Ozone, Coronavirus, Sonoff

In these times there is a lot of talk about ozone in the various media: the faction of enthusiasts is attacked by violent critics.
I believe it is above all a commercial and cultural problem: on the one hand we have *stakeholders* (producers and suppliers of 'ecological' services) who have an interest in the diffusion of ozone, but essentially as a technology for "professionals", on the other hand we find *players* who react to the 'esoteric' management of the topic, and often with equally specious arguments. A dialectical contradiction in the inevitable phase of implosion under technological-commercial pressure and the emergency COVID-19

It reminds me the evolution experienced by the world of IT, which began in 1981: the transition from centralized services ('computer centers', IBM, UNIX, COBOL) to a 'widespread computer science' (PC, Microsoft, Linux, Java), subjected to technological (micro 8088) and commercial pressure (' Chinese IBM clones').
The echoes of these dialectics remain evident even in language: just as the terms used within a SW house are different from those used by a hacker, even the websites of the Ozone stakeholders often have similar and peculiar characteristics: poverty of verifiable technical information, self-referencing with excess of advertising enthusiasm, etc ... typical of fake news.

What if we try to make an objective point instead? To increase awareness of the advantages and risks of domestic sanitation with Ozone? Find DIY (Do It Yourself) spaces on the subject, to free it from this dialectical impasse? I believe it is an almost dutiful contribution in the current situation. It could be important, I would say almost vital, for someone to be able to make rational choices.

Here is the plan:

A) *objective and documented information on ozone:*
   - **Ozone PROS: facts**
   - Ozone CONS: facts

B) *Uses of ozone, with a small sample of representative products on the market, to inquire about the state of the art and to make informed choices:*
   - Strategies in the use of ozone
   - **Air purification ozone generators**
     - Some examples
     - Analysis
     - Good practices
   - **Shock ozone generators**
     - Some examples
     - Analysis
     - Good practices

C) *Finally, how to use ozone at home? 5 DIY projects*
   - simulOzone simulator of diffusion processes on PC or smartphone.
   - ozoneMeter (work in progress) simple ozone alarm
   - ozoneTimerPDM (work in progress) timer with PDM function
   - ozoneMaster (work in progress) a timer, with measurements in real time
   - O'safe (project) an ozone sanitizing device for everyone.

D) References

To trace the sources of information and to document themselves, here is the indispensable bibliography. Before making any decision, develop your skills and act only on the basis of rational and thoughtful personal choices..

Nota: To save time, contrary to my habit, I decided to publish this research as a work in progress. Not all projects are finished and therefore there will be updates.
I hope this decision also involves some feedback that will help me improve it.
Last version: https://github.com/msillano/Ozone-coronavirus-sonoff

Thanks.

Note: links don't work in github pdf viewer. In order to click the links, download this file and use a pdf-viewer on your PC.

Ozone PROS, facts

Obviously, the main sources of information on the benefits of Ozone are the stakeholders (manufacturers of equipment and suppliers of health services), but there are also authoritative international and Italian studies on the subject..

FP1: The Italian Ministry of Health with protocol 24482 of 31 July 1996 recognized the use of ozone in the treatment of air and water, as a natural aid for the sterilization of environments contaminated by bacteria, viruses, spores, molds and mites.. [1]

FP2: The strong oxidizing power of ozone allows the gas to oxidize and inactivate numerous organic compounds (phenols, benzene, trihalomethanes, pesticides) and inorganic (cyanides, sulphites, nitrites). [2]. Harmful substances are usually decomposed into less harmful substances, or even completely mineralized in media such as water, carbon dioxide and nitrogen. [28]

FP3: The units of measurement for the concentration of ozone in the air (and in the water) are [35][32]:

1 mg/m^3 = 1000 $\mu g/m^3$ (in air)
1 mg/l = 1000 µg/l (in water)
1 ppm = 1000 ppb = 1 mg/l (in water) = 2,14 (48/22,71109) mg/m^3 (in air)

FP4: Ozone can be generated in various ways, the most common are

- *Corona effect, economic and with high efficiency, requires dry air and maintenance.*
- *UV lamps, with lower efficiency but less maintenance.*

FP5: Ozone is unstable and spontaneously decomposes to O_2 minimizing the risks to human health, related to the chemical residue in the "food and effluent" since, after reacting, it decomposes, not producing undesirable compounds and leaving no odors unpleasant.[14]

FP6: Its half-life in air varies according to weather conditions such as temperature, humidity and air movement. Some unverified indications claim that ozone can have a short half-life, about thirty minutes in atmospheric conditions.[23]. Air half-life: 20 minutes +/- 10 minutes. [10]

FP7: Being a gas, it penetrates the interstices and porous materials, which is not the case for example with UV rays, which do not act in the 'shaded' areas.[24][10]

FP8: Sanitizes and purifies the air. Eliminates any odor. Eliminates organic and chemical pollutants. It is possible to use it to sanitize (not only rooms but also) mattresses, sofas, armchairs, rugs, carpets, cars, etc. [3][24][39]

FP9: Domestic use: In refrigerators to increase the duration of food and remove bad odors. To remove the stale air where you smoke or where there are infirm. To break down mites, spores etc. For cooking deodorization and removing bad smells. In the swimming pools. To remove pesticides from fruit and vegetables. To remove the chlorine flavor from the water and thus save on the cost of mineral water. To combat respiratory allergies in general, etc ... [5][7][39]

FP10: Ozone can be eliminated, in water and air, with activated carbon filters [5] or catalytic recombiners [40].

FP11: Recent press articles: La Repubblica.it “Sanificare con l’ozono ai tempi del coronavirus” [34], Il Gazzettino: “Trasporto pubblico: ogni notte interventi di sanificazione su bus, vaporetti e fermate”[4].

FP12: Many studies confirm the effectiveness of Ozone against viruses [10][24].

FP13: The effect on viruses increases with humidity (70%, 90%)[10].

FP14: Inactivation of bacteria, viruses, fungi, molds and insects following ozonation in air [2][24]

ORGANISMO	CONCENTRAZIONE	TEMPO DI ESPOSIZIONE
BATTERI *(E. Coli, Legionella, Mycobacterium, Fecal Streptococcus)*	0,23 ppm - 2,2 ppm	< 20 minuti
VIRUS *(Poliovirus type-1, Human Rotavirus, Enteric virus)*	0,2 ppm - 4,1 ppm	< 20 minuti
MUFFE *(Aspergillus Niger, vari ceppi di Penicillum, Cladosporium)*	2ppm	60 minuti
FUNGHI *(Candida Parapsilosis, Candida Tropicalis)*	0,02 ppm - 0,26 ppm	< 1,67 minuti
INSETTI *(Acarus Siro, Tyrophagus Casei, Tyrophagus Putrescientiae)*	1,5 - 2 ppm	30 minuti?

FP15: Against insects and rodents (about 70 species can infest food and food environments) it acts through the irritation of the mucous membranes, the inhibition of the synthesis of cellular lipo-protein-polysaccharides and the imbalance of neuro-receptors and transmitters.[18][24]

In this context, controversial opinions regarding the benefits of various forms of ozone therapy are not of interest [20]. They are outside the chosen target: the domestic sanitation..

FP16: The effectiveness of Ozone against COVID-19 has not yet been demonstrated, but based on experience with SARS, (killing rate 99.22%) "it is reasonable to predict that ozone is equally effective in preventing and controlling the new coronavirus. ". [8]

FP17: "Wet and dry films of viruses were found to be equally susceptible to the treatment regimen", "The ozone gas is also capable of efficiently killing aerosol-borne viruses." [10].

Ozone dissolved in water

FP18:

Solubility Ozone in water: 1050 mg/l (a 0°C) [23]
Solubility Ozone in water: [22]

Temperatura dell'acqua °C	Concentrazione dell'ozono in fase gas (% peso)				
	0,1%	1,0%	1,5%	2,0%	3,0%
	Solubilità dell'Ozono (mg/lt)				
5	0.74	7.39	11.09	14.79	22.18
10			9.75	13.00	19.5
15			8.40	11.19	16.79
20			6.43	8.57	12.86
25	0.35	3.53	5.29	7.05	10.58
30	0.27	2.70	4.04	5.39	8.09

FP19: Ozone is a very reactive gas, which reacts in two ways with the substances contained in the water:

- Direct oxidation: in water, ozone reacts directly with a whole series of organic and inorganic substances. This is a very selective reaction, i.e. certain bonds are preferably attacked (e.g. double bonds C = C, phenolic compounds, amino groups). For this reason, there are substances that are attacked very quickly while others are persistent with respect to ozone.
- Indirect oxidation: in the water, in the presence of organic carbon and hydroxide ions (OH-), a part of the ozone decomposes into hydroxyl radicals (OH ·). These react very quickly and non-specifically with a variety of substances.[21]

FP20: Indications for saturation in water with 500 mg / h generator

1l 5'
4l 15'
8l 30'

FP21: Depending on the quality of the water, the half-life of the ozone ranges from seconds to hours. Half-life in water at different temperatures.[26]:

15°C	30 minutes
20°C	20 minutes
25°C	15 minutes
30°C	12 minutes
35°C	8 minutes

Ozone CONS: facts

FC1: **Ozone is dangerous, potentially deadly**. It's true !

*We continuously use or come into contact with **surely deadly** natural or artificial substances: paints and solvents, gas, varechine, gasoline, carbon dioxide, carbon monoxide, etc ... I continue to think that it is above all a cultural problem, the effect of the dialectic between conflicting interests.* [*31*]

- Since its discovery and production, ozone has never created accidents or fatal events.[5]

Risks for humans

Epidemiological studies of the effects of ozone as an environmental pollutant are not relevant in this context, see for example an APAT report on the health impact of ozone [6] in 13 Italian cities, or the WHO report [9]. They are outside the domestic sanitation..

FC2: It should however be kept in mind that the ozone levels in the urban summer atmosphere (atmospheric background) can reach even high peaks (0.180 ppm) [9], interfering with the sanitation processes (incorrect measurements, alarm triggering, etc.) [11] Daily data are provided by local environmental agencies [35].

The ozone level in an apartment is generally lower than the atmospheric background if the room is closed (due to spontaneous decomposition) except in cases where local ozone sources exist: devices with high voltages (such as printers, faxes, copiers, etc.) or UV lamps, but also cigarette smoke.

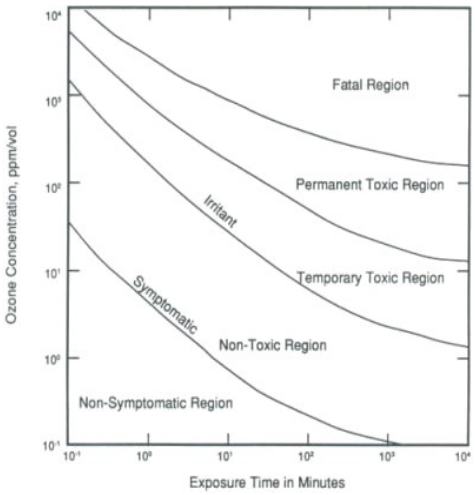
FC3: The olfactory perception threshold of ozone is 0.04 mg / m3 (~ 20 ppb), approximately five times lower than the safety value (see below). Fortunately, ozone can therefore be perceived already at low concentrations, which have no effect on human health, unlike, for example, odorless carbon monoxide.

At low concentrations, ozone is perceived as pungent, penetrating. At higher concentrations it has an odor similar to chlorine. Warning: there is an addiction to the smell, therefore after a short time it is no longer perceived. [11] [15]

FC4: Ozone mainly attacks the mucous membranes of the eyes, nose, oral cavity and respiratory tract and is harmful to health already at low concentrations(> 0,2 mg/m3 ~ 0,1 ppm). [11] [25]

FC5: In higher concentrations, ozone can cause health effects following inhalation. Symptoms, such as mucosal membrane irritations often followed by migraines. These symptoms may also occur during photochemical smog episodes. [23][9]

Ozone concentration	Possible health effects
> 0,2 mg/m^3 (~ 0,1 ppm)	*Cough, chronic bronchitis*
> 1,0 mg/m^3 (~0,5 ppm)	*Strong eye and respiratory tract irritation with severe cough, nosebleeds and respiratory problems*
> 2.0 mg/m^3 (~ 1.0 ppm)	*Sense of chest tightness, dizziness, headaches, circulatory disorders*
> 20 mg/m^3 (~ 10 ppm)	*Loss of consciousness, hemoptysis, death*
10 000 mg/m^3 (~ 5 000 ppm)	*Immediate death*



FC6: The greatest damage to humans occurs when free radicals produce a series of lesions to DNA, causing breakages, distortions of the double helix and cross-links between the nitrogen bases. [2]

FC7: For workers exposed to ozone, the threshold limit values (TLV) [33] are related to the physical activity performed (as the volumes of inspired air change). The values indicated by ACGIH, the American Conference of Governmental Industrial Hygienists, are:

- For heavy, moderate or light work, but carried out in a period of less than 2 hours, the TLV-TWA is set at **0.2 ppm,** equal to 0.4 mg/m^3
- For work done beyond two hours
  for light work the TLV-TWA is set at 0.1 ppm, equal to 0.21 mg/m^3;
  for moderate work the TLV-TWA is set at 0.08 ppm, equal to 0.16 mg/m^3;
  for heavy work the TLV-TWA is set at 0.05 ppm, equal to 0.1 mg/m^3. [12][14]
- For Ozone industrial plants
  - "warning level": from 0.2 mg/m^3 (~0,1ppm)
  - "alarm level": from 0.4mg/m^3 (~**0,2ppm**) [11]

"Listen to what your body is telling you… if you think you may be breathing in too much ozone, you may just be. Get to an area with fresh oxygen and the symptoms of ozone exposure should quickly go away." [19].

FC8: Limits California Ambient Air Quality Standards (CAAQS) of 90 parts per billion (ppb), 1-hour average, and **70 ppb**, 8-hour average, for ozone. [38]

FC9: The limits for atmospheric ozone in Italy are: 120 µg / m3 (~ 60 ppb "target") 180 µg / m3 (~ **90 ppb** "information") 240 µg / m3 (~ 120 ppb "alarm") [36] [36]

FC10: The limit value of ozone discharge into the outside air, pursuant to the ordinance against atmospheric pollution (Italy), is 0,12 mg/m^3 (~ 0,06 ppm; average hourly value). [11]

Risks for animals, plants

FC11: For pets, consider what has been said for humans.

FC12: For plants the limit is lower: 0.05-0.12 ppm (0.1 - 0.2 mg/m$^{3)}$).[13]

Other risks

FC13: Ozone can oxidize metals and attack some synthetic materials and rubbers. In particular: [20][23]

- *Metals at risk*: untreated steel sheets, cutting surfaces.
- *Ozone-proof metals:* Stainless steel, aluminum (Alumite treatment) and all those with galvanizing or coating surface treatments. [20]
- *Rubbers at risk*: natural rubber, latex, polyurethane foam, chlorprene
- *Ozone proof rubbers*: Teflon, Viton, silicone rubbers, chlorine vinyl rubbers, fluorinated rubbers.

"We suggest computers and valuable electric devices be removed. Leave the clothes, furniture, and everyday items"[19].

FC14: When the ambient air contains high humidity, it reacts with ozone. This leads to a reduction in the yield of ozone produced per KWh. An additional problem resulting from high humidity is the presence of unwanted reactions in the crown unit. [29]

Limits of the action of ozone in the treatment of waste water

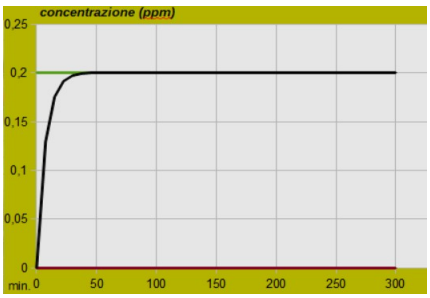
FC15: "Il est reconnu que l'ozonation d'eaux usées ayant une charge spéciale, par exemple à cause d'apports industriels, peut induire une augmentation de la toxicité. De même, des eaux usées ayant des concentrations élevées en bromure ne sont pas adaptées à un traitement à l'ozone (3 – 5 mg/l)".[16]

FC16: The elimination rate depends on the substance and quantity of ozone. There are substances that already at very low doses of ozone are completely removed while others degrade to a limited extent even with very high doses. Among the substances that are easy to remove there are, for example, hormonal substances and antibiotics. On the contrary, most radiological contrast media, some biocides or the active ingredient painkiller ibuprofen are difficult to remove.

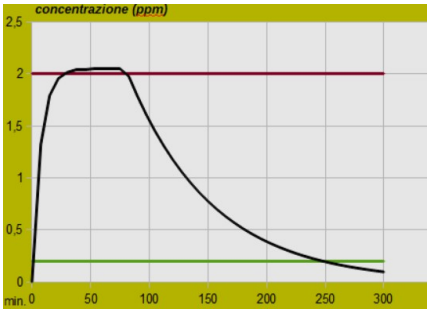
With an ozone dose of 0,7-0,9 gO3/gDOC (ca. 3-5 mgO_3/l), the micropollutants were optimally removed.[17]

Strategies in the use of ozone

Ozone is used according to two main strategies:



Air purification: Ozone is continuously diffused in the presence of people. The goal is deodorization and the reduction of pollutants in the air.
In no case should the use of Ozone involve health risks. The **200 ppb** limit (CF7) concerns adult workers in good health.
The limits for the entire population, made up of individuals most at risk, children, the elderly, patients with asthma and lung diseases, defined with reference to the atmospheric background, are more stringent (120 µg / m³. About **60 ppb**). In California: **90 ppb** (1 hour average) and **70 ppb** (8 hour average) [38]



Shock treating: ozone is diffused at high concentration in empty environments, without people, animals and plants, for a limited time.
The goal is the elimination of germs, viruses, molds. Excluding the more resistant molds, it seems that a minimum ozone level of **2 ppm, for 20 min**, is adequate for a complete (FP13) sanitation [37].
It is advisable to keep the concentration as low as possible, to avoid unnecessary risks and reduce time

Air purification ozone generators

The devices in this group are intended for continuous use in the presence of people. Generally they do not have control to regulate or limit the production of Ozone (timer).
They are of low power (max 500 mg/h), with the implicit hypothesis that *in no situation they can produce in the air levels of Ozone harmful to health*.
Some have the outlet of the pressurized air, with a pipe and a porous stone, in order to diffuse Ozone also in water..

Some examples:

	Air, battery. Ozone production: 8 mg/h, up to 10 m^2 ebay price: 15.29 US$ reference
	Air, water with pipe and porous stone. Ozone production: 500 mg/h aliexpress price: 18.20 € reference
	Air Ozone production: 500 mg/h (with people) 8000 mg/h (shock) Cyclic timer (PDM) to reduce ozone production. Price 1550.00 € reference
	Air Ozone production: 500 mg/h 2 Cycles PDM at 10%, 50’ o 80’ Until 20 – 60 m^2 price 118.60 € reference
	Air, Ozone + negative ions. Ozone production:120 mg/h Until a 20m^2 Banggood price: 37.70 US$ reference
	Air, water with pipe and porous stone. Ozone production: 500 mg/h timer: 15, 30 minutes, start delay. price 150 € reference
	Kitchen Disinfection Washing Machine Ozone production: ?? timer Banggood price 79,54 US$ reference

To get a more complete idea of the characteristics and uses of this category of generators, you can read the following manual (Italian) or this, or the manual (English) or this.

Analysis

The generators in this category are quite safe, but the basic hypothesis is at least questionable:

1. The ozone levels that can be reached with a generator in this category depend on many factors: the volume of the environment, the duration of the treatment and many other variables. It is impossible to guarantee that the safety limits (0.06 - 0.2 ppm) are never exceeded.[38]
2. In the presence of photovoltaic atmospheric ozone, the total concentration is given by:
   Natural background ozone + Ozone from the generator
   and can exceed security levels.(FC2)

At a safe concentration (0.06 - 0.2 ppm), virus sanitization is not guaranteed (FP13). Generators up to 500 mg/h are therefore not usable for sanitizing environments in a chock way (they do not reach the minimum concentration of 2 ppm if not with very small volumes), but they can be useful in a myriad of domestic occasions, especially if have porous stone:

- Deodorization of medium or small rooms: bedrooms, bathrooms, walk-in closets, garages, cellars etc ...
- Deodorization and eventual sanitization of small volumes: refrigerators, washing machines, shoe racks etc... By inserting the generator inside (if small, with battery) or through the pipe.
- Water treatments of vegetables, fruit, etc...(FP7).
- Against COVID-19 they can also be useful for the sanitization of small objects, for example when returning to the home: reusable masks, glasses, wallet, keys, mobile phones (with some risk, see FC12), shoes etc ... can be placed in a closed plastic box, where the tube that carries the Ozone enters. The treatment can be very effective as long as the required minimum conditions are reached (2 ppm, for 20 min).

good practices

Before using an ozone generator in a new application, always use the simulator to be aware of the maximum achievable concentrations, recovery times, etc…

1. When using these generators with small volumes:
   - Work in rooms with open windows.
   - Use a timer
   - After turning off the generator, wait a little time (e.g. 30 min) before opening the container, to allow the ozone decomposition to reduce the concentration
   - Open the containers in the open air, not in a room.
2. When using these generators for a long time in environments frequented by people or animals:
   - If upon entering the room the smell of Ozone is too pungent, turn off the Ozone generator and ventilate the room for a few minutes before accessing it for a long time.
   - *Use one or more ozone alarm indicators, which may also be readable outside the treated environment*
   - On days of alert for excess atmospheric ozone do not use ozone generators.
3. When using these porous stone generators in water, e.g. vegetable washing:
   - Work in kitchens with closed doors and open windows
   - *Use an ozone alarm device.*
   - Use the timer
   - Use gloves

Shock ozone generators

The heavier generators (> 500 mg / h) are used for 'professional' shock treatments: high concentrations to sanitize environments without people, animals or plants, for a limited time.

Some examples:

Air, water with pipe and porous stone.
Ozone production: 2000 mg/h
With electromechanical timer 0-60 ' + hold
aliexpress price: 23.82 €
(I used this model)
reference

Air, for air conditioning systems, indoor greenhouses...
Dia. 150 mm
Ozone production: 5 g/h
without fan
price 268,71 €
reference

Air, with fan
Ozone production: 24 g/h
Without timer.
aliexpress price: 33,62 €
(I used this model)
reference

Air, with fan
Ozone production: 3 g/h
Timer 0-120’ + hold
Banggood price: 96,54 US$
reference

Air, "*should only be used by licensed professionals*."
Ozone production: 18 gr/h
Timer,
I.O.T. boad, to report the recorded values of the treatments carried out.
price 3’050.00 €
reference

To get an idea of the characteristics and uses of this category of generators, you can read the following manual (Italian) or the manual (English) or this, of some commercial ozone generators.

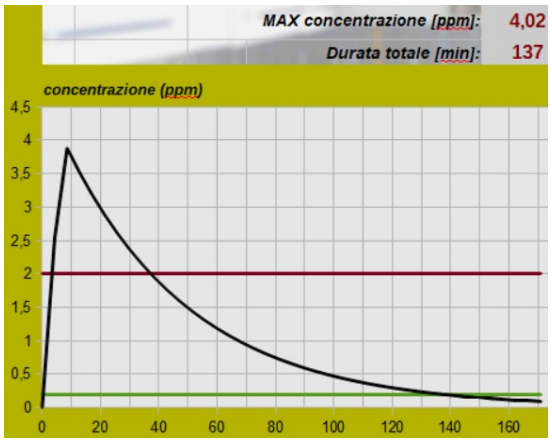
Analysis

For this type of treatment the premises must be empty, **without people, animals, plants** for many hours.

While this condition is easy to reach in offices, public places, shops, where no one remains at night and on the weekend, it is more difficult to achieve in a normal home.

However, there are some possibilities:

- a separate room (garage, cellar, etc ...) can be easily sanitized without major problems.
- the individual rooms can be sanitized at night, carefully sealed. Obviously not the bedrooms.
- use very controlled treatments of short duration (2-4 hours) more compatible with domestic dynamics.



Example:
average room sanitized in about 2 hours.

Room: 20 m^2
Generator: 24 g/h
Activation: 7', PDM 20%
Treatment: 30'@2ppm
Total duration: 137' =2h17'

To seal a single room, masking tape can be used, with plastic sheeting for wider openings.

Even the foam gaskets sold in rolls, to be glued to the doors, can be useful for windows and doors.

A small opening is recommended towards the outside (a window open for one or two centimeters) to facilitate the supply of oxygen.

To promote the homogeneous distribution of ozone in the environment:

- Position the generator as high as possible
- We recommend one (or more) oscillating fans positioned on the floor and directed upwards

The recovery phase is speeded up by promoting the exchange of air with the outside. The use of fixed fan-extractors on the windows with timed activation is recommended.

A portable system can be created with flexible fabric conditioning tubes of 15 cm. and beyond, equipped with a fan on one side, while the other side comes out of an ajar window, sealed with plastic and adhesive tape. Not very simple but very valid.

It is important for safety to foresee the unpredictable:

- Place signs at the access points to the treated zone to avoid any risk.
- Always use ozone meters and alarms, possibly with a reading outside the treated room.

good practices

Before using the ozone generator in a new application, always use the simulator to check the parameters involved: volumes, activation times, maximum concentrations reached, recovery times, etc.
More simulations allow us to orient ourselves towards the best strategy.

1. Due to the high Ozone values, the use of a Timer (better PDM to be able to reduce production) is absolutely essential to switch off the generator without human intervention, at the end of the foreseen operations.

2. To have the guarantee of reaching the concentration levels necessary for sanitizing, a timer is not enough. An on-off control is needed that measures the achieved ozone concentration in real time and controls the generator accordingly. Unfortunately, these devices are not present in almost all commercial generators. They are found in industrial plants, in research laboratories or in medical devices.

3. To avoid the need to rely on forecasts of the duration of the treatment, always uncertain, even using a simulator, it is certainly advisable to use ozone meters and alarms.

4. Prepare the environment:
   - Move pets and plants away.
   - Remove or pack electronic devices in an airtight plastic bag.
   - Seal all openings, possibly leaving a crack towards the outside.
   - Generator at the top, fans on the floor
   - Place warning signs in the access routes

5. If there is a centralized air conditioning system, seal the vents
   If, on the other hand, an air conditioner is present, switch it on in 'fan' mode: not only will it contribute to the movement of the air, but also its filters will be perfectly disinfected.

6. Always use a PDM timer, or better yet an on-off control.
   For very large rooms or whole apartments, multiple generators and multiple fans can be used simultaneously. In these cases it is essential to use an on-off control for each generator, to ensure uniform distribution.

7. Connect the ozone generator to a socket outside the room to be sanitized, using an extension if necessary. (***Alternative in case of emergency: do not enter! Use the main switch to disconnect the power!***)..

8. Wait at least for the time provided by the simulator before returning to the environment.

9. As a first step, open the windows and doors that open to the outside..

Ozono, strategie e dispositivi

"We must secure the help of ozone at the time of the new coronavirus epidemic. We must work together to make good use of ozone to defeat the epidemic." [8]

One thing is the sanitization of public environments, with high turnout of people, which must be repeated on a daily basis, another thing is the sanitization of apartments and houses, especially in lockdown.

For domestic sanitation, after maybe a general sanitation, we must above all worry to not import contaminated materials from the outside by transport, even when correct and prudent behavior has been taken outside the home.

Scenario:

in a supermarket an asymptomatic patient sneezes. A sphere of droplets with a minimum radius of 1 or 2 meters is formed accordingly. Nobody present: all right!
Mistaken!
A certain percentage of droplets settles on the surfaces, affecting only a circular area of 1-2 m radius. However, with an ability to infect again for 12-36 hours.
In this area, the shopping cart, exhibitors, food packages and the food on display are contaminated.
An attendant, with gloves of course, tidies up an hour after that exhibitor shelf, then moves on to unloading packs of coffee in another sector...
That cart is used by other users, who will then drive their car...
You can imagine the diffusion that results from it, with a simple comparison: has a ballpoint pen ever broken to you or your child? The ink comes out. In a short time you can find ink spots everywhere: on your hands, on your clothes, on everything you've touched. Here, this is the idea of transportation.
Last act: unwashed hands carry the virus to the eyes, nose, mouth (with a sandwich?): COVID-19 from airborne virus has acted as a contact virus.

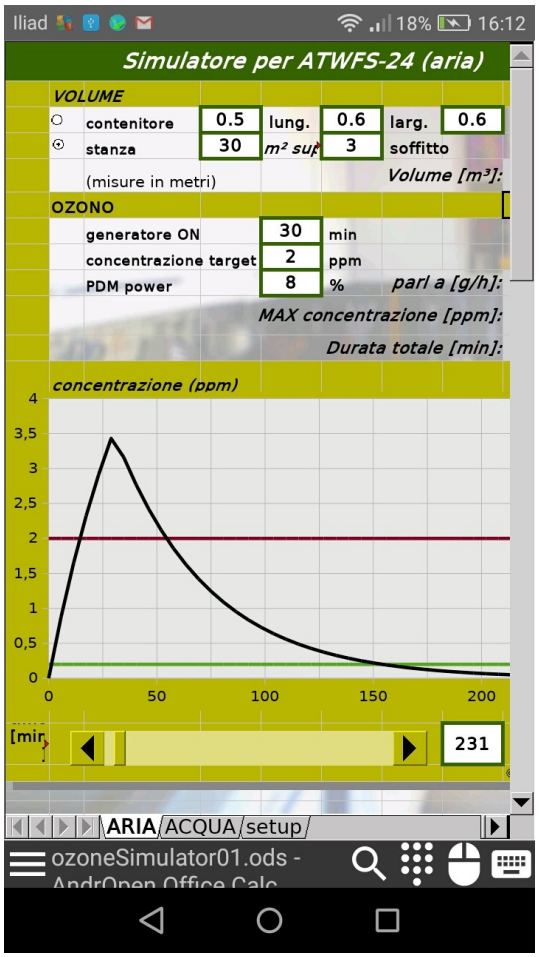
With this in mind, an environment (garage, anteroom etc.) can be used to sanitize used clothes and shoes outside, and anything else from outside must enter the house.
Returning, always with gloves, you put down shoes, external clothes, all objects coming from outside. You no longer have to touch them and now you can take off your gloves and disinfect your hands. Put on the 'indoor' shoes and clothes that you left there when you left.
This environment can be subjected to sanitization with Ozone after every return home: once sanitization is complete, clothing and every object and food from outside can be used safely.

That reminds you a science fiction movie with decontamination chambers? Me too, but this is the situation without vaccines: same problems, same solutions.
The new scenarios that the current world health situation has created have found everyone unprepared, even the ozone stakeholders.

Some DIY projects follow to simplify domestic sanitation with ozone, some analogous to existing solutions, others totally innovative.

1) simulOzone

The *concentration of ozone* in a given volume depends on 2 main factors:



- **Ozone quantity** generated in the unit of time (mg/h or g/h). *It depends on the generator used, and may vary due to the drop in efficiency over time, the presence of high humidity in the air, the lack of oxygen, etc..*

- **Ozone consumed** in the unit of time, proportionally to the concentration. *It is assessed with a parameter, half-life or half-life (Ozone in the air: from 20 min to a few hours, FP6, FP21) equal to the time required to halve the concentration. The main mechanism is the self-recombination of ozone in oxygen (FP5), but other factors also intervene: humidity and movement of the ozonated air, leakage of ozone from the treated environment, presence of substances with a catalytic effect, etc...*

- *In the presence of one production mechanism and another of consumption, the concentration tends to an equilibrium value that cannot be overcome. In other words, for each generator / environment combination there is a limit to the maximum concentration that can be obtained, even in very long times.*

This constitutes the problem: the concentration is defined by differential equations and follows an exponential trend, therefore it is a non-linear quantity that cannot be calculated with simple mathematical operations.

For these reasons I developed "simulOzone", an app for PC and smartphone that allows you to view the trend of ozone concentration in air and water.

It is a simulator, therefore it simplifies the reality it represents, e.g. considers an instantaneous and homogeneous distribution of nitrogen in the volume to be treated, but it clearly displays the reduction that is obtained using the PDM, the trend of concentration over time, the limit levels.
It is true that experience is a great teacher, but an instrument of this type I believe is fruitful in the first steps of using an ozone generator or at least it helps not to make big mistakes and to get a better understanding of the factors at stake.

For more information and to download the application, see simulOzone:
*(*https://github.com/msillano/Ozone-coronavirus-sonoff/tree/master/PROJECTS-DIY/simulOzone)

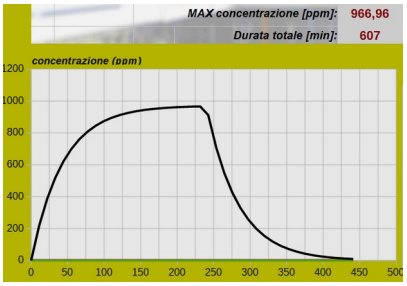
On the other hand, providing empirical values such as the following is not so useful and reassuring:

"But understand each project will rely on your own trial & error as much as anything else. That being said, here is a simple chart to get you started…"
(for a generator 8 g/h):

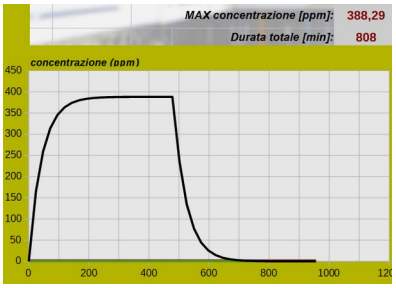
	Degree of Odor		
Size of Room	**Light**	**Moderate**	**Heavy**
100sq/ft	1 hour	2 hours	4 hours
250sq/ft	2 hours	4 hours	8 hours

The simulator provides:

100 ft^2, 4 ore



250 ft^2, 8 ore



In the total time of shock treatment, the following should also be considered:

1. *Charging time*, the time required to reach the expected concentration.
   It is minimized by using generators with high ozone production..
2. *Diffusion time*, required for the ozone to disperse homogeneously throughout the environment
3. *Active time*, required for sanitization (e.g. 20').
4. *Recovery time*, in which the concentration is brought back to a non-critical level (eg 200 ppb or 60 ppb).

SimulOzone provides user interventions on two simple global parameters, to better adapt the simulator to all real situations:

- ***Generator efficiency.*** It can include all the factors that affect the hourly production of ozone: air humidity, temperature, oxygen deficiency, progressive aging of the cells in the generator, etc.

- ***Ozone half-life.*** It can include all the factors involved in reducing the concentration of ozone in the air, such as temperature, humidity, presence of fans or openings etc.

2) DIY ozoneMeter

Given the current dynamics of the use of ozone, the little diffusion and the high cost of ozone measuring instruments should not be surprising. They are for scientists and 'professionals'! For example, the cheapest I have found:

Range: 0-9.99mg/m^3
precision: +/- 0,03 mg/m^3
price AliExpress: 113 €
reference

But do you really need a sophisticated measure in the home? An objective measure seems to me absolutely essential, but in my opinion a simpler alarm, similar to gas leak detectors or fire alarms, is very useful.

What is important is to know for sure if a room is accessible or not, without relying only on the time spent or on the smell. Such a device is not available on the market. Obviously.

Instead, a simple Ozone meter, which indicates the presence of safe or dangerous Ozone concentrations, is actually quite cheap and simple to make. DIY.

I designed and built a simple ozone tester:

- *Humidity and temperature compensation is obtained with a calibration on the level of the atmospheric background.*
- *LEDs are used to indicate some levels of ozone present in the environment: 60 ppb, 200 ppb, 1000 ppb.*

*For more information, see the complete **ozoneMeter** project:*
https://github.com/msillano/Ozone-coronavirus-sonoff/tree/master/PROJECTS-DIY/ozoneMeter

OzoneMeter can be made in two versions:

- A version is portable or wall-mounted, for example useful in the kitchen if you wash vegetables with ozone
- Another version is 'split' for wall mounting, with the sensor connected with a cable to the display. Assembled near the door of an environment usually sanitized with ozone (e.g. a garage, a shop) it informs us if it is safe to enter.

3) ozoneTimerPDM

The **timer** is a time switch, which turns off the ozone generator. It is present in many generators and in case of lack it can be replaced with an external timer, electromechanical or electronic, inserted in the power outlet (attention: the minimum interval of electromechanical timers is often 15 ', sometimes too high).

A timer becomes essential in shock treatment, when it is not possible to enter the environment due to the high ozone content, but it can also be found in generators for air purification.

Otherwise "*one way to do this is to hold your breath when entering the room, turn off your MaxBlaster, open a window or two if possible, and exit the room quickly. This can be accomplished in 20 seconds if you are prepared* "[19]

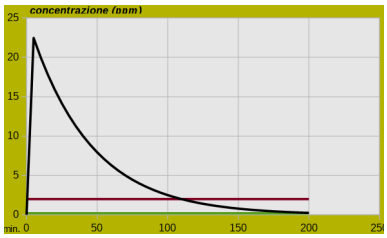
A better solution is to always use an extension cord and an outlet outside the treated environment. In this way it is always possible to switch off the generator without entering.

- Some timers have a start delay, to allow exit from the room.
- Some timers have a remote control, to allow their operation from outside the treated environment
- Some timers are cyclical, typically with a 24h cycle.

PDM adjustment

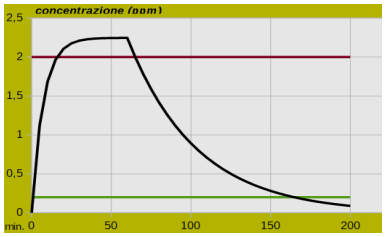
This technique allows to reduce the ozone production of a generator, controlling the on and off time during small repeated time intervals (Pulse Duration Modulation): it ranges from 0% (always off) to 50% (eg 1 min off, 1 min on) at 100% (always on).

Example



Generator 24 g/h; room 10 m^2, half-life 30 min, PDM 100%, time ON 5 min.
In just 5 minutes the ozone level reaches 22.5 ppm.
The concentration remains above the target value of 2 ppm for 1h: 50 '.
The whole cycle takes almost 3 hours.

Generator 24 g/h; room 10 m^2, half-life 30 min, PDM 5%, time ON 60 min.



In a 10 m^2 room reducing the Ozone production to 5% (equivalent to 1.2 g/h) the maximum concentration value is 2.25 ppm, the total duration 2h: 40 '.
Under these conditions 2.25 ppm represents the limit value of the ozone concentration, so the time of the generator (in figure 60 ') can be varied without affecting the concentration.
Consumption is lower than in the previous case, in fact 5% of 60' corresponds to 3 minutes of continuous operation.

This technique is used, for example, to commercially propose the use of a single generator both in shock mode (at 8000 mg / h, 100%) and in purification mode (at 500 mg / h = 6.2%).

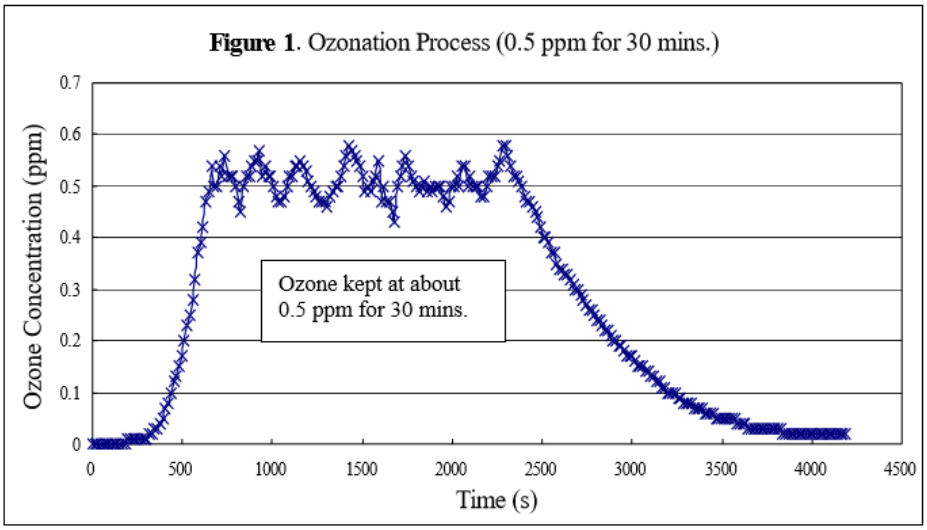
A simple timer, with PDM function, specially designed for controlling the ozone generators, is developed in the ozoneTimerPDM project. Very cheap and performing, it can be controlled from a PC or smartphone, in complete safety.
For more information, see the complete ozone ***timerPDM*** *project:*
https://github.com/msillano/Ozone-coronavirus-sonoff/tree/master/PROJECTS-DIY/timerPDM

4) DIY ozoneMaster

On-off regulators are control devices that turn off the ozone generator when a pre-established concentration of ozone in the air is reached and turn it back on when the concentration decreases. They maintain the desired concentration as the oven thermostat maintains the required temperature.

- The **timers** allow you to turn the ozone generator on and off in time, as is the case for nighttime street lighting
- **PDM timers** add the ability to control the amount of ozone produced, such as the knob that adjusts the intensity of a stove flame.
- The **on-off regulators** allow to reach and maintain the desired concentration, like a shower with thermostatic regulation that always supplies the water at the right temperature.

Would you bake a cake by turning on the oven to the maximum and then you would only base yourself on the clock and on the cooking time indicated in the recipe? I have many doubts. So why do it with ozone?



The main advantage is that, by measuring the actual concentration of ozone, this system guarantees the achievement of the objective, regardless of the various factors (generator power, losses, etc.). Another advantage is that it is possible to use more powerful generators, without however reaching excessive ozone values, thus speeding up the initial phase of charging the environment.

"The Ozone is easy to produce, but difficult to be controlled at a certain level, because of the cost of ozone sensors. Without the real-time test of sensors, it is out of the question to control its concentration"[8].

Using state-of-the-art components it is possible to create a simple and inexpensive on-off regulator for Ozone.
For more information, see the complete ***ozoneMaster*** *project:*
https://github.com/msillano/Ozone-coronavirus-sonoff/tree/master/PROJECTS-DIY/ozoneMaster

5) O’safe

Finally, the most ambitious but truly innovative project: an autonomous and portable sanitation system, in the shape of a shopping cart.

During the return home from the market (by car or on foot) the contents are sanitized with an automatic and safe cycle, because the container is hermetically sealed. The purchases that enter the house can thus be handled in complete safety and reliability.

At home, the container can be separated from the wheels, and can be used anywhere to sanitize anything: for example, clothing and accessories used outside: shoes, overcoat, hat, gloves. But also reusable masks, wallet, glasses etc …

The outside of the container is sanitized with a cloth soaked in alcohol.
It recharges like a mobile phone during the night

There are many applications of an ozone sanitizing basket also in specialized areas: clinics, hospitals, shops, bars, restaurants etc ... But it has been designed thinking above all of everyone's needs.
For more information see the ***O’safe*** project
https://github.com/msillano/Ozone-coronavirus-sonoff/tree/master/PROJECTS-DIY/O'safe

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