SimulOzone, ozone concentration simulator ver. 01

"But understand each (ozone sanitation) project will rely on your own trial & error as much as anything else". (MaxBlaster Ozone Generator <u>Owner's Manual</u>).

Really? I unbelive. Let see.
The concentration of ozone in a given volume depends on two factors:

1. *Amount of Ozone* generated in the unit of time (mg/h or g/h). This is a characteristic of the generator used, but may vary due to the decrease in efficiency of the generator over the time, or due to the presence of high humidity in the air, the lack of oxygen, etc ...

2. *Ozone consumed* per unit of time, proportionally to the concentration. It is assessed with a parameter, half-life, equal to the time required to halve the concentration present (Ozone in the air: from 20 min to a few hours; in water, from seconds to minutes). The main mechanism is the self-recombination of ozone in oxygen but many factors intervene
   ◦ temperature, movement of the ozonated fluid, air humidity,
   ◦ presence of substances with catalytic effect,
   ◦ ozonated air escaping from the treated environment, etc ...

Since there is a production and a consumption mechanism at the same time, the ozone concentration tends to an equilibrium value which cannot be overcome. In other words, for each combination of generator/environment there is a limit to the maximum concentration that can be obtained, even keeping the generator ON for 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 and cannot be evaluated with simple mathematical operations.

But it can be calculated with appropriate tools! This is the motivation that pushed me to create **simulOzone**, an *ozone concentration simulator*.
For the mathematical analysis of the model used, see <u>info on Malthus</u> law.

Features
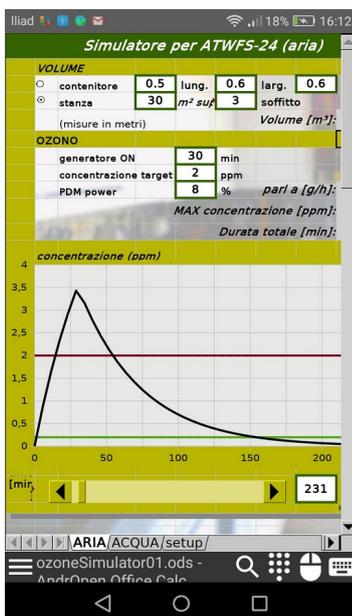
It shows the trend of the ozone concentration in a given volume (room or container, air or water), with a first phase in which the generator is active and a second in which the concentration decreases up to a safety value.

- It calculates the maximum concentration reached (in ppm) and the total time [min] to return to safety conditions.
- The graph is expandable on the time axis up to a maximum of 6000 minutes (over 4 days).
- It is easy to use, a setup page allows the user to enter the main options once and this simplifies the two main pages.
- It can be used on PC (Win, Linux, OS), on tablets and smartphones (Android).

Usage notes

On the Setup page

Model: enter a generator identifier. Better to use a different copy of the simulator for each generator you use, in order not to modify the setup data.

Ozone production: nominal value of the generator.

Efficiency: 0-100%, takes into account all negative factors in ozone production (generator efficiency, solution efficiency, air humidity, etc.).

Safety limit: concentration deemed safe from 0.6 ppm to 2 ppm.

Ozone half-life: half-life of the ozone used in the calculations. It must also take into account all the factors involved (temperature, leaks to the outside, etc.) Two half-life values, one for air and the other for water.

Solution efficiency: 0% - 100% takes into account the effectiveness of the ozone dispersion system in water, for example the performance of the porous stone.

Options: the user can choose the units of measurement to use: meter or feet, liters or US gallons. Save the file after changing the setup page.
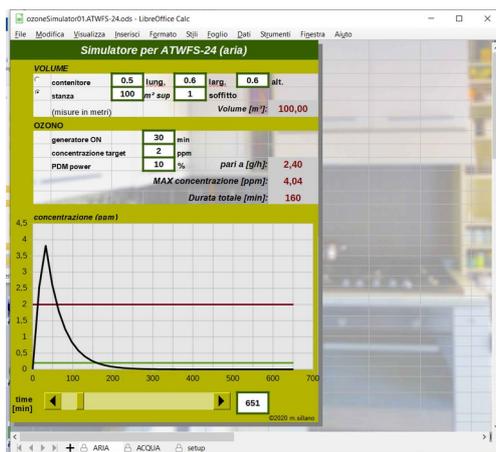
On the AIR page

Enter the dimensions for the **volume** calculation, two options:

- *container*: insert three sizes in the chosen unit.
- *room:* enter the surface and height of the ceiling.

Generator ON: time with ozone generator ON.

Target concentration: desired value, draw a red reference in the graph.

PDM power: 0% - 100% Reduction of the ozone produced by repeated switching ON and OFF (Pulse Duration Modulation). If not used put 100%.

Bottom: slider and numerical box to size the horizontal axis of the graph in minutes. The simulator also displays some numerical results in red: calculated volume, equivalent production using PDM, maximum concentration reached and total time until the safety value indicated on the setup page is restored.
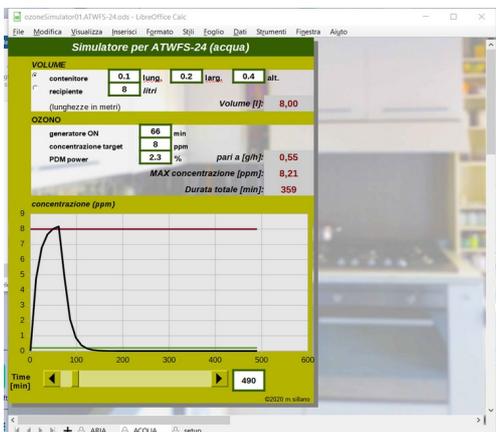
On the WATER page

This page is almost identical to AIR, only the way of defining the volume changes:

- *box*: insert three sizes in the chosen unit.
- *container*: directly enter the capacity in liters (or gallons).

Of course, the half-life and the performance values defined for the water on the setup page are used in the calculations.

SW installation

- *Windows, Linux, OS X*: download **OpenOffice** (free) from http://www.openoffice.org/ and install it following the online instructions..
- *Android*: install **AndrOpenOffice** (free) from *GooglePlay* https://play.google.com/store/apps/details?id=com.andropenoffice&hl=en
- The last version of **simulOzone** is in the repository https://github.com/msillano/Ozone-coronavirus-sonoff/tree/master/PROJECTS-DIY/simulOzone.

Download the `simulozone01_en.ods` file and copy it to a known location on the PC or device, for example: `documents/ozone` for Windows or `internal memory/ozone` for Android (use a management program suitable for your mobile to copy the file from the PC).
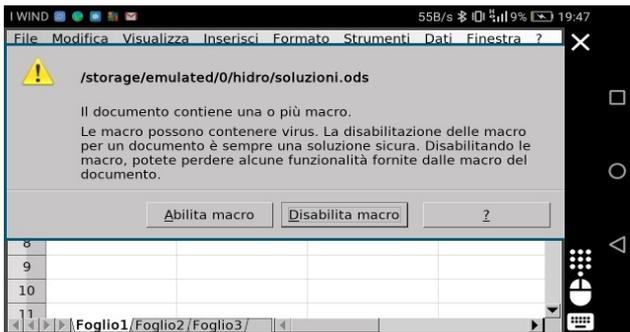
Run *OpenOffice/AndrOpenOffice* then open `simulozone01_en.ods` from menu *File/open*.

You can associate '.ods' files with *OpenOffice*, or *AndrOpenOffice* to open them automatically.

If required you must allow macros.

You can also create a shortcut to the `simulozone01_en.ods` file on the desktop for quick launch it. If you use more than one generator you can create a copy of `simulozone01_en.ods`, for each generator. So you don't have to change the setup data every time.

References

- The updated version of this project, with all the files to download, can be found here https://github.com/msillano/Ozone-coronavirus-sonoff/tree/master/PROJECTS-DIY/simulOzone
- A general documentation on Ozone and sanitation, with the information that has served to develop this project can be found here https://github.com/msillano/Ozone-coronavirus-sonoff
- Mauro Saita, Equazioni differenziali ordinarie, http://www.maurosaita.it/documenti/equazioni_differenziali_2016.pdf

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.

Note: The spreadsheet is protected only to avoid accidental changes in daily use.
The password to open them is '*ozone*'.

info: ozone concentration, Malthus law

1. Decomposition

In a closed volume, the present Ozone is halved every $t_{emivita}$ minuts (half-life) for oxygen recombination. The concentration (ρ) therefore decreases over time with an exponential trend. The corresponding differential equation is known as Malthus's law:

$$\frac{d\rho(t)}{dt} = -\lambda \rho(t)$$

The solution is found by solving the following Cauchy problem:

$$\begin{cases} \dfrac{d\rho(t)}{dt} = -\lambda \rho(t) \\ \rho(0) = \rho_0 \end{cases}$$

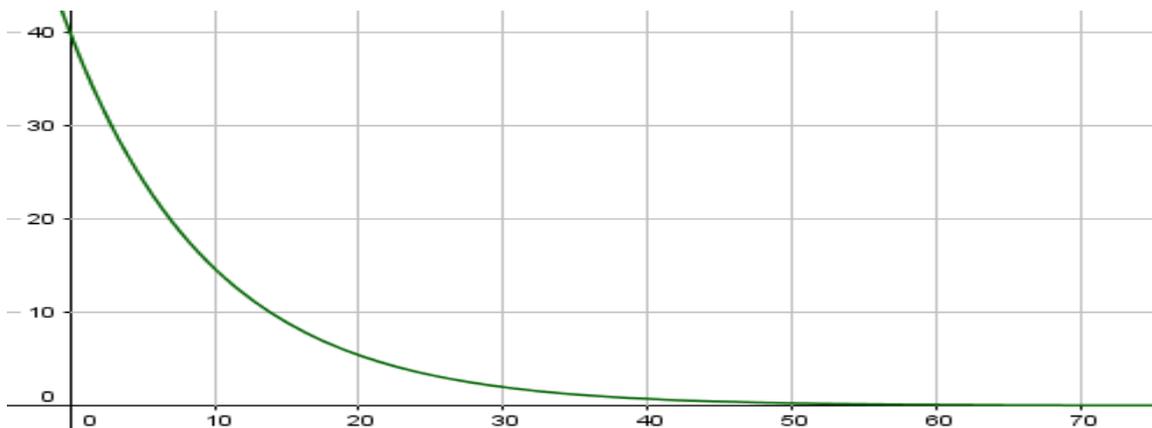You get the equation:

$$\rho(t) = \rho_0 e^{-\lambda t}$$

with

$\rho(t) = concentration\ [mg/m^3]\ or\ [mg/l]\ at\ time\ t\ [min]$
$\rho_0 = ozone\ starting\ (t=0)\ concentration\ [mg/m^3]\ or\ [mg/l]$
$\lambda = \dfrac{\ln(2)}{t_{emivita}}$ *decay constant*

   $t_{emivita} = half\text{-}life\ of\ ozone\ [min]$

2. Creation and decomposition

In a closed volume, a generator supplies a constant amount of Ozone per unit of time, increasing its concentration. At the same time the decomposition eliminates a part of the ozone present, proportionally to the concentration.
So concentration grows more and more slowly to a level where the creation and the decomposition are in balance.
The corresponding differential equation:

$$\frac{d\rho(t)}{dt} = -\lambda\rho(t) + a$$

In the case of interest, the solution is found by solving the following Cauchy problem:

$$\begin{cases} \dfrac{d\rho(t)}{dt} = -\lambda\rho(t) + a \\ \rho(0) = 0 \end{cases}$$

You get the equation:

$$\rho(t) = -\frac{a}{\lambda}e^{-\lambda t} + \frac{a}{\lambda}$$

with

$\rho(t) = concentration\ [mg/m^3]\ or\ [mg/l]\ at\ time\ t\ [min]$
$a = ozone\ production\ [mg/m^3 min]\ or\ [mg/lmin]$

$$\lambda = \frac{\ln(2)}{t_{emivita}} \qquad decay\ constant$$

$t_{emivita} = half\text{-}life\ of\ ozone\ [min]$