## USE OF ULTRA VIOLET LIGHT AND OXIDATION

IN WATER TREATMENT

1:00   INTRODUCTION

This Engineering Bulletin discusses the application of two oxidation procedures individually and in combination with the emphasis on wastewater treatment.

Essentially the two procedures, first using UV light and the second using ozone achieve similar results by oxidising contaminants to gaseous or innocuous end products. Each has specific properties that have individual uses or in combination provide effectiveness over a wider spectrum. There are other oxidisers for example chlorine and hydrogen peroxide commonly used in water treatment but the use of UV light and ozone is gaining in popularity as the range of wastewaters now being treated for re-use increases.

Combination of these two procedures is known as Advanced Oxidation Process (AOP). Simplified sequence can be shown as:

$$O_3 + H_2O \longrightarrow O_2 + H_2O_2 \text{ (in the presence of UV light)}$$

$$2O_3 + H_2O_2 \longrightarrow 2OH + 3O_2$$
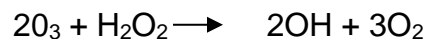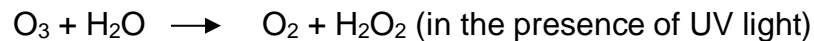
In this process photons in the UV spectrum convert ozone in the presence of water to oxygen and peroxide. This peroxide then reacts with ozone to form the hydroxyl radical. Organic oxidation is the result of reaction with these radicals, molecular ozone and direct photolysis.

2:00   KEYWORDS

UV Light	Reduction Potential
Ozone	Hydroxyl
Oxidation	UV Transmittance
Advanced Oxidation Process (AOP)	Germicidal Effectiveness
Nanometres (nm)	Types of Lamps
UVA	Inorganic Compounds
UVB	Organic Compounds
UVC	Ozone Decomposition
OzoneDemand	Ozone Transfer Efficiency

3:00   ULTRAVOILET LIGHT

Ultraviolet (UV) light is part of the light spectrum and is only visible at certain wavelengths.
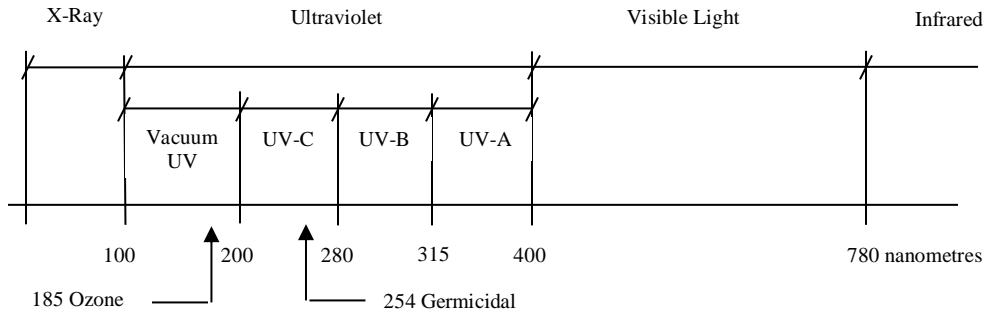
Figure #1 Light Spectrum

Photochemical generally classified as UVA or more commonly Blacklight is the longest wavelength area of the spectrum peaking at approximately 365 nanometres (nm). It is perhaps better known to the frequent visitors to Beauty Parlours as Sun Bed Tanning UV.

Erythemal generally classified as UVB is located around the centre of the spectrum at around 312nm wavelength. Principle use is in medical applications for the treatment of skin disorders.

Bactericidal generally classified as UVC is the shortest wavelength peaking at 253.7nm but usually described as 254nm for convenience. This is the most efficient for bacteria and micro-organism destruction.

Ozone is the gaseous allotrope of oxygen and can be generated photochemically through UV lamps at 185nm in the UV spectrum. There are other methods of producing ozone that are outside the scope of this Engineering Bulletin. Its principle use is as an oxidising and sterilising agent.

4:00   REDUCTION POTENTIAL

As mentioned in **1:00 INTRODUCTION** there are other oxidising agents used in water treatment Table #1 lists their effectiveness:

Oxidant	Oxidation Potential V
Fluorine	3.0
Hydroxyl Radical	2.8
Ozone	2.1
Hydrogen Peroxide	1.8
Potassium Permanganate	1.7
Chlorine Dioxide	1.5
Chlorine	1.4

Table #1 Reduction Potential

It can be seen from Table #1 that the only UV sourced potential is ozone that is produced at the 185nm wavelength. The reason for this apparent anomaly is that while all have sterilisation capability 254nm wavelength is deemed a more efficient bactericide as it renders bacteria and micro-organisms inactive by a not really understood mechanism but general consensus is destruction of the DNA nucleus without damage to the shell.

Fluorine and Hydroxyl Radicals while having good oxidation potential have this advantage outweighed by difficulty in handling and compatibility issues.

Ozone is short lived and easily disassociated by UV at 254nm wavelength but the major disadvantage is a lack of residual bactericide.

Hydrogen Peroxide is an efficient oxidiser and does generate a residual bactericide with the major advantage over potassium permanganate and chlorine derived compounds of leaving no residual deposits essential in such applications as pharmaceutical production.

For ozone disassociation utilising UV a 254nm wavelength lamp requires an output of approximately 90mJ/cm^2 to disassociate 1.0mg/l ozone.

Probably the single most critical factor in performance of UV applications is the water's "UV Transmittance" usually expressed in % and known as %UVT.

This unique value is influenced by the type of lamp, its spectrum, and the characteristics of the water to be treated. Because of the infinite range of variation that these three infinite variables initiate a base value is always determined by experiment for each lamp using a clear water blank. This blank is usually laboratory

grade deionised water with an NTU <1. (Herein lies a problem as most turbidity monitors are not reliable <1 therefore for a high purity blank NTU is just ignored).

The energy provided by a UV lamp is termed "UV Dose" although the term "UV Fluence" is becoming more common. Historically it was measured in $mW.s/cm^{-2}$ but the term mJ/cm^{-2} is gaining acceptance as is $J.m^{-2}$:

$$1 \text{ mJ.cm}^{-2} = 1000 \text{ mW.s/cm}^{-2} = 10 \text{ J.cm}^{-2}$$

UV Dose is defined as the amount of UV energy multiplied by the contact time:

$$\text{Dose} = \text{Average Intensity (mW.s/cm}^{-2}) \times \text{contact time (secs)}$$

UV intensity claimed for a reactor is actually the average intensity and is affected by the spacing of lamps.
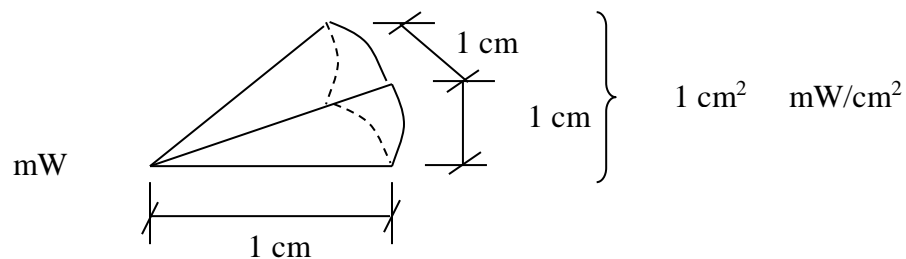
Figure #2

Figure #2 illustrates the intensity of travel across a fixed plane perpendicular to direction. For standardisation purposes this is taken as a plane area of 1 cm^2 at a distance of 1 cm from the radiation source. Should the distance vary for example 2L then intensity falls to:

$$mW \times 10^{\wedge} \ (-A \times L)/2cm \times 2cm = mW \times 10^{\wedge} \ (-A \times L)/4cm^2$$

where $\qquad$ A $\quad = \quad$ Absorbance coefficient

$\qquad 10^{\wedge} \ = \ $ Base 10

taking into account the spreading of the applied radiation and water absorbance.

%UVT is measured using a calibrated UV sensor selected as compatible with the optimum wavelength of the lamp under test through a 1cm sample of the water being investigated. This measured value is expressed as the total amount of UV energy available to treat the water. From this it follows that the greater the %UVT the higher the UV dose will be. In germicidal applications the more UV absorbance by substances in the water the less the efficiency is bacteria reduction.

From this it can be seen that the more contaminated the water the more UV power is need for transmittance.

What also has to be considered is lamp age. Typically, for low pressure lamps an 8,000 hour life is the optimum. Thus, any transmittance considerations should be at end of lamp life as worse case.

Figure #3 shows a GE 3-260 Watt Amalgam 254nm wavelength UV lamp performance at a steady 150usgpm flow rate against varying %UVT .

Figure #4 shows the same result but graphically

Care is needed in evaluating this data as it is unique for the particular lamp. In discussions with lamp suppliers this information should be available for each lamp, it is not propriety and should be in the public domain. If not the lamp has not been fully developed and should be avoided.

%UVT	mJ/cm^2 Lamp Life end	Total % Loss
100	151.8	0
95	120.8	20.42
90	97.4	35.84
85	79.6	47.56
80	65.9	56.59
75	55.1	63.70
70	46.5	69.37
65	39.6	73.91
60	34	77.6
55	29.3	80.70
50	25.4	83.27
45	22.0	85.51
40	19.2	87.35
35	16.7	89.00
30	14.6	90.38
25	12.7	91.63
20	11.0	92.75
15	9.4	93.81
10	7.9	94.80
5	6.4	95.78

Figure #3 Effect of %UVT
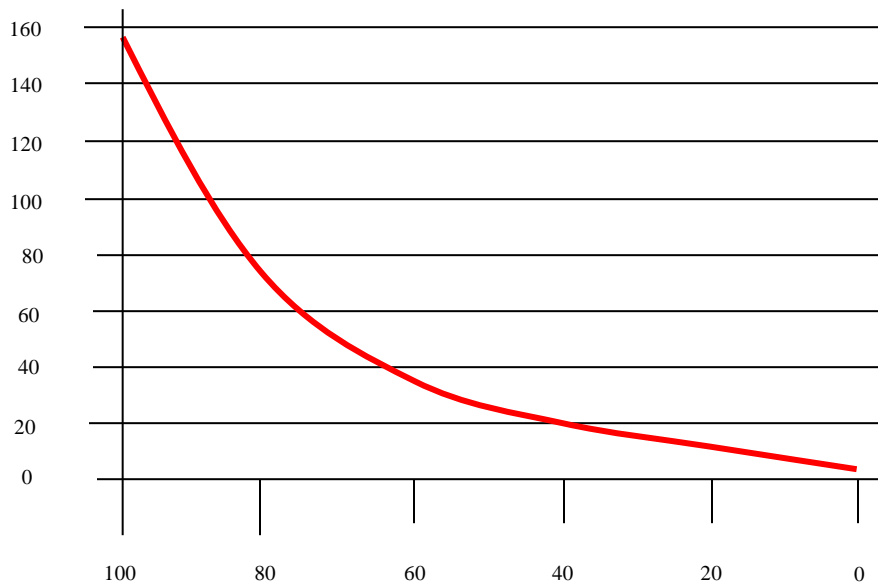
Figure #4 Graphical Presentation of Figure #2 Data

Figure #1 is used by the lamp manufacturer to determine the mean UV value of the lamp. This is almost always universally 1cm and follows the various procedures of ASTM and ISO test institutes. Since the passage of UV light through a liquid depends on the purity of the liquid the closer the light reading is taken to the light source the higher the intensity and the further away the lower the intensity. This statement has an important role in the selection of lamp power.

When speaking of "low" and "medium" pressure it is the vapour pressure inside the lamp tube that is being considered.

Low pressure lamps can generally (but not always) be considered 254nm wavelength while medium pressure can be considered 185nm wavelength. Since a medium pressure lamp has a higher emissivity of intensity the effective distance is greater and the lamps can be spaced further apart than for lower pressure lamps.

A further consideration is the mean UV intensity quoted by the manufacturer will be for clear water at 1cm effective length. This value is directly proportional to distance so if the monitor is 2cm from the light source with unchanged lamp intensity and water quality the mean UV intensity will be halved. Conversely, if the lamp intensity and distance remain unchanged but the water quality declines mean UV intensity will fall as illustrated by Figures #3 & #4.

Figure #3 is based on the total amount of UV lamp energy available to treat the water. The greater the %UVT value the higher the dosage. In germicidal terms this is critical since the UV light absorbed by substances in the water to be treated is not available for

bacteria destruction. For treatment of waste water it is even more crucial as reduction of contaminants and bacteria destruction is required.

Many UV lamp manufacturers publish data regarding UV amount needed for inactivation of bacteria, virus' and protozoa but these are laboratory derived utilising pure cultures and deionised water and are usually expressed of log reduction (1 log, 2 log etc). In wastewater applications were such organisms can be attached to particulates 2, 3 or even higher multiples of UV energy is required.

As mentioned above such data should always be weighted for end of lamp life intensity.

Note that the relationships stated in Figures #3 + 4 are not linear. Figure #4 is a graphically presentation of Figure #3 to better illustrate the effect of %UVT on lamp performance.

In specifying UV treatment for wastewater applications there are 23 design steps the final one being the Scheible Dose Calculation proposed by Scheible – 1987, USEPA -1986b) this addresses significant backmixing when the lamps are not parallel to flow or the flow paths in the reactor are short or laminar:

$$N = N_o \cdot \exp\left[\frac{Ux}{2E}\left\{1 - \left\{1 + \frac{4E\left[a \cdot I_{nom}F_yF\right]^b}{u^2}\right\}^{\frac{1}{2}}\right\}\right]$$

Where:

N   = final coliform count

N_o = initial coliform count

U   = wastewater velocity = $x(v_e/Q)$

x   = reactor characteristic length = average length of water travelled

while exposed to UV light

V_e = reactor liquid side irradiated volume

Q   = wastewater flowrate

E   = reactor dispersion coefficient (none plug flow in reactor)

a   = Uv inactation constant

I_{nom} = normal intensity of reactor – new lamp and clean sleeves

F_p = UV power at end of lamp life compared with initial UV Power

F_t = fraction of UV lamp output transmitted through sleeve

b   = experimental constant

c   = experimental constant

SS   = wastewater suspended solids concentration

m   = experimental constant

This is a complex calculation, as are the other 22. Included in the bibliography are terms not in the Scheible Dose Calculation but are included to illustrate their influence and are used in the earlier chain of calculations.

After this there are a further 4 calculations derived from later work by Wright – 2000, Blatchley – 2000 and USEPA "Ultraviolet Disinfection Guidance Manual" – November 2006 all that address the reduction in UV effectiveness for number of factors affecting germicidal performance.

For all the above reasons UV reactor design is more of a "black art" than a science and actual performance should be established with pilot tests.

Table #2 is typical values for Absorbance's and %UVT for wastewaters. These values are for guidance only and must not be considered firm in every case. For accuracy pilot test data should be compiled.

Type of Wastewater	Absorbance (base 10, cm^{-1})	%UV Transmittance (%, cm^{-1})
Primary effluent	0.55 ~ 0.30	28 ~ 50
Secondary effluent	0.35 ~ 0.15	45 ~ 70
Nitrified effluent	0.25 ~ 0.10	56 ~ 79
Filtered nitrified effluent	0.25 ~ 0.10	56 ~ 79
Microfiltration or MBR	0.10 ~ 0.04	79 ~ 91
Reverse Osmosis	0.05 ~ 0.01	89 ~ 98

**Table #2 Typical Absorbance's and %UVT of Wastewaters**

There is difference between lamp manufacturers between Filtered and Unfiltered Transmittance due to the argument that particulate or colloidal matter scatter rather than absorb light.

Several studies have addressed this by actinometry (Linden 1998) and bioassay (Qualis, 1983) that indicate that unfiltered UVT underestimates and filtered UVT overestimates the true values. On balance if a spectrometer is unavailable the use of unfiltered UVT values should be made as it is closes to the true UVT and conservative for sizing germicidal lamps.

Hydraulic design of the reactor chamber also has an effect on %UVT that Scheible addresses mathematically. Figures #5and 6 illustrates these considerations:
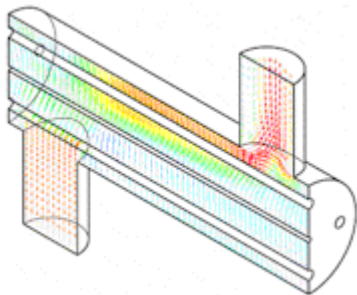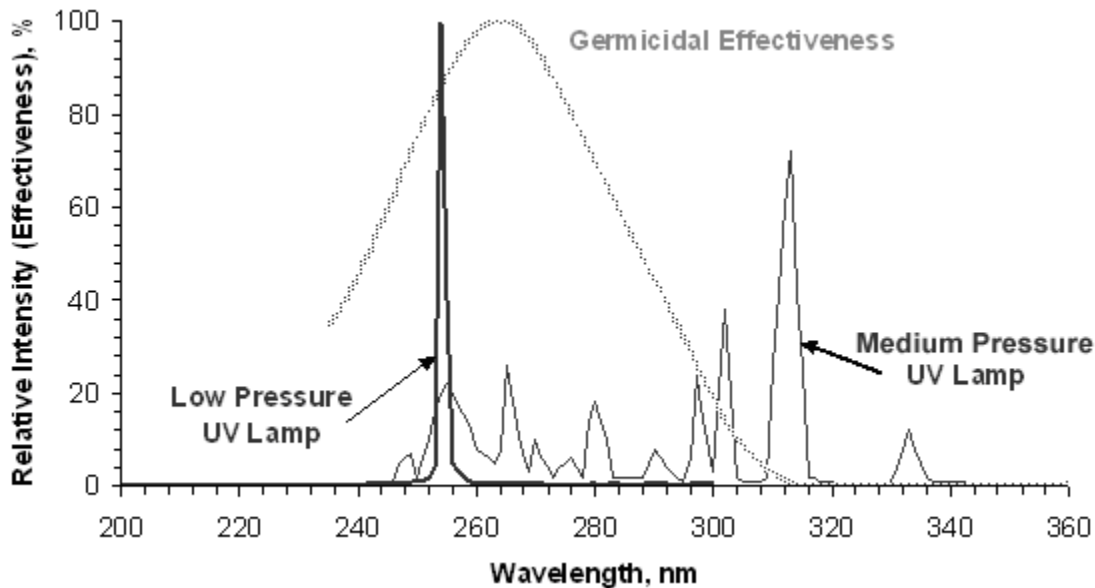

Figure #5

Flow path parallel to lamps
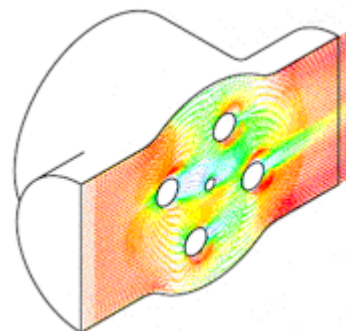
Figure #6

Flow path perpendicular to lamps

5:00   UV Lamps – History

In low and medium pressure lamps UV is artificially produced by mercury vapour. Low pressure lamps are most effective since they produce the majority of radiation energy in the germicidal wavelength or 253.7nm in the UVC portion of the spectrum. These lamps are commonly known as "amalgam" lamps since they contain solid amalgam spots to control the mercury vapour pressure. These "amalgam spots" are an alloy usually of indium or gallium.

All lamps have a spectrum or secondary emission including amounts of UVA, UVB and visible light (<400nm) together with heat. This statement is important as the blue "glow" emitted by a UV lamp is not indicative of their effectiveness since the wavelengths of interest are beyond human eye sight range. Only a calibrated UV monitor can measure their performance.

Figure # 7

Germicidal Effectiveness

The majority of development work historically with UV lamps has been related to germicidal applications. Figure #7 (with kind permission for American Air and Water) illustrates the spectrum of a low pressure and a medium pressure UV lamp over a spectra range of 240 ~ 340nm. There is little published data on the below 240nm spectra of medium pressure lamps in the organics reduction range.

However, it can be seen that across the spectra both lamps have varying performance at individual wavelengths. The task of the lamp applications engineer is to match the spectra against the required performance.

Common with all gas discharge lamps the output is reduced when the surface temperature deviates from optimum. This has a greater influence on low rather than medium pressure lamps but should not be neglected in design calculation if the feed water temperature varies.

As discussed elsewhere in selecting a lamp any factors depleting the effective UV dose needs consideration.

From a water treatment viewpoint effective development of UV lamps for disinfection of water commenced in the 1940's with the economic production of Cold Cathode lamps. Those basic rules established then apply today.

6:00   UV Lamp Family

Probably the most important factor in deciding on the type and rating of a UV lamp is their behaviour and capability under load in working conditions. Laboratory or

desktop analysis is useful but no substitute for this. Hence the emphasis on the necessity of pilot tests.

6:01   Cold Cathode Germicidal UV Lamps

These are instant-start lamps utilising a cylindrical cathode electrode operated either singly or in multiples.

Used in conjunction with quartz glass tubing, cold cathode electrode have a sturdy electrode construction providing longevity compared with other types of lamps. At lower, stable temperature good ultraviolet maintenance is provided and lamp life appears to be unaffected from frequent starts.

These lamps are classified as ozone producing or non-ozone producing depending on the quality of the glass case. Although of nominally 253.7nm wavelength for ozone production the glass is modified to produce a controlled amount of radiation at 184.9nm to produce ozone.

6:02   Hot Cathode Germicidal UV Lamps

These are similar in operation to standard fluorescent lamps in that the ballast (or transformer) requires a "starter" to incite the lamp. The electrodes for this type of lamp are coated tungsten and are limited by the number of "starts" thus, lamp life if limited and rated by number of times the lamp is started. These lamps are also temperature sensitive that has proved unreliable becoming rapidly obscured with UV strength depreciation.

6:03   High Output Germicidal UV Lamps

Developed from the experience of the past 5 decades in lamp deployment and manufacture these lamps are stable in varying temperatures, and have good, consistent spectra performance together with long life; 12,000 hours being typical.

Usual application of these lamps is in air duct sterilisation but they are used in water application.

6:04   Slimline Germicidal Lamps

These are instant-start lamps rather like slimline fluorescence lamps and are available for low, high and very high ozone applications Lamp life is susceptible to number of starts and electrode life.

These lamps are typically used for air disinfection, conveyor systems and airborne insect eradication.

6:05   Light Emitting Diodes (LED) Lamps

This is the emerging technology in UV that eventually will be the norm. However, there is no commercially available equipment that matches the current performance of high output UV lamps in working conditions.

7:00   OZONE DEMAND

UV, ozone and AOP provide useful benefits in reduction or removal of organic compounds and some inorganic compounds from water streams. In addition ozone also acts as a micro-flocculent assisting in the reduction or removal of suspended solids. They are also efficient disinfecting agents effective over a wide range of micro-organisms and compounds causing taste, colour and odour.

However, the fundamental question is how much of these separately or in combination is required for a given application. Most common applications are reduction or removal of organic and/or inorganic compounds and disinfection.

UV alone is almost wholly employed in the 254nm wavelength format for disinfection only and in 185nm wavelength format for TOC reduction.

Ozone alone is used for both disinfection and reduction within its reduction potential of 2.1 (Figure #1).

Ozone in conjunction with Hydrogen Peroxide (H_2O_2) and / or UV (254nm) is used for both disinfection and reduction with an enhanced reduction potential of 2.8 (Figure #1) due to the formation of radical hydroxyl's.

Considering the reduction of organic / inorganic compounds since disinfection is covered extensively in textbooks it is difficult to be precise as to the amount of ozone required due to the complexity of water and the difficulties caused by incomplete or inaccurate analysis. However, there are several "rules of thumb" established by experience that provide estimates sufficient for design purposes. It must be emphasised that only pilot tests and monitoring during commissioning can absolutely establish the amount of ozone required for the application.

7:01   Inorganic Compounds

These can include complexes found in industrial wastes for example metallic oxides common in metal finishing and mining processes and the simpler applications in potable water treatment for example reaction with Hydrogen Sulphide (H_2S), Iron (Fe) or Manganese (Mn).

Considering Fe and Mn removal it is important to avoid deposits in distribution systems and discolouration of water. These metals are oxidised to insoluble compounds that are then removed by precipitation or filtration. Amount of ozone required is 0.44mg / mg Fe and 0.88mg / mg Mn.

Hydrogen Sulphide (H_2S) perhaps better known as "rotten eggs" is not only an unpleasant odour and taste but in sufficient concentration in a confined space highly toxic. Presence of H_2S in potable water is unacceptable above threshold values. Theoretically the amount of ozone is 3mg / mg H_2S but in practice an excess is provided at 6mg / mg H_2S to ensure complete oxidation to sulphate which is an innocuous soluble salt.

7:02 Organic Compounds

Some organic compounds typically ketones, carboxylic acids and aldehydes do not react with ozone despite it being a powerful oxiff. Even some compounds that do react with ozone do not fully oxidise reverting to smaller unreactive compounds. Thus, it is difficult to predict the amount of ozone required. Even pilot and laboratory tests require a degree of caution due to representative sample, age of sample, scale of sample against actual flow rates etc.

Rule of Thumb #1

Use the COD value.

Establishment of the COD value uses a powerful oxidant (potassium dichromate) at elevated temperature to establish the amount of oxygen required to reduce all organic carbon present to CO_2.

In the laboratory the COD test result samples can be challenged with ozone to establish the amount of ozone required. If this cannot be done, field investigation for example then Rule of Thumb #1 that states:

$$\frac{COD}{2.7} = O_3$$

If COD is not available then other relationships are:

$$\frac{COD}{2.7} = DOC = TOC = O_3$$

Rule of Thumb #2

$$\frac{KMNO_4}{2.4} = COD$$

Rule of Thumb #3

TOC : O_3 is 1:1

TOC is useful in approximately in establishing the ozone requirement but differentiation must be made between Total Carbon (TC) and Total Organic

Carbon (TOC). The difference is the presence of Inorganic Carbon (IC) for example carbonates. Therefore:

$$TC - IC = TOC$$

Ozone will oxidise organic compounds but many will remain in solution in an oxidised state so the change in TOC value across the ozone system may not be large. To achieve significant reduction of TOC AOP needs to be deployed:

Some removal efficiencies:

APPLICATION	COMPOUNDS	UV	O_3	UV + H_2O_2	O_3 + H_2O_2	O_3 + H_2O_2 + UV
Industrial Chemicals	1,4-Dioxane	a)	a)	b)	c)	c)
	MTBE	a)	a)	a)	c)	c)
	NDMA	b)	a)	c)	b)	c)
Pesticides	Atrazine	a)	b)	b)	c)	c)
	Bromacil	a)	c)	c)	c)	c)
Pharmaceuticals	Diclofenac	b)	c)	c)	c)	c)
	Carbamazephine	a)	c)	b)	c)	c)
	Ibruprofen	a)	b)	b)	c)	c)
	Hormones	a)	c)	b)	c)	c)
Taste & Odour	Geosmin	a)	b)	b)	c)	c)
	MIB	a)	b)	b)	c)	c)
Decolourisation		a)	b)	a)	c)	c)
TOC Reduction		a)	a)	a)	b)	b)
Disinfection		c)	b)	c)	b)	c)

Removal Rates

a)   <50%

b)   51 ~ 80%

c)   81 ~ 100%

Table # 3 Rates of Reduction by Oxidation

7:03   Ozone Decomposition

In pure water in the absence of oxidisible species ozone will naturally decompose with temperature having a marked effect. For a constant pH this can be summarised as:

Temperature (C)	Half Life (mins)
15	30
20	20
25	15
30	12
35	8

Table #4 Ozone Decomposition / Temperature

This decomposition has to be allowed for in addition to any demand by organic or inorganic in defining the CT (Contact Time) value. This value is not to be confused with a Ct value.

Contact Time (CT) is the contact time required for ozone to destruct oxidisible material in the water being treated.

As pH rises ozone decomposition rate increase. Table #4 shows the effect of temperature at pH7.5 but at pH10 at 25°C half life is <1minute. Carbonate and bicarbonate have an important role in this being natural scavengers of OH radicals. Products from these reactions produce passive carbonate or bicarbonate radicals that do not react further with ozone or organic compounds.

7:04   Ozone Transfer Efficiency (OTE)

To be effective ozone must be transferred from the gaseous phase to the liquid phase and into solution with the water to be treated. Ozone Transfer Efficiency (OTE) is that % of ozone measured in the gaseous phase (Applied Dose AO$_3$D) that is retained in solution.

OTE is influenced by:

a)   Ratio of gas volume to liquid volume (G/L ratio), a lower ratio being more efficient

b)   Bubble size. Smaller bubbles has higher efficiency

c)   Pressure, higher pressure yields smaller bubbles and increase efficiency

d)   Ozone demand

e)   Ozone concentration, higher concentration increase efficiency

f)   Contact Time, the longer the better

g)   Temperature, lower temperatures increases ozone half life

h)   pH with higher values causing operational problems

i)   Alkalinity in the form of bicarbonate and carbonate reduces the effectiveness of ozone treatment and should be treated by other means

7:05   Ozone Requirement

Generators are usually rated in terms of O_3 g/hr taken as the AO_3D but it is important to know the solution flow rate as ozone calculations are generally summated as grams or milligrams/l.

For disinfection applications:

$AO_3D(g/h) = O_3(g/l) \times CT(h) \times \text{Flow Rate}(l/h) \times OTE$

For organic / inorganic reduction:

$AO_3D(g/h) = O_3(g/l) \times OTE \times \text{Flow Rate}(l/h)$

However, the only certain method of determining the ozone required is the use of pilot tests replicating the ozone equipment to be used in full scale application. Were possible pilot tests should be conducted on site to avoid problems arising from aged or samples affected by travel or storage.

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Terry Cummings
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ABOUT AUTHOR

Since entering the industry the author has now accumulated 50 years of experience in design, engineering, execution and troubleshooting water and wastewater systems with experience in building services, power both fossil and nuclear, potable and municipal water and wastewater systems including desalination and tertiary, pharmaceutical, microelectronics, petro-chemical and general industry. He is the author of many published works including Engineering Bullietins of which this document is one. While primary contact is via UK involvement is and has been worldwide with ongoing international activities.

APPENDIX A

ULTRA VIOLET AND OZONE LAMPS

PRE-HEAT TYPE

Type	Lamp Watts	UV Output Watts	µw/cm² @ 1 metre	Ozone Generation	Tube Dia. Mm	Rated Life hours	Part no
GPH287T5L	14	4.6	42	0	15.0	10,000	1013
GPH287T5VH	14	4.6	42	3.7	15.0	10,000	1014
G30TB	30	8.3	85	0	25.4	10,000	1030
G25T8	25	5.0	54	0	25.4	10,000	1009

COLD CATHODE TYPE

Type	Lamp Watts	UV Output Watts	µw/cm² @ 1 metre	Ozone Generation	Tube Dia. Mm	Rated Life hours	Part no
782L10	20	2.8	28	0	15.0	10,000	1001
782VH10	20	2.8	28	3.0	15.0	5,000	1001VH
782L20	24	5.5	52	0	15.0	10,000	1002
782VH20	24	5.5	52	6.0	15.0	5,000	1022VH

SLIMLINE TYPE

Type	Lamp Watts	UV Output Watts	µw/cm² @ 1 metre	Ozone Generation	Tube Dia. Mm	Rated Life hours	Part no
G10T5	16	5.3	55	0	15.0	10,000	1016
G10T5VH	16	5.3	55	4.5	15.0	5,000	1015
G36T6L	39	13.8	120	0	15.0	10,000	1043A
G36T6VH	39	13.8	120	14	15.0	5,000	104A

AMALGAM TYPE

Type	Lamp Watts	UV Output Watts	µw/cm² @ 1 metre	Ozone Generation	Tube Dia. Mm	Rated Life hours	Part no
G64T6L	200	65	500	0	15	10,000	1052

The above are a small extract from one UV lamp manufacturer's itinerary.