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LENNTECH**Disinfectants****Hydrogen peroxide**

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Hydrogen peroxide

Most people know hydrogen peroxide as a compounds that bleaches hair. It can also be used for water disinfection.

When was hydrogen peroxide discovered?

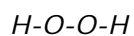
Louis Jacque Thenard discovered hydrogen peroxide in 1818. Hydrogen peroxide consists of [oxygen](#) and [hydrogen](#) atoms. These can be found everywhere on earth. Hydrogen peroxide contains a combination of two hydrogen atoms and two oxygen atoms.

In the environment, hydrogen peroxide can be found in very low concentrations. Gaseous hydrogen peroxide is produced by photo chemical reactions in the atmosphere surrounding the earth. It can also be found in water in small quantities.

What are the characteristics of hydrogen peroxide?

Peroxide is a chemical compound that contains the peroxide ion (O_2^{2-}).

The peroxide ion consists of a single bond between two oxygen atoms: $(O-O)^{2-}$. It is a strong oxidiser. Hydrogen peroxide has the chemical formula H_2O_2 and the following structural formula:



The hydrogen peroxide molecule contains one extra oxygen atom, compared to the more stable [water molecule](#). The bond between the two oxygen atoms, the so-called peroxide bond, is broken while two H-O radicals are formed. These radicals quickly react with other substances, while new radicals are formed and a chain reaction takes place. Hydrogen peroxide solutions look like water and can be dissolved in water unrestrainedly. At high concentrations these solutions give off an irritating, acidic smell. Hydrogen peroxide is inflammable. At low temperatures it becomes solid. The amount of hydrogen peroxide in the solution is expressed in weight percentage. For water treatment, concentrations of 35 or 50 % hydrogen peroxide are used.

Selectivity

Hydrogen peroxide is used for different applications, because it is very selective. By changing the reaction conditions (temperature, [pH](#), dose, reaction time and the addition of a catalyser), hydrogen peroxide will attack different pollutions.

Corrosiveness of hydrogen peroxide

The corrosiveness of process water due to hydrogen peroxide depends on the amount of dissolved oxygen that is produced. Oxygen corrodes iron-containing metals. The amount of iron and the pH are a greater influence on corrosiveness than the concentration of hydrogen peroxide is.

Destruction of hydrogen peroxide

Hydrogen peroxide can disintegrate during transport. Oxygen and heat are released. Hydrogen peroxide itself is inflammable, but the oxygen can enhance the inflammation of other substances. In diluted solutions, the heat is absorbed by water. In concentrated solutions, the temperature of the solution is increased, accelerating hydrogen peroxide destruction. The rate of destruction is multiplied with 2,2 for every 10 °C of rise in temperature. The alkalinity and presence of pollutions also accelerate the destruction of hydrogen peroxide. For the production of hydrogen peroxide, special catalysers are used to make sure that hydrogen peroxide is not destroyed by pollutants in the water.

How is hydrogen peroxide produced?

Since 1880, hydrogen peroxide is a commercial product. It was first produced in the United Kingdom by burning [barium](#) salt (Ba), which produced barium peroxide (BaO₂). Subsequently the barium peroxide was dissolved in water and hydrogen peroxide was produced. Since the 19th century the production of hydrogen peroxide has largely increased. Nowadays about half a billion kilograms are produced annually.

How is hydrogen peroxide transported and stored?

Hydrogen peroxide must be transported in polyethylene, [stainless steel](#) or [aluminium](#) containers. When hydrogen peroxide comes in contact with flammable substances, such as wood, paper, oil or cotton (cellulose), spontaneous ignition may occur. When hydrogen peroxide is mixed with organic matter, such as alcohols, acetone and other ketones, aldehydes and glycerol, heavy explosions may occur. When hydrogen peroxide comes in contact with substances, such as [iron](#), [copper](#), chromium, [lead](#), [silver](#), [manganese](#), [sodium](#), [potassium](#), [magnesium](#), [nickel](#), [gold](#), [platinum](#), metalloids, metal oxides or metal salts, this may result in powerful explosions. This is why hydrogen peroxide is usually transported in diluted form.

What are the applications of hydrogen peroxide?

The eldest known application of hydrogen peroxide was bleaching straw hats, which were fashionable in the beginning of the twentieth century. From 1920 to 1950, hydrogen peroxide was produced through electrolysis. This method produced pure hydrogen peroxide. Nowadays, self-oxidation processes are used to produce hydrogen peroxide. During these processes, hydrogen is the raw material.

Versatility of hydrogen peroxide

Hydrogen peroxide is versatile, it can be used for many applications. It can be used in all media; air, water, waste water and soils. It is sometimes used combined with other agents, to enhance and accelerate processes. Hydrogen peroxide is most commonly used to remove pollutants from waste water and from air. It contests bacterial growth (for example bio fouling in water systems) and it can enhance bacterial growth (for example bio remediation of polluted soils and ground water) through [oxygen](#) addition. It can also be used to treat pollutions that can be easily oxidized (for example [iron](#) and sulphides) and pollutions that are difficult to oxidise (for example dissolved solids, gasoline and pesticides). Finally, it can be used to bleach paper, textile, teeth and hair or to produce food, minerals, petrochemical substances or washing powder. In pure form, hydrogen peroxide is used as an oxygen provider to drive Russian submarines.

Can hydrogen peroxide be used as an oxidiser?

Hydrogen peroxide is a strong oxidiser. It is more powerful than [chlorine](#) (Cl₂), [chlorine dioxide](#) (ClO₂) and potassium permanganate (KMnO₄). Through catalysis, hydrogen peroxide can be converted into hydroxyl radicals (OH). The oxidation potential of hydrogen peroxide is just below that of ozone.

Table 1: Oxidation potentials of various oxidisers

Oxidiser	Oxidation potential
fluorine	3,0
hydroxyl radicals	2,8
ozone	2,1
hydrogen peroxide	1,8
potassium permanganate	1,7
chlorine dioxide	1,5
chlorine	1,4

How is hydrogen peroxide dosed?

Most hydrogen peroxide applications consist of hydrogen peroxide injection into flowing water. No other chemicals or equipment are required. This application is used to control biological growth, to add oxygen, to remove chlorine residues and to oxidize sulphides, sulphites, metals and other easily oxidized materials. The suitability of hydrogen peroxide for these applications is influenced by pH, temperature and reaction time.

Catalytic hydrogen peroxide

Pollutants that are not easily oxidized, require hydrogen peroxide activation by catalysers (iron, [manganese](#) or other metalloids). These catalysers can also be used to enhance hydrogen peroxide reactions, which would otherwise take hours or days.

What are advanced oxidation processes?

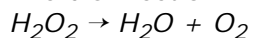
Advanced oxidation processes are a new development in the field of hydrogen peroxide disinfection. These processes produce reactive oxygen radicals, without the interference of metal catalysers. Examples are the combination of hydrogen peroxide with [ozone](#) ([peroxone](#)) or [Ultra Violet Light](#). The result of these methods is far-reaching oxidation of difficultly degradable substances, without the production of residues or sludge. These methods are used worldwide for groundwater treatment, for drinking water and process water treatment and for organic matter disinfection and removal from industrial wastewater.

How does hydrogen peroxide disinfection work?

Among other applications, hydrogen peroxide is used as a disinfectant. It is used to treat inflammation of the gums and to disinfect (drinking) water. It is also used to combat excessive microbial growth in water systems and cooling towers.

In the United States, hydrogen peroxide is used more and more frequently to treat individual water supplies. It is used to prevent the formation of colors, tastes, corrosion and scaling by pollution degradation (iron, manganese, sulphates) and micro-organism degradation. Hydrogen peroxide reacts very fast. It will then disintegrate into [hydrogen](#) and water, without the formation of byproducts. This increases the amount of oxygen in water.

The disinfection mechanism of hydrogen peroxide is based on the release of free oxygen radicals:



Pollutants are decomposed by free oxygen radicals, and only water remains. Free radicals have both oxidising and disinfecting abilities. Hydrogen peroxide eliminates proteins through oxidation.

Peroxides such as hydrogen peroxide (H₂O₂), perborate, peroxiphosphate and persulphate, are good disinfectants and oxidisers. In general these can adequately remove micro-organisms. However, these peroxides are very unstable.

Perborates are very toxic. Peracetic acid (PAA) is a strong acid. It can be very aggressive in its pure form. Stabilised persulphates can be used to replace chlorine for [waste water](#) treatment.

Is hydrogen peroxide used for drinking water disinfection?

In the 1950's, hydrogen peroxide was first used for drinking water disinfection in Eastern Europe. It is known for its high oxidative and biocidal efficiency. Hydrogen peroxide has not been used often for drinking water disinfection, but it's popularity seems to increase. It is often used combined with [ozone](#), [silver](#) or [UV](#).

Is hydrogen peroxide used for swimming pool disinfection?

The application of peroxides for disinfection and water treatment are limited. Recently, more stable forms have been developed, which can be used for application in swimming pools.

Hydrogen peroxide disinfection requires a high dose. The main disadvantage is the small disinfecting and oxidising ability of hydrogen peroxide at active concentrations (tens of milligrams per litre), which are required for swimming pool disinfection. Another problem is the quick decomposition of hydrogen peroxide in water and the presence of oxygen radicals. Through stabilizer addition, the decomposition of hydrogen peroxide is delayed and the disinfection ability can be maintained.

Compared with [chlorine](#), [bromine](#), ozone and other disinfectants, hydrogen peroxide is not a very powerful disinfectant. Swimming pools disinfection by hydrogen peroxide is not allowed, unless it is used in combination with other disinfectants (UV, ozone, silver salts or ammonia quart salts). Hydrogen peroxide improves the disinfection ability of other disinfectants.

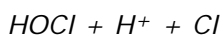
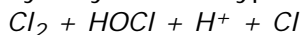
Can hydrogen peroxide be used for cooling tower water disinfection?

Hydrogen peroxide can be used for cooling tower water disinfection, when it is combined with other disinfectants. Peracetic acid (CH₃COOH, PAA) can also be used for cooling tower water disinfection.

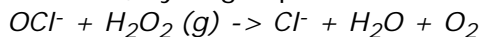
Does hydrogen peroxide remove chlorine?

Hydrogen peroxide can be used for dechlorination, in other words to remove residual chlorine. Residual chlorine forms corrosive acids when it is oxidised by air or condensates on process systems.

When chlorine reacts with hydrogen peroxide, hydrogen peroxide falls apart into water and oxygen. Chlorine gas hydrolyses into hypochlorous acid (HOCl), which subsequently ionises into hypochlorite ions (OCl⁻).



After that, hydrogen peroxide reacts with hypochlorite:



The reaction between hydrogen peroxide and hypochlorite takes place very quickly. Other organic and inorganic substances cannot react with hypochlorite.

What are the advantages and disadvantages of hydrogen peroxide use?

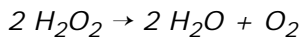
Advantages

Contrary to other chemical substances, hydrogen peroxide does not produce residues or gasses. Safety depends on the applied concentration, because hydrogen peroxide is completely water soluble.

Disadvantages

Hydrogen peroxide is a powerful oxidizer. It reacts with a variety of substances. It is therefore diluted during transport, as a safety measure. However, for hydrogen peroxide disinfection, high concentrations are required. Hydrogen peroxide slowly decomposes into water and oxygen. An elevation of temperature and the presence of pollutions enhance this process.

The concentration of hydrogen peroxide in a solution slowly decreases. This is caused by the following reaction:



This is a [redox](#) reaction. Hydrogen molecules partly function as reductors and partly as oxidizers.

Is hydrogen peroxide efficient?

The efficiency of hydrogen peroxide depends on several factors, such as pH, catalysers, temperature, peroxide concentration and reaction time.

What are the health effects of hydrogen peroxide?

Exposure to hydrogen peroxide takes place through inhalation of damp or mist, through food uptake and through skin or eye contact. Hydrogen peroxide can irritate the eyes, skin and mucous membranes. Exposure of the eyes to concentrations of 5% or more can result in permanent eye damage. Tests with laboratory animals from the American International Agency on Cancer Research (IARC) show that hydrogen peroxide can be carcinogenic to animals. Laboratory tests with bacteria show that hydrogen peroxide is mutagenic; it changes and damages DNA. When humans inhale hydrogen peroxide, it causes lung irritation. Skin exposure causes painful blisters, burns and skin whitening. Organs that are extra susceptible to hydrogen peroxide exposure are the lungs, the intestines, the thymus, the liver and the kidneys. The effects of chronic exposure on humans are unknown. Effects on reproduction and development are not demonstrated so far.

What is the legislation for hydrogen peroxide?

EU

Hydrogen peroxide is not mentioned in the European Drinking Water Standard 98/83/EC.

USA

In the USA, hydrogen peroxide is registered as a pesticide by the EPA in 1977.

Which substances can be combined with hydrogen peroxide?

For disinfection, hydrogen peroxide can be combined with other agents. For example peracetic acid and peroxone.

More information on water disinfection?:

[Introduction water disinfection](#) [Necessity water treatment](#) [History of drinking water treatment](#)

[What is water disinfection?](#) [Necessity of drinking water disinfection](#) [History of water disinfection](#) [Waterborne diseases](#) [Factors that influence disinfection](#) [Conditions of water disinfection](#) [Regulation drinking water disinfection](#)
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