Annexe 4

Chlorination of drinking-water

Chlorination of drinking water

In this annexe we will show how the chlorine demand of water can be determined, and how to calculate the amount of chlorine that should be added in the treatment of a batch of water, and in a continuous supply.

Materials needed:

- Turbidity tube (preferably)
- Chlorine-generating product (e.g. HTH)
- Tablespoon (or other object which contains around 15 ml)
- Measuring jug
- Non-metallic vessels (e.g. plastic buckets) with a volume of 5 litres or more
- Syringe (without needle)
- Pooltester with DPD1 tablets
- A watch
- Possibly a calculator

Assessing whether the raw water can be chlorinated directly

The water which is going to be treated should be relatively limpid (transparent). Suspended matter in the water can protect pathogens from the effect of chlorine, and chlorination will only be effective if the water contains little suspended material.

The amount of suspended matter in the water can be determined by measuring its turbidity. This can be done with a turbidity tube. A turbidity tube is a closed tube with a mark on the bottom. The tube is completely filled with water and the mark is observed through the water in the tube. The water is tipped out in small quantities until the mark is just visible. The turbidity of the water is determined by reading up to where the water comes on the scale on the side of the tube.

If no turbidity tube is available, the turbidity is probably acceptable if a small black cross on a white background is visible through about 0.6 metres of water (this is a turbidity of roughly 5 NTU).

Although chlorination is relatively effective at a turbidity of up to 20 NTU, the water should normally have a turbidity below 5 NTU [(21)]. If the turbidity of the water is higher, than some form of treatment (e.g. sedimentation, rough filtration, coagulation) will be necessary to remove the suspended material.

It should be remembered that the turbidity of surface water will normally fluctuate with the seasons.

The mother solution and chlorine-generating products

The most appropriate way of chlorinating water is usually by adding a mother solution to the raw water. A mother solution is a solution with a specific percentage of chlorine. Often a mother solution with a chlorine content of 1% (containing 10 grams of chlorine per litre) is used.

The mother solution is made by mixing the chemical which generates chlorine with water. How much of the chemical is needed to make a 1% solution will depend on its chlorine content. Table A4.1 present some common chlorine-generating products with their form, their chlorine content in percentage, and how 1 litre of mother solution of 1% chlorine can be made.

Table A4.1. Common chlorine-generating products with some of their characteristics

Product	***Form***	***Chlorine content***	***How to make 1 litre of mother solution***
High Test Hypochlorite (HTH)	granules	± 70 %	Mix 15 gram (± 1 tablespoon [a]) with 1 litre of water
Bleaching powder	powder	± 30 %	Mix 33 grams (± 2 tablespoons [a]) with 1 litre of water
Liquid laundry bleach	liquid	± 5 %	Mix 200 ml of liquid bleach with 800 ml of water

[a]: 1 tablespoon has a volume of 15 ml

If other chlorine-generating products are used, the quantity of product needed to make one litre of a 1% mother solution can be calculated with the formula:

$$Qty = 10 \times \left(\frac{100}{Cl_{cont}} \right)$$

Qty : amount of product needed to make 1 litre of a 1% mother solution (in grams or ml)

Cl_{cont} : chlorine content of the product (in %)

Thus if stabilised tropical bleach would be used with a chlorine content of 25%, the amount that would have to be dissolved in 1 litre of water to make a 1% mother solution is (10 x 100/25) = 40 grams.

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Chlorine-generating products do not support being exposed to light, air, metal, or high temperatures. They should therefore be stored in dark, covered, non-metallic containers in a cool place. As they can emit chlorine gas, the storage room should be well ventilated.

Determining the chlorine demand of the raw water

The amount of mother solution that is needed to chlorinate the raw water will have to be determined by experimentation.

A number of non-metallic vessels (e.g. plastic buckets or jerrycans) are filled with a known amount of the raw water (e.g. 4 buckets filled with 10 litres of water). Specific amounts of mother solution are added to each of the buckets with a syringe (e.g. 0.5 ml, 1.0 ml, 1.5 ml and 2 ml). The water is well mixed, and left for 30 minutes.

After 30 minutes no more chlorine should be lost to consumed or combined residual chlorine, and the content of free residual chlorine of the water can be determined with a pooltester. A DPD1 tablet is added to the water in a pooltester, and the tester is closed and vigorously shaken to dissolve the tablet. Chlorine in the water will turn the water pink; the more chlorine there is, the darker the colour. The content in free residual chlorine is determined by comparing the colour of the water with a colour scale. We are looking for the dose which results in a free residual chlorine content of 0.2-0.5 mg/l.

Imagine that our series would give the results:

Bucket	*Mother solution added to 10 litres*	*Free residual chlorine (in mg/l)*
1	1.5 ml	0 mg/l
2	2.0 ml	0 mg/l
3	2.5 ml	0.1 mg/l
4	3.0 ml	0.5 mg/l

In this case a dose of 2.7 ml to 3.0 ml of mother solution per 10 litres of raw water would normally be adequate to reach a free residual chlorine content of 0.2-0,5 mg/l.

This method gives a rough indication of the chlorine demand of the raw water. The free residual chlorine should be 0.2-0.5 mg/l at the point of distribution. As the content of free residual chlorine may reduce during distribution, we may want to have a higher content of free residual chlorine when the water leaves the treatment plant.

The content of the free residual chlorine in chlorinated water will have to be tested continuously to make sure that treatment is still adequate. The chlorine demand of the raw water will often not be constant over time.

Chlorinating a batch of water

If a batch of water has to be treated, the amount of mother solution that is needed can be calculated with the formula:

$$Ms_{bat} = \left(\frac{Vol_{bat}}{Vol_{test}} \right) \times Ms_{test}$$

Ms_{bat} : the amount of mother solution required to chlorinate the batch of raw water (in ml)
Vol_{bat} : the volume of the batch of water which has to be treated (in litres)
Vol_{test} : the volume of water that was used in the test (in litres)
Ms_{test} : the amount of mother solution which was required to chlorinate the water in the test (in ml)

Thus, if in our example we need a free residual chlorine content of 0.5 mg/l, and we want to treat the water in a reservoir of 15m^3 (15,000 litres), the amount of mother solution we would have to add would be (15,000/10 x 3) = 4,500 ml (= 4.5 litres).

Chlorinating a continuous supply of water

If a continuous supply of water has to be chlorinated, the amount of mother solution that has to be added per unit of time can be calculated with the formula:

$$Rate_{Ms} = \left(\frac{Flow_{sup}}{Vol_{test}} \right) \times Ms_{test}$$

$Rate_{Ms}$: the rate at which mother solution has to be added to the supply (in ml/second)
$Flow_{sup}$: the flow of the supply of raw water (in litres/second)
Vol_{test} : the volume of water that was used in the test (in litres)

Ms_{test}: the amount of mother solution which was required to chlorinate the water in the test (in ml)

If we would want to treat the raw water of our example in a system with continuous supply which has to deliver 1.67 litres/second (100 litres/minute), the mother solution would have to be added to the raw water at a rate of (1.67/10 x 3) = 0.5 ml/second.