



# HALAMID®

## BIOCIDAL MODE OF ACTION

### Historical view on the biocidal mode of action

Since the first publication by Chattaway(1) in 1905 on Chloramine T and the first introduction as a disinfectant by Dakin(2) in 1916, this product has been seen as slow hypochlorite (HOCl and/or OCl<sup>-</sup>) releasing agent. This despite some authors reported about properties conflicting with this theory(3,4).

Product properties conflicting with the theory of slow hypochlorite release in comparison to hypochlorite and chloro-isocyanurates are:

- excellent stability of the aqueous solution
- moderate pH dependence of the biocidal efficacy
- moderate influence of organic matter on the biocidal efficacy
- hardly any skin irritation
- hardly any chlorination ability

### New Studies I

Recently some studies have been published that prove that the biocidal mode of action of Halamid® is not based on the release of hypochlorite but must be explained by a different chemical mechanism.

Gottardi(5) calculated the theoretical composition of an aqueous Chloramine-T solution at various pH values. In an aqueous solution of Chloramine-T the following equilibriums exist: (R= CH<sub>3</sub>-C<sub>6</sub>H<sub>4</sub>-SO<sub>2</sub>)



According to these equilibriums, seven different compounds can be present in a Chloramine-T solution.

Based on the known equilibrium constants, Gottardi calculated for various pH values the concentrations of the individual compounds. If Chloramine-T would be a slow hypochlorite-releasing agent, then the compounds HOCl and/or OCl<sup>-</sup> should be present at a significant level. However Gottardi showed that for a 0.1 % Chloramine-T solution the hypochlorite concentrations [OCl<sup>-</sup>] and [HOCl] are:

at pH 3 : [ OCl<sup>-</sup> ] = < 0.01 µg/l, [ HOCl ] = 14 µg/l  
 at pH 7 : [ OCl<sup>-</sup> ] = 4 µg/l, [ HOCl ] = 14 µg/l  
 at pH 10 : [ OCl<sup>-</sup> ] = 35 µg/l, [ HOCl ] = 0.5 µg/l  
 at pH 12 : [ OCl<sup>-</sup> ] = 200 µg/l, [ HOCl ] = < 0.01 µg/l

The biocidal effects of Chloramine-T can never be explained by these minimal quantities of hypochlorite.

### New Studies II

Hahn et al(6) proved the theory of Gottardi by analysis. They developed an electrochemical analytical method by which they could detect very low concentrations of hypochlorite in a Chloramine-T solution. They found that in an aqueous solution containing 2.5 g Chloramine-T per liter, the hypochlorite concentration is lower than 100 µg/L (this is the detection limit of the analytical method). Even if they deliberately add hypochlorite to the solution, it reacts quickly with solution components. At neutral and alkaline pH values, it reacts with R-NH<sub>2</sub> (para-toluenesulfonamide), which -as Gottardi shows- is present at minor concentrations in a Chloramine-T solution, to form Chloramine-T. At acidic pH values it is reported to react with R-NHCl to form RNCl<sub>2</sub> (dichloramine-T).

So based on theoretical as well as analytical proven facts one has to conclude that Halamid® is not a slow hypochlorite releasing agent.

## Present view on the biocidal mode of action of Halamid®

Gottardi calculated that the compounds responsible for the biocidal properties of a Chloramine-T solution are:

- at pH < 3: R-NHCl and R-NCl<sub>2</sub> (Chloramine-T acid and Dichloramine-T)
- at pH 3 to 6: R-NHCl, R-NCl<sup>-</sup> and R-NCl<sub>2</sub> (Chloramine-T acid; Chloramine-T ion and Dichloramine-T)
- at pH > 7: R-NCl<sup>-</sup> (Chloramine-T ion)

At all pH values, these molecules represent more than 99.99 % of the total amount of Chloramine-T present in the solution.

## Biocidal mode of action of Halamid®

Halamid®, dissolved in water, ionizes and forms the Chloramine-T ion. This ion reacts directly with microorganisms such as bacteria, fungi, viruses, with which it comes into contact. Its action is based on an irreversible destruction of the envelope and cell material of microorganisms. This oxidizing action ensures that microorganisms are effectively killed and do not have a chance to develop resistance to Halamid®.

### References:

- 1 F.D. Chattaway, J. Chem. Soc. 87, 151 (1905)
- 2 H.D Dakin, J.B. Cohen, M. Daufresne, J. Kenyon, Proc. Royal Soc. London Ser. B. 232-251, 1916
- 3 Kirk-Othmer, Encyclopedia of Chemical Technology, 5th edition, Volume 5, page 921
- 4 Ullmann's Encyclopedia of Industrial Chemistry, 4th edition, Band 9, page 389
- 5 W. Gottardi, Arch. Pharm., 325, 377-384, (1992)
- 6 M. Hahn, A. Liebau, H.H. Rüttinger, R. Thamm, Anal. Chim. Acta, 289, 35-42, (1994)

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# HALAMID®

## LISTING OF SPECIES TESTED

**Halamid® has proven effective against all types of microorganisms (Gram positive and Gram negative bacteria, naked and enveloped viruses, fungi and parasites) ensuring a reliable result where disinfection is vital.**

**Check the list of microorganisms against which Halamid® is effective to discover its large active spectrum.**

**The applied concentration and contact time required are the critical parameters thus contact us for more details on a specific microorganism for your application.**

### Bacteria

Achromobacter anitratus  
 Acinetobacter spp  
 Actinobacillus pleuropneumoniae  
 Aeromonas hydrophila  
 Aeromonas salmonicida  
 Agrobacterium tumefaciens  
 Alcaligenes faecalis  
 Bacillus anthracis  
 Bacillus cereus  
 Bacillus diptheria  
 Bacillus dysentery  
 Bacillus flavothermus  
 Bacillus mesentericus  
 Bacillus subtilis spores  
 Bacillus subtilis  
 Bacillus thuringiensis  
 Bacterium enteritidis Gaertner  
 Bacterium paratyphi  
 Bacterium rhusopatha  
 Bacterium septamicariae haermorigicael  
 Bacterium typhi gallinarum  
 Brachyspira intermedia  
 Brachyspira pilosicoli  
 Brucella abortus bang  
 Brucella suis  
 Campylobacter spp. Jejuni  
 Carnobacterium piscicola  
 Citrobacter spp.  
 Clavibacter michiganese  
 Clostridium welchii  
 Clostridium sporogenes  
 Clostridium bifermentas  
 Clostridium tertium  
 Clostridium histolyticum  
 Clostridium caloritolterans  
 Corynebacteriummichiganese  
 Corynebacterium spp.  
 Enterobacter aerogenes  
 Enterobacter cloacae  
 Enterobacteriaceae Citrobacter

Enterobacteriaceae Hafnia  
 Enterobacteriaceae Klebsiella  
 Enterobacteriaceae Kluvera  
 Enterobacteriaceae Serratia  
 Enterococcus faecium  
 Erwinia carotovora  
 Escherichia coli  
 Escherichia tarda  
 Flavobacterium branchiophilum  
 Flavobacterium columnaris  
 Flavobacterium haematocrits  
 Flexibacter maritimus  
 Geotrichum candidum  
 Isaria farinose  
 Klebsiella oxytoca  
 Klebsiella pneumoniae  
 Lactonacillus spp.  
 Lawsonia intracellularis  
 Legionella pneumophila  
 Listeria monocytogenes  
 Micrococcus avium  
 Micrococcus citreus  
 Micrococcus pyogenes  
 Moraxella spp  
 Mycobacterium avium  
 Mycobacterium lacticola  
 Mycobacterium minetti  
 Mycobacterium pellegrino  
 Mycobacterium phlei  
 Mycobacterium piscium  
 Mycobacterium smegmatis  
 Mycobacterium vole bacillus  
 Pasteurella  
 Pediococcus cerevisiae  
 Proteus mirabilis  
 Proteus vulgaris  
 Providencia alcalifaciens  
 Pseudomonas aeruginosa  
 Pseudomonas fluorescens  
 Pseudomonas fragi  
 Pseudomonas putida  
 Pseudomonas putrefaciens  
 Pseudomonas pyocyanea  
 Pseudomonas solanacearum

Pseudomonas tolaasii  
 Pyocyaneus  
 Salmonella anatum  
 Salmonella dublin  
 Salmonella durban  
 Salmonella livingstone  
 Salmonella newbrunswick  
 Salmonella newport  
 Salmonella oranienburg  
 Salmonella paratyphi B  
 Salmonella pullorum  
 Salmonella rostock  
 Salmonella senftenberg  
 Salmonella thompson  
 Salmonella typhimurium  
 Sarcina lutea  
 Serratia marcescens  
 Serratia liquefaciens  
 Shigella boydii  
 Shigella sonnei  
 Spicaria pracina  
 Staphylococcus aureus  
 Staphylococcus aureus haemolyticus  
 Staphylococcus bag  
 Staphylococcus epidermidis  
 Staphylococ. paratyphosa B  
 Staphylococcus pyogenes  
 Streptococcus agalactiae  
 Streptococcus faecalis  
 Streptococcus faecium  
 Streptococcus lactis Blaser Sveitsi  
 Streptococcus suis  
 Tail rot disease  
 Vibrio alginoliticus  
 Vibrio anguillarum  
 Vibrio cholerae  
 Vibrio harveyi  
 Vibrio parahaemolyticus  
 Vibrio salmonicida  
 Vibrio vulnifious  
 Yersinia enterocolitica  
 Yersinia pseudo-tuberculosis  
 Yersinia ruckerii  
 Xanthomonas hyacinthi

## Viruses

Adenovirus  
African swine fever virus  
Aujeszky Disease virus  
Avian influenza A virus  
Avian reovirus  
Canine parvovirus  
Celovirus  
Classical swine fever virus  
Corona virus  
Coxsackie virus  
Diphtheria virus  
Ektromelie virus  
Encephalomyocarditis virus  
Enteric cytop. bovine orphan virus (ECBO)  
European swine fever virus  
Foot and Mouth Disease virus  
Fowl plague virus  
Fowl pox virus  
Gumboro Disease virus  
Hepatitis A virus  
Hepatitis B virus  
Hepatitis contagiosa canine virus  
Herpes virus  
Human Immuno-Deficiency virus (HIV)  
Human rotavirus  
Infectious bronchitis virus  
Infectious bursitis virus  
Infectious pancreatic necrosis  
Infectious salmon anaemia (ISA) virus  
Influenza virus  
Irido virus (ASFV)  
Myxomatosis virus  
New Castle Disease virus (NCD)  
Nuclear polyhedron virus  
Orthopox commune virus (vaccinia)  
Parainfluenza virus  
Paramyxo virus  
Picorna virus  
Poliovirus  
Porcine parvovirus  
Pox virus  
Pseudo Bird Pest virus  
Rabies virus (fixed)  
Reovirus  
Retro virus  
Rhino pneumonic virus  
South African Pest virus  
Swine fever virus  
Systematic ectodermal and mesodermal  
baculo virus (SEMBV)  
Teschen virus  
Toga virus  
Vaccinia virus  
Vesicular Swine Disease virus  
White spot disease virus (SMBV)

## Fungi

Aspergillus amstellodami  
Aspergillus flavus  
Aspergillus fumigatus  
Aspergillus gr. glaucus  
Aspergillus niger  
Aspergillus oryzae  
Aspergillus ochraceus  
Aspergillus versicolor  
Byssochlamys nivea  
Chaetomium globosum  
Cladosporium herbarum  
Cladosporium cladosporoides  
Entomophthora destruens  
Entomophthora thaxteriana  
Entomophthora virulenta  
Epidermophyton floccosum  
Fusarium moniliforme  
Geotrichum candidum  
Microsporum canis  
Microsporum gypseum  
Myrothecium verrucaria  
Oöspora lactis  
Paecilomyces variotii  
Penicillium cyclopium  
Penicillium funiculosum  
Penicillium granulatum  
Penicillium roqueforti  
Penicillium verrucosum  
Saprolegnia parasitica  
Tilletia caries  
Trichoderma viride  
Trichophyton equinum  
Trichophyton mentagrophytes  
Walleimia ichthyophaga

## Algae

Chlorella vulgaris  
Skeletonema sp.  
Tetraselmis sp.

## Yeasts

Candida albicans  
Cryptococcus spp  
Saccharomyces cerevisiae  
Saccharomyces diastaticus

## Parasites

Epistylis  
Gill trematoda  
Gyrodactylus salaris  
Ichtyobodo necator  
Ichthyophthirius multifiliis  
Labyrinthuloides haliotides (Labyrinthomorpha)  
Neoparamoeba pemaquidensis

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# HALAMID® IN FORMULATIONS

For most applications, Halamid® is simply dissolved in water and used as such with excellent results. In some peculiar situations, it can however be interesting to formulate Halamid®. Such applications include for example laundry and dish washing detergents, kitchen and lavatory cleaners, cow-teat disinfectants, where Halamid® is used either for its properties as a disinfectant or as an oxidizing agent. Because of its excellent stability together with the wide range of compatible products, Halamid® is an excellent product to be used in liquid or solid formulations.

## Compounds to avoid

Halamid® being an oxidizing compound, reducing compounds should not be mixed with it, to avoid inactivation. Compounds containing amine or ammonium groups should also be avoided as exchange of the active chlorine might occur with Halamid®.

Acidic compounds (or compounds forming acidic compounds by oxidation) cannot be used in Halamid® formulations: they induce a decomposition of Halamid® over time, thus reducing stability and shelf life of the formulation (cf below pH control).

## Surfactants

Halamid® itself does not have any surface tension activity, but it can perfectly be used in combination with non-ionic surfactants (eg ethoxylated fatty acids and ethoxylated nonylphenols), or anionic surfactants (such as alkylsulphonates or alkylsulfates).

## Viscosity

To increase the viscosity of liquid Halamid® solutions, carboxymethyl cellulose, polyvinyl alcohol and polyacrylates can be added.

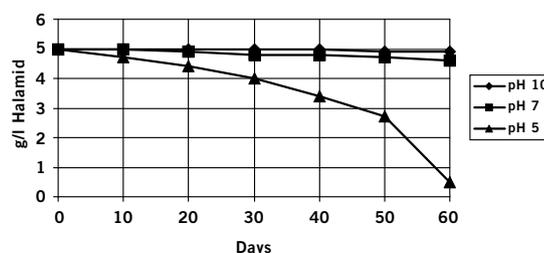
## Chelating agents

Chelating agents such as polyphosphates, aminopolycarboxylates and phosphonic acid based chelates can be used in Halamid® formulations to reduce the influence on properties of water hardness (calcium and magnesium ions) and presence of other trace metals.

## pH control

When dissolving Halamid® into water, a neutral to weakly alkaline solution is obtained, depending on the concentration. Acidic pH has a negative effect on Halamid® stability as shown on the graph below, but additives to increase the pH / buffer Halamid® formulations can easily be used. Such compounds include sodium and potassium carbonates, metasilicates, sodium and potassium hydroxide.

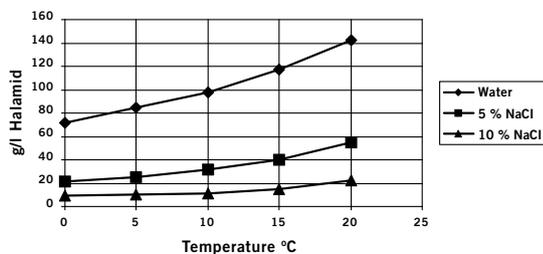
Stability of Halamid® solutions at various pH



## Solubility

For liquid formulations it is important to avoid crystallization. The graph below shows the solubility of Halamid® in water at different temperatures as well as the influence of salt content of this parameter.

**Solubility of Halamid® in water at various temperature and salt content**



## Influence of light

Halamid® stability is negatively influenced by light, therefore an opaque container is required to ensure Halamid® formulations are stable over time.

Examples of liquid and solid formulations containing Halamid® are available in the literature and can be obtained on request.

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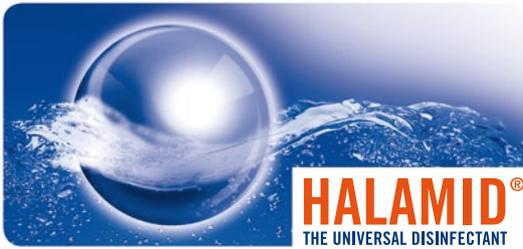
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# CORROSION DATA

## NOT CORROSIVE TO EQUIPMENT, HOUSING, ETC.

According to EC-regulations Halamid® is to be labeled as a corrosive substance. However, this classification is based on the result of a skin irritation test performed with Halamid® as a moistened solid powder. These tests have no relevance for determining material corrosion.

When applied as a disinfectant, Halamid® is always used in an aqueous solution. The results of material corrosion tests with a 0.5% Halamid® solution tests are presented in the table on the reverse side of this bulletin. From the results it can be concluded that Halamid® has no or only a minor corrosive effect on materials commonly used in farms, shops, institutes and industries, like stainless steel, aluminum, concrete, wood, polymers.

### HALAMID®, A UNIQUE PRODUCT

- Large activity spectrum
- Non corrosive in solution for materials
- Easy to use and versatile
- Stable
- Readily biodegradable
- No risk of building up resistant microorganisms

### Corrosion table of Halamid® solution (0.5% in water)

Objects exposed to continuous agitation at 50°C for 48 hrs.

Material	Weight g/m <sup>2</sup> /day	Description of the object	Description of solution after treatment	Judgment
Nickel free Chromic Steel	- 0.66	light corrosion on the welding seam	practically unchanged, clear	practically fully resistant
Iron	58.92	etched	clear, colourless, dark brown deposit	not very good resistant
Iron, tinned	- 0.48	build-up of a mat-layer with good adhesion	practically unchanged, clear	practically fully resistant
Brass	0.11	practically unchanged	practically unchanged, clear	practically fully resistant
Copper	- 3.58	not attack. build-up of a rough layer with good adhesion	practically unchanged, clear	practically fully resistant
Alu-composition	0.16	darkly coloured with many white spots	practically unchanged, clear	practically fully resistant
Pure aluminum	- 0.80	darkly coloured	practically unchanged, clear	practically fully resistant
Wood-teak	- -	whitened slightly more porous surface	light yellow	resistant
Oak	- -	some yellowing	light yellow	resistant
Mahogany	- -	some yellowing	light yellow	resistant
Rubber	- -	some yellowing	light yellow	fully resistant
Plastics (PE-PVC etc.)	- -	unchanged	unchanged	fully resistant

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# HALAMID® - STABILITY DATA

Halamid® is a universal, effective, readily biodegradable disinfectant with superior storage stability. Tests have shown that Halamid® is a very stable product, both as a powder and as a solution, ensuring that it remains ready for use with full efficacy whenever you need it.

Halamid® has a shelf life of two years after production date when stored in the closed original packaging, in a cool and dry place, away from direct sun light and heat.

## Storage stability

Tests have shown that, if properly stored, Halamid® will not undergo significant changes in quality even after several years of storage.

In order to determine the storage stability of Halamid® under tropical conditions a test was performed at 35°C and 85% relative humidity.

25 kg of Halamid® packed in its original 4 ply paper bag were placed in a constant climate cupboard for 120 days. During this period the weight and the content of the Halamid® were regularly checked. After 120 days of storage at 35°C and 85% relative humidity the Halamid® packed in its original bag proved not to have been changed in weight or content.

A similar test was run with Halamid® in open contact with the humid air.

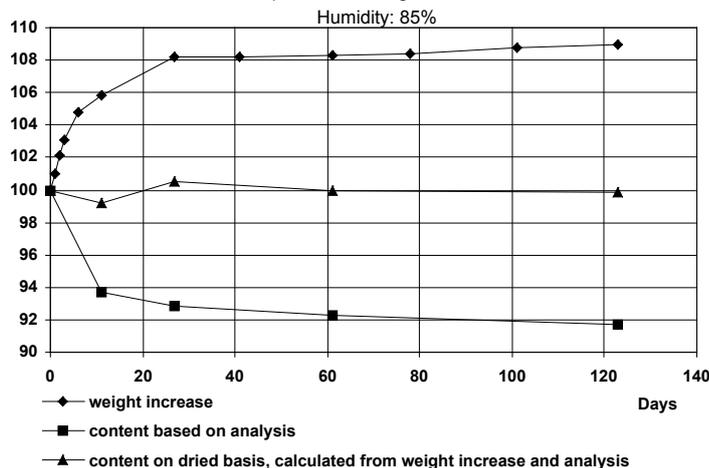
In the first 30 days of this experiment the weight of the Halamid® increased while the content declined. After that period the weight and content of the Halamid® were more or less stable.

The weight increase was caused by water adsorption, which resulted in a content reduction exactly proportional to the content decrease analyzed. No decomposition of Halamid® could be detected.

All this proves that Halamid® is a product with superior storage stability even under non-ideal conditions.

## Halamid® Stability under Tropical Conditions

Test condition: direct contact between Halamid and air  
Temperature: 35 degrees Celsius



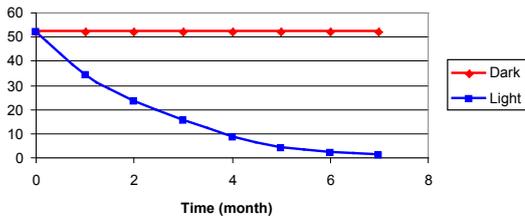
## STABILITY IN SOLUTION

The available data show that Halamid® solutions prepared with clean water and store away from light and heat are very stable, which makes possible to prepare stock solutions.

### Influence of light

From the graph below, it is clear that a Halamid® solution stored in the dark (using an opaque container) can be stored for several months without decomposition.

**Influence of light, 5% Halamid® solution**

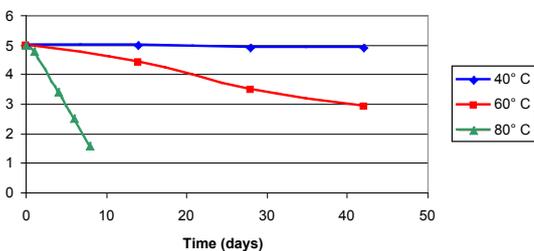


It is important to avoid exposure of Halamid® solutions to sunlight if they are to be kept for a certain period of time.

### Influence of temperature

Even at elevated temperature, Halamid® solutions show good stability. For example, after 4 weeks at 40°C, only 2% of activity is lost.

**Influence of temperature, 0.5% Halamid® solution**

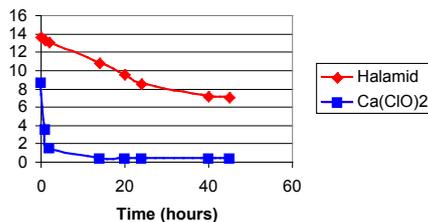


### Influence of organic matter

Presence of organic matter has only a limited effect on Halamid® efficacy. It is for example recognized that Halamid® is much less affected by organic matter than hypochlorite.

To illustrate this, Halamid® and hypochlorite solutions were prepared using river water. After only a couple of hours, the vast majority of hypochlorite is degraded by reaction with the organic matter present, while after 2 days, there are still about 50% of the original Halamid® concentration available.

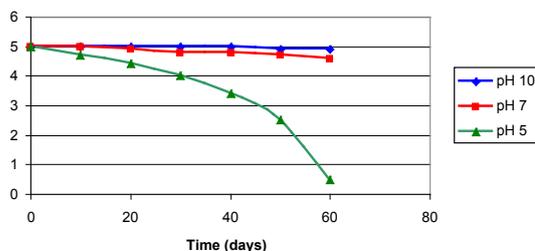
**Halamid® vs hypochlorite (river water)**



### Influence of pH

The graph below show the influence of pH on stability of a Halamid® solution. Under neutral / alkaline pH condition, the Halamid® solution is very stable. Under acidic conditions, Halamid® is degraded, one of the reasons why acidic compounds should not be mixed with Halamid® in formulations.

**Influence of pH, 0.5% Halamid® solution**



All the available data point to the stability of Halamid®, both as a solid as well as in solution

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