Make your own Electro-Clean Disinfectant
Instructions for batch process, 4-Liters.

Revised and Corrected: May 06, 2021

Materials Needed (with comments):

One plastic bottle (e.g., a disposable bottle of water) of capacity 1.5L or 2L, depending on availability. (Cola bottles such as Pepsi or Coke work fine)

2 carbon welding rods , about 30 cm long, about 10mm diameter. (We also call these as "electrodes" in the text below)

3 rubber bands

5 cm length of PVC / rubber household pipe or garden hose (1-2 cm diameter), sliced lengthwise (see figure later)

3 plastic or rubber spacers (can be made by cutting a plastic or rubber pipe) with inner diameters snugly fitting the carbon electrodes (see figures below). You can also make a spacer by using multiple wraps of a single rubber band on an electrode.

1 sharp blade, X-acto knife or box cutter.

A 1L measuring cup.

A small digital scale with 1gram accuracy (a typical kitchen weighing scale will do).

30 grams of common household table salt (NaCl). Both Iodized and non-iodized versions of table salt are acceptable.

4 Liters of ordinary drinking water.

1 standard size pliers.

2m length of insulated electrical wire, with 4 sq.mm. cross-section of the copper-core. This can be a multi-strand electrical wire used in buildings construction. In the US-Canada markets, use 12 AWG wire, designated for 20 Amps. In international (or metric) units, use 4 sq.mm. wire, that has a slightly larger conductor cross-section than 12 AWG.

A 5V DC, 40amp "SMPS" power supply (Switching Mode Power Supply) such as commonly used in desktop computers, or internet routers (can be found in discarded old desktops!). Or a comparable power supply. In a pinch, a 20Amp SMPS will also work, but they cost about the same, and will not allow you to run several units in parallel if you need to, later on.

Paper pH-strips (or a pH meter)

A 4L (or larger) plastic container or bucket.

White distilled-vinegar used in cooking (about 20 mL), or diluted (10%) industrial grade muriatic acid, also sold as industrial grade hydrochloric acid, or HCl.

Very strongly recommended: An Ammeter or a multimeter that can measure up to 10 Amps DC. (This is very strongly recommended, but can do without only if you must).

Recommended, but not required: A kit for measuring "free chlorine" We recommend ones made by Hach or Hanna. (The chlorine measuring kits from swimming pool supply stores commonly can measure up to 5 ppm, which can also work -- but will require a 100-fold dilution of the finished product to measure 500 ppm).

PURPOSE:
To create disinfectant from a salt water solution by passing an electrical current through it.

PROCEDURE:
Step 1. Dissolve 30 grams of ordinary table salt in 1L drinking water.

Step 2. Take the 1.5L plastic bottle and the sharp blade. Now proceed as follows: First fill the bottle with 1L water. Then, above the water-level, mark the position of a large H-shaped cut with a marker. The horizontal cut of the H should be about 3cm, and the vertical cuts about 2.5 cm each. (see photo for step 6 below). Position the H mark so that the lower ends of the vertical cuts of H are about 2 cm above the water level. Then, empty the bottle and use the blade or sharp knife to make the H cut.

Step 3. Pour 1L salt water solution into the bottle.

Left Picture: Freshly received carbon (graphite) rods. These rods are 15 mm diameter, and 30 cm long.
Photo Credit: Vijay Matange

Step 4. **Prepare the rod assembly**: EITHER: Using one rod, wrap a rubber band at three places top, middle, and near the bottom. OR: Insert one rod through three plastic or rubber washers that fit snugly around the rod without slipping.

Next, place the second rod parallel and adjacent to the first rod. Place two or three rubber bands, about equidistant along the rods' length holding together the two rods. When completed, you should have two parallel rods held together with rubber bands, but with a small, approximately 2-3mm, clear gap between them, maintained with the spacers.

Right picture: Step 4 shows the completed electrode assembly, with three rings (each made from slices of a PVC tube) to create a gap between the electrodes, and rubber bands to hold them close to each other, but without touching.
Photo credit: Vijay Matange

Connect the wires to the electrodes.

Step 5.Take a 5cm piece of the rubber hose and cut it lengthwise as shown in the picture above.

Left photo: an example of a multimeter, that was used to measure current (as Ammeter) in this series of experiments. Photo credit: Vijay Matange

Step 6. Cut the wire in half. You will have two pieces of 1m each. Peel 12 to 13 cm of insulation from one end of each of the two wires.

Left photo: Step 6. Photo credit: Vijay Matange

Step 7: Split the multiple strands into two braids, and wrap tightly around one end of the electrode rod, each strand going in the opposite direction, and wrapping around twice before coming together. Twist tightly with pliers to keep the wires under tension. See picture for Step 7.

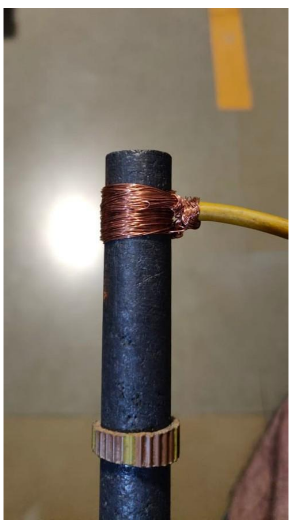


Photo showing Step 7. Wrapping bare copper wire around the end of each electrode, each half-strand going in opposite directions around the rod twice, and then tightly twisting the two different braids of wire together with pliers. This is the most important practical step to ensure very small contact resistance. You can cover the bare wire generously with electrical insulating tape (not shown here) to protect the bare copper wires from reacting over time with some of the humid chlorine fumes from electrolysis.

Photo credit: Vijay Matange

Step 8. Insert the split length of PVC or rubber hose on one of the electrode tips to cover wire windings. This serves as an electrical insulation and spacer for the electrode assembly, preventing short-circuiting.

Right photo: Step 8. Photo credit: Vijay Matange

Step 9. If you have an Ammeter, put it in line with one of the wires, between one rod and the SMPS connection. If you don't have an Ammeter, skip this step. We very strongly recommend the Ammeter (or a Multimeter used as a DC Ammeter) since that is the only physical measurement of the magnitude of current flowing through the salt-water. Without that measurement, you would not know how many Coulombs you pushed through the salt-water. If by accident some contact is poor (leading to high electrical resistance) the current can fall by a factor of 10, and you won't be able to know!

Step 10. Before turning the system on, check your assembly again. Review steps 4-8 if you are unsure. Attach the free ends of the copper wires to the positive and negative terminals of the SMPS power source that can deliver 5 volts DC. KEEP THE POWER OFF.

Step 11. Turn ON the SMPS power source. Note the time, and the current (on the Ammeter). Keep checking the current every 10 minutes or so. Operate for the desired duration. The goal is to deliver ~18,000 Coulombs to the bottle reactor. (Coulombs, a unit of charge, are calculated by multiplying the duration of the experiment in seconds, with the average current in Amps).

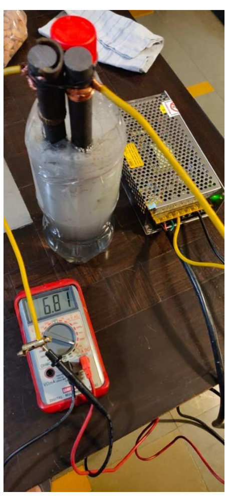
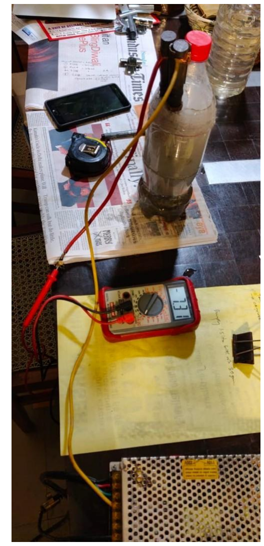


Photo for step 11. The power has been just switched on, producing a current of 6.8Amps at the start of the experiment. Microbubbles of hydrogen rise from the cathode, and make the water look milky.
Photo credit: Vijay Matange

Step 12. After delivering 18,000 Coulombs (18,000 Coulombs delivered in 60 min with 5A current), turn OFF the SMPS. Remove the rods assembly from the bottle. Rinse all wet parts with fresh water and dry them (with a dry cloth or paper towel). Keep the assembly and other parts to use again.



Picture for Step 12. Showing a current of 7.3 Amps. Assuming this was the average value, then (7.3 Amps X 41 minutes X 60 seconds =) 18,000 Coulombs were delivered to the water in 41 minutes. The current through the system may fluctuate by about 10% during the experiment, so we need to estimate the average current.
Photo credit: Vijay Matange

Step 13. Dilution. In a large plastic bucket or container, combine drinking water with the solution in the bottle. If you delivered 18,000 Coulombs, then you have 1L of a 946 ppm HOCl in the bottle. Mixing it with 3 L drinking water will produce 4 Liters of dilute HOCl solution of about 236 ppm HOCl.

Step 14: Removal of small carbon deposits. The process of electrochemical generation of HOCl with a carbon electrode leads to slow degradation of the electrode. Small carbon particles get released into the liquid. They can be removed by filtering through a coffee filter, or just letting them settle to the bottom (this may take time). We have confirmed that passing the HOCl concentrated solution through a paper coffee filter does not reduce the HOCl concentration. (You may choose to use two nested paper filters if needed, based on how fine the carbon powder is). The resulting solution should be clear and transparent, with a mild smell of chlorine.

pH ADJUSTMENT, STORAGE, AND USE

To adjust the solution pH:
Using a pH paper strip (or a pH meter), adjust the pH of the solution to a value between 5.0 and 6.5. Adjusting the pH will increase the disinfecting power of the solution by 60 to 100 times.

First, use a paper test strip to determine the initial pH of the solution. The amount of acid to be added will depend on the dissolved salts in your local drinking water, which vary from place to place, and can also shift seasonally. The acidity in vinegar can vary as well. We recommend doing this measurement once a month, or every time you change the source water or vinegar source, to catch any changes in the underlying chemistry. We expect that about 5ml vinegar per 1000 mL will be enough.

Slowly add white vinegar, (or dilute solution of HCl hydrochloric acid, also called Muriatic acid), 1 mL at a time while stirring, monitoring the pH, and stop on reaching the desired pH. If the chemistry of source water remains unchanged, this same amount of acid for pH adjustment can be used every time.

If you accidentally add too much vinegar, the pH will drop too much and you will need to raise it. Adding baking soda in small steps (in 1/2 g increments) will accomplish this. Stir well after adding. Test again with a pH strip, adjusting as necessary to reach a pH of between 5.0-6.5.

Storage:
The solution will keep its potency for 4 weeks if stored in a plastic or glass bottle, away from light (e.g., in a closet), at room temperature. At the end of its useful life, the solution returns to just a simple salt solution.

Use:
The solution has only 7,500 ppm salt, less saline than tears, and will not cause noticeable salt deposits on cleaning surfaces. It can be also used to wash food items to disinfect them (these can be consumed directly afterwards).

SCIENTIFIC UNDERSTANDING
Batch Process for 4 L of dilute HOCl, ~250 ppm, in ~30 minutes.

Key equations:
Current (amperes) x time (seconds) = Coulombs
96,485 Coulombs = 1 Faraday of charge (releases 1 gram-mole chemical with single charge)
1 ppm = 1 mg/L

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1 Background Calculations.

Molecular weight of Cl is 35.5, so the molecular weight of Cl_2 is 71.
TWO electrons are needed to release one molecule of Cl_2.

By Faraday's law, 2 X 96,485 Coulombs will release 1 mol of two-electron molecule
One mol of Cl_2 is 71 grams, because the molecular weight of Cl_2 is 71.

So, (2 X 96,485) Coulombs of charge release 71 g of Cl_2.
I.e., ~200 Coulombs releases 71 mg of Cl_2

We want to obtain 710 ppm (=mg/L) of "free Chlorine" per liter of water.
That is 710 mg Cl_2 per liter of water.
That requires (710 mg / 71 mg) X 200 Coulombs = 2000 Coulombs.

The minimum Faradaic efficiency of our graphite-rod reactor is only 15%, so we need to release 2000/(0.15) = 13,333 Coulombs in the water. E.g., 5 Amps for 2667 seconds (= 2667/60 = ~45 minutes). 60 minutes of current will deliver ~18,000 Coulombs.

Take 1 Liter of water at 30,000 ppm salt (that is only slightly less salty than sea water), pass 5 Amps current for 60 minutes, and 18,000 Coulombs will deliver (at 15% efficiency) 710 X (60/45) = 946 ppm of free chlorine in the water.

Then dilute this 4X (by adding 3 L drinking water) and you get 236 ppm free chlorine with only 7,500 ppm salt in it (that is about as saline is tears).