# HYPOCHLOROUS EFFICACY

AQUAOX™

The Aquaox Advantage

# HYPOCHLOROUS EFFICACY

Chlorine is one of the most commonly used disinfectants for water disinfection. It is used to deactivate most microorganisms and it is relatively inexpensive.

Chlorine is commercially available as gaseous chlorine (Cl2) and sodium hypochlorite (NaOCl) in liquid or powder form. Both chlorine (Cl2) and sodium hypochlorite (NaOCl) have very limited disinfecting properties, but the formation of chlorine by-products such as hypochlorous acid (HOCl), hypochlorite ion (OCl-), hydrochloric acid (HCl) and oxygen atom exhibit strong disinfecting properties.

### Hypochlorous Acid

When gaseous chlorine (Cl2) is added to water (H2O) the following hydrolysis reaction takes place:

$Cl_2 + H_2O = H^+ + Cl^- + HOCl$

### Sodium Hypochlorite

Sodium hypochlorite is better known as bleach (NaOCl) and it cannot be combined with acids. When (NaOCl) comes in contact with acids the hypochlorite becomes unstable, causing poisonous gaseous chlorine (Cl2) to escape.

Sodium hypochlorite (NaOCl) is produced by adding gaseous chlorine (Cl2) to Sodium hydroxide (NaOH). When this is done, sodium hypochlorite (NaOCl), water (H2O) and salt (NaCl) are produced according to the following reaction:

$Cl_2 + 2NaOH + \rightarrow NaOCl + NaCl + H_2O$

### Hypochlorite Ion

Sodium hypochlorite (NaOCl) reacts with water (H2O) to form hypochlorous acid (HOCl) and hypochlorite ions (OCl-):

$NaOCl + H_2O \rightarrow HOCl + OCl^-.$

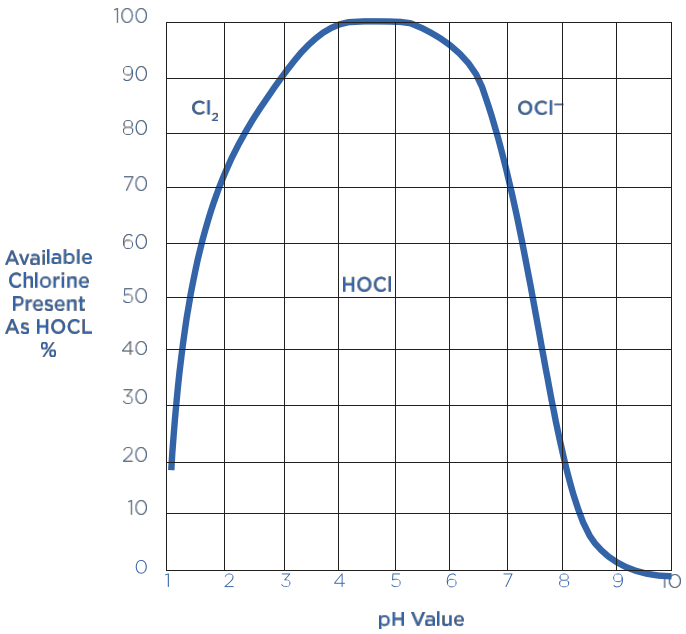
Hypochlorite ion breaks down to chlorine and oxygen atoms:
$OCl^- \rightarrow Cl^- + O$

Depending on the pH value, the concentration of hypochlorous acid (HOCl) is related to the concentration of hypochlorite ions (OCl-):

$HOCl + H_2O \rightarrow H_3O^+ + OCl^-$

## Disinfection Efficacy is Determined by the pH.

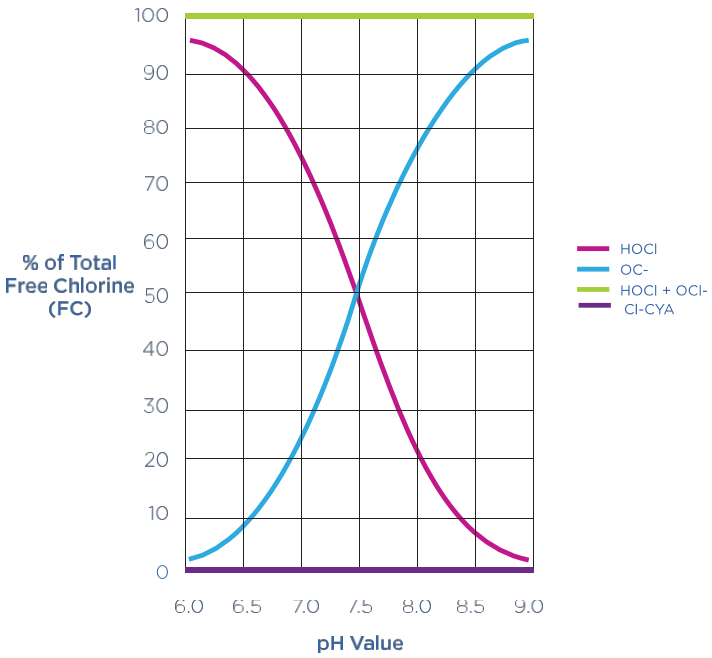
Disinfection will take place ideally when the pH is between 5 and 7, as then an optimal level of hypochlorous acid (HOCl) is present.




The maximum level of hypochlorous acid (HOCl) is between 4 to 5.5 pH. Hypochlorous acid (HOCl) decreases when the pH is below 4 and above 5.5

## Free Available Chlorine

Free Available Chlorine (FAC) is chlorine that is present in the form of hypochlorous Acid (HOCl), hypochlorite ions (OCl-) or as dissolved elemental chlorine. FAC includes all chlorine species that are not combined with ammonia (or other nitrogenous compounds) to form chloramines. It is 'free' in the sense that it has not yet reacted with anything, and "available" in the sense that it can and will react if needed.




A pH value of 6 to 7 is the most effective and the safest pH-range, due to absence of chlorine gas. Therefore, when Free Available Chlorine (FAC) is mentioned, it is assumed that Free Available Chlorine (FAC) solely consists of hypochlorous acid (HOCl) and hypochlorite ion (OCl-)

Free Available Chlorine compounds with regard to pH. Hypochlorous acid (pink) and hypochlorite ion (blue).

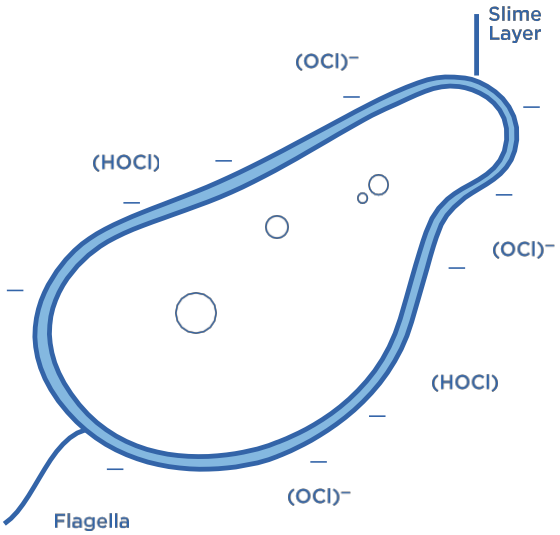
## Superiority of Hypochlorous Acid (HOCl) Compared to Hypochlorite Ion (OCl-)

Hypochlorous acid (HOCl) is 80-100 times more effective and kills microorganisms faster than hypochlorite ions (OCl-).

Hypochlorous acid (HOCl) which is electrically neutral and hypochlorite ions (OCl-) which is electrically negative will form Free Available Chlorine (FAC). This results in disinfection, but both substances have very distinct behaviors.

The cell wall of a pathogenic microorganisms is negatively charged by nature. The negative charge of the hypochlorite ion (OCl–) will be repulsed by the negative charge of the pathogenic microorganism cell wall making it a weak disinfectant. The neutral hypochlorous acid (HOCl) molecule can penetrate the cell wall of the pathogenic microorganism very easily, thus making it a very effective disinfectant.

Hypochlorous acid (HOCl) can also penetrate slime layers, cell walls and protective layers of microorganisms and effectively kills pathogens as a result. The microorganisms will either die or suffer from reproductive failures.




The pH neutral hypochlorous acid (HOCl) can penetrate cell walls of pathogenic microorganisms whereas the negatively charged hypochlorite ion (OCl-) cannot penetrate cell walls.

Besides the neutrality of hypochlorous acid (HOCl), it is also a much more reactive and stronger disinfectant than hypochlorite ion (OCl-), as hypochlorous acid (HOCl) is split into hydrochloric acid (HCl) oxygen atom which in itself is a powerful disinfectant.

## Hypochlorous Acid (HOCl) Guarantees Optimal Disinfecting

The disinfecting properties of chlorine (Cl2) in water (H2O) are based on the formation and oxidizing power of oxygen and hypochlorous acid (HOCl). These conditions occur when the pH is between 6 and 7.

Hypochlorous acid (HOCl) produced onsite from the AQUAOX™ EAW systems have a pH of 6.5. At this pH, more than 90% of the Free Available Chlorine (FAC) is hypochlorous acid (HOCl), less than 10% hypochlorite ion (OCl-) and no chlorine (Cl2) are formed.

# COMPARISON TO BLEACH

**AQUAOX™ Disinfectant 275 < compared to > Commercially available bleach**

The strength of Free Available Chlorine (FAC) in “Disinfectant 275” is pre-set to 275 ppm FAC. In order to make a solution with 275 ppm FAC from commercially available bleach (NaOCl), it must be diluted in water (H2O). But, the problem with diluting bleach in water is twofold.

The volume to dilute bleach is very small. The fact that water has naturally different pH levels can cause the addition of the same volume of bleach to have a different pH which in turn will affect the concentration properties of the hypochlorous acid (HOCl). So, although bleach can be diluted to a 275 ppm FAC level, the pH of the mixture and consequently the amount of active compounds of hypochlorous acid (HOCl) and hypochlorite ion (OCl-) may vary considerably.

Therefore, disinfecting properties using bleach vary whereas the disinfecting properties of hypochlorous acid (HOCl) are kept stable. As a result, hypochlorous acid (HOCl) may exceed the disinfecting properties of bleach by **300** times.

Hypochlorous acid (HOCl) does not evaporate and does not cause severe corrosion like chlorine. Chlorine exposed in air can be very explosive and evaporation should be avoided. For this reason, the ideal pH is between 6 and 7, as no chlorine is present.

**Safety**

When producing hypochlorous acid (HOCl) by acidifying sodium hypochlorite (NaOCl), relatively high prices and the possibility of adverse reactions limit the use of weak organic acids; use of cheaper inorganic acids provokes gaseous chlorine discharge and a raise of toxicity level. Because of this, the method above is only used for water treatment, where residual chlorine concentration values do not exceed 0.5-5mg/l.

Dilution of gaseous chlorine in water (H2O) to produce hypochlorous acid (HOCl) demands special safety measures and is only used for disinfecting large volumes of water where active chlorine concentration is below 10-15mg/l. Companies that once manufactured gaseous chlorine have stopped production and moved exclusively to manufacturing sodium hypochlorite (NaOCl) because of safety clonsiderations.

Sodium hypochlorite (NaOC) solutions tend to have a high pH, but the AQUAOX™ Systems is a unique method of non-reagent synthesis of hypochlorous acid (HOCl) at a pH range of 6 to 7.

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