



**An investigation into the production of
SODIUM DICHLOROISOCYANURATE
in Iran**

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Abstract

Hypochlorous acid is a weak acid that is used to disinfect and kill bacteria and viruses. This acid is produced in the body of mammals by white blood cells. A safe material that can be used in various fields.

Hypochlorous acid can be produced by many methods, which we discuss in this article. Chlorine gas and sodium or calcium hypochlorite and electrolysis can be used to produce this material. Each of these methods has advantages and disadvantages that have been examined. Sodium dichloroisocyanurate, with the trade name NaDCC or SDIC, is a product in the form of powder or tablet that needs to be dissolved in a specific amount of water to produce hypochlorous acid.

Sodium dichloroisocyanurate is obtained from the combination of cyanuric acid, sodium hydroxide, and chlorine. It is more durable and easier to transport. According to the conditions of today's world, especially the spread of the coronavirus, the human need for a safe and available disinfectant is increasing day by day, for this reason, the market for the production of sodium dichloroisocyanurate is expanding every day. According to the obtained statistics, a large amount of this product is imported into Iran. Currently, no factory is working to produce this material in Iran. In this project a brief techno-economic investigation of establishing such a production plant in Iran was conducted and based on the available data, it was found to be feasible and advantageous.

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Acknowledgments

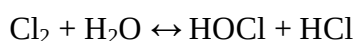
I am grateful to the Baha'i Institute of Higher Education (BIHE) for providing me with the opportunity to continue my studies. Next, I would like to thank my family for supporting me in all situations and being with me in this way. I am grateful to my classmates for the time we helped each other on the way to learning. I am grateful to the supervisor of this project Mr. Soha Rouhani for all his help and guidance.

Introduction

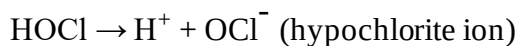
To have a healthy life, we need to protect ourselves against viruses, bacteria, fungi, etc. For this reason, disinfectants entered our lives. Especially today, due to the spread of the corona disease, antiseptics have played a prominent role in our lives. From alcohol to other disinfectants, all these items have many uses. But some of these substances cause problems and diseases for humans over time. Hypochlorous acid is a strong disinfectant and a weak acid that has many uses. Since this substance is found in the body of mammals, it is clear that it is not harmful to us. To obtain hypochlorous acid, there are many methods such as injecting chlorine into water or using sodium and calcium hypochlorite, or electrolysis of water and salt solution. Another method that is newer than the other methods is the use of sodium dichloroisocyanurate anhydrate or dihydrate tablets. We will further examine this method and estimate the cost of establishing a sodium dichloroisocyanurate production plant.

Hypochlorous acid

From the past until today, there have been many methods of disinfection. Using alcohol or bleach are disinfection method. Another method of disinfection is the use of chlorine and its derivatives. Chlorine was first used as a disinfectant in the form of hypochlorite, then sodium hypochlorite was marketed and is still used today. But not all chlorine compounds are equally effective for disinfection. By adding chlorine to the water, a product called **hypochlorous acid (HOCl)** is created. (The science of chlorine-based disinfectant, 2013)



The breakdown of hypochlorous acid (HOCl) is as follows:



Hypochlorous acid is a weak acid and a strong oxidizing agent. This substance is found in the body of all mammals because white blood cells release this substance to defend the body. Hypochlorous acid is a powerful disinfectant that kills:

1. viruses
2. mushrooms
3. bacteria

for this reason, it is used in many fields, especially medicine. Compared to bleach and alcohol, hypochlorous acid is a more effective and safer disinfectant. Alcohol or bleach cannot destroy all germs, bacteria, and viruses, but hypochlorous acid with a high probability (99.9%) can destroy them without any harm to the organisms. Hypochlorous acid is 80 to 100 times more effective than bleach. On the other hand, excessive use of alcohol causes skin problems, but this product does not cause such problems. (Hypochlorous Acid: Nature's germ killer, 2022)· (Hypochlorous acid: harnessing nature's germ killer, 2019)· (What Is Hypochlorous Acid? And Why Should You Use It?, 2021)

Of course, there are other reasons for the popularity of hypochlorous acid:

1. Hypochlorous acid can be easily produced
2. This product is environmentally friendly
3. doesn't leave any traces
4. doesn't have Toxic vapor
5. Even if you accidentally eat this product, it will not harm you

All these things make hypochlorous acid superior to other chemical disinfectants. (Why is hypochlorous acid a better disinfectant?, 2021) The instability of this product is one of the disadvantages that scientists were looking for a way to solve this problem. Today, with technological progress, hypochlorous acid solutions can be produced with long-term stability and are cheaper. (Harnessing the benefits of hypochlorous acid, 2022)

Pure HOCl when combined with water produces fewer byproducts than oxidizers such as chlorine. Also, unlike ozone, it does not produce additional products such as aldehyde, ketone, ketone acid, etc., unless it is under special conditions. (Disinfectants Chlorine Dioxide, n.d.)¹

Applications of hypochlorous acid

- Hypochlorous acid has many uses in industry. One of its main and important uses is water disinfection. This product is also used in other industries. For example, we can mention wastewater disinfection, industrial water treatment, and cooling tower water disinfection. In cooling towers, hypochlorous acid disinfects the flowing water and prevents the formation of biofilm² in the cooling towers, and does not allow the equipment and pipes to be damaged. (Disinfectants Chlorine Dioxide, n.d.)

- Another application of this product is the use of hypochlorous acid vapor to isolate and disinfect the operating room. They use a fog dispenser to do this. You can use it without worrying about the chemical effects of the product. (Hypochlorous Acid: A Review, 2020)

¹ n.d. (no date)

² A community is a microorganism's cells attached to a surface and covered by extracellular polymeric substances.

- Hypochlorous acid can also be used as a hygienic solution on the skin of the eyes. Many bacteria, fungi, and microscopic organisms live on our skin. Some of these are good and some are bad for us. With the help of research on the skin around the eyes, researchers found that some species of bacteria cause dry eyes and corneal damage. Hypochlorous acid is used to treat dry eyes. HOCl has different methods than antibiotics for killing bacteria and acts as an oxidant. HOCl is very effective in vitro against a wide range of microorganisms, helping to fight infection, reduce inflammation, control the body's response to injury, and enhance its natural ability to heal. (Reduction in bacterial load using hypochlorous acid hygiene solution on ocular skin, 2017). (The Science Behind Bruder Hygienic Eyelid Solution, n.d.)

- Hypochlorous acid also plays a role in agriculture. Every year, many cases of poisoning by contaminated vegetables and agricultural products refer to the doctor. These poisonings can be from bacteria or fungi transferred from contaminated water and can be due to bacterial contamination of food processing surfaces. With HOCl, these problems can be solved and contaminations can be eliminated. (Imran, SUGIYAMA, & ISOBE, 2015)

- The water used in poultry farming, from drinking water to cooling water and water for washing equipment, etc., must be clean and disinfected. In the poultry house, due to the presence of feces and manure, the place becomes contaminated and bacteria can grow quickly. The disease in poultry can be transmitted from one chicken to another through drinking water. The use of hypochlorous acid can minimize the presence of bacteria, but its use must be continuous, except when the birds are receiving medical treatment. (Disinfection Of Poultry Drinking Water And Processing Water, 2000)

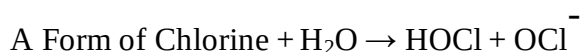
- The water supply of the dental surgery unit is provided by the city water or packaged water system. The water lines of the dental unit must be regularly cleaned and disinfected because over time the biofilms in these lines (such as bacteria, fungi, etc.) cause contamination, and this causes problems for the dentist, the dental team, and the patients. To eliminate these biofilms, the water lines of the dental unit must be disinfected. One of these ways of disinfection is the use of hypochlorous acid, which is very effective in this work. (Dental unit waterlines disinfection using hypochlorous acid-based disinfectant, 2016). (Dental Unit Waterlines, 2018)

The production process for hypochlorous acid

To have drinkable water, it must be disinfected. The best way to do this is to use hypochlorous acid. There are three ways in which hypochlorous acid can be produced.

a. Injection of chlorine gas into water

One of the most common ways to disinfect water is chlorination. Chlorine is one of the most widely used and important chemicals used in water treatment. This powerful substance is used for disinfection, control of microorganisms, removal of ammonia, control of taste and odor and color reduction, decomposition of organic matter, oxidation of hydrogen sulfide, and oxidation of iron and manganese. But we must keep in mind that the use of chlorine is very dangerous for us. (Chapter 27 - Chlorine And Chlorine Alternatives, n.d.)



Adding chlorine to prepare hypochlorous acid can also be done with chlorine-containing ingredients, but it remains to be seen how much product and how much pH we need. The three most common types of chlorine used in chlorination are (What is Chlorination?, 2016):

1. **chlorine gas**
2. **sodium hypochlorite**
3. **calcium hypochlorite**

1. chlorine gas

Chlorine is one of the most widely used substances in the industry. Chlorine is a toxic gas and its color is yellow and green. Its density is higher than the density of air (2.5 (Air = 1)), therefore it is heavier than air. Chlorine is an oxidizer and is very toxic to aquatic animals. May cause or exacerbate fire, and in case of lethal inhalation. (SAFETY DATA SHEET Chlorine) However, chlorine gas, after entering the water, is converted to hypochlorous acid and hypochlorite ions, and its toxic properties are eliminated for human consumption of drinking water. (What is Chlorination?, 2016)

Chlorine gas is the least expensive form of chlorine to use. The usual amount of chlorine gas required for water treatment is 1-16 mg per liter of water. Depending on the quality of the water that needs to be treated, different amounts of chlorine gas are used. (What is Chlorination?, 2016)



Water pH	Dominant molecule
pH < 6.5	hypochlorous acid
6.5 < pH < 8.5	hypochlorous acid and hypochlorite ions
pH > 8.5	hypochlorite ions

Table 1 - pH value for hypochlorous acid production

The best material for disinfection is hypochlorous acid, and according to the table above, for the production of hypochlorous acid, the pH of the water should be low.

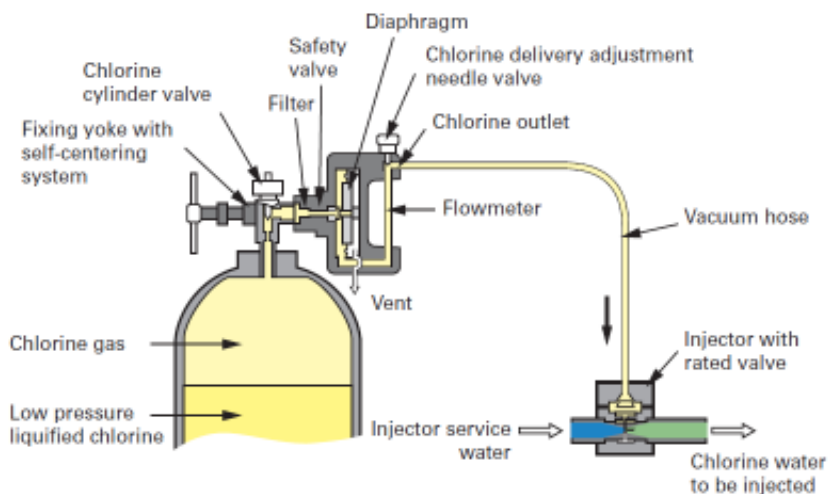


Fig 1 - Injection of chlorine into water

But how much chlorine should be added to water? The amount of chlorine measured in water should be as much as the amount of chlorine added when the water is pure but we know that water is never 100% pure. There are always other substances in water that will chemically combine with chlorine, such as iron, manganese, and turbidity, and when chlorine is combined with these substances, chlorine can't disinfect water well. Disinfecting water is done with free chlorine. (Disinfection, 2018) We have three types of chlorine for water disinfection. The first is free chlorine, which is available to inactivate disease-causing organisms and can disinfect contaminants. The second is combined chlorine that reacts with additives in the water such as iron, nitrates, etc., and has

little power for disinfection. Another case is total chlorine, which is the sum of free chlorine and combined chlorine. (Difference Between Free Chlorine and Total Chlorine, n.d.) (Free and Total Chlorine, n.d.) (What's The Difference Between Free Chlorine And Total Chlorine?, 2020)

Now let's see how chlorine is consumed in water. According to the diagram, when chlorine is added to water, it is initially consumed by disturbing agents. Here, little or no disinfection is performed. As chlorine is added, the total residual chlorine increases. At this time, chlorine reacts with organic matter and ammonia, all of which are combined chlorine residuals. Due to chemical reactions, the total actual residue is reduced. So, we have to add more chlorine to the water. By adding chlorine, the residue is converted to free chlorine, which is called the breaking point in chlorination. (Disinfection, 2018)

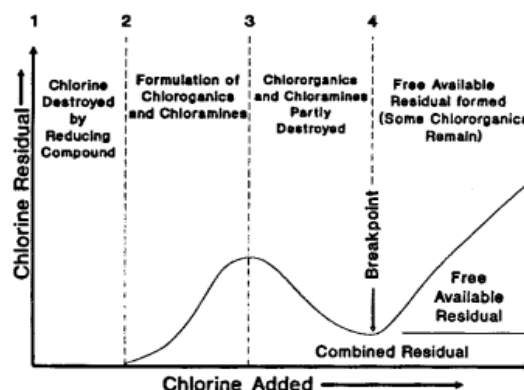


Fig2 - Breakpoint chlorination curve

Using chlorine has advantages and disadvantages. Disinfecting with chlorine kills a wide range of viruses and bacteria. Chlorine can be used to oxidize organic and inorganic compounds. You can also control the chlorine dosage. Chlorine can eliminate many odors during disinfection. But residual chlorine is toxic to aquatic life. On the other hand, chlorine is highly corrosive and toxic, making it dangerous to transport. Also, the combination of chlorine with some organic substances in wastewater may be dangerous. Chlorine is also dangerous for humans and it may cause problems for our bodies by creating a new combination. (Pros and Cons of Chlorine in Water, 2020) (wastewater technology fact sheet chlorine disinfection, 1999)

2. Sodium hypochlorite

Sodium hypochlorite (NaOCl) is a compound that can be used to treat water. Sodium hypochlorite is a clear, slightly yellow solution. The boiling point is 111°C in solution. Sodium hypochlorite is unstable in the air. This substance is very toxic to aquatic animals and has long-term effects. (Sodium hypochlorite, n.d.) Some properties of sodium hypochlorite such as reacting to heat or sunlight and contact with acids, etc. should be considered during transportation, storage, and use. (Understanding Sodium Hypochlorite, 2013) (Disinfectants Sodium hypochlorite, n.d.)

How can sodium hypochlorite be produced? There are generally two methods for producing sodium hypochlorite. One way to produce sodium hypochlorite is to dissolve salt in water, which is electrolyzed to form a solution of sodium hypochlorite in water. Electrolysis of salt in water gives chlorine gas and hydrogen gas and sodium hydroxide. Chlorine, if not released, reacts reversibly with water to produce HOCl and HCl . In a simple undivided cell, NaOH reacts with HCl and HOCl ,

directing the equilibrium to produce NaOCl and NaCl. (Disinfectants Sodium hypochlorite, n.d.) (Hypochlorite Generation from a Water Softener Spent Brine, 2018) In the following sections, we will talk in detail about electrolysis.

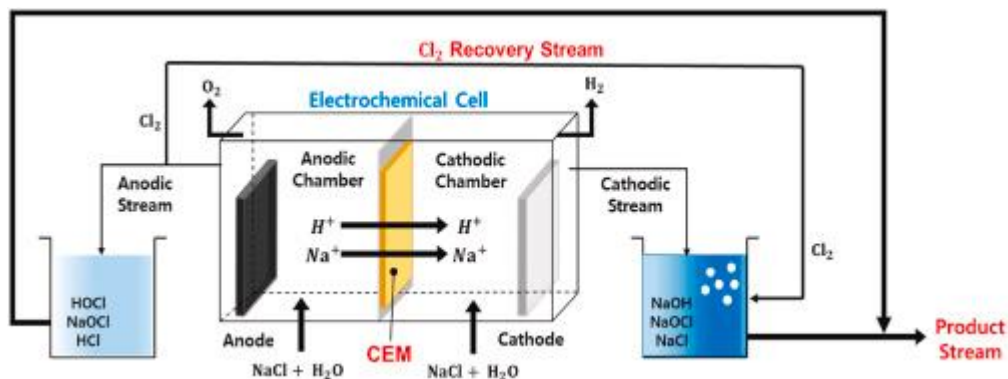


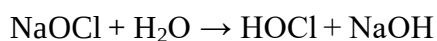
Fig 3 - Sodium hypochlorite production method

The second method that can be used to produce sodium hypochlorite is to add chlorine to the caustic soda. By combining these two substances, sodium hypochlorite, water, and salt are obtained. (Disinfectants Sodium hypochlorite, n.d.)



Sodium hypochlorite has many applications in various fields. For example, bleaching agents and removing stains from clothes. It is used for water purification and even in the field of dentistry for the treatment of tooth roots. (10 Sodium Hypochlorite Uses in Everyday Life – Laboratory – Hospital, 2017) This product is used in industries such as agriculture, chemical, paint, and even food, as well as in waste disposal and pharmaceutical industries. Another application is to reduce odors in industrial wastewater. In addition, it can prevent the growth of algae in cooling towers. (Sodium Hypochlorite Uses, 2021) (What is Sodium Hypochlorite (SH)?, 2021)

When sodium hypochlorite is added to water, they react together to produce hypochlorous acid and sodium hydroxide, and as you know, hypochlorous acid is used for disinfection. (Disinfectants Sodium hypochlorite, n.d.)

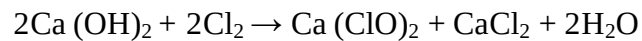


3. Calcium hypochlorite

Another substance used to disinfect water is calcium hypochlorite. Calcium hypochlorite is a white or gray solid that smells of chlorine. Calcium hypochlorite is stable at room temperature but decomposes slowly in humid environments. The common name for calcium hypochlorite is bleach powder. Calcium hypochlorite is a compound that is known to be an active ingredient in most commercial bleaches such as chlorinated lime and chlorinated powder bleach. (Calcium Hypochlorite, n.d.) These substances decompose easily in water or when heated, releasing oxygen and toxic chlorine gas. Calcium hypochlorite is not flammable, but acts as an oxidant with combustible materials and may react explosively with ammonia, amines, or organic sulfides. (Escudero-Oñate, 2015) (Calcium hypochlorite, n.d.)

There are two ways to produce calcium hypochlorite:

- i. The first method is method calcium. Based on chlorination of dried lime using direct chlorine gas:



- ii. The second method is the sodium method, which is based on the reaction of sodium hypochlorite with calcium chloride:

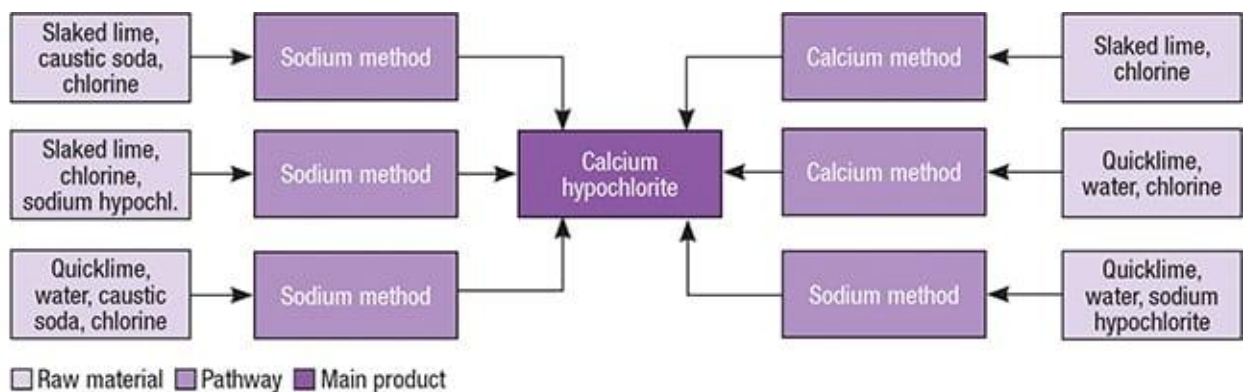
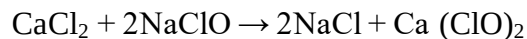
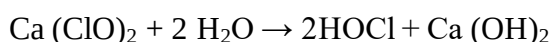


Fig 4 - Calcium hypochlorite production method

Calcium hypochlorite is used to disinfect large volumes of water so that it can be used. It is also widely used in swimming pools to disinfect water and kill germs in it. Calcium hypochlorite is a good oxidizing agent, so it is used in organic chemistry. Used to obtain aldehydes and carboxylic acids and to produce chloroform. In addition to water purification, calcium hypochlorite is used in kitchens to disinfect surfaces and equipment. Other common uses include bath cleaners, household disinfectant sprays, herbicides, herbicides, and laundry detergents. (Calcium Hypochlorite; advantages and disadvantages, 2017)· (Calcium hypochlorite - $\text{Ca}(\text{ClO})_2$, n.d.)

When treating water, less calcium hypochlorite is required than using chlorine gas. When calcium hypochlorite is added to water, hypochlorous acid and calcium hydroxide are produced.



Calcium hypochlorite raises the pH of water instead of lowering it like chlorine gas. As the pH of the water decreases, hypochlorous acid will still be present in the water. As a result, calcium hypochlorite and chlorine gas both produce the same type of residue. (What is Chlorination?, 2016) (Disinfection, 2018)· (Escudero-Oñate, 2015)

With these three methods, adding chlorine or chlorinated compounds to water, hypochlorous acid can be produced.

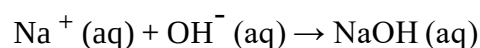
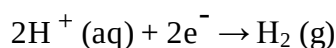
b. Electrolysis of brine

One of the fastest and easiest ways to produce hypochlorous acid is by electrolysis. Hypochlorous acid can be obtained by electrolysis of water solution and sodium chloride (salt). Electrolysis was first explained in 1830 by Michael Faraday. The main basis of the electrolysis method is the exchange of atoms and ions by removing or adding electrons from the external circuit. (Chemistry, n.d.) Electrolysis requires electrodes, an electrolyte, an external power supply, and a wall for ion exchange. The vessel in which the electrolysis process takes place is usually called an electrolytic cell in which there are two electrodes (cathode and anode) connected to a direct current source and one electrolyte molten or dissolved in a suitable solvent. (Electrolysis, n.d.) In the following, we will get acquainted with three technologies in the field of electrolysis:

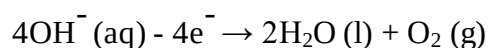
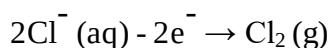
1. Membrane cell technology

In membrane technology, there is a membrane between the cathode and anode chambers that separates the two and allows only positive ions to pass through. (Chemistry , n.d.) (Membrane electrolysis, n.d.) (MANUFACTURING CHLORINE USING A DIAPHRAGM AND A MEMBRANE CELL, n.d.) Sodium chloride solution and water decompose into negatively charged chloride (Cl^-) and sodium positively charged (Na^+) during electrolysis. Hydroxide ions (OH^-) and hydrogen (H^+) are produced simultaneously. In the anode part, negatively charged ions such as Cl^- and OH^- ‘oxygen gas (O_2), chlorine gas (Cl_2), hypochlorite ion (OCl^-), hypochlorous acid (HOCl), and hydrochloric acid (HCl) is formed. Also at the cathode, positively charged ions such as H^+ and Na^+ produce hydrogen gas (H_2) and sodium hydroxide (NaOH). (Aniyyah, 2022)

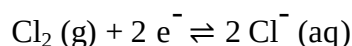
Reactions performed at the cathode:



Reactions performed in the anode:



When chlorine is added to water, hydrochloric acid (HCl) and hypochlorous acid (HOCl) is produced:



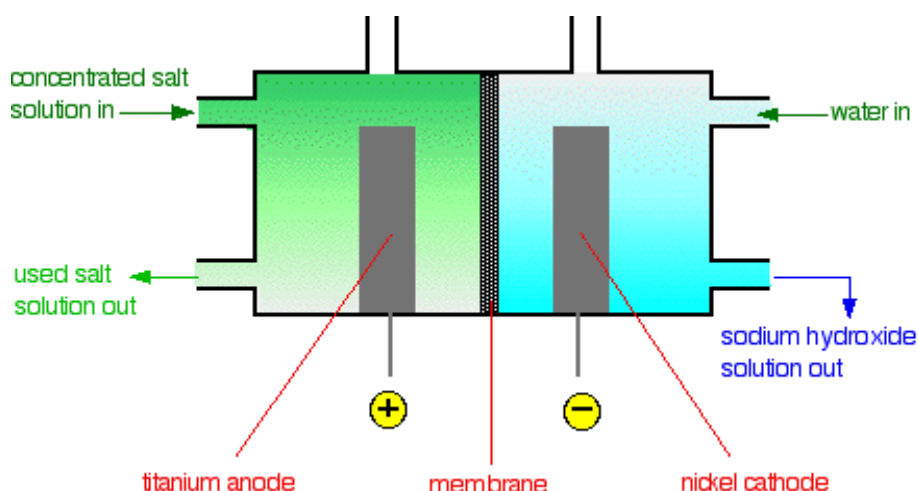


Fig 5 - Membrane cell

To produce hypochlorous acid better and more, you need to pay attention to some points such as the amount of sodium chloride input and the type of electrode. The higher the sodium chloride input, the more hypochlorous acid is produced. On the other hand, the electrode material has a high effect on the transparency of hypochlorous acid. Based on experiments performed between three electrodes made of carbon, titanium, and graphite, the graphite electrode produces a clearer hypochlorous acid. In the meantime, vinegar can be used to reduce the alkaline pH of the solution.

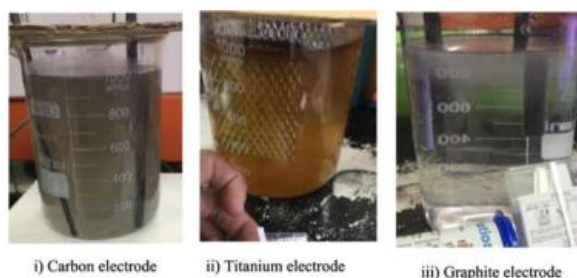


Fig 6 - The role of the electrode in product production

2. diaphragm cell technology

Diaphragm technology is almost like membrane technology with few differences. In the diaphragm cell process, the anode region is separated from the cathode region by a permeable diaphragm made of a porous mixture of asbestos and polymers. The salt and water solution first enters the anode chamber and then enters the cathode section through the diaphragm. We need to know that the level of solution at the anode is higher than in the cathode chamber, and this means that the flow

of our solution is always from left to right (from the anode to the cathode). (MANUFACTURING CHLORINE USING A DIAPHRAGM AND A MEMBRANE CELL, n.d.) (Diaphragm Cell anode, n.d.) (DIAPHRAGM CELL PROCESS, 2019)

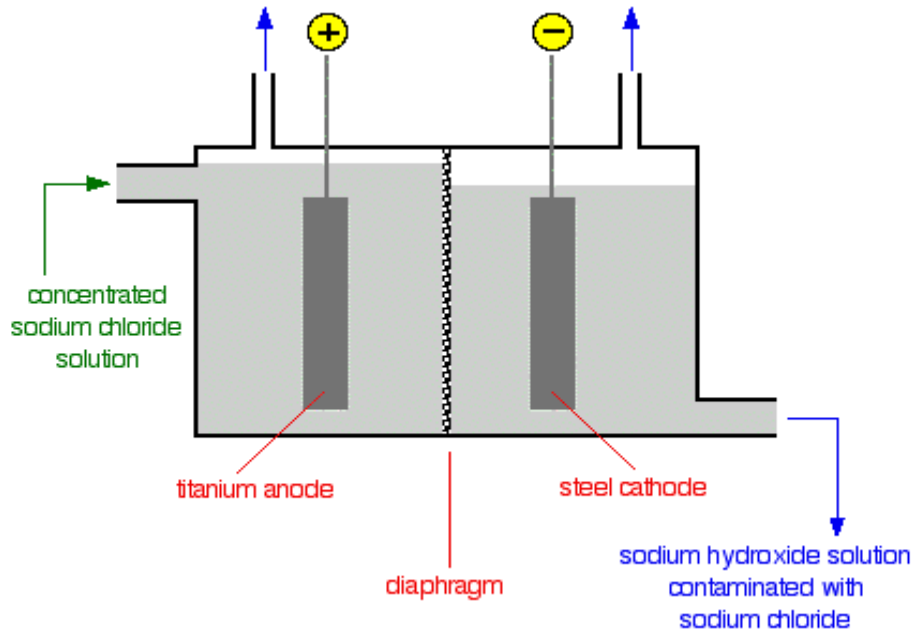
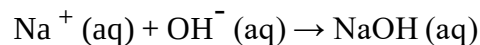
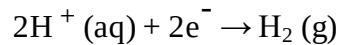


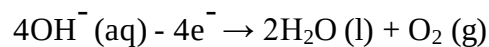
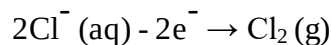
Fig 7 - diaphragm cell

The reactions that take place in the diaphragm process are similar to the process within the membrane process, therefore:

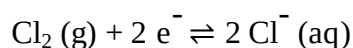
Reactions performed at the cathode:



Reactions performed in the anode:



When chlorine is added to water, hydrochloric acid (HCl) and hypochlorous acid (HOCl) is produced:



3. Single-cell technology

One of the greatest advances in electrolysis was the advent of single-cell technology. Single-cell technology is one of the most effective methods for producing hypochlorous acid. There is no membrane or diaphragm in this technology and it is just a single flow system that produces hypochlorous acid anolyte and does not produce a by-product such as sodium hydroxide. This technology produces a more stable hypochlorous acid and controls the pH of the free chlorine produced more easily. Hypochlorous acid molecules are inactivated only when exposed to an organic surface or oxygen in the air. (Hypochlorous Acid: a force of nature., n.d.) (Electrolyzed Water, n.d.) (Electrolyzed Water Generator: Understanding the science and technology, 2021) (Electrolysis Technology - Generating Hypochlorous Acid (HOCl) , n.d.)

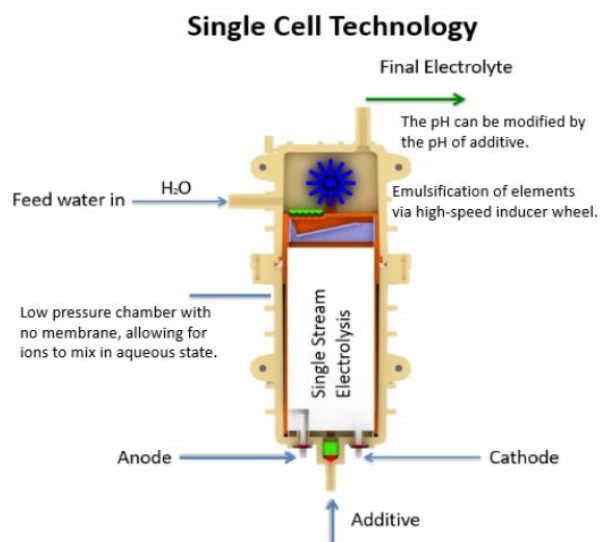
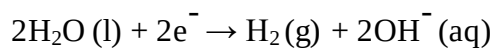


Fig 8 - Single-cell

Cathodic reaction:



Free chlorine production:

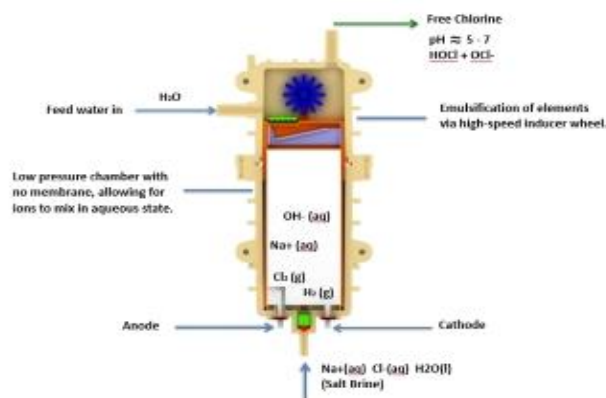
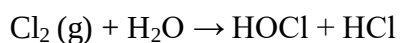


Fig 9 - Products produced in Single-cell

c. Sodium dichloroisocyanurate

Above, you are familiar with methods for producing hypochlorous acid, but today a new method for producing this product has been introduced to the market. Sodium dichloroisocyanurate (NaDCC or SIDC) is a new method of producing hypochlorous acid. This product has special advantages over sodium hypochlorite. Like other chlorinated products, it has a high ability to disinfect water and antiseptic. Due to the presence of isocyanurate, which has the property of cyanuric acid, it causes chlorine is in a solid, stable, and dry state. Sodium dichloroisocyanurate can be produced as anhydrous salt or dihydrate. (Sodium dichloroisocyanurate (NaDCC) tablets as an alternative to sodium hypochlorite for the routine treatment of drinking water at the household level, 2006) (SODIUM DICHLOROISOCYANURATE, n.d.) (Chlorine (NaDCC), 2021)

Sodium dichloroisocyanurate is a white solid with a whitening odor (chlorine). Its melting point is 230-250 degrees Celsius and its density is less than the density of water (0.96g / cm³). (Sodium Dichloroisocyanurate, 2020) This product comes in different shapes such as tablets and crystals. They are effective in killing bacteria, viruses, etc. After mixing with water, it does not smell and the water does not taste. If not used, it should be kept away from heat and moisture. (Chlorine (NaDCC), 2021); (Sodium Dichloroisocyanurate, 2020)

When sodium dichloroisocyanurate is added to water, it is rapidly hydrolyzed to form free chlorine. The percentage of free chlorine in pure sodium dichloroisocyanurate is 64.5%. Not all of the chlorine in sodium dichloroisocyanurate is hydrolyzed to hypochlorous acid, and some of the chlorine is still present in the NaDCC, which is called limited chlorine. When sodium

dichloroisocyanurate is added to water to disinfect it, hypochlorous acid and sodium cyanurate are produced as shown in the following reaction

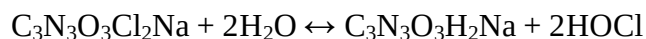


Fig 10 - Sodium dichloroisocyanurate

Equilibria occur in this reaction, resulting in six chlorinated isocyanates and four non-chlorinated isocyanates. Free chlorine reacts with the organic matter in the water and is consumed. Chloroisocyanurate is then rapidly decomposed and free chlorine is introduced into the water. (SODIUM DICHLOROISOCYANURATE, n.d.)· (Chu Thanh Phong, 2018)· (Sodium Dichloroisocyanurate in Drinking-water, 2008)

The production method for sodium dichloroisocyanurate

The subject we have to deal with is the production method of sodium dichloroisocyanurate. This product can be obtained from cyanuric acid. It is better to examine this process from the production of cyanuric acid. Urea is used to produce cyanuric acid. Urea is pyrolyzed at a temperature of 200 to 300 degrees Celsius. Then acid (hydrochloric, nitric, or sulfuric) is added to neutralize it. Of course, in the meantime, side products are also produced by breaking down urea. After various reactions, we arrive at purified cyanuric acid (99%). Then this product is washed with water to remove the remaining acid and acid salts. (Making cyanuric acid method, 2018) (Kuznesof, 2004)

Then add sodium hydroxide to react with cyanuric acid dihydrate slurry and the result of this reaction is disodium cyanurate solution. Chlorine (gas) is then added, which precipitates dichloroisocyanuric acid monohydrate (DCCA). This reaction also has a side product (sodium chloride). DCCA is then filtered and washed. After redissolving dichloroisocyanuric acid monohydrate, sodium hydroxide is added to it again, and after the reaction, the obtained product is sodium dichloroisocyanurate dihydrate. After dewatering and drying, NaDCC dihydrate powder is packaged. But if anhydrous sodium dichloroisocyanurate is the desired product, the wet cake of sodium dichloroisocyanurate dihydrate should be dried directly using a desiccator at temperatures

between 300 and 375 degrees for less than one second. Then the dried powder is granulated and packed. (Kuznesof, 2004) (What Is Sodium Dichloroisocyanurate Dihydrate And How To Buy Sodium Dichloroisocyanurate Dihydrate?, 2021) The following figure shows the general process of producing sodium dichloroisocyanurate dihydrate:

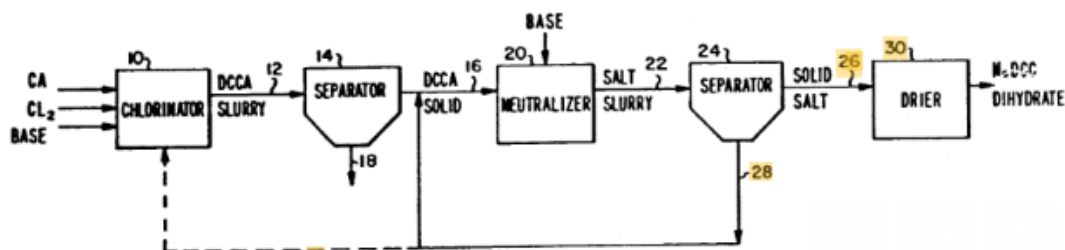


Fig 11 - Production process of NaDCC dihydrate

Applications of Sodium dichloroisocyanurate

Sodium dichloroisocyanurate has different applications in different fields. In the following we will get acquainted with the fields of using this product. One of the main uses of sodium dichloroisocyanurate is to disinfect swimming pools. Due to its antiseptic properties, this product can kill many viruses, bacteria, etc. It can also be used to make water drinkable. (Chu Thanh Phong, 2018) (Making cyanuric acid method, 2018) NaDCC is also used in medicine, for example, it is used to sterilize surgical instruments. Sodium dichloroisocyanurate is also used in agriculture, animal husbandry, and fishing. In agriculture, it can be used to disinfect crops, kill germs, and facilitate the transportation of crops over long distances.

In the field of fish farming, it can be used for fish health. Other items that can be mentioned for disinfecting salads, vegetables, non-peeling fruits, disinfecting sewage, sinks, W.C., disinfecting kitchen surfaces and dishes, whitening fabrics, and preventing wool from shrinking. (Sodium Dichloroisocyanurate, 2020) (CHEMGENE NaDCC TECHNICAL DATA, 2010) (Chlorojeevan: A Sodium Dichloroisocyanurate dosing potable water chlorination system, n.d.)



Fig 12 - Fields of application of sodium dichloroisocyanurate

Benefits of using sodium dichloroisocyanurate

Sodium dichloroisocyanurate has more advantages than other methods. As mentioned earlier, this product is distributed in the form of tablets, crystals, and powder that make it easy to carry. For example, in nature, if you need drinking water, you can pour a certain amount of it into a container that contains water without mud from rivers and springs to have drinking water after a short time. Because sodium dichloroisocyanurate is an effervescent tablet, it dissolves faster and easier in water, so hypochlorous acid dissolves faster in water. It does not have an unpleasant taste, smell, and color after using water. Some water purification pills cause allergies, but NaDCC pills are non-allergenic. This product is affordable and has high durability. It also gives us a certain level of chlorine. It is more environmentally friendly than other disinfectants. Sodium dichloroisocyanurate kills almost all bacteria, viruses, spores, and other water-borne diseases. It has better safety than other products and can be stored more easily. (Chlorojeevan: A Sodium Dichloroisocyanurate dosing potable water chlorination system, n.d.) (Advantages, Features, Benefits of NaDCC Sodium Dichloroisocyanurate Tablets, n.d.) (Everything You Must Know About NaDCC Disinfectant Tablets, 2021) (Sodium Dichloroisocyanurate, 2020)

Countries producing sodium dichloroisocyanurate

The sodium dichloroisocyanurate market is developing day by day. According to research, the market for this product will grow significantly. Throughout life, man needs purified water in all things such as drinking, agriculture, animal husbandry, and so on. This is just a requirement for the production of sodium dichloroisocyanurate. As mentioned in the previous sections, this product has countless uses. This increases the demand for sodium dichloroisocyanurate, so more products must be produced. All of this is boosting the NaDCC market.

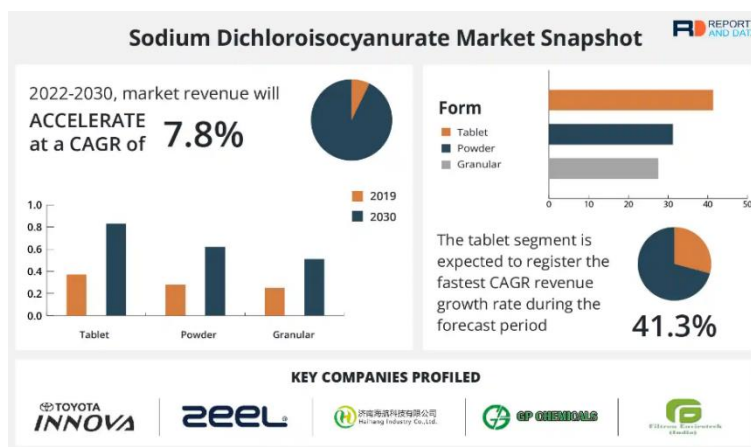


Fig 13 - sodium dichloroisocyanurate market

The sodium dichloroisocyanurate market is generally divided into two categories: (Everything You Must Know About NaDCC Disinfectant Tablets, 2021)· (Sodium Dichloroisocyanurate, 2020)

a. Based on product types:

- 1) powder
- 2) Particles
- 3) Tablet

b. Based on applications:

- 1) Swimming pool
- 2) Drinking water
- 3) Hospital
- 4) Others

Areas in the market are sodium- dichloroisocyanurate:

- North America
- Europe
- The Asia Pacific
- The Middle East and Africa
- Latin America



Fig 14 - Sodium dichloroisocyanurate market in the world

As shown in the chart, Asia and Oceania had the largest share of revenue in the market of sodium dichloroisocyanurate in 2021. One of the reasons for the increase in income in this region is the effort for sanitation and health against diseases such as water-borne diseases. This increases demand. Of course, regions such as North America will also see increased demand due to the pharmaceutical industry and health. (Global Sodium Dichloroisocyanurate Market 2022 |

Development Strategy, Growth Factor, Industry Latest Updates, Future Demands, Business Statistics, Share, Size, and Revenue Expectations to 2028, 2022) (Sodium Dichloroisocyanurate Market 2022 | Worldwide Industry Gross Margin, Trends, Share, Size, Future Demand, Analysis by Top Leading Player, Progression Status and Forecast till 2027, 2022) (Sodium Dichloroisocyanurate Market Size, Share, Trends, By Form (Tablet, Powder), By End-use (Water and Wastewater Treatment, Food) By Application (Cleansing Agent, Biocide), and By Region, Forecast to 2030, 2022) (Sodium Dichloroisocyanurate Market Outlook, 2022)

Names of several countries producing sodium dichloroisocyanurate in the world:

- THE US
- Canada
- Brazil
- Argentina
- Germany
- The UK
- France
- Spain
- Italy
- Nordics
- BENELUX
- Australia & New Zealand
- China
- India
- ASEAN
- GCC
- South Africa

companies producing sodium dichloroisocyanurate

Below are the names of several factories producing sodium dichloroisocyanurate in the world:

Row	Name	Country	Address	Communications
1	Occidental Petroleum Corporation	United States	Houston, TX, US (HQ) 5 Greenway Plaza, Suite 110. Berwyn, PA, US. 1055 Westlakes Drive, Suite 300. Dallas, TX, US. 14555 Dallas Pkwy #400. Lisle, IL, US. 3030 Warrenville Rd. Midland, TX, US. 6001 Deauville Blvd.	

			The Woodlands, TX, US. 10077 Grogans Mill Rd #225.	
2	Ouya Chemical	China	Pu Cheng Town Chemical Industry Park of Country Fanxian	Email: wallace@oyachem.com General manager : +86- 13839285558 wechat : 13839285558 MOB.: +86-15157973244 Whatsapp: +86-15157973244 Wechat:+86-15157973244
3	Huayi-Chem	China	1 East Jianshe Road Juancheng, Shandong, China	Dept1: Mr.liankui Hong Tel:+86-530-2992299 E-mail: sales@huayi-chem.com Dept2: Mr.xusheng Shi Tel:+86- 530-2402588 Email: chem6@huayi-chem.com Dept3: Mr.Liang Feng Tel:+86- 530-2400689 Email: chem3@huayi-chem.com Dept4: Mr.DiWei Zhao Tel:+86- 530-2429008 Email: chem8@huayi-chem.com
4	Huayi-Chem	China	ADD: No.8, Jiheng Road,Wuyi Country, Hengshui City,Hebei 053400	Tel: +86-318-5950119 Fax: +86- 318-5950968 E-mail : sale@jihengchem.com Website : www.jihengchem.com
5	Henan GP	China	No.8 Building, Phase3, Zhenghong Cyberport, No.15 Yinping Road, Zhengzhou 450000, China Rm1727, NO.1 Building, Kaixuan Plaza, NO.122 Huayuan Road, JinShui District, Zhengzhou City, Henan Province China	+86-371-89916809、89916515 89916519、89916521 89916525、89916528 info@gpcchem.com www.gpcchem.com www.gpcchem.en.alibaba.com
6	Jingwei Disinfection Products	China	Province/State: Shandong City: Jinan Street: Harmony Square	Tel:86-0531-87977101 Fax:86-0531-87977103 www.jingwei-chemicals.lookchem.com
7	Zeel Products	India	09, Alok Society, Near Prabhat Society, Waghodia Road, Vadodara- 390019, Gujarat. India	M: +91-9724593964 Email: sales@zeelproductonline.co.in Website: www.zeelproduct.net

8	Innova Corporate	India	2B / BW Shalimar Bagh, Opp. BQ Market, Near DLF Mall New Delhi - 110088, India.	+91-11-27473243 +91-9312871070 – +91-9911130697 vinod@innovacorporate.com
9	Haihang Industry	China	No.100 South Gongye Road, Jinan City, China. PC.250100	+86-531-8803-2799 +86-531-8582-1093 sale@haihangchem.com
10	Taian Huatian Chemical Co.Ltd.	China	Huayang industrial park, Ningyang County, Shandong, China	Department 1: Ning Fangtao Email: sales@huatianchem.com chem1@huatianchem.com Tel:0538-5826593 Moble:008613954845233 Department 2: Kris Xu Tel : +86-538-6299957 Mobile: +8613583837604 E-mail: krisexport@yahoo.com krisxu@huatianchem.com WeChat :13583837604 SKYPE: rainsamir WhatsApp: +8613583837604 Department 3: Peter sun Tel:008617515280788 Tel:0538-5826592 Email: htchemical@188.com SKYPE: fly161202
11	Filtron Envirotech	India	ED-39B, Madhuban Chowk, Near Pitampura Metro Station, Pitampura, New Delhi- 110088	Email us: filtronenvirotechindia@gmail.com Call us: +91-11-27314564 Also, call us on: +91-78-27-649-429
12	Capot Chemical	China	Joinhands Science Park, No.4028, Nanhuan Road, Hangzhou, P.R.China. Hangzhou Gulf Fine Chemical Zone, Shangyu, 312368, P.R.China. Hangzhou Jiande Chennan Industrial zone, 311600, P.R.China.	+86 (0)571-855 867 18 +86 (0)571-858 647 95 +86 (0)133 3619 5806 sales@capotchem.com ; capotchem@gmail.com www.capotchem.com *** +86 (0)575-82040114 sy@capotchem.com *** +86 (0)133-36094967 hz@capotchem.com

			15735 Rue de la Caserne, Sainte-Geneviève, Montréal , Quebec, Canada	*** ca@capotchem.com ***
13	Acuco Organics Limited	India	B-19, Sector-1, Noida - 201301, UP, India *** No.27, Ashoka Chambers, 5-B, Rajendra Park, New Delhi - 110060, INDIA Landmark: Rajendra Place Metro Station	TEL: +91-120 - 4888444 (100 lines)

Table 2 - NaDCC production companies

Average annual demand for sodium dichloroisocyanurate in Iran

The research was conducted to find out the amount of consumption of this substance in Iran. Finally, information was obtained by referring to the import list for 2019 in Iran customs. By entering the customs tariff of the desired product (31031100), you can see the amount of import of this product. During 3 months in 2019, a large amount of this product was imported from China (100 Ton, 39,375Ton, 3,9375Ton). Government currency (1\$ = 4200 Toman) was used to buy this product. طرح توجیهی تولید سیانوریک اسید سال 1401, (آشنایی با انواع دلار در صرافی ها, 2020), (واردات 99, بدون تاریخ 2022)

آمار واردات طی سال ۱۳۹۹									
سال	ماه	نام گمر	نام کشور	کد تعرفه	شرح تعرفه	وزن (کیلوگرم)	ارزش (ریال)	ارزش (دلار)	
۱۳۹۹	۱۱	منطقه ویژه چین	چین	۳۱۰۳۱۱۰۰	دارا ۳۵ درصد وزن؟ ب؟ شتر	۱۰۰,۰۰۰	۳,۲۲۰,۹۶۵,۰۰۰	۷۶,۶۹۰	
۱۳۹۹	۵	منطقه ویژه چین	چین	۳۱۰۳۱۱۰۰	دارا ۳۵ درصد وزن؟ ب؟ شتر	۳۹,۳۷۵,۰۰۰	۵۹۷,۹۳۱,۸۱۸,۷۵۰	۱۴,۲۳۶,۴۷۲	
۱۳۹۹	۷	منطقه ویژه چین	چین	۳۱۰۳۱۱۰۰	دارا ۳۵ درصد وزن؟ ب؟ شتر	۳۹,۳۷۵,۰۰۰	۶۰۷,۶۱۸,۲۶۵,۶۲۵	۱۴,۴۶۷,۱۰۲	

Fig 15 - Import amount of NaDCC in 2019-2020 in Iran

Discussion of results

Above, different methods for producing hypochlorous acid were introduced and we examined them. Now we want to compare these methods. Each of these methods is suitable for producing hypochlorous acid, but some of them have risks and drawbacks. (The Dangers of Chlorine, n.d.) (What chlorine is, 2018) The use of sodium hypochlorite also has problems. Although it is easier to transport than chlorine, it is still a dangerous substance and breaks down when exposed to air. It May

cause disease in humans. It has a short shelf life. (Disinfectants Sodium hypochlorite, n.d.)· (Sodium Hypochlorite; advantages and disadvantages, 2017)· (What is Sodium Hypochlorite (SH)?, 2021) Calcium hypochlorite is more stable and more economical than the previous two methods. But if this product is exposed to heat and humidity, it will cause severe explosions, fire, and release of chlorine gas. So, you have to be careful in maintaining it. (Calcium Hypochlorite; advantages and disadvantages, 2017)· (Pros & Cons of Calcium Hypochlorite, 2010) Although the electrolysis method is the easiest and cheapest method to produce hypochlorous acid, the product it gives us is soluble and difficult to move and transport on a large scale. Using NaDCC, although it costs a lot to produce, it is more cost-effective with its advantages. This product is easy to move and store. It is more stable than other products. They are less toxic and corrosive. (Advantages, Features, Benefits of NaDCC Sodium Dichloroisocyanurate Tablets, n.d.)· (Everything You Must Know About NaDCC Disinfectant Tablets, 2021)

A proposed process flow sheet production of sodium dichloroisocyanurate

In this project, to get the capital cost, it was necessary to design a factory for the production of this product. To get this information, I contacted many companies, but none of them gave me useful and practical information, and some did not answer my email. Much of my time was spent communicating with companies.

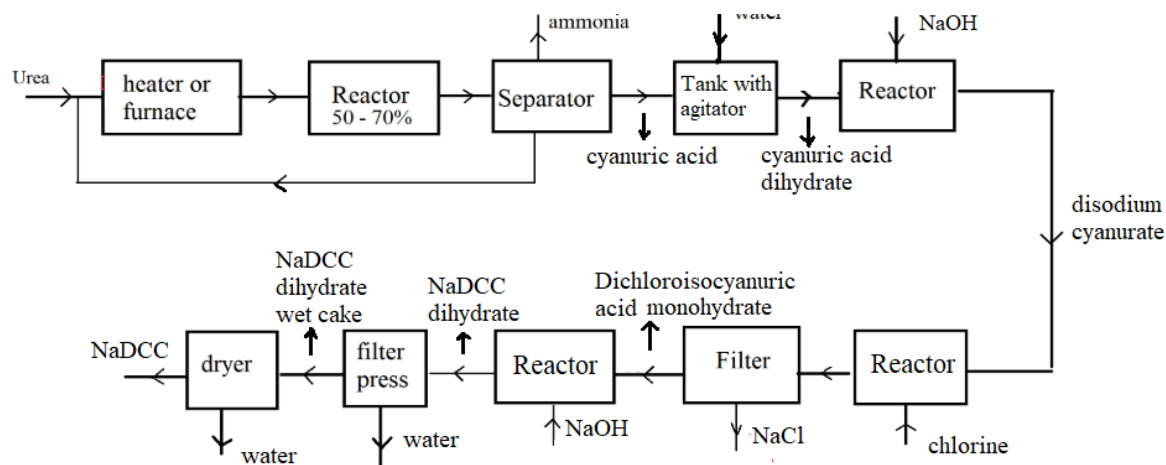
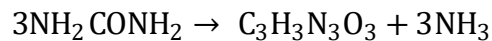


Fig 16 - Sodium dichloroisocyanuric production plan

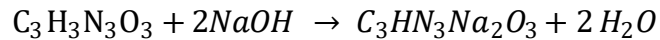
On the other hand, I looked for information on the Internet, but I still did not find much. For this reason, I decided to design a general plan for this factory using the incomplete and little information that I have read.

Urea is used as the main feed. Urea enters a heater or furnace to be heated. After heating, urea enters the reactor so that the necessary reactions to produce cyanuric acid take place. To produce cyanuric acid, the desired reaction needs to be carried out in the presence of a solvent or catalyst. We

use kerosene as a solvent (kerosene does not participate in the reaction). According to the following reaction, urea is converted into cyanuric acid and ammonia.



Then the product containing cyanuric acid and ammonia enters a separator to separate them. The remaining and untouched urea is also separated and recycled. The obtained cyanuric acid enters the tank as shown above and is mixed with water. The obtained product enters the reactor. On the other hand, sodium hydroxide is added to the reactor. After the reaction, our new product, disodium cyanurate, is obtained.



The obtained product (disodium cyanurate) enters the reactor and reacts with chlorine. Our product enters the separator to separate the desired product from the side product. Our byproduct here is sodium chloride. Dichloroisocyanuric acid slurry enters another reactor and reacts with sodium hydroxide again. Our product is sodium dichloroisocyanurate dihydrate slurry, which must enter a filter press to remove excess water. The obtained wet cake is put into the dryer to dry to the desired extent. This is how our final product, sodium dichloroisocyanurate, is obtained. (Liquid-Phase Synthesis of Cyanuric Acid from Urea, 2010) (Kuznesof, 2004)

Simulation with HYSYS

In the following, I simulated this plan using Aspen HYSYS, but in some parts, it has differences with the previous plan.

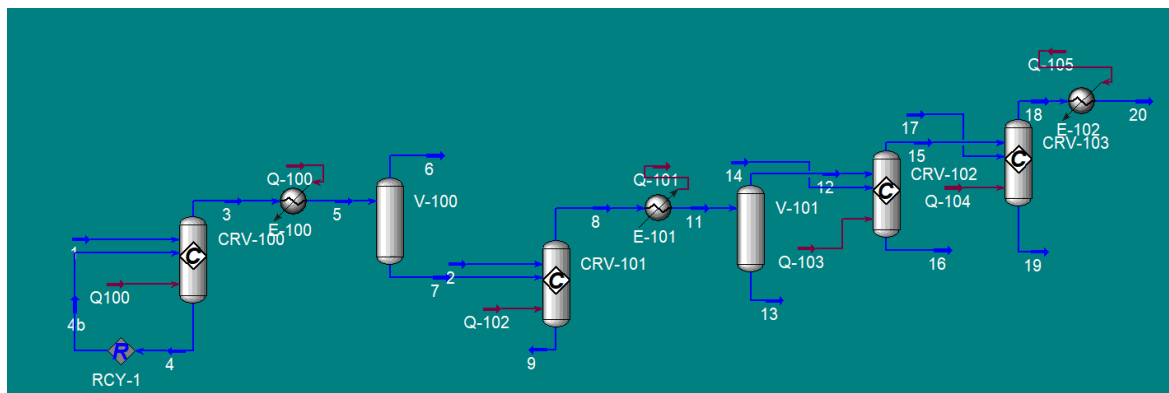


Fig 17- Simulation of sodium dichloroisocyanuric production process

In this simulation, we used urea as the main feed to produce cyanuric acid. Urea enters the reactor from stream 1. Then in the reactor, using the reaction data that we gave to HYSYS, the desired reaction will happen. Our products leave stream 3 and enter a heater to be heated. Stream 4 is urea that does not participate in the reaction and is recycled. You can see the information about the reactor in Figure 18.

Conversion Reactor: CRV-100 - Set-1

Design Tab:

	1	4b	4	3
Name				
Vapour	0.0000	0.0000	0.0000	1.0000
Temperature [C]	25.00	250.0	250.0	250.0
Pressure [kPa]	101.3	101.3	101.3	101.3
Molar Flow [kgmole/h]	3600	396.4	399.6	4796
Mass Flow [kg/h]	2.162e+005	2.381e+004	2.400e+004	2.160e+005
Std Ideal Liq Vol Flow [m3/h]	161.9	17.83	17.98	187.9
Molar Enthalpy [kJ/kgmole]	-2.456e+005	-2.173e+005	-2.173e+005	-8.267e+004
Molar Entropy [kJ/kgmole-C]	230.9	300.0	300.0	45.60
Heat Flow [kJ/h]	-8.841e+008	-8.612e+007	-8.682e+007	-3.965e+008

Composition Tab:

	1	4b	4	3
Urea	1.0000	1.0000	1.0000	0.0000
NaDCC*	0.0000	0.0000	0.0000	0.0000
DCCA*	0.0000	0.0000	0.0000	0.0000
Cl2	0.0000	0.0000	0.0000	0.0000
NaCL	0.0000	0.0000	0.0000	0.0000
disodium cyanurate*	0.0000	0.0000	0.0000	0.0000
NaOH	0.0000	0.0000	0.0000	0.0000
H2O	0.0000	0.0000	0.0000	0.0000
Ammonia	0.0000	0.0000	0.0000	0.7500
cyanuric acid*	0.0000	0.0000	0.0000	0.2500

Fig 18- Information about the reactor1

After stream 3 passes through the heater and is heated, stream 5 enters a separator to separate ammonia and cyanuric acid from each other. This separation happens at high temperature and pressure, and ammonia with flow 6 and cyanuric acid with flow 7 leave the separator. In Figure 19, information about the temperature and pressure of the separator is available.

Separator: V-100

Design Tab:

	5	7	6
Name			
Vapour	0.8101	0.0000	1.0000
Temperature [C]	300.0	300.0	300.0
Pressure [kPa]	9119	9119	9119
Molar Flow [kgmole/h]	4796	910.7	3885
Mass Flow [kg/h]	2.160e+005	1.076e+005	1.084e+005
Std Ideal Liq Vol Flow [m3/h]	187.9	63.08	124.8
Molar Enthalpy [kJ/kgmole]	-8.043e+004	-2.009e+005	-5.219e+004
Molar Entropy [kJ/kgmole-C]	245.3	-412.0	126.9
Heat Flow [kJ/h]	-3.857e+008	-1.829e+008	-2.028e+008

Composition Tab:

	5	7	6
Urea	0.0000	0.0000	0.0000
NaDCC*	0.0000	0.0000	0.0000
DCCA*	0.0000	0.0000	0.0000
Cl2	0.0000	0.0000	0.0000
NaCL	0.0000	0.0000	0.0000
disodium cyanurate*	0.0000	0.0000	0.0000
NaOH	0.0000	0.0000	0.0000
H2O	0.0000	0.0000	0.0000
Ammonia	0.7500	0.0972	0.9030
cyanuric acid*	0.2500	0.9028	0.0970

Fig 19- Information about the separator1

Stream 7 containing cyanuric acid enters the reactor. Sodium hydroxide enters the reactor with stream 2. These two react together according to the reaction given in the program and the obtained product is removed from flow 8 and the rest of the unreacted materials are recycled by flow 9 and returned to the reactor by flow 10. Stream 8 enters the heater and then enters the separator. In the

separator, disodium cyanurate is separated from water, and disodium cyanurate leaves the separator with flow 12 and water with flow 13.

Conversion Reactor: CRV-101 - Set-2 (Worksheet)

Name	2	7	9	8
Vapour	0.0000	0.0000	0.0000	1.0000
Temperature [C]	25.00	300.0	200.0	200.0
Pressure [kPa]	2026	9119	2026	2026
Molar Flow [kgmole/h]	953.6	910.7	650.7	1214
Mass Flow [kg/h]	3.814e+004	1.076e+005	4.470e+004	1.011e+005
Std Ideal Liq Vol Flow [m3/h]	21.40	63.08	38.44	98.37
Molar Enthalpy [kJ/kgmole]	-8.342e+004	-2.009e+005	-2.621e+005	-2.301e+005
Molar Entropy [kJ/kgmole-C]	-80.86	-412.0	-44.85	61.62
Heat Flow [kJ/h]	-7.954e+007	-1.829e+008	-1.705e+008	-2.792e+008

Conversion Reactor: CRV-101 - Set-2 (Composition)

	2	7	9	8
Urea	0.0000	0.0000	0.0000	0.0000
NaDCC*	0.0000	0.0000	0.0000	0.0000
DCCA*	0.0000	0.0000	0.0000	0.0000
Cl2	0.0000	0.0000	0.0000	0.0000
NACL	0.0000	0.0000	0.0000	0.0000
disodium cyanurate*	0.0000	0.0000	0.1612	0.3065
NaOH	1.0000	0.0000	0.0000	0.0000
H2O	0.0000	0.0000	0.6027	0.4626
Ammonia	0.0000	0.0972	0.0047	0.0704
cyanuric acid*	0.0000	0.9028	0.2313	0.1605

Fig 20- Information about the reactor2

Separator: V-101 (Worksheet)

	11	13	12
Urea	0.0000	0.0000	0.0000
NaDCC*	0.0000	0.0000	0.0000
DCCA*	0.0000	0.0000	0.0000
Cl2	0.0000	0.0000	0.0000
NACL	0.0000	0.0000	0.0000
disodium cyanurate*	0.3065	0.0000	0.6562
NaOH	0.0000	0.0000	0.0000
H2O	0.4626	0.8678	0.0000
Ammonia	0.0704	0.1322	0.0000
cyanuric acid*	0.1605	0.0000	0.3438

Fig 21- Information about the separator2

Stream 12, which contains disodium cyanurate, enters the reactor together with stream 14, which is chlorine. In the reactor, the desired reaction is carried out and it gives products such as DCCA, water and sodium chloride. DCCA is separated from the rest of the products and exits with stream 15. The rest of the products leave the reactor with stream 16. In the other reactor, DCCA stream 15 reacts with sodium hydroxide stream 17 and the desired product, NaDCC, is produced along with side products.

Conversion Reactor: CRV-102 - Set-3					
Design	Reactions	Rating	Worksheet	Dynamics	
Worksheet					
Conditions	Name	14	12	16	15
Properties	Vapour	0.0000	1.0000	0.0000	1.0000
Composition	Temperature [C]	50.00	-200.0	10.00	10.00
PF Specs	Pressure [kPa]	2026	2026	2026	2026
	Molar Flow [kgmole/h]	1875	566.7	1685	756.3
	Mass Flow [kg/h]	1.329e+005	8.950e+004	1.195e+005	1.029e+005
	Std Ideal Liq Vol Flow [m3/h]	85.15	85.87	76.54	94.48
	Molar Enthalpy [kJ/kgmole]	-1.673e+004	-3.025e+005	-8.590e+004	-2.178e+005
	Molar Entropy [kJ/kgmole-C]	206.2	-185.3	-45.48	-42.68
	Heat Flow [kJ/h]	-3.136e+007	-1.714e+008	-1.448e+008	-1.647e+008
Delete OK Ignored					

Conversion Reactor: CRV-103 - Set-4					
Design	Reactions	Rating	Worksheet	Dynamics	
Worksheet					
Conditions	Name	15	17	19	18
Properties	Vapour	1.0000	0.0000	0.0000	1.0000
Composition	Temperature [C]	10.00	30.00	100.0	100.0
PF Specs	Pressure [kPa]	2026	1013	1013	1013
	Molar Flow [kgmole/h]	756.3	953.6	1394	316.3
	Mass Flow [kg/h]	1.029e+005	3.814e+004	9.843e+004	4.264e+004
	Std Ideal Liq Vol Flow [m3/h]	94.48	21.40	76.26	39.62
	Molar Enthalpy [kJ/kgmole]	-2.178e+005	-8.260e+004	-1.186e+005	-1.996e+005
	Molar Entropy [kJ/kgmole-C]	-42.68	-78.65	8.436	30.09
	Heat Flow [kJ/h]	-1.647e+008	-7.876e+007	-1.653e+008	-6.313e+007
Delete OK Ignored					

Conversion Reactor: CRV-103 - Set-4					
Design	Reactions	Rating	Worksheet	Dynamics	
Worksheet					
Conditions	Urea	15	17	19	18
Properties	NaDCC*	0.0000	0.0000	0.0000	0.0000
Composition	DCCA*	0.0000	0.0000	0.0000	0.0000
PF Specs	Cl2	0.2507	0.0000	0.0724	0.2804
	NaCL	0.0000	0.0000	0.0000	0.0000
	disodium cyanurate*	0.4917	0.0000	0.1530	0.5015
	NaOH	0.0000	1.0000	0.6843	0.0000
	H2O	0.0000	0.0000	0.0000	0.0000
	Ammonia	0.0000	0.0000	0.0000	0.0000
	cyanuric acid*	0.2576	0.0000	0.0903	0.2181
Delete OK Ignored					

Material Stream: 20			
Worksheet	Attachments	Dynamics	
Worksheet			
Conditions	Stream Name	20	Liquid Phase
Properties	Vapour / Phase Fraction	0.0000	1.0000
Composition	Temperature [C]	50.00	50.00
Oil & Gas Feed	Pressure [kPa]	3040	3040
Petroleum Assay	Molar Flow [kgmole/h]	316.3	316.3
K Value	Mass Flow [kg/h]	4.264e+004	4.264e+004
User Variables	Std Ideal Liq Vol Flow [m3/h]	39.62	39.62
Notes	Molar Enthalpy [kJ/kgmole]	-2.191e+005	-2.191e+005
Cost Parameters	Molar Entropy [kJ/kgmole-C]	18.79	18.79
Normalized Yields	Heat Flow [kJ/h]	-6.929e+007	-6.929e+007
Emissions	Liq Vol Flow @Std Cond [m3/h]	35.91	35.91
	Fluid Package	Basis-1	
	Utility Type		
Delete Define from Stream... View Assay			

Fig 22- Information about the reactor3&4, stream20

Capital cost estimate

You have to go a long way to get capital cost. In this way, information about Total Investment, annual sales, and annual total expenses should be calculated. Annual total expenses are divided into three parts: annual direct, annual indirect, and annual general. First, to calculate the Total Investment (IT), three things must be obtained: plant investment, working capital, and cost of land. For plant investment (IF), we use the information provided by HYSYS. working capital (IW) is the cost spent in the first year of operation, which includes salaries, parts, etc., which is equal to 15% of plant investment. The cost of land (IL) is related to the cost of land, which, if this is a government factory, its cost will be 0\$. Depreciation (AD) can be calculated using plant investment. Depreciation can be calculated by dividing IF by the life of the factory. Here, the life of the factory is considered to be 15 years. You can see the obtained information in Table 3.

Capital: 4,925,920 USD Utilities: 124,644 USD/Year Energy Savings: ___MW (___%) Exchangers - Unknown: 0 OK: 0 Risk: 0

Flowsheet Case (Main) - Solver Active **Economic Equipment Data Summary**

Enabled by Aspen Process Economic Analyzer (APEA)

Template: <Default> Save Save as new Reset Paste Send to Excel/ASW

Summary Utilities **Unit operation** Equipment Agitated reactor TEMA HEX Quoted equipment Vertical vessel

Name	Equipment Cost [USD]	Installed Cost [USD]	Equipment Weight [LBS]	Installed Weight [LBS]	Utility Cost [USD/HR]
CRV-102	85,400	237,300	7900	23759	0
E-100	16,400	97,900	2900	17315	0
E-101	0	0	0	0	0
RCY-2	0	0	0	0	0
V-101	19,500	153,400	3900	19910	0
CRV-101	754,800	1,181,300	257500	302065	0
E-102	13,000	83,400	1800	11453	1.49196
RCY-1	0	0	0	0	0
CRV-100	0	0	0	0	0
CRV-103	71,400	221,400	6000	21409	0
V-100	34,900	155,700	11000	25099	0

Fig 23- Factory equipment prices

IF	2177300
IW	326595
IL (USD)	0
IT (without IL)	2503895
AD (annual depreciation)	145153.3333

Table 3- Total Investment

Next, we have to calculate the annual sales. In this factory, we don't only produce NaDCC. We also produce a lot of ammonia. So, we can also sell ammonia and benefit from its sale. So, we take the production amount of ammonia and NaDCC that we obtained with HYSYS and calculate our sales amount in one year and get its selling price. The price of ammonia is \$2.2/kg and the price of NaDCC is \$3.5/kg.

annual sales	
stream 6 (kg/h) Ammonia	59744.63207
cost of Ammonia (USD/kg)	2.2
Ammonia in a year (kg)	430161350.9
selling Ammonia in a year (USD)	946354972
stream 20 (m3/h) NaDCC	34724.7713
cost of NaDCC (USD/kg)	3.5
NaDCC in a year (kg)	250018353.4
selling NaDCC in a year (USD)	875064236.8
sum	1821419209

Table 4 - Annual Sales

In the next step, annual total expenses should be calculated. annual direct, annual indirect, and annual general are three items that must be calculated.

- Annual direct (A_{DME})

Annual direct is related to costs such as raw materials, employee salaries, electricity, and fuel costs, and other things. We get the cost of the *number* of raw materials needed in the same way we used to get the cost of selling the product. You can see the calculations made in the table below.

raw material (USD)	
stream 1 (kg/h) Urea	216201.2421
cost of Urea (USD/kg)	0.47
Urea in a year (kg)	1556648943
Purchasing of Urea in year (USD)	731625003.1
stream 2,17 (kg/h) NaOH	76280
cost of NaOH (USD/kg)	0.78
NaOH in a year (m3)	549216000
Purchasing of NaOH in year (USD)	428388480
stream 14 (m3/h) Cl2	132941.6605
cost of Cl2 (USD/kg)	0.11
Cl2 in a year (kg)	957179955.7
Purchasing of Cl2 in year (USD)	105289795.1
raw material (USD)	1265303278

Table 5 - Raw Material

Another cost that should be included in this section is the cost of employees. Using Ulrich Table 6.2, the number of operators can be calculated *about* the number of units.

Pumps	
Reactors	0.5
Separators	

Fig 24- Ulrich Table 6.2

According to this table, we need half an operator for each reactor. We have four reactors, so we need two operators. On the other hand, per shift, we need the cooperation of three people for safety *technicians*, two people for safety labor, six people for labor, and five people for the technical crew. The salary of each in Toman currency is as follows:

- ✓ operator 11MT
- ✓ safety technician 8.5 MT
- ✓ num. safety labor 6MT
- ✓ num. labor 6MT
- ✓ technical crew 19MT

This is the salary of employees in one shift. Three shifts per day are considered. The number of employees in one shift is 18 people.

total labor per shift	18
total labor cost per year (USD)	240700
annual working hours	6720
num. of annual shifts	840

Table 6 - Staff salaries

There are other costs such as maintenance and repair, operating supplies and laboratory expenses that must be calculated. Maintenance and repair are equal to 6% of fixed capital cost. Operating supplies are equal to 15% of the maintenance cost. laboratory expenses are equal to 15% of the labor cost. By calculating all these items and adding them together, you can get the annual direct.

raw material (USD)	1265303278
total labor cost per year (USD)	240700
maintenance and repair	130638
operating supplies	19595.7
laboratory expenses (USD)	36105
total	1265730317

Table 7 - Annual Direct

- Annual indirect (A_{IME})

The next part is annual indirect. Expenses that indirectly affect the factory, which include three parts: overhead, insurance, and property taxes, and annual depreciation. There are formulas to calculate each. Overhead that means fringe benefits, and unemployment insurance (UI) for employees and is equal to 60% of the sum of all the labor and maintenance costs. Insurance & property taxes is equal to 2% of the fixed capital cost. Depreciation costs are the costs that the accountant considers as tax incentives. Depreciation costs are equal to plant investment divided by the life of the plant.

annual indirect	
overhead	33420.42
insurance and property taxes	43546
annual depreciation	145153.3
total	222119.8

Table 8 - Annual indirect

- Annual general (A_{GE})

These are charges to a plant to keep the head office operating. administrative costs are equal to 25% of plant overhead. Research & development is equal to 5% of annual total expenses. Distribution & sales are equal to 10% of annual total expenses.

annual general	
administrative cost	8355.105
research and development	63297621.8
distribution and sales	147695379
total	211001356

Table 9 - Annual general

According to the calculations, total annual expenses is equal to \$1476953793.

We considered the duration of setting up the factory for 4 years. Therefore, we divide the fixed capital cost (I_F) by these 4 years. The annual cash income, A_{CI} , of a plant is equal to the annual sales, A_S , minus annual total expenses, A_{TE} .

years	IF	IW	AS	ATE	ACI=AS-(IW+ATE)
1	544325	0	0	0	-544325
2	544325	0	0	0	-544325
3	544325	0	0	0	-544325
4	544325	0	0	0	-544325
5		326595	910709604.4	1476953793	-566570783.6
6	0		1821419209	1476953793	344465415.8
7	0		1821419209	1476953793	344465415.8
8	0		1821419209	1476953793	344465415.8
9	0		1821419209	1476953793	344465415.8
10	0		1821419209	1476953793	344465415.8
11	0		1821419209	1476953793	344465415.8
12	0		1821419209	1476953793	344465415.8
13	0		1821419209	1476953793	344465415.8
14	0		1821419209	1476953793	344465415.8
15	0		1821419209	1476953793	344465415.8
16	0		1821419209	1476953793	344465415.8
17	0		1821419209	1476953793	344465415.8
18	0		1821419209	1476953793	344465415.8
19		-326595	1821419209	1476953793	344792010.8

Table 10 - Annual cash income

Next, we need to get the annual income taxes. By subtracting the annual depreciation, A_D , and the government annual incentives, A_I , from the annual cash income, A_{CI} , multiplied by the taxation rate, t , which is usually around 35%, you get the annual income taxes. To get the annual net cash income A_{NCI} , we must subtract the annual cash income A_{CI} from the annual income taxes A_{IT} . (Design Course Plant _ Dr.S Rohani)

years	ACI=AS-(IW+ATE)	AD=IF/15 years	AIT=t*(ACI-AD)	ANCI=ACI-AIT	cum ANCI
1	-544325		0	-544325	-544325
2	-544325		0	-544325	-1088650
3	-544325		0	-544325	-1632975
4	-544325		0	-544325	-2177300
5	-566570783.6	145153.3333	0	-566570783.6	-568748083.6
6	344465415.8	145153.3333	120512091.9	223953323.9	-344794759.7
7	344465415.8	145153.3333	120512091.9	223953323.9	-120841435.7
8	344465415.8	145153.3333	120512091.9	223953323.9	103111888.2
9	344465415.8	145153.3333	120512091.9	223953323.9	327065212.1
10	344465415.8	145153.3333	120512091.9	223953323.9	551018536
11	344465415.8	145153.3333	120512091.9	223953323.9	774971860
12	344465415.8	145153.3333	120512091.9	223953323.9	998925183.9

13	344465415.8	145153.3333	120512091.9	223953323.9	1222878508
14	344465415.8	145153.3333	120512091.9	223953323.9	1446831832
15	344465415.8	145153.3333	120512091.9	223953323.9	1670785156
16	344465415.8	145153.3333	120512091.9	223953323.9	1894738480
17	344465415.8	145153.3333	120512091.9	223953323.9	2118691804
18	344465415.8	145153.3333	120512091.9	223953323.9	2342645127
19	344792010.8	145153.3333	120626400.1	224165610.7	2566810738

Table 11 - Annual net cash income

Then with different interest rates (0.1, 0.15, and 0.25 respectively) we calculated the Annual net cash income for the future:

$fd=1/(1+i)^n$	ADCI	cum ADCI	$fd=1/(1+i)^n$	ADCI	cum ADCI	$fd=1/(1+i)^n$	ADCI	cum ADCI
0.9090909	-	-494840.91	0.8695652	-	-	0.8	-435460	-435460
0.8264463	-	-944696.28	0.7561437	-	-	0.64	-348368	-783828
0.7513148	-408959.429	-1353655.7	0.6575162	-	-	0.512	-278694.4	-1062522.4
0.6830135	-	-1725437	0.5717532	-	-	0.4096	-222955.52	-
0.6209213	-	-	0.4971767	-	-	0.32768	-	-
0.5644739	126415812.9	227105505	0.4323276	96821202.1	186418646	0.262144	58708020.1	-
0.5131581	114923466.3	112182038	0.375937	84192349.7	102226297	0.2097152	46966416.1	-81264956
0.4665074	104475878.4	-7706159.9	0.3269018	73210738.9	29015557.9	0.1677722	37573132.9	-
0.4240976	94978071.3	87271911.4	0.2842624	63661512	34645954.1	0.1342177	30058506.3	-
0.3855433	86343701.19	173615613	0.2471847	55357836.6	90003790.7	0.1073742	24046805.1	10413488.2
0.3504939	78494273.8	252109886	0.2149432	48137249.2	138141040	0.0858993	19237444	29650932.3
0.3186308	71358430.73	323468317	0.1869072	41858477.5	179999517	0.0687195	15389955.2	45040887.5
0.2896644	64871300.66	388339618	0.162528	36398676.1	216398194	0.0549756	12311964.2	57352851.7
0.2633313	58973909.7	447313527	0.1413287	31651022.7	248049216	0.0439805	9849571.35	67202423.1
0.239392	53612645.18	500926173	0.1228945	27522628.5	275571845	0.0351844	7879657.08	75082080.1
0.2176291	48738768.34	549664941	0.1068648	23932720.4	299504565	0.0281475	6303725.66	81385805.8
0.1978447	44307971.22	593972912	0.0929259	20811061.2	320315626	0.022518	5042980.53	86428786.3
0.1798588	40279973.84	634252886	0.0808051	18096575	338412201	0.0180144	4034384.42	90463170.7
0.163508	36652868.61	670905755	0.0702653	15751068.5	354163270	0.0144115	3230566.91	93693737.7

Table 12 - Annual net cash income with different interest rates (0.1, 0.15, and 0.25 respectively)

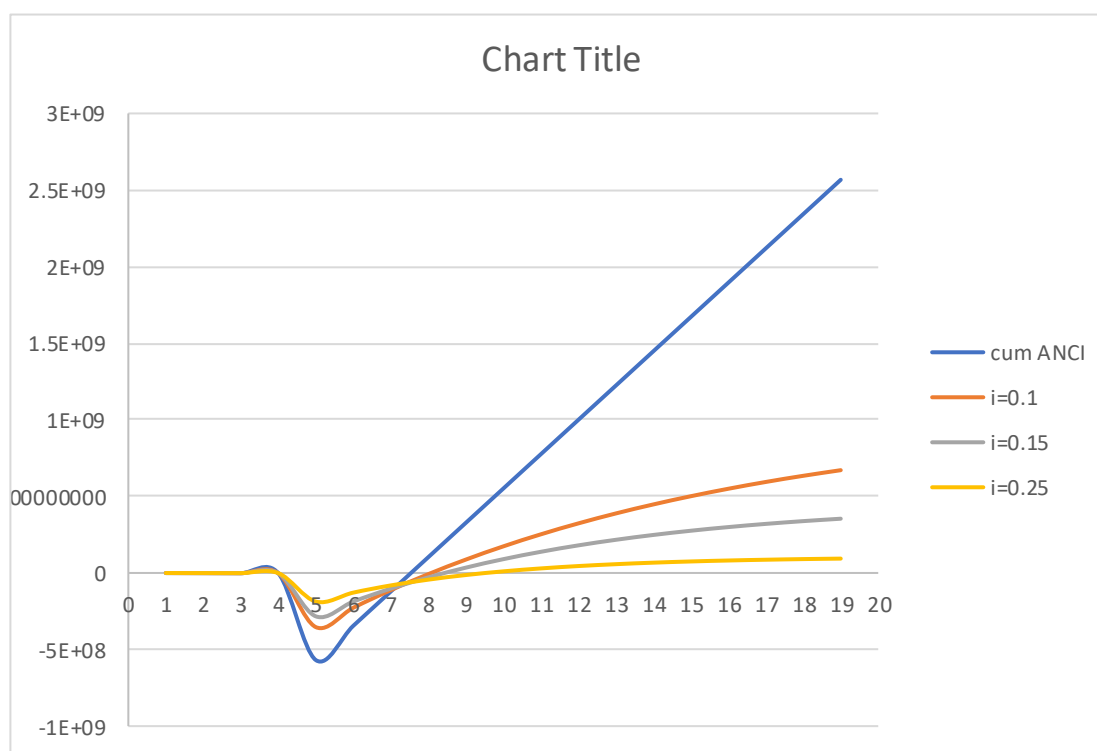


Fig 25- Annual net cash income chart

Using the obtained information, we drew a graph. According to the chart, we can see that the profitability of the factory starts between the seventh and eighth year. In fact, 3-4 years after the establishment of our factory, we reach profitability.

Conclusions

During the project, we talked about different types of disinfectants. We learned about Hypochlorous acid and its benefits and uses. We recognized and examined the different methods of its production. We got acquainted with a substance called Sodium dichloroisocyanurate. We found that this method is less dangerous and has a longer shelf life than other Hypochlorous acid production methods. It is safe for the environment. It is very easy to use this product and you can easily access Hypochlorous acid. This product has many fans around the world and different countries produce this product. China is ahead of other countries in the production of sodium dichloroisocyanurate. This product will be profitable in the future market. To produce NaDCC, we introduced a method that can produce sodium dichloroisocyanurate from the combination of cyanuric acid, chlorine, and sodium hydroxide. We designed a factory and calculated the necessary investment costs. With the graph we drew, we concluded that after 3 to 4 years after the factory starts working, profitability will begin. Although the establishment of a factory has a heavy cost, its establishment can also be beneficial. If

the sodium dichloroisocyanurate production factory is established in Iran, instead of getting this product from other countries, we can use the domestic product, which has a more reasonable price than other countries, and it is easier to get it. This makes it possible to help the country's economy. So, it can be concluded that the establishment of this factory in Iran can be a good proposal.

Recommendations for future work

Sodium dichloroisocyanurate can be an important product for humanity. At this time, when there are problems of lack of potable water in the world, this product can convert non-potable water with a specific pH into drinkable water. My suggestion for the future is to find a cheaper way with better quality to produce Sodium dichloroisocyanurate. They can even make my proposed method more complete and use it. Maybe they can find a more suitable way to make water usable. In any case, science is progressing and we should progress along with it and use it for a better and healthier life.

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