Ozone and Water Purification

(1/12/2017)

About 0.1 to 0.6 liters of ozone will dissolve in one liter of water.

The solubility of ozone in water is quite good, about 10 to 15 times greater than for oxygen under normal drinking water treatment conditions.

A bubble size of 2 to 3 microns is desired. For good gas to liquid transfer, the smaller the bubble the better. Micro bubbles produced via a venturi, or sheared via a turbine are good examples.

Ozone is quite short lived in water, enduring only about 20 to 30 minutes in distilled water at 20 C and not nearly that long if contaminants are present.

Ozone oxidizes many materials into insoluble oxides that can precipitate or settle out (normally all are filterable), occasionally some are foamy (so can be skimmed). Some combinations of soluble organics and polyvalent cations produce insoluble materials with ozonation.

Ozonation causes surface charges to change from positive to negative. Colloidal Particles are usually held in suspension by their surface charges. Thus, ozone can induce some flocculation in turbid waters, depending on the water composition.

The following contaminants or problems can all be potentially treated with ozone;

- Bacteria - all known, including iron bacteria
- Minerals - inorganics, dyes and others
- Metals - Iron, Manganese and many other
- Organics - color, algae, other carbon compounds
- Protozoans - all known, including Cryptosporidium, Giardia and all Amoebae
- Viruses - all known
- BOD & COD - reacts quickly, as ozone is a really active form of oxygen

Although ozone is currently known to be the disinfectant most effective for Cryptosporidium, in most cases it should still be combined with or followed by conventional treatment or filtration.

An ORP meter (oxidation-reduction potential) will give a reading of ozone activity in the water, quite economically.

Worker exposure levels are not to exceed 0.002 g/m3 in the air for an 8 hour work day, or 0.1 ppm by volume. Fortunately, this is well above the threshold a person is able to detect by smell.

The human nose is extremely sensitive to ozone, being able to detect concentrations of about 0.01 to 0.05 ppm or 0.0002 g/m3. This sensitivity is superior to some monitors on the market.

However, it's sensitivity is slightly reduced with prolonged exposure. In high concentrations, ozone will burn (oxidize) the mucus lining in your nose, like no sinus medicine you have ever encountered.

You can notice a whiff of ozone when the concentration is 1/10 the safe legal limit for a whole workday exposure. If you notice a whiff of chlorine gas, run for your life and warn others (if you can).

We cannot live in contact with excessive ozone nor can we live totally without it. Consequently, striking a balance by using ozone properly seems a logical and intelligent path to follow. Even though ozone has a very short half life, less in water than in air, it merits a great deal of respect while it is briefly present. It is a very strong and efficient oxidant and disinfectant. Any life form, including man, can be disinfected by ozone --- permanently.

Both pre- and post-ozonation with filtration is best and is normally recommended.

WHAT ARE THE SIDE EFFECTS AND DOWN SIDES WITH OZONE ?

Good:

- short half-life in water, works quickly;
- ozone breaks down Trihalomethane and Total Organic Halide precursors to
- lower THM and TOX production potentials. This reduces the amount of
- chlorine required to maintain a residual (a nice double edged sword).
- increases biodegradability in humic and fulvic compounds.
- reduces BOD and COD.
- initially oxygenates ground water.
- can prolong filter media life.
- adds only oxygen to the water.

Bad:

- short half-life in water, little residual for distribution systems.
- filtration required in virtually all cases.
- filtration is always recommended with O3 treatment.
- corrosive as a gas and in solution (that's how it works).
- reputation of being expensive.
- not yet well understood by many designers and regulators.

Ozone gas might be likened to an airborne acid, because it will rust or corrode nearly anything that it contacts. This includes electrical terminals in test instruments.

O3-resistant materials must be used in parts, plumbing and seals. Anything that suffers weather deterioration, rust, corrosion or other natural deterioration will be destroyed by ozone. Stainless steel, glass, Teflon and Hypalon are some good choices when handling ozone gas. Ozone is so corrosive that only 316L stainless steel is recommended in specific parts of some systems.

Example

Many brands of 3g/h 120v AC Ozone generators can be purchased for less than $18-$30 from eBay. The following uses less than 10 watts and is but one example.

Ozone is produced by pumping air though the unit. This is then bubbled through water needing purification. The Ozone is absorbed. The result is water where the pathogens have been killed. The follow details notes to determine how much air flow is needed and for how long for a given amount of water.

Design Notes

A typical small aquarium air pump for 5-15 gallon fish tank will produce 1200 cm^3/min = 0.07 m^3/h = 18.5 (US)gal/h

Note: 1 m^3 = 35.3 **ft^3** = 1000 **liters** = 1,000,000 cm^3; 1cm^3/min = 0.000060 m^3/h = 0.0158 (US)gal/h; 1 m3/h = 264.17 (US)gal/h

What minimum volume flow rate of air needed to get about 3g/hr of ozone?

Air is 20% oxygen and has a density of 1.29 Kg/m^3. Thus .2*1.29*X = 3g/hr of ozone made in air. How much air is this? X =3/(.2*1.29) (g/h)/(kg/m^3) = 11.6/1000 m^3/h = .0116 m^3/h of air flow.

(1,000 Liters = 1 m^3 = 264 US gallons) (1L/h = .264 gal/h) (1gal = .1337 ft^3)
Thus, X= 11.6 Liters/h = 3.07 gal/h = .411 ft^3/hr = .00685 ft^3/min = 11,600 cc/h = 193 cc/min.

This flow rate is an absolute minimum if all of the O2 in air were to be converted to O3. Thus it should be safe to assume a minimum of at least 10 times this would be more likely to work in practice, as this would indicate 10% of the O2 would be changed to O3. Thus we are expecting a flow of 1900 cc/min = .068 ft^3/min as a minimum needed flow rate.

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What is the practical from experience air flow rate needed for 3g/hr O3 Generator?

For pure O2 converted to O3 a typical generator by example produces 120 g/m^3. Thus for air that is 20% O2 this concentration would be 5 times less or 24 g/m^3 as being able to be practically done.

Liter/min = (gen g/min)/((1000Liter/m^3)*(gen concentration for air 24 g/m^3))
= (3g/60min)/(24g/m^3/1000) = 2.08 Liter/min = 2,080 cc/min = 33 gal/h = 0.0735 cubic ft/min or two small fish tank pumps or one larger fish tank pump.

(1L/min = 15.85 gal/h) (1 gal/h = 0.00223 cubic ft/min)

How Long to Run O3 Gen for a given amount of Water?

To get 2 PPM of O3 concentration in water a 3g/h generator will produce 6 gal/min and take about 9 min for 50 gallon tank.

Estimate need to handle brackish water at 1 gO3/h per/30gal water. One generator put out about 3g/hr of O3 flow, and would do 90gal in one hour, or 1600 gal tank would take 18 hours run time. A 50 gal tank would take little over half hour.

To keep the run time down, best to use a 50 gal barrel. It would need to run between 9 and 30 min for a full tank depending on purity of the water.

Note: This rate of 3 g/hr is not even close to what water will hold of ozone. At this rate of 3g/hr it would take one hour of ozone treatment for each gallon of water to maximize absorption in water of ozone.

Approximate Diameter of Air Hose for Fish Tanks

Inside diameter: 4mm = 5/32" = 0.15625”
Outside diameter: 6mm = 1/4" or about 5.2 mm = .2” for silicon rubber
Mail connector: 3/16” = .1875”

Air pumps

For fish tanks they can range up to 800 GPH (gal/h). They can run off of 120v AC, 12 v DC, or 24 v DC. They can typically pump air to a maximum depth of 4 to 8 ft of water. Wattage used is between 3-18 watts. For greater depth or more pressure one could use the 12 v DC approximate 6 amp tire inflation pumps of various types. How fast it inflates a large balloon can be used to measure volume flow rate (1 cubic ft/min = 448.8 GPH).

Summary: We need a flow rate of about 0.0735 cubic ft/min (33 gal/h) or greater for each 3g/h O3 generator that is running. Plan to run the O3 generator for about 10-30 min for each 50 gallons of water depending on condition of the water. Need to put an exhaust fan on the tank that would continue to run well after the generator turns off. Say 1-2 hours.

Or seal the top and vent to out doors or put the tank out doors. This would be done to minimize power usage.

Conversion factors:

- Density of ozone: 2.14 kg/m^3
- Molecular weight of ozone: 48
- Density of oxygen: 1.43 kg/m^3
- Molecular weight of oxygen: 32
- Density of air: 1.29 kg/m^3
- Density of water: 1,000 kg/m^3

Useful Conversion Factors: (for water)

- 1,000 liters = 1 m^3 = 264 US gallons
- 1 gal = 3.785 liters = 3,785 ml
- 1 m^3= 35.3 ft^3 = 264 US Gallons

Ozone Concentration in Water

- 1 mg/l = 1 PPM O_3 = 1 g O_3/m^3 water {By weight}

Ozone Concentration in Air By Volume

- 1 g O_3 / m^3 = 467 PPM O_3
- 1 PPM O_3 = 2.14 mg O_3/m^3
- 100 pphm (parts per hundred million) = 1 ppm (parts per million)

Ozone Concentration in Air by Weight

- 100 g O_3/m^3 = 7.8% O_3 (Approximate)
- 1% O_3 = 12.8 g O_3/m^3 (Approximate)
- 1% O_3 = 7,284 PPM Ozone

Ozone Concentration in Oxygen by Weight

- 100 g O_3/m^3 = 6.99% O_3 (Approximate)
- 1% O_3 = 14.3 g O_3/m^3 (Approximate)
- 1% O_3 = 6,520 PPM Ozone

References:
See http://www.ozonesolutions.com/info/ozone-conversions-equations