DISINFECTION – Using Chlorine

By David Karrol

DISINFECTION – Using Chlorine

Topics to focus on are:

1. Chlorine Compounds
   - Sodium Hypochlorite
   - Calcium Hypochlorite
   - Chlorine Gas

2 Associated Chlorine Compounds

3 Chlorination
   - Purpose
   - Principles
   - Factors Influencing (Affecting) Chlorination

4 Efficiency of Kill

5 Taste & Odour in Distribution System

6 Dechlorination

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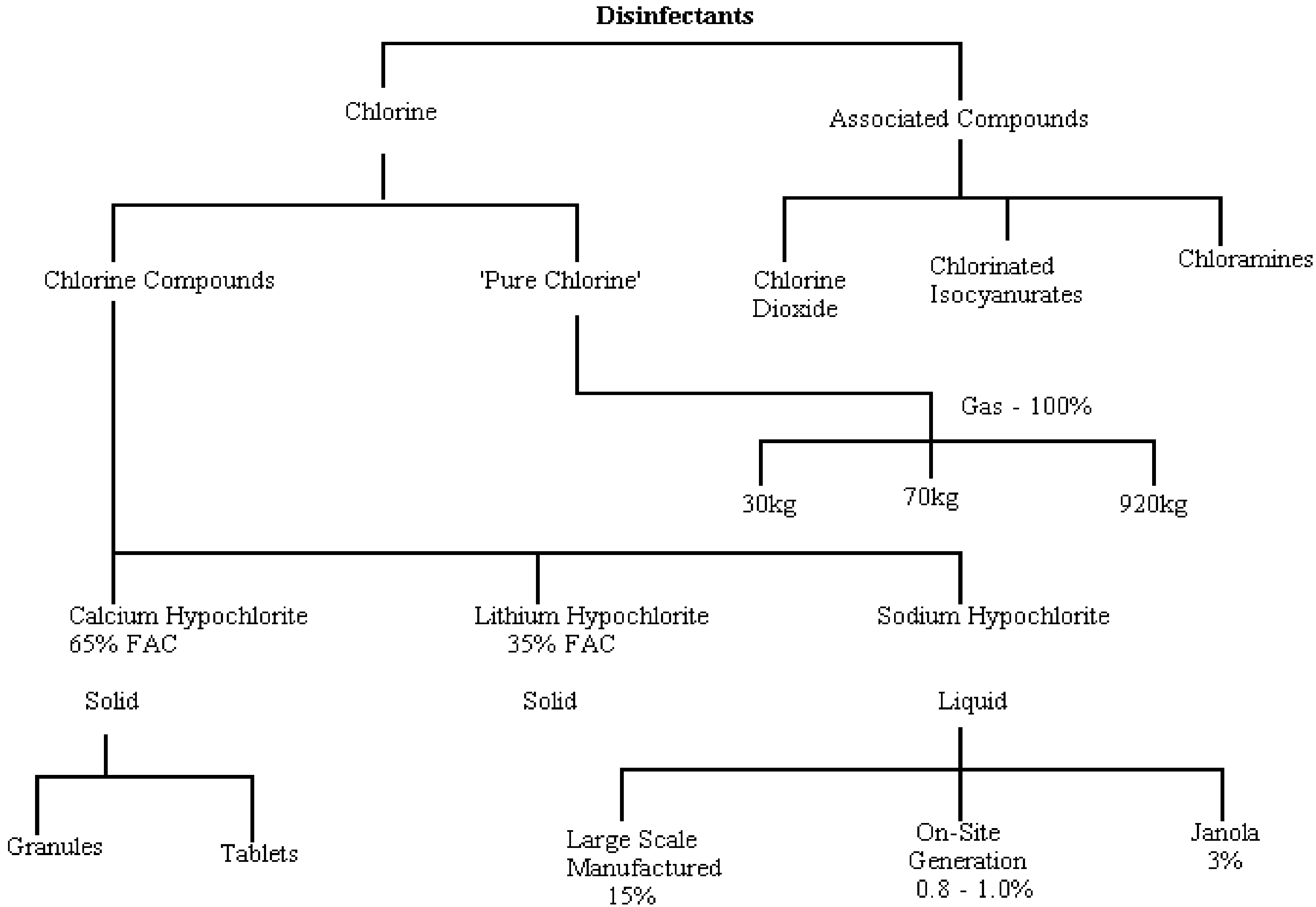
Chlorine Compounds



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Disinfection - The term **Disinfection** of water may be generally defined as the treatment of water by **physical** or **chemical** means to limit the active bacterial contamination, including those micro-organisms known to be pathogenic or infectious, to an acceptable degree

Sterilisation - The term **sterilisation** of water, may be defined as treatment to completely destroy all living organisms, which may be in water.

Brief on Chlorine Compounds

The **main forms that chlorine** is sold and used in, for potable water disinfection are:

- sodium hypochlorite (12.5 - 15% liquid
- on site generated (mostly at approx 1%)
- calcium hypochlorite or HTH granules, (60-65%)
- liquefied chlorine gas in 4.5, 30, 70 and 920kg pressurised containers. (100%)

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Sodium Hypochlorite (NaOCl)

The concentration produced and sold commercially yields 15% available chlorine.

The reaction equation for sodium hypochlorite in water is:

$NaOCl + H_2O \rightarrow HOCl + NaOH$

Thus yielding a by-product (caustic soda) which will raise the waters alkalinity and pH, and the disinfecting compound *hypochlorous acid*.

Safety – Sodium Hypochlorite (SDS)

Physical Safety

- The product is normally delivered by tanker and "air pad" loaded to the clients holding tank ie. it is blown into the clients reservoir by pressurising the delivery vessel.
- 6 m head appears to be about the normal maximum head possible.
- Spillages in this or any other process are possible and a water shower must be readily accessible to handlers
- Gloves, goggles, or face shield, and suitable overalls are necessary where spillages can occur

Generally short term skin contact will result in moderate irritation. Repeated or prolonged contact may result in contact dermatitis or skin burns. It is, however, a severe eye irritant and prolonged eye contact may result in blindness or permanent eye injury.

- If clothes are splashed liberally douse the affected area with water.
- Concrete is readily etched.

Practical Storage & Application of Sodium Hypochlorite

In theory the most stable solution is of low hypochlorite concentration, with a pH 11, of low iron, copper, nickel content stored in the shade at low temperatures.

In practice all that is required is provision of either a bulk alkali resistant tank with tanker access or adequate storage for 200 litre drums.

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Dosing of Sodium Hypochlorite

The dosing system requires a non-metallic pipe from storage to dose point coupled to a corrosion resistant pump. Positive displacement pumps are -normally used eg. diaphragm (glandless) pumps.

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Calcium Hypochlorite (HTH) ($Ca(OCl)_2$)

The modern HIGH TEST HYPOCHLORITE

These compounds usually contain 60 to 65% available chlorine by weight, more recently, stronger versions have also become available. This compound is prepared from calcium hydroxide and chlorine gas forming calcium hypochlorite, calcium chloride and water.

$$2Ca(OH)_2 + 2Cl_2 \rightarrow Ca(OCl)_2 + CaCl_2 + 2H_2O$$

These powders are more stable and deteriorate less quickly in storage than the previously used chloride of lime. They are more soluble than chloride of lime, and in -solution provide a relatively clear liquid. They do, however, contain significant quantities of -insoluble calcium.

The reaction of calcium hypochlorite in water is:

$$\mathbf{Ca(OCl)_2 + 2H_2O \rightarrow 2HOCl + Ca(OH)_2}$$

Yielding the disinfecting compound ***hypochlorous acid*** and slaked lime which raises the alkalinity and pH.

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Preparation of Calcium Hypochlorite Solutions

Calcium hypochlorite in powder or granule form and must be dissolved in water and added as a settled, clear solution.

- Always allow adequate time for sludge to settle after preparing -solutions before feeding.
- A small amount of sludge left in the mixing tank will aid solution clarity but excess accumulations must be discarded from time to time,
- A wooden float with legs 100 mm in length should be attached to the end of the dose pump feed line, to ensure that solution is always drawn from near the top of the tank and that the last 100 mm depth of solution in the tank cannot be drawn out. A fine filter should also be placed on the solution tank end of the line.

It is generally most convenient to make up sufficient solution each day for a further 25 - 26 hours continuous dosing. The ***solution strength should not exceed 3%*** of calcium hypochlorite (2% chlorine), or the solubility limit of calcium hypochlorite will be approached.

Calcium hypochlorite solutions lose about 3% of their available chlorine during a period of 14 days when protected from light and 7% when exposed to light.

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Calcium Hypochlorite (HTH)

Stability of Hypochlorite Solutions

The stability of sodium and calcium hypochlorite solutions in general is dependent on five factors.

1 **Hypochlorite concentration.**

2. **Concentration of certain catalysts. (High Copper, Nickel & Cobalt)**

3. **Alkalinity, and pH value of the solution.**

4. **Temperature of the solution.**

5. **Exposure to light.**

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Chlorine Gas (Cl_2)

Chlorine gas has the following physical properties:

- greenish yellow in colour;
- has a pungent odour;
- is approximately 2½ times heavier than air;
- if released will seek low levels;
- Is non inflammable under normal circumstances;
- Is non explosive under normal circumstances.
- solubility in water under vacuum conditions is 0.5% and under atmospheric pressure is 0.7%.

The element chlorine does not occur naturally since it is a very active element. It is, however, abundant in combination with other minerals such as sodium chloride in sea water.

The reaction of chlorine in water is:

$Cl_2 + H_2O \rightarrow$ **HOCl** $+ HCl$

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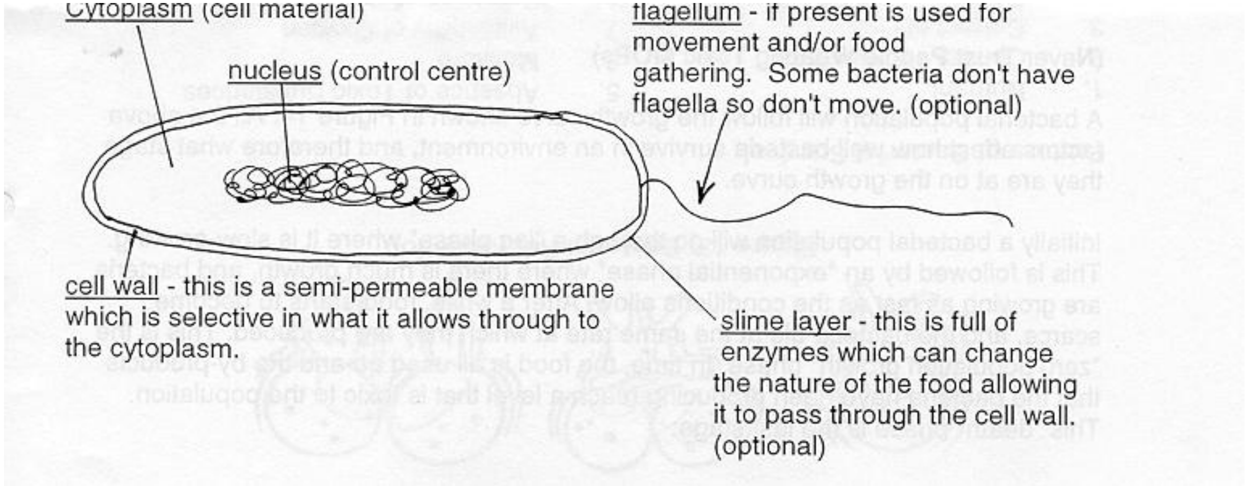
Disinfection - systematic ***inactivation*** of water-borne diseases.

Chlorine is still the most commonly used disinfectant, both for immediate organism kill, and for maintenance of a residual in the treated water.

Purpose of Chlorination

The **primary object** of chlorination of potable waters is the destruction of microorganisms through the germicidal effects of chlorine.

How chlorine kills or inactivates the microbe depends on the type of microbe, and is not fully understood. On bacteria, it is thought that the uncharged hypochlorous acid more readily penetrates the cell wall and has a "multiple hit" effect, where **enzymes, the cellular membrane, and genetic material can all be attacked and damaged.**



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As well as disinfection, there are also several important **secondary uses** for chlorination:

(a) Oxidation of iron;
(b) Oxidation of manganese;
(c) Destruction of some taste and odour producing compounds;
(d) Oxidation of hydrogen sulphide;
(e) Control of algae and slime organisms;
(f) An aid to coagulation.

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Principles

Chlorine gas or chlorine compounds may be used as the chlorine source, but in all cases the active disinfectant is hypochlorous acid.

Effective chlorination is achieved when the following are observed:

(a) Uniform application of chlorine to all portions of the water;

(b) Uninterrupted application of chlorine;

(c) Selection of the dose of chlorine to meet the needs of the specific water being treated, that is to say to satisfy the chlorine demand and provide an adequate residual;

(d) Control of chlorination so as to produce a safe potable water that is at the same time pleasing to use.

Factors Influencing Chlorination

A number of substances which will influence chlorination may be present in water.

Suspended Solids

The presence of "suspended solids" impedes chlorination by absorbing chlorine, solids may also shield microbes if insufficient chlorine has been added.

Organic Matter

Reacts with chlorine so that it has only weak disinfecting properties .

The rate of reaction often varies considerably with the concentration of chlorine, pH and alkalinity. Chlorine reacting with organics such as colour may also produce TOX's, some of which are carcinogens

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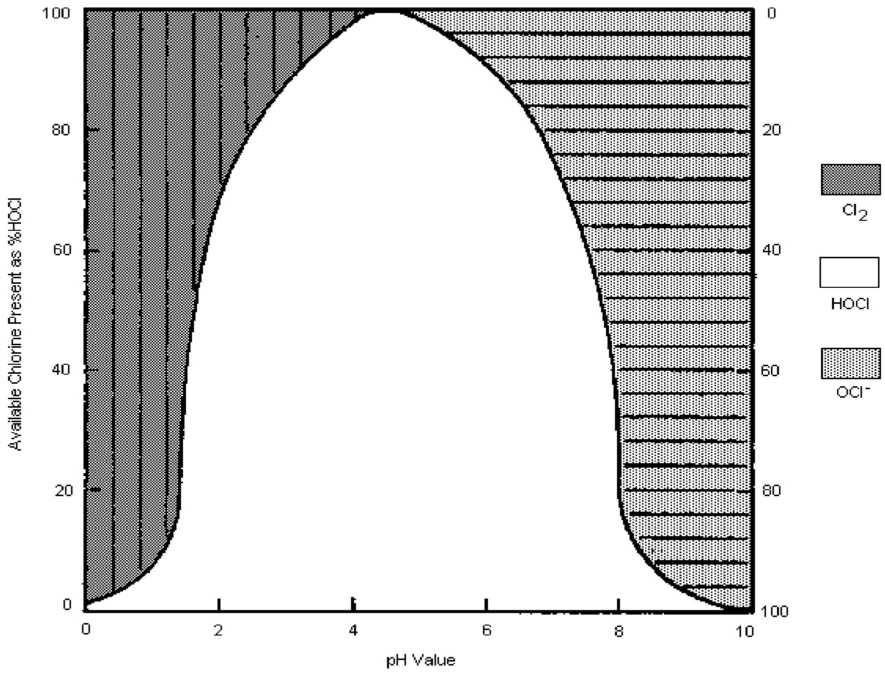
pH

High pH in water influences chlorination; disinfection being more rapid in waters of low pH than in the higher pH range, but, with a high pH, residuals are maintained much longer, thus partly compensating for the slower action, assuming adequate contact time is provided.



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pH	% age of chlorine as HOCl
4.5	100%
7.0	80%
7.5	45%
8.0	20%
8.5	8%
9.0	2%

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Ammoniacal Nitrogen (NH_3)

When chlorine is added to water containing organic matter or ammonia the formation of three other compounds is possible. These are combinations of chlorine and ammonia called chloramines

Monochloramine	NH_2Cl)	
Dichloramine	$NHCl_2$)	Combined Available Chlorine
Trichloramine	NCl_3)	
Hypochlorous acid	HOCl)	Free Available Chlorine, but note that OCl^- also tests as FAC

(TAC = FAC + CAC)

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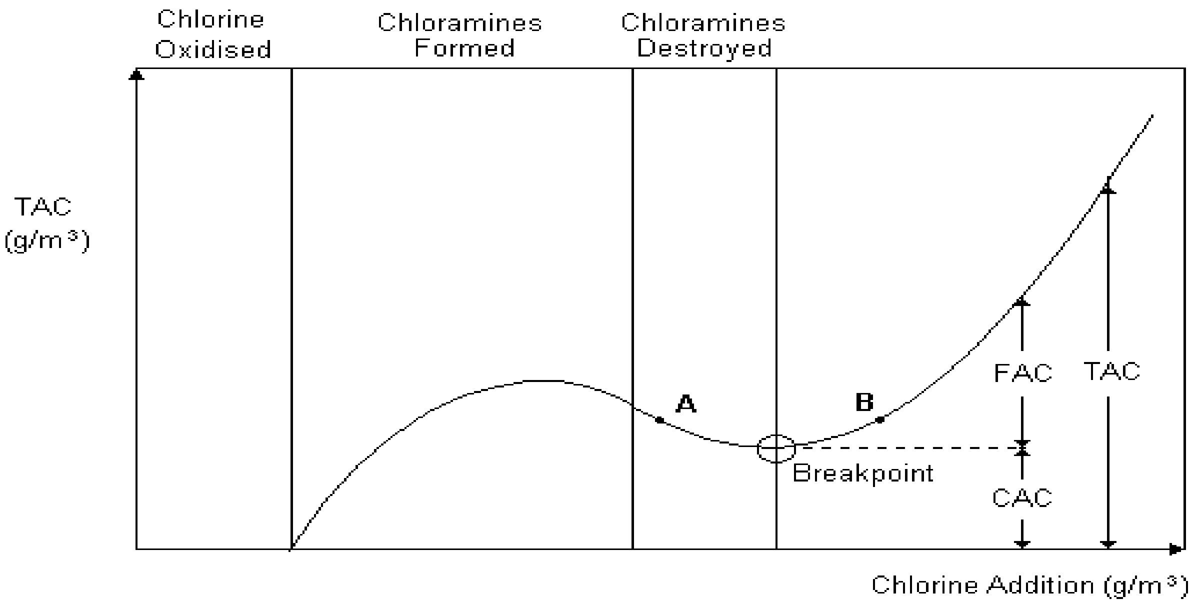
The Breakpoint Curve



- **To reach the breakpoint dose, we must satisfy the demand - which is oxidation of iron, manganese, organic material, and ammonia, before a disinfecting residual of HOCl is obtained.**

- **If the water is at point A, then there will still be dichloramines remaining, producing a noticeable chlorine flavour.**
- **If, however, more chlorine is added, the water will move past the breakpoint to point B, some of the dichloramines are "burnt off", and we have the strange situation where adding more chlorine reduces the chlorinous flavour.**

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Nitrite therefore acts as an dechlorinating agent.

Iron. Is oxidised to the ferric state immediately upon application of the chlorine

Manganese & Hydrogen Sulphide

Temperature The speed of disinfection increases as the temperature rises. Cold causes delay both in germicidal action and in the absorption of chlorine

Contact Time They must be sufficient to satisfy the DEMAND of the water under all conditions, and produce a RESIDUAL, AVAILABLE to kill microbes.

Ultraviolet Rays Loss of chlorine by the sun's rays are considerable. When the intensity of sunlight reaches the power of 3000 ft candles break down of Hypochlorous acid starts

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Aeration

Water samples containing chlorine residuals of different types and -magnitudes were aerated vigorously by a stream of air passed through a packed cylinder. The tests were carried out indoors, in the daylight.

RESIDUAL CHLORINE IN g/m^3										
MINS	HOCl			NH_2Cl			$NHCl_2$		NCl_3	
0	2.8	2.0	1.9	2.1	1.2	0.5	1.5	1.4	0.6	0.6
10	2.5	1.8	1.7	1.9	1.1	0.5	1.2	1.3	0.4	0.4
60	2.2	1.5	1.5	1.8	1.0	0.5	0.5	0.9	0.1	0.1

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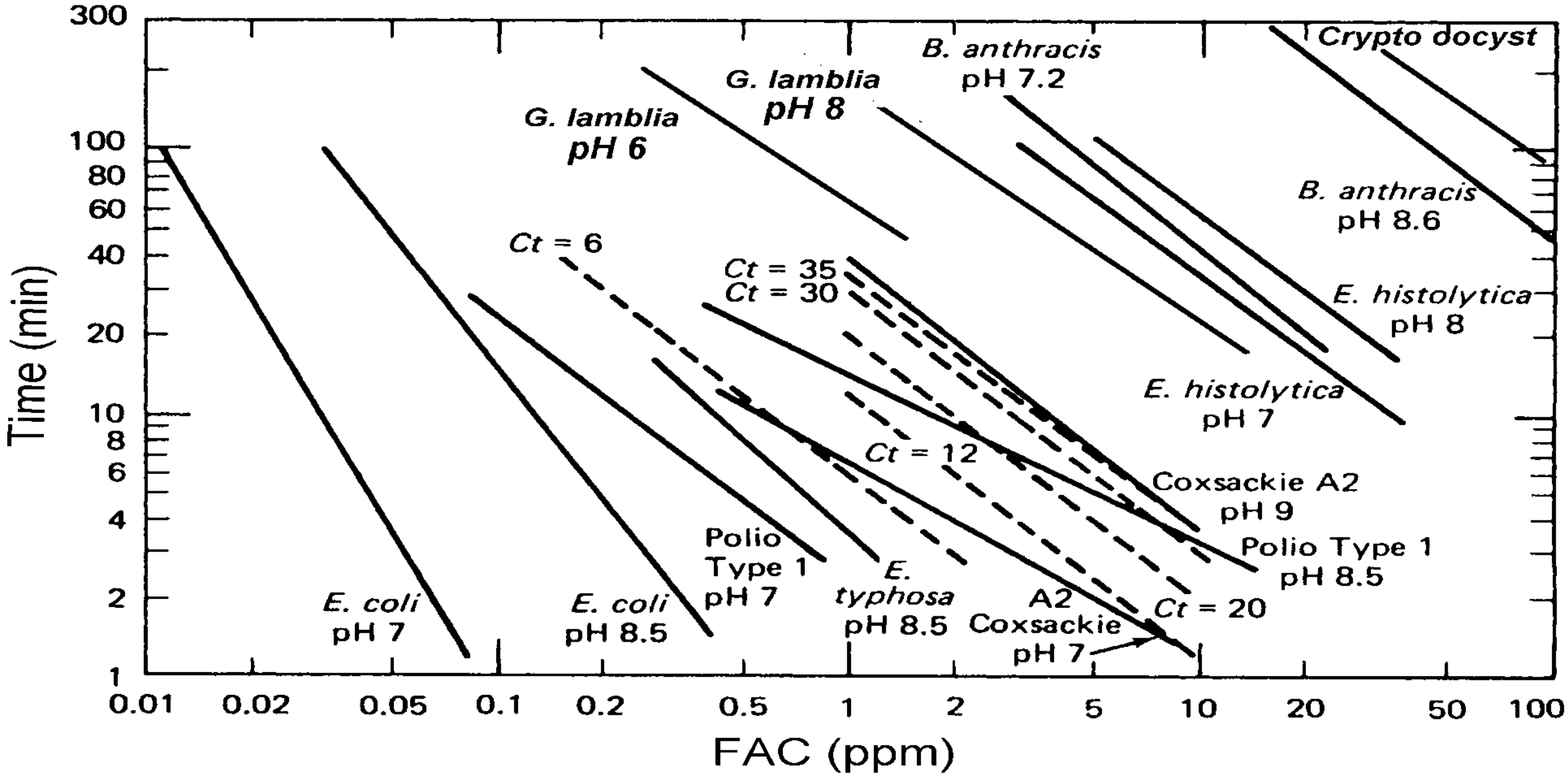
Efficiency of Kill

The graph below shows how dose and time can be interchanged to some degree to obtain the same level of kill



Taste and Odours in Distribution Systems

T & O is cause by:

FAC residual in the water leaving the plant coming in contact with pipe slimes or coatings, which the chlorine then reacts with or oxidises.

As the progressive oxidation of this coating takes place the taste and odour complaints will progress onward along the line.

Mostly on :

- Dead ends
- Following mains repairs
- Installation of new water mains
- Old and rusty mains
- Low flow areas
- Low pressure zones

Dechlorination:

Whilst chlorine is an effective disinfectant, excessive chlorine levels, discharged into the environment, eg streams and rivers, or possibly even into a municipal sewer, may cause serious fish kills or sewage plant malfunctions. In these circumstances, Dechlorination is the best option prior to discharge.

Whilst a number of chemicals can be used for dechlorination purposes, the most effective for small to medium scale one off use is likely to **be sodium thiosulphate.**

This yields a requirement of approx. **3.0 kgs** of sodium thiosulphate per **1.0 kg** of chlorine to be removed.

THANKS FOR LISTENING

QUESTIONS?

References:

- Handbook of Chlorination and Alternative Disinfectants, White, 3rd edition
- Safety Data Sheets, Orica Chem-Net and other Chlorine Suppliers.