# Basic Facts About Hypochlorous Acid

*Courtesy of HypochlorousAcid.com*

Hypochlorous acid is naturally produced by white blood cells of all mammals. It plays an important role in the immune system killing pathogens through oxidation and chlorination.

Hypochlorous acid can also be produced through a process called electrolysis. Electrolysis is a technique that uses a direct electric current (DC) to drive an otherwise non-spontaneous chemical reaction. Specifically engineered electrolysis cells can generate a solution of free chlorine species by running electricity through NaCl (table salt) and water. The oxidants hypochlorous acid (HOCl) and hypochlorite (OCl-) are formed at the anode. If the pH of the solution is weakly acidic to neutral, the free chlorine solution will be dominated by hypochlorous acid.

*Hypochlorous is a powerful oxidant and is 100 times more efficient at killing microbial pathogens than sodium hypochlorite (aka. chlorine bleach).*

**New Technology & Research**

The use of chlorine for disinfection has been researched for over 100 years. It has been an undisputable fact that hypochlorous acid offers far superior disinfecting properties than sodium hypochlorite (chlorine bleach). One of the most well-known authorities for the use of chlorine as a disinfectant is *White's Handbook of Chlorination, Fifth Edition,* Black and Veatch Corporation, 2009. This book is comprehensive in explaining the chemistry and effectiveness of chlorine and alternative disinfectants.

The challenge has been in engineering a system for producing a free chlorine solution that is dominated by the molecule of hypochlorous acid (HOCl) rather than sodium hypochlorite (NaOCl-). The development of electrolysis cells for generating electrolyzed water became a huge innovative breakthrough in the 1970s. Since then, improvements in electrolysis cells have been made that can generate a solution of free chlorine that is near 99% hypochlorous acid and that is stable.

One of the most recent improvements has been the development of single cell technology to replace membrane cell technology allowing for the production of just one stream of solution at a near neutral pH. Prior technology used membranes and high pressures that forced two streams to be generated, an unstable anolyte of hypochlorous acid and an unstable catholyte of sodium hydroxide. With the development of single cell technology, a stable solution of just anolyte can be produced yielding a solution of near 99% stable hypochlorous acid.

Over 30 years of research exists for the use of hypochlorous acid and new research is being published every year. Recent research has focused on the use of hypochlorous acid for sanitizing food and food processing facilities. Research has also been done on poultry farms, water treatment and disinfection, and healthcare related applications such as wound care and equipment sterilization.

**Safe on Eyes and Skin**

Hypochlorous acid does not cause irritation to eyes and skin. Even if it were ingested, it causes no harm. Because it is so safe, it is the ideal sanitizer for direct food sanitation and food contact surfaces. It is also ideal in healthcare where it is used for wound cleansing, eye drops, and patient room disinfection replacing toxic chemicals such as bleach and quaternary ammonium (quats).

**Non-Toxic, Non-Hazardous**

Sanitation chemicals distributed in concentrated form are toxic and can be hazardous. Contact with skin or inhalation of fumes can cause irritation. These risks do not exist with hypochlorous acid. Electrolyzed water systems generate hypochlorous acid from just table salt, water and electricity. No personal protective gear is required.

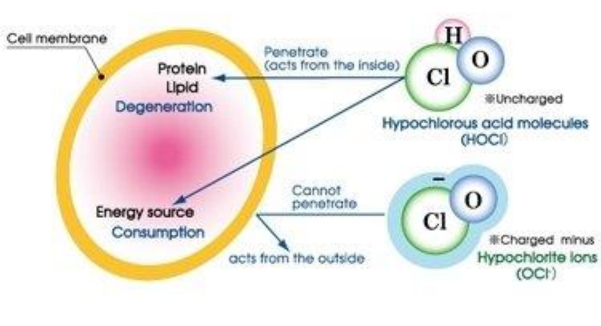
**How does HOCl kill microbial pathogens?**

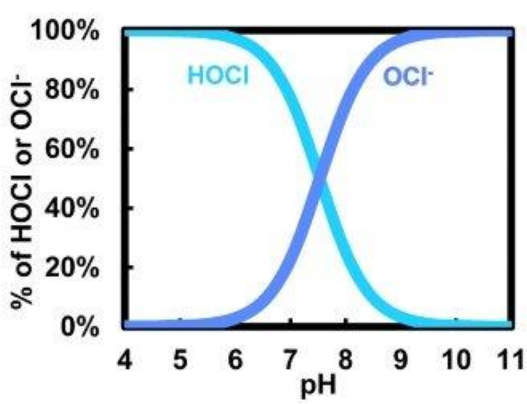
The molecule of hypochlorous acid is HOCl. This molecule is unique in that it is neutrally charged unlike hypochlorite (OCl-) which is negatively charged. So why is this important?

Disinfectants and microbial pathogens interact with each other similar to magnets. If you bring together two negatively charged magnets, they will repel each other. Bacteria and hypochlorite (OCl- aka. bleach) are both negatively charged and behave like two negatively charged magnets repelling each other. Hypochlorous acid (HOCl) is neutrally charged and is not repelled by bacteria. HOCl easily penetrates the walls of the bacteria and destroys them with its strong oxidation potential.

**Why is pH important?**

A free available chlorine (FAC) molecule is one that is not attached. There are three forms of free available chlorine: chlorine gas, hypochlorous acid and hypochlorite. Assuming a constant temperature of 25 degrees Celsius, when the pH is below 3, free chlorine will leave solution as chlorine gas. When the pH is above 7.5, over 50% will be hypochlorite (OCl-) and will increase in hypochlorite as it rises toward pH 14. Between pH 3 and pH 7.5 the free chlorine solution will be dominated by hypochlorous acid (HOCl).



## Chemistry

### Hypochlorous Acid

**IUPAC Name :** Hypochlorous acid, chloric(I) acid, chloranol, hydroxidochlorine
**Other Names :** Hydrogen hypochlorite, chlorine hydroxide, electrolyzed water, electrolyzed oxidizing water, electro-activated water
**CAS Number :** 7790-92-3
**Molar Mass :** 52.46 g/mol
**Molecular Formula :** $HOCl$
**Appearance :** Colorless aqueous solution
**Solubility in water :** Soluble
**Acidity :** 7.53

### Electrolysis

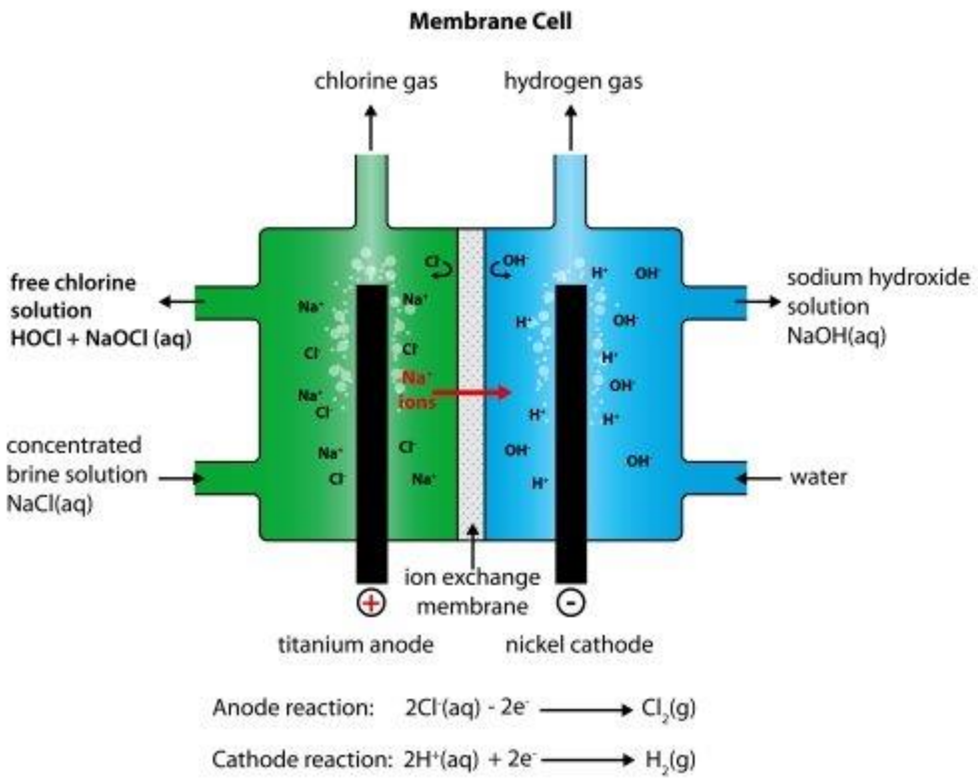
In chemistry and manufacturing, electrolysis is a technique that uses a direct electric current (DC) to drive an otherwise non-spontaneous chemical reaction. Electrolysis is commercially important as a stage in the separation of elements from naturally occurring sources. Electrolysis of sodium chloride (NaCl) and water (H2O) can be used to generate hypochlorous acid. Electrolysis technology was first explained by Michael Farraday when he developed the Laws of Electrolysis in the 1830s. Conducting electrical current across two electrodes in a salt brine solution may produce chlorine gas, sodium hypochlorite (bleach or NaOCl), hypochlorous acid, sodium hydroxide, hydrogen gas, ozone, and traces of other nascent oxidants.

The key process of electrolysis is the interchange of atoms and ions by the removal or addition of electrons from the external circuit. An electrical potential is applied across a pair of electrodes immersed in the electrolyte. Each electrode attracts ions that are of the opposite charge. Positively charged ions (cations) move towards the electron-providing (negative) cathode. Negatively charged ions (anions) move towards the electron-extracting (positive) anode. In chemistry, the loss of electrons is called oxidation, while electron gain is called reduction.

For example, the first step in making hypochlorous acid is the electrolysis of a salt water brine to produce hydrogen and chlorine, the products are gaseous. These gaseous products bubble from the electrolyte and are collected.

$$2\ NaCl(s) + 2\ H20(l) \rightarrow 2\ NaOH(aq) + H2(g) + Cl2(g)$$

**Membrane Cell Technology**




The ion exchange membrane is made from a polymer which only allows positive ions to pass through it. That means that the only the sodium ions from the sodium chloride solution can pass through the membrane, and not the chloride ions. The advantage of this is that the sodium hydroxide solution being formed in the right-hand compartment never gets contaminated with any sodium chloride solution. The sodium chloride solution being used has to be pure. If it contained any other metal ions, these would also pass through the membrane and so contaminate the sodium hydroxide solution.

Hydrogen is produced at the cathode:
$2H^+(aq) + 2e^- \rightarrow H_2(g)$

Sodium hydroxide is produced at the cathode:
$Na^+(aq) + OH^-(aq) \rightarrow NaOH(aq)$

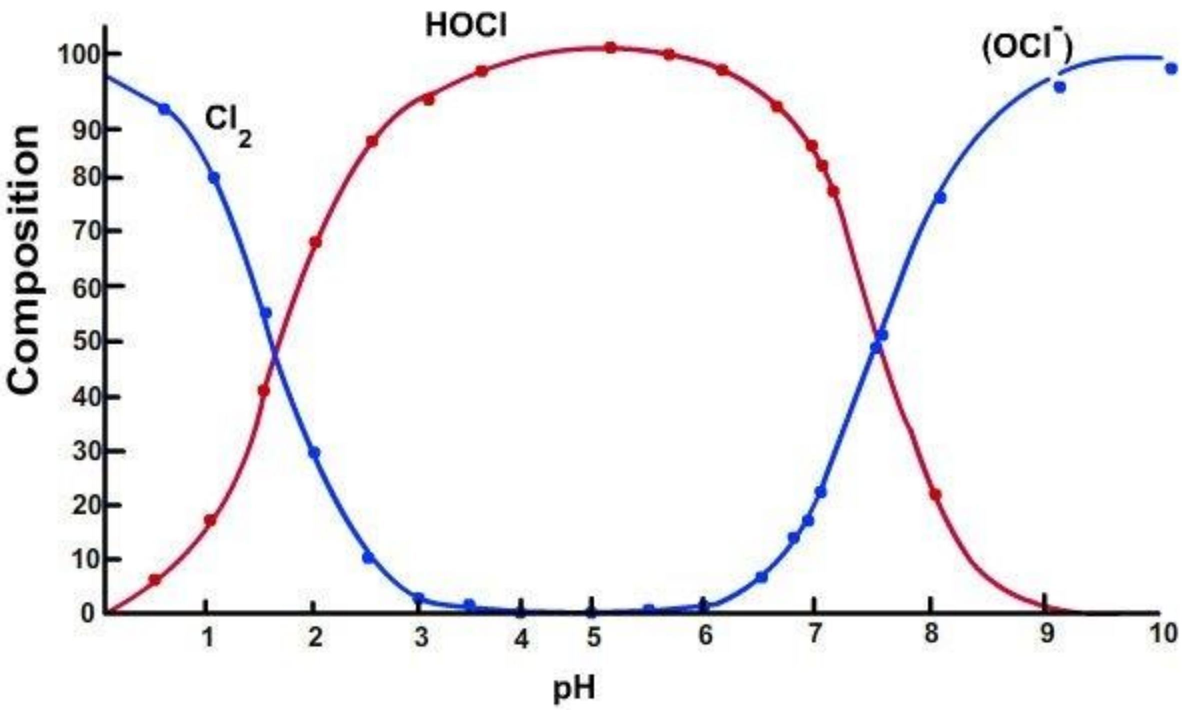
Chlorine is produced at the anode :
$2Cl^-(aq) - 2e^- \rightarrow Cl_2(g)$

It is contaminated with some oxygen because of the reaction :
$4OH^-(aq) - 4e^- \rightarrow 2H_2O(l) + O_2(g)$

Addition of chlorine to water gives both hydrochloric acid (HCl) and hypochlorous acid (HOCl) :
$Cl_2(g) + H_2O \rightleftharpoons HOCl(aq) + HCl(aq)$

$Cl_2(g) + 4\ OH^- \rightleftharpoons 2\ ClO^-(aq) + 2\ H_2O(l) + 2\ e^-$
$Cl_2(g) + 2\ e^- \rightleftharpoons 2\ Cl^-(aq)$

The pH dictates the free chlorine species present in aqueous solutions. At a pH of between 5-6, the chlorine species is nearly 100% hypochlorous acid (HOCl). As the pH drops below 5, it starts to convert to Cl2 (chlorine gas). Above a pH of 6, it starts to convert to the hypochlorite ion (OCl-).




Hypochlorous acid is a weak acid (pKa of about 7.5), meaning it dissociates slightly into hydrogen and hypochlorite ions as noted in equation: $HOCl \rightleftharpoons H^+ + OCl^-$

Between a pH of 6.5 and 8.5 this dissociation is incomplete and both HOCl and OCl- species are present to some extent. Below a pH of 6.5, no dissociation of HOCl occurs, while above a pH of 8.5, complete dissociation to OCl- occurs.

As the germicidal effects of HOCl is much higher than that of OCl-, chlorination at a lower pH is preferred. The germicidal efficiency of hypochlorous acid (HOCl) is much higher than that of the hypochlorite ion (OCl-). The distribution of chlorine species between HOCl and OCl- is determined by pH, as discussed above.

Because HOCl dominates at low pH, chlorination provides more effective disinfection at low pH. At high pH, OCl- dominates, which causes a decrease in disinfection efficiency.

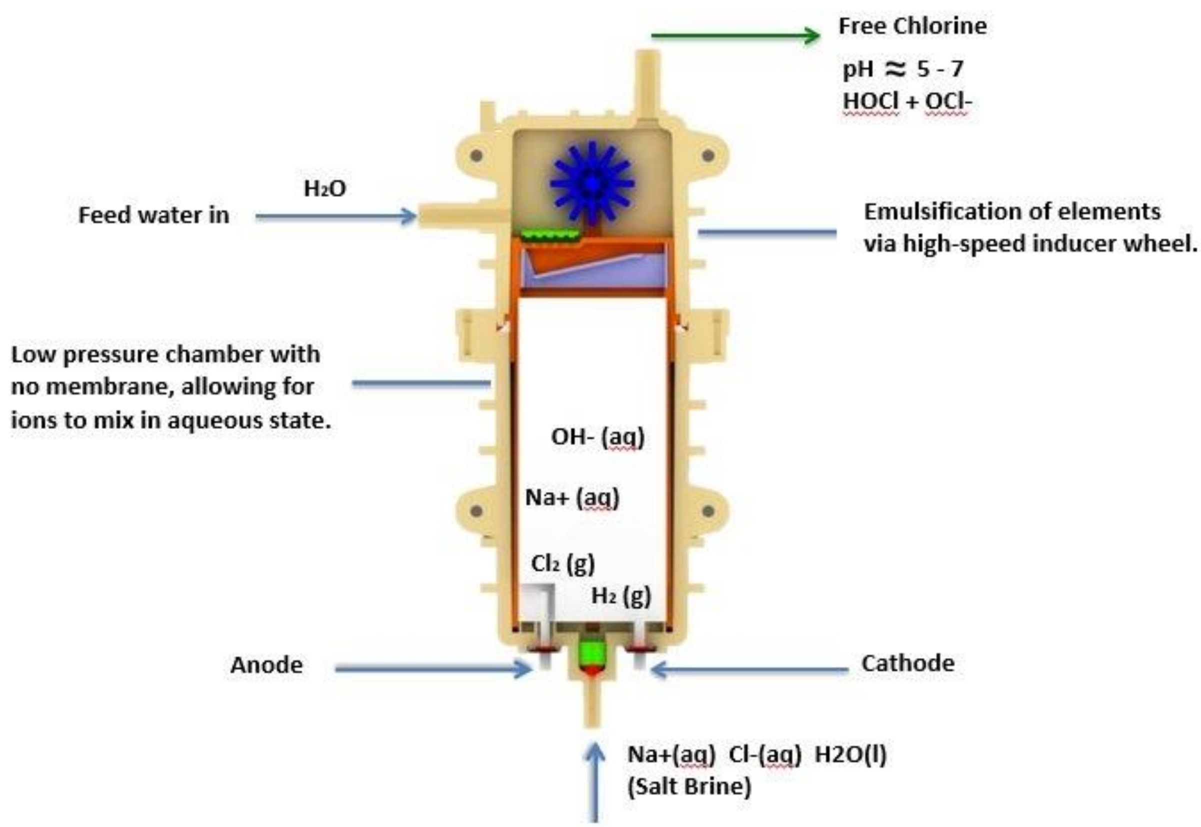
**Bacteria Inactivation**

Chlorine is an extremely effective disinfectant for inactivating bacteria. A study conducted during the 1940s investigated the inactivation levels as a function of time for E. coli, Pseudomonas aeruginosa, Salmonella typhi, and Shigella dysenteriae (Butterfield et al., 1943). Study results indicated that HOCl is more effective than OCl- for inactivation of these bacteria. These results have been confirmed by several researchers that concluded that HOCl is 70 to 80 times more effective than OCl- for inactivating bacteria (Culp/Wesner/Culp, 1986). Since 1986, there have been hundreds of publications confirming the superiority of HOCl over OCl-.

This biggest challenge has been to create hypochlorous acid at a near neutral pH instead of chlorine gas or hypochlorite, and to do so in a stable form. Hypochlorous acid is a meta-stable molecule. It wants to revert back to salt water or convert to hypochlorite.

**Single Cell Technology**

One of the greatest advancements has been the development of single cell technology where a single stream of free chlorine is generated without a byproduct of sodium hydroxide (NaOH). This technology has led to the development of more stable solutions of hypochlorous acid and has allowed for greater control over the pH of the free chlorine generated. Since water pH is different depending on its source throughout the world, altering the pH of the brine allows for greater control and consistency in generating a free chlorine solution between pH 5 and 7 that is dominated by hypochlorous acid (HOCl).



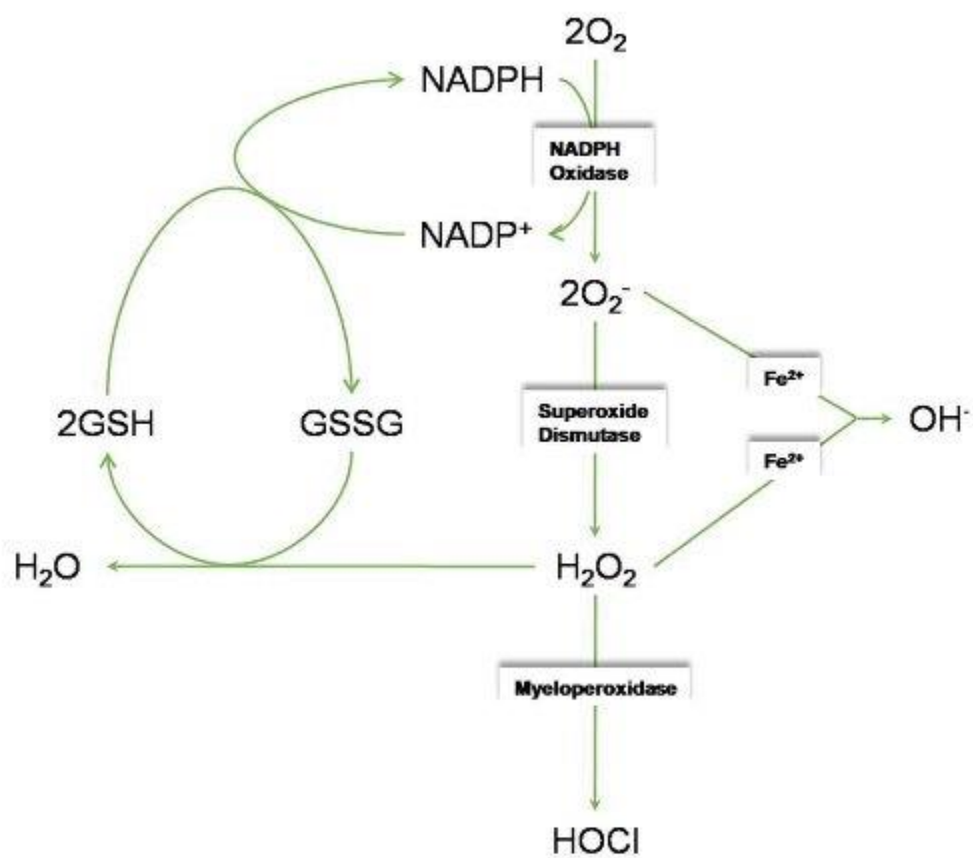

Anode reaction :
2Cl-(l) → Cl2(g) + 2e-

Cathode reaction :
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

Free Chlorine Generation :
$Cl_2(g) + H_2O \rightarrow HOCl + HCl$
$Cl_2(g) + 2OH^-(aq) \rightarrow OCl^-(aq) + Cl^-(aq) + H_2O(l)$

**Physiology**

Hypochlorous acid is one of the most effective known biocides. The chemical structure is HOCl.It is produced by the human immune system to kill invasive organisms and fight infection. White blood cells in the human immune system produce hypochlorous acid through the myeloperoxidase-mediated peroxidation of chloride ions. White blood cells release this natural oxidant to fight invading pathogens.




When a wound breaks human skin, it creates a gateway for harmful pathogens to invade human cells. Neutrophils, which are a type of white blood cell, travel in the blood to the site of the wound where the pathogens are invading. When an invading pathogen or infection threatens a human cell, the body's immune system responds by destroying the pathogen before it can harm the cell. The invading pathogens are engulfed by white blood cells through a process called phagocytosis. Once engulfed, the white blood cell produces an oxidant, hypochlorous acid. Hypochlorous Acid is a biocide and kills the microbial pathogen within milliseconds of contact. This antimicrobial process is called the Oxidative Burst Pathway.