

## Chapter 2

# How Ozone Is Generated and Its Concentrations Measured?

Owing to ozone instability, it needs to be generated only when needed and used at once. Generation of ozone can be achieved by: (1) UV radiation, (2) an electrochemical process and (3) by corona discharge but it must be noted that the first two methods yield a low ozone output and a poor regulation of production **The ozonetherapist must have an ozone generator that is safe, atoxic, and reproducible.** The instrument (Fig. 2.1) must be built with the best ozone-resistant materials, such as Inox 316 L stainless steel, pure titanium grade 2, Pyrex glass, Teflon, Viton and polyurethane avoiding any material that could be released due to ozone oxidation. It is strongly suggested to purchase only a generator that allows to measure in real time the ozone concentration by mean of a reliable photometer.

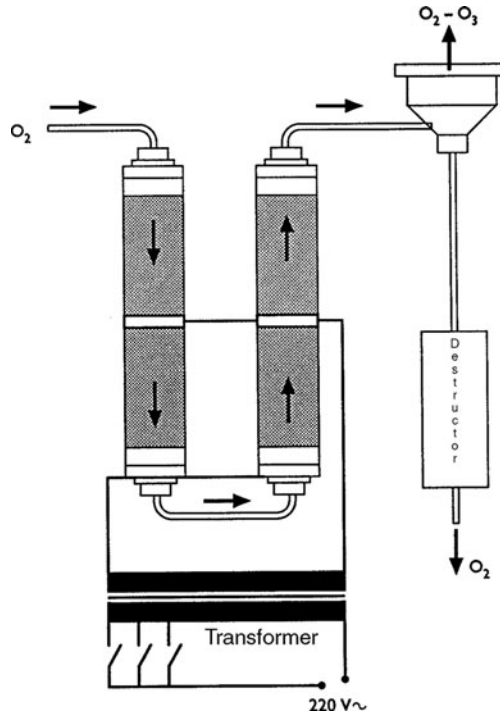
Unused ozone cannot be dispersed into the environment and it must be decomposed to oxygen by a catalytic reaction inside the indispensable destructor that contains heavy metal oxides maintained at about +70°C by an electric thermostat.

The medical ozone generator consists of 2–4 high-voltage tubes connected in series to an electronic programme able to set up voltage differences between 4,000 and 13,000 V. **In the system defined as the corona discharge ozonator, the ozone is formed when oxygen passes through a gap between high voltage and ground electrodes to create an energy field, denominated corona.** The energy from the electric discharge allows the breakdown of oxygen molecules into oxygen atoms which, in the presence of an excess of oxygen molecules, form the three-atom ozone molecule. The generator is fed with pure medical oxygen and, at the supply nozzle, a gas mixture composed of no more than 5% ozone and 95% oxygen can be collected at a slightly positive pressure. The synthesis of ozone is allowed by the energy released by the electric discharge while the decomposition of ozone is accompanied by energy release. For medical purposes, air cannot be used because, by containing 78% nitrogen, the final gas mixture will contain, beside oxygen and ozone, a variable amount of highly toxic NOx

The ozone concentration is determined by three parameters:

1. **THE VOLTAGE:** the final ozone concentration increases with the voltage, albeit in a non-proportional manner.
2. **THE SPACE BETWEEN THE ELECTRODES:** this serves to modulate a gradual increase of the ozone concentration.

**Fig. 2.1** A schematic view of an ozone generator: O<sub>2</sub> inlet, transformer, ozone destructor, nozzle for collecting O<sub>2</sub> + O<sub>3</sub>. Ozone is generated while oxygen flows through the two tubes



3. **THE OXYGEN FLOW:** this is expressed as a volume of litres per minute (l/min) and normally can be regulated from 1 up to about 10 l/min. The final ozone concentration is inversely proportional to the oxygen flow; hence, per time unit, the higher the oxygen flow, the lower the ozone concentration and vice versa.

The criteria for calculating the ozone dose are the following:

- (A) Total volume of the gas mixture composed of oxygen and ozone.
- (B) Ozone concentration, expressed as micrograms per ml (mcg/ml).
- (C) Barometric pressure (mmHg), if different from normal. For safety reasons we must avoid hyperbaric pressure.

### **2.1 The Total Ozone Dose Is Equivalent to the Gas Volume (ml) Multiplied by the Ozone Concentration (mcg/ml)**

As an example, for a volume of 100 ml blood, we use an equivalent volume of gas (1:1 ratio) with an ozone concentration of 40 mcg/ml, the total ozone dose is:  $100 \times 40 = 4,000$  mcg or 4.0 mg.

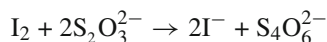
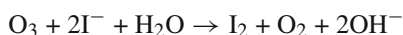
***A good ozonetherapist with an unreliable ozone generator cannot deliver an efficacious ozonotherapy.***

Therefore, it is indispensable that the generator undergoes periodic maintenance including a control by iodometric titration of the photometer, to insure delivery of a precise ozone concentration.

The normal medical generators deliver ozone concentrations from 1 up to 70–100 mcg/ml. As the use of ozonotherapy will soon expand, **I envisage the usefulness of a small, precise and handy generator able to produce ozone concentrations equivalent to 2, 5, 10, 20 and 30 mcg/ml.** This range is suitable for treatments such as rectal insufflation, topical treatments, quasi-total body exposure, preparation of ozonated water and oil for patients to use at home under the supervision of an ozonetherapist. **For several practical reasons, this new device will allow the use of ozone to many chronic patients that, otherwise, find impossible, or time-consuming, or too expensive to be treated, in a clinic.**

Even today there are a number of obsolete or unchecked instruments in use so that clinical results remain questionable and often are not reproducible. If we really want ozonotherapy to progress, we need precise and reliable ozone generators. ***This is so because ozonotherapy is not based on a homeopathic concept that even a trace amount will be active, but on the firm pharmacological basis that ozone is and acts as a real drug and, as such, it must be quantitatively precise.*** Luckily European generators give the ozone concentration directly in terms of mcg/ml and the range 1–100 is sufficient for medical use. Modern generators allow to assess the ozone concentration by photometric determination. This is possible because there is a pronounced absorption of ozone within the Hartley band with a peak at 253.7 nm. At this wavelength, UV radiation (mercury vapour lamp) is linearly absorbed in a concentration-dependent fashion (in agreement with Lambert-Beer's law) on being passed through a tube containing ozone. This system is quite sensitive and precise but the ozonetherapist must know that tends to decay due to lamp ageing. There is also the possibility of measuring ozone concentration at 600 nm (Chappuis band) that, although less sensitive, is more stable. **The great advantage of the photometer is the possibility of checking on a digital display the ozone concentration in the gas mixture flowing into the syringe during withdrawal.** However the photometer must be checked from time to time and possibly adjusted on the basis of ozone concentrations measured by the iodometric method considered the gold standard.

When ozone reacts with the KI solution, iodine is generated and the solution immediately acquires an amber colour which, upon reduction with a titrated solution of  $\text{Na}_2\text{S}_2\text{O}_3$  and a starch indicator allows the determination of the ozone concentration:



The concentration of ozone in gram per liter equals  $24 \times$  volume of thiosulphate in  $l \times$  normality of thiosulphate divided by the inlet volume of gas flow, accurately measured in liters with a precise flowmeter. Both the entities of the gas and of the solution volumes per min were precisely determined at  $21^{\circ}\text{C}$  and normal atmospheric pressure. The detection limit of this analytical procedure was  $0.1 \text{ mg/l}$  and the reproducibility was  $\pm 2\%$  of the measured ozone concentration.

The method has been approved by the IOA and the details have been reported by Masschelein in 1996.

When ozone reacts with buffered potassium iodide, iodine is generated and the colourless solution suddenly acquires an amber colour which, upon reduction with a titrated solution of sodium thiosulphate and a starch indicator allows the determination of the ozone concentration in gram/liter with a reproducibility of about 2% of the measured ozone concentration.

While the need of having a precise instrument is a must, in daily practice a couple of tips can be useful. Firstly, I learnt that what is important is the immediate use of the gas and not so much small changes ( $\pm 1\%$ ) of concentration. Secondly, polypropylene, silicon-coated syringes must be used only once. Finally the generator must be regularly checked because the efficacy of the treatment depends upon the required ozone concentration.

## 2.2 Conclusions

Ozone must be produced using medical oxygen with a reliable, atoxic generator that allows the measurements of precise ozone concentrations ( $1\text{--}100 \text{ mcg/ml}$ ) by mean of a photometer often controlled by iodometric titration.

The total ozone dose is equivalent to the gas volume (ml) multiplied by the ozone concentration (mcg/ml). For different medical applications, the ozonetherapist must know the optimal ozone doses and these will be specified in [Chapter 9](#).