs and piped sources	Twice yearly	Twice yearly
Rainwater collection systems	Once yearly	Once yearly

Classification vs degree of health concern (Wisner & Adams, 2002)	
0 E.coli / 100ml	Guideline compliant
1-10	Tolerable
10-100	Requires treatment
>100	Unsuitable without proper treatment

Microbiological testing

The degree of microbiological contamination of water is usually measured by identifying the quantity of faecal (or thermotolerant) coliform in 100ml of water. Faecal coliform live in human or animal intestines and hence when identified provide an indication that there may be pathogens present in the water. The most common of the faecal coliforms which is tested for using the membrane filtration method is the *E.coli*.

Most common broth types for use with the Membrane Filtration method

1. Membrane Lauryl Sulphate Broth – thermotolerant / faecal coliforms produce a colour change from red to yellow on formation of the colonies. When using the MLSB broth, the larger yellow colonies are usually *E.coli*.

2. MFC broth comes in 2ml pre-packaged ampoules — these **must** be kept in a refrigerator – faecal coliform produce blue colonies.

Delagua water testing kit

Water Testing Kit
1. Case
2. Incubator
3. Battery
4. Spares Case
5. Turbidity Tubes (pair)
6. Chlorine and pH Comparator
7. Chlorine Test Tablets
8. pH Test Tablets
9. Membrane Filters
10. Incubator Lid
11. Incubator Pot
12. Petri Dishes
13. Power Socket
14. On/Off Switch
15. Power 'On' Indicator
16. Heater 'On' Indicator
17. Methanol Dispenser
18. Culture Medium Bottle
19. Lighter
20. Tweezers
21. Filtration Assembly with Sample Cup
22. Vacuum Cup
23. Sample Cable
24. Vacuum Pump
25. Absorbent Pad Dispenser
26. Storage Space

Charger Unit
27. Battery Charger/Mains Power Unit
28. Power 'On' Indicator
29. Charged battery Indicator
30. Incubator Plug
31. Mains Supply Plug

Filtration Apparatus and Components
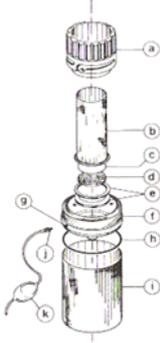
a. Plastic Collar
b. Funnel
c. Membrane Filter
d. Bronze Disc
e. Silicone Rings (pair)
f. Aluminium Base
g. Vacuum Connection
h. Black Rubber O-Ring
i. Vacuum Cup
j. Vacuum Pump Connector
k. Vacuum Pump

Contents of the Spares Case

A. Base
B. Lid
C. External Battery Connection Cable
D. Silicone Rings (pair)
E. Bronze Disc
F. Black Rubber O-Ring
G. Silicone Grease

Testing of faecal coliform in water which has been treated with chlorine

If a water supply has been treated with chlorine, after a contact time of 30 minutes (for a pH<8), a turbidity of <5TU and the residual free chlorine is greater than 0.2mg/l, then it is highly unlikely that the sample will contain thermotolerant (faecal) coliform bacteria and hence analysis is usually not necessary.

However on occasions it may be appropriate to test the chlorinated supply, for example to dispel concerns over the effectiveness of the treatment process by the users, or when the results are not within the above limits.

When testing water that has been chlorinated, the following apply:

1. It is essential that the sample cup is totally sterile as the numbers of resultant bacteria may be very low.

2. *'Resuscitation time is particularly important for chlorinated waters or marine water where the thermotolerant (faecal) coliform bacteria are 'stressed' due to environmental exposure. For these types of waters it is beneficial to leave processed membranes for 4 hours after the last sample has been processed before switching on the incubator'* (OXFAM Delagua Users Manual, 1993).

Preparing for microbiological testing in the field

Purchasing the remaining items of equipment:

Even if the team has brought a full Delagua kit and associated consumables with them to the field, there will still be a need for a few items to be purchased locally. As soon as the logistics team are up and running ask them to procure:

1. 100ml of methanol – usually this will be found in a hospital laboratory if it is not possible to procure it in local chemist shops. Methanol cannot be carried in an aircraft unless it is specially packaged as it is flammable, so this poses problems for travel with a full kit in-country when flights are required.

2. A small pressure cooker.

3. A box of 2ml and 5ml syringes (without the needles if possible) – these are useful items to have available for dilutions, preparing the media and also for undertaking jar tests if chemical coagulation is needed.

4. A permanent marker pen, masking tape (if autoclave tape is not available), sealable plastic bags and a packet of tissues or antiseptic wipes.

Other preparations:

1. Make sure that the instruction manual is available.

2. Check the function of the charging unit and charge the Delagua kit up to full charge.

3. Check the temperature of the incubator using the thermometer and adjust as necessary.

4. Sterilise the equipment and media – see below.

Field tips for sterilisation using the Delagua kit

Sterilisation of Petri dishes:

The metal Petri dishes can be sterilised in the field in the following ways:

1. Use a pressure cooker – these can usually be purchased locally in most big cities and towns.

2. Boil the metal dishes in a saucepan of water. Care must be taken when removing them from the water and storing them for use. Use sterilised tweezers and place the Petri dishes on a sterilised surface before putting into a sealable bag and taping with masking tape to ensure they remain sealed until use.

Sterilising the MFC broth:

1. Prepare the broth and sterilise the bottles at full pressure for about 15 mins. The bottles should not touch the bottom of the pressure cooker and should be supported vertically throughout. The lids should only be loosely tightened.

2. If no pressure cooker is available then place the bottles of medium in a cooking pan of boiling water, making sure that they do not come into contact with the bottom of the pan and remain vertical throughout, and boil for 20 minutes.

Preparing the sample cup and filter funnel:

1. Follow the instructions for sterilising the sample cup and filter funnel by lighting methanol and inverting the filter funnel into the sample cup and leaving for 15 minutes.

2. If methanol is not available then immerse the filtration apparatus and sample cup in boiling water for 5 minutes.

3. If methanol is not available, or there is not enough time to leave between samples to use the methods of sterilisation, then subsequent samples can be tested if the filter funnel and the sample cup are thoroughly washed in the water of the new sample, several times. The first sample must be the sample which is expected to have the least amount of contamination and the subsequent samples expected to have increasing levels of contamination. **This method should be used only as a last resort**.

Microbiological testing – alternative kits

The OXFAM Delagua Kit as designed by the Robens Institute at the University of Surrey which uses the membrane filtration method, is still the most widely used equipment and method, but still has a number of constraints. There are also a number of alternative methods currently on the market, but none have so far have exceeded the membrane filtration method in terms of the provision of useful results. Three of the currently available alternative methodologies are identified in the table below and compared against the membrane filtration methodology. Samples are also shown in the photo below.

Humanitarian and development organisations are still waiting for a simple kit to be developed, which would identify the degree of faecal pollution with a simple, cheap and easy to learn methodology.

(l-r) Colilert test tubes and fluorescent light; H_2S strips; Dipslides

Table - Comparison of microbiological test kit types

Kit type	Positive attributes	Negative attributes
Membrane filtration (Uses *E.coli* / thermotolerant / faecal coliform as an indicator)	Can be used to determine the actual number of faecal coliform per 100ml *E.coli* is currently considered the *'most suitable indicator of faecal pollution'. In most circumstances thermotolerant coliform are mostly comprised of E.coli and hence [thermotolerant coliform] is considered a less reliable but acceptable index of faecal pollution'* (WHO, 2004). Can test either faecal coliforms (at 44°C) or total coliform (at 37°C)	Lengthy process to prepare MLSB media (pre-prepared MFC media in tubes is simpler, but needs to be stored at a specified temperature) Equipment needs to be sterilised - many risks to contaminate the equipment and sample It is not a suitable test for turbid water Training and practice are required to undertake the test and interpret the results Requires an incubator and hence a power source *E.coli* / thermotolerant bacteria are less resistant to chlorine than pathogenic virus' and protozoal cysts and oocysts and *'there is some evidence that coliforms, possibly including E.coli, can proliferate in tropical and sub-tropical waters'* (Sobsey and Pfaender, no date).
H₂S strips (Uses the production of Hydrogen Sulphide by enteric bacteria as an indicator)	Small and cheap Simple to undertake and does not need much training Sterilisation is not necessary P/A testing *'is appropriate only in a system where the majority of tests for indicators [faecal coliform] provide negative results'* (WHO, 2004, p72)	It is a presence / absence test and provides only positive or negative results – even 1 faecal coliform will provide a positive result Reasonable quality water (< 10 faecal coliform) may be rejected inappropriately Can also provide a positive result from non-faecal bacteria and from sulphides already present in ground water - the problem is the risk of more positive results than more negative, but this can lead to water being rejected inappropriately *'There remain too many uncertainties about the reliability, specificity and sensitivity of the test for detecting faecal contamination of drinking water and its sources'* (Sobsey and Pfaender, no date). They recommend however that it can be used when the alternative is no testing at all if it is used with caution and for educational and motivational purposes.
Colilert tubes and fluorescent light (Uses Coliphages as an indicator, which are Bacteriophages or virus' which use bacteria as hosts for replication, in this case *E.coli*)	Can be incubated at 37°C Simple to undertake and does not need much training Sterilisation is not necessary, although sterile water is required for determining quantities of *E.coli* >16 / 100ml Coliphages model the behaviour of enteric virus' in water and in response to disinfection better than *E.coli* and hence are a better indicator of their presence (WHO, 2004).	Uses the 'Most Probable Number' method – it is expensive as large numbers of consumable needed Requires an incubator and hence a power source (except if incubated against the body) 'White powder' in tubes – may cause problems for international travellers A 5 tube test will only indicate up to >16 per 100ml - to determine higher levels, dilution is required with sterile water The absence of Coliphages does not confirm the absence of enteric virus' or protozoa (WHO, 2004). WHO (2004, p291) notes that due to some conflicting data, that at this present time they are *'not suitable for operational or verification (including surveillance) monitoring'.*
Dipslides (Uses *E.coli* / thermotolerant / faecal coliform as an indicator)	Easy to use with limited risks to contamination Simple to undertake and does not need much training Sterilisation is not necessary Can test either faecal coliforms (at 44°C) or total coliform (at 37°C)	Expensive - high number of consumables Only one ml tested at a time, so if 1 faecal coliform is found this will indicate 100 / 100ml, and intermediary figures (between 0 to 100 / 100ml) are not possible to determine Requires an incubator and hence a power source Dipslides need to be stored in a refrigerator (0-2°C)

Chemical testing

Table - Chemical parameter water quality testing as recommended by OXFAM-GB

Parameter	Kit (consumables for 50 tests)	Range	WHO guideline 3rd Edn, 2004	Comment by WHO, but no guideline value given	Comments
	Standard comparator kit PT520T				
	De-oinisation bag PT500	Makes approx 5 litres of deionised water			
Aluminium	Comparator disc CD 166 kit	0 – 0.5 mg/l	**0.2 mg/l** (aesthetic criteria, but will possible health risks with long term exposure)		
Arsenic	See the 'Further information' list on the final page		**0.01 mg/l** (health – long term exposure)		
Chloride	Comparator PK079 kit (250 tablets)	0-1000 mg/l	Not of health concern at levels in drinking water	**250 mg/l** (possible taste threshold)	
Fluoride	Comparator disc CD 179 kit	0-1.5 mg/l	**1.5 mg/l** (health – long term exposure)		
Iron	Comparator disc CD 292 kit	0-5 mg/l (medium range)	Not of health concern at levels in drinking water	**0.3 mg/l** (taste, staining)	
Manganese	Comparator disc CD 173 kit	0-0.03 mg/l	**0.4 mg/l** (health) & comment – lower values may affect taste, staining	**0.05-0.1mg/l** (taste, colour, black deposits)	Dilution will be required to be able to reach the WHO g/l
Nitrate	Comparator disc CD 163 kit (200 tests)	0-20 mg/l as N	**11 mg/l as N** which is the same as **50 mg/l as NO₃⁻** (health – short term exposure)		
Nitrite	Comparator disc CD 109 kit	0-0.5 mg/l as N	**0.9 mg/l as N** which is the same as **3 mg/l as NO₂⁻** (health – short term exposure) **0.2 mg/l as NO₂⁻** (health – long term exposure)		Dilution will be required to be able to reach the WHO g/l level
Sulphide	Comparator disc CD 168 kit	0-5 mg/l	No value given		
Total Dissolved Solids (or Conductivity)	LR TDS sensor PT152 LR Conductivity sensor PT159	10 – 1990 ppm 10 – 1990 µS/cm	No health based guideline	**TDS: 1,000 mg/l** (objectionable taste) (Conduct: approx equiv, 1,400 µS/cm)	
Calibration / buffer solution	Standard conductivity / TDS solution (mid-range) PT142/3				
Zinc	Comparator disc CD 148 kit	0-4.0 mg/l	Not of health concern at levels in drinking water	**3 mg/l** (taste)	

OXFAM's recommended kits for chemical testing

Comparator kit with discs and tablets

Tablet count kits e.g. chloride
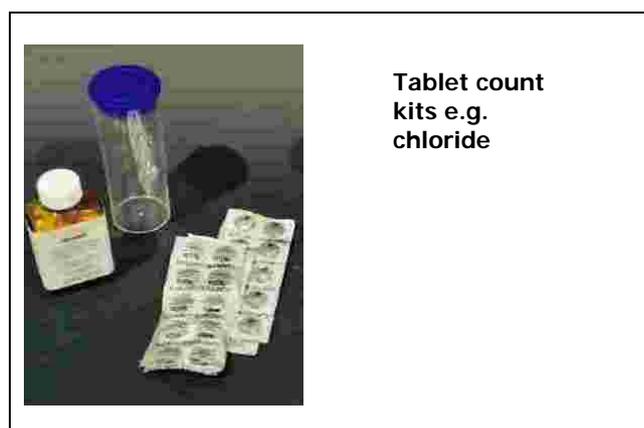
Chemical and physical testing – Alternative kits

An electronic photometer is an alternative to the individual coloured discs and comparator. The method of preparation of the sample is similar, but the resulting solution is read electronically. A wide range of chemical parameters can be tested with the photometer by buying the appropriate reagents.

Photometer – a range of different photometers are available

Additional useful items of kit

The Palintest deionisation bag is a useful addition to both the chemical and microbiological test kits as deionised water can be easily prepared when it is difficult to obtain deionised or distilled water in the field.

Palintest deionisation bag – makes around 5 litre of deionised water – useful for preparing dilution water or making MLSB broth

Useful items 1 litre measuring jug, permanent marker pen, 1ml / 2ml and 5ml syringes, antiseptic wipes / tissues, autoclaveable sample bottles

A range of other small items can also help the field testing: 1 litre jugs are useful for making dilutions, for preparing the broth for microbiological testing; a permanent marker pen for marking the metal dishes; syringes for preparing the media for the microbiological testing and making dilutions; tissues or antiseptic wipes for keeping the working environment clean; sealable plastic bags for keeping the sterilised metal dishes; autoclave tape to indicate when the metal dishes are sterilised to a high enough temperature; and autoclaveable (polypropylene) sample bottles or 'twirl em' sterile plastic sample bags, for use to take and transport samples when it is not possible to undertake testing immediately in the field.

When chemical parameters should be tested

Arsenic, Fluoride, Iron, Manganese	Test when these parameters are known to be a problem in the area. Red staining may indicate iron, black deposits may indicate manganese and mottling of teeth in the local population may indicate fluoride.
Nitrate, nitrites	Test groundwater when nitrates or nitrites are suspected to be a problem.
TDS or Conductivity, Chlorides	Test when 'salty' water may pose a problem for consumer acceptability. Deep boreholes in arid and semi-arid areas may have particular problems with high salt levels.
Aluminium and zinc	Test for aluminium when using aluminium sulphate a coagulant and test zinc when providing water from rainwater harvesting when the roofing material is corrugated zinc sheets.
Other chemical parameters	Should be considered when there are particular risks identified in an area through sanitary survey or catchment mapping, such as risks from mining or industrial effluents.

Chemical parameters – guideline notes

The following guideline values are based on the WHO, 2004, 3rd Edn Guidelines for Drinking Water Quality, Volume 1, Recommendations.

Aluminium

Aluminium is an element that is present in all natural waters and is the third most common element in the earth's crust. Aluminium slats such as aluminium sulphate are also used as coagulants. It has been posed that a higher concentration of aluminium residual in drinking water might have an association to the development of Alzheimer's disease when the water is consumed over the longer term. High residuals can also result in colour and turbidity formation. **WHO guideline figure (based on aesthetic levels, but may also have health implications with long term use) for allowable residual aluminium, is 0.2 mg/l for small water treatment works**

Arsenic

Arsenic is a contaminant which can cause cancer when consumed over long periods of time through drinking water. It occurs through out the earth's crust in the form of arsenic sulphides, metal arsenates and arsenides. In water it commonly occurs as metal arsenate and arsenides and levels in natural waters are usually between 1 and 2 µg/l. Arsenic can be introduced into water through the dissolution of rocks, minerals and ores (up to values of 12 mg/l) and from industrial effluents including mining wastes. **WHO guideline value (health) for arsenic is 0.01mg/l**.

Chloride

Chlorides occur in nature as different types of salts such as Sodium Chloride, Potassium Chloride, and Calcium Chloride. Chlorides can occur in nature and from saline intrusion, but chlorides are also concentrated in human and animal urine and therefore pollution of surface water by sewage waste can increase the chloride content of the surface water. Chlorides with sodium cations have a detectable salty taste, but if combined with the cation calcium or manganese, the salty taste might not be apparent even up to higher level of chloride as high as 1000mg/l. Increased level of chlorides in water increase its corrosivity and hence an increase in the levels of metal in the water. **WHO (2004, 3rd Edn) does not provide a health based guideline figure for chloride**, **but notes that there may be a detectable taste above 250 mg/l**. Note that some users in dry-land, arid and semi-arid areas in particular, sometimes drink much higher levels than 250 mg/l. The acceptability will depend very much on what level the person is used to drinking.

Fluoride

Fluorides are compounds of the element fluorine which does not occur in its elemental state because it is highly reactive. Fluoride traces are present in water, mainly in waters associated with ground water sources. The usual levels occurring naturally are below 10mg/l, but levels of up to 2,800 mg/l have been found. In lower concentrations, it causes staining of teeth (mild dental flourosis has been found to occur in some cases between 0.9 – 1.2 mg/l depending on intake), and at higher levels it can cause deformities of the bones in adults and at old age. **WHO allowable guideline value (health – long term consumption) for Fluoride is 1.5 mg/l.**

Note that countries sometimes have their own standards for fluoride, often higher than the WHO guidelines.

Iron

Iron is a metal that exits in nature abundantly (the second most abundant) and is found in natural fresh waters at levels between 0.5-50 mg/l. It mostly exists in nature in the form of oxides. Iron occurs in anaerobic ground waters at different concentrations. Higher concentrations of iron in water cause a noticeable (disagreeable) taste and staining and discoloration of pipes and pipe-fittings. **WHO (2004, 3rd Edn) does not provide a health based guideline for iron but notes that due to staining and taste**, **users may find water unacceptable when iron is above 0.3 mg/l.**

Manganese

Manganese is an element that occurs naturally and is found in rock, soil, water and food. Levels in fresh water usually range from 1 to 200 µg/l but can be as high as 10 mg/l in acidic groundwater. It usually occurs together with iron. Surface waters do not usually contain manganese, because the oxygen in the water oxidises the manganese and settles down as sediments. Higher concentration of manganese in water causes black-brown staining of pipes and pipe fittings and creates an objectionable taste for drinking. **WHO allowable guideline figure of manganese (health based) in water is 0.4 mg/l**, **but it notes that lower levels,** **from 0.1 mg/l may cause users to reject water because of taste and staining**.

Nitrate & Nitrite

Nitrate and Nitrite occur naturally as ions as parts of Nitrogen Cycle. Concentrations of nitrate and nitrite can also be high in water as a result of contamination from agricultural run-off (fertilisers), run off from refuse dumps, and contamination of water with human and animal wastes. The main risk from nitrate and nitrites is methaemoglobinaemia or 'blue-baby' syndrome, to which babies under 0.5-1 year are more prone. **WHO guideline figures (health – short term use) for Nitrate is 11mg/l as N (50 mg/l as NO_3^-), and for Nitrite it is 0.9 mg/l as N (3 mg/l as NO_2^-) for short term use, and 0.2mg/l as NO_2^- for long-term use.**

Zinc

Zinc is an element that occurs in almost all rocks in small amounts. In surface and ground waters it exits in small concentrations, usually less than 0.01 – 0.05 mg/l. The concentration of zinc in water can increase as a result of leaching from pipes and pipe fittings and from zinc corrugated sheeting used for roofing. **There is no health based WHO (2004, 3rd Edn) guideline level for zinc in water, but WHO notes that people may reject water due to the taste at levels of 3mg/l or above.**

Further information

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Wisner, B & Adams, J (2002) Environmental health in emergencies and disasters, A practical guide, WHO

WHO (1993, 2nd Edn.) Guidelines for drinking-water quality, Vol 2 – Health criteria and other supporting information, and Vol 3 – Drinking-water quality control in small community supplies

WHO (2004, 3rd Edn.) Guidelines for drinking-water quality, Volume 1, Recommendations

www.who.org

www.palitest.com

Suppliers of arsenic test kits which can measure down to the WHO guideline of 0.01mg/l or lower:

OXFAM – TB3 (V1)

1. VWR -
   http://uk.vwr.com/app/search/Search?en_GB_go
2. Wagtech – www.wagtech.co.uk

1. VWR -
   http://uk.vwr.com/app/search/Search?en_GB_go
2. Wagtech – www.wagtech.co.uk