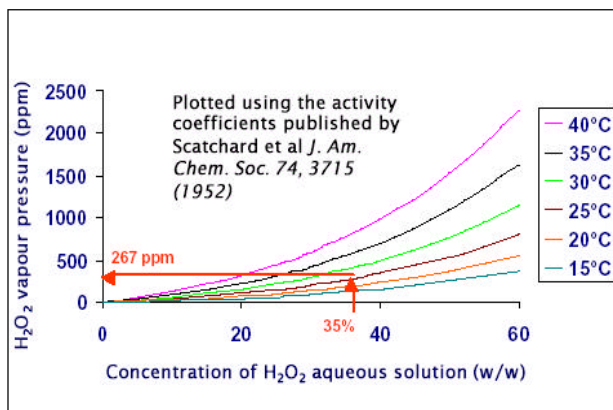


Wet Vs Dry - The Facts about Hydrogen Peroxide Vapour

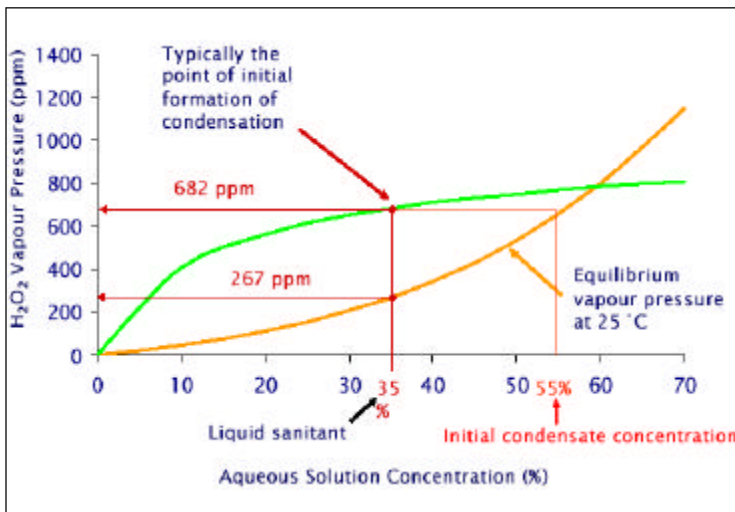
Many potential users of hydrogen peroxide vapour (HPV) for high level disinfection of rooms or enclosures are confused by the different marketing messages that are spread by equipment manufacturers regarding the benefits of their systems. In particular the subject whether this is a wet or dry process?, is one of the issues that appears to be an ongoing debate. This paper provides the facts about the physical chemistry of hydrogen peroxide in simple terms and dispels many of the myths about its use in practice.

Hydrogen peroxide is normally a clear liquid at room temperature with a faint odour. It can typically be purchased as an aqueous solution with different concentrations ranging from 3% to 85% w/w. For use in the vapour phase the liquid concentration is usually in the range of 15% to 60% with the main equipment manufacturers recommending a solution of 30% - 35% H_2O_2 as it is readily available.

Because the aqueous solution is a mixture of two chemicals i.e. hydrogen peroxide (H_2O_2) and water (H_2O) - (which have very different properties when it turned into a vapour), the component parts have very different effects. You will note that the term vapour rather than gas is normally used to describe the gaseous phase of H_2O_2 . This is because it is not a true gas - It cannot be bottled as a gas. The gaseous state is achieved by evaporating hydrogen peroxide into air. However the concentration of HPV in air is much lower than the concentration of hydrogen peroxide in the liquid from which it is evaporated. This can be explained when you look at the relative vapour pressures of water and hydrogen peroxide. The vapour pressure of water is nearly one hundred times higher than hydrogen peroxide. Vapour pressure is a measure of how readily the liquid evaporates, therefore water evaporates much more quickly than hydrogen peroxide. If an aqueous solution of hydrogen peroxide is allowed to evaporate naturally many more water molecules escape from the liquid than H_2O_2 molecules which results in a low concentration of HPV in air. Because of this 'forced' or 'flash' evaporation techniques are used to create HPV. This normally involves evaporating the aqueous solution on a heated plate in a warm airstream. This creates a much higher concentration of H_2O_2 in air.



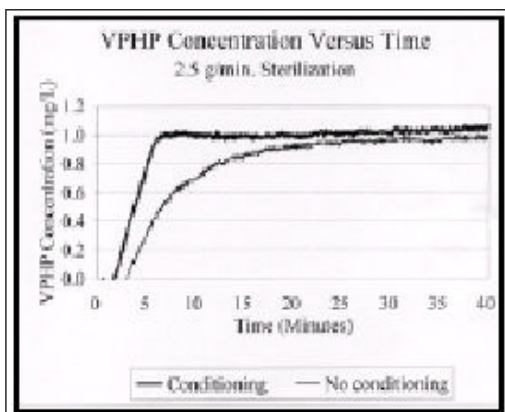
This is illustrated by the graphs. The natural evaporation of 35% hydrogen peroxide solution at 25 degrees Celsius with a starting relative humidity of 40% will achieve a maximum concentration of HPV in air of 267 ppm. With the flash evaporation process at the same starting conditions the concentration of HPV rises to 678 ppm.



The concentration of HPV in the flash evaporation process is dependent on the concentration of the liquid, the starting relative humidity of the air and the temperature. The vapour produced is hot and when it cools down it will revert back to a liquid again, just like steam.

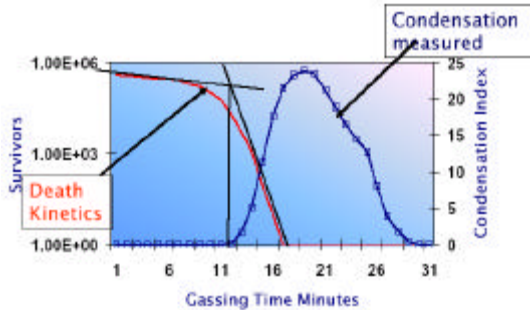
If the relative humidity of the air is low more of the molecules of water and hydrogen peroxide can be evaporated into the air stream before the air becomes saturated.

In hydrogen peroxide generation the concentration of the vapour is typically in the range of 2100 ppm to 2800 ppm (equivalent to 3 to 4 mg/l), this is because the air stream is very warm and can carry a high concentration of vapour without reaching a saturation limit. However when the vapour is delivered into a room or chamber it cools down quickly to ambient conditions. At room temperature the air can hold much less of the vapour, hence the concentration of vapour in a room or chamber is typically between 350 ppm and 700 ppm (equivalent to 0.5 to 1mg/l of H₂O₂). The concentration of HPV in air rises until the air can hold no more vapour and it plateaus at a constant value, providing the temperature does not rise. This is the point where the air has become saturated with vapour -i.e. the dew point of the vapour has been reached. This process is clearly described by Marcos et al. 1



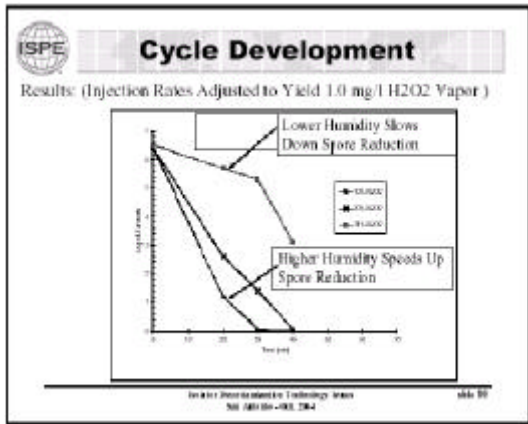
Effectively what this means is that whenever the concentration of HPV plateaus at a level less than the concentration leaving the generator the dew point of the vapour has been reached. It is interesting to note that irrespective of the concentration of the incoming vapour the maximum concentration in the room temperature and relative humidity are the same. This is illustrated by the graph presented by Steris at the ISPE Annual Conference in San Antonio in 2004. Vapourisation at a rate of 1 g/minute and 2.5 g/min gave the same measured concentration in the chamber.

If the vapourisation process continues after the concentration of HPV has levelled off the additional hydrogen peroxide and water vapour is deposited on all surfaces cooler than the vapour in the form of micro-condensation. This cannot be seen with the naked eye but is shown by extreme magnification in the paper by Marcos et al.¹

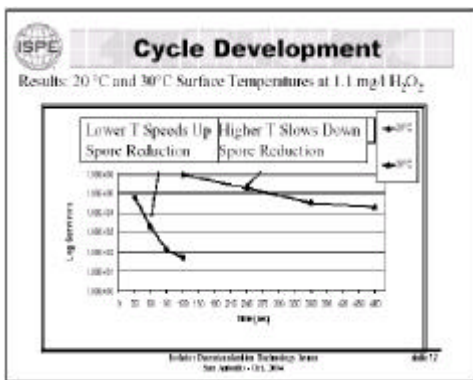


When the impact of the changing condition of HPV in a room or enclosure is compared with the effect of HPV to inactivate micro-organisms a very interesting correlation is identified. The rate of inactivation is rapidly increased when the vapour becomes saturated.

There is a marked transition between the relatively slow gradient of the inactivation curve before the dew point is reached and the very rapid rate of inactivation achieved after the saturation point of the vapour is achieved as shown on the chart.



The effect of reaching saturated vapour conditions is quite dramatic in terms of the effectiveness of the disinfection process using HPV. Micro-condensation slows means that many more molecules of hydrogen peroxide are in contact with organisms on surfaces causing rapid inactivation. This means that any vapourisation process that reaches the dew point faster will result in faster kill. This includes higher presence of moisture and lower surface temperature causing saturated vapour conditions to be reached earlier.

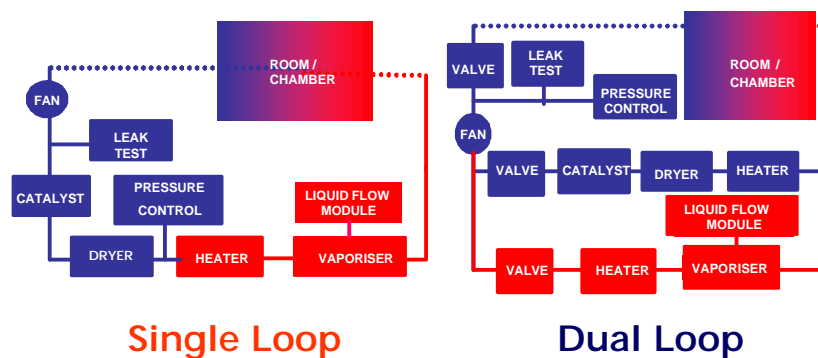


This is clearly illustrated by the information presented by Steris at the ISPE Conference in San Antonio in 2004. The data that they presented clearly illustrates rather more rapid inactivation of micro-organisms is achieved with increasing moisture content and lower temperature.

So to be efficient, the process needs to reach saturated vapour conditions quickly. Why therefore should any manufacturer of hydrogen peroxide vapour generators suggest that a DRY process is better?

This is simply a marketing term coined to try to explain the difference between the two types of commercial generators that are available- namely the single loop and the dual loop. These generators are represented in the simplified schematic diagram below.

Gas generator technology



Both types of generators produce hydrogen peroxide by forced evaporation of an aqueous solution on a hot plate. The warm vapour stream is then delivered into the enclosure/chamber in a closed circuit. The vapour concentration in the chamber rises until it plateaus.

In the single loop configuration generator the vapour that returns to the generator is passed through a catalyst where the HPV is reduced to water vapour and oxygen. The air stream is then dried and heated before fresh peroxide solution is evaporated. This is the 'so-called' DRY process. However the following features of this process are apparent:

- Hydrogen peroxide is constantly consumed during the disinfection process
- Water is constantly removed and so it takes longer to reach the saturated vapour condition is necessary for rapid biological inactivation to occur
- A plateau in the concentration of HPV in the chamber is reached confirming that the vapour in the chamber eventually becomes saturated despite this process being described as DRY. If the process was dry the concentration of HPV in the chamber would rise to the same as that leaving the generator (i.e. 2100 ppm to 2800 ppm).

- The vapour concentration in the chamber is higher because the starting relative humidity is lower because the air is constantly dried. Despite this higher concentration of HPV the single loop process is not faster because there is less of the essential moisture available and it takes longer to reach the dew point.

By comparison the Dual Loop configuration of generator has a separate circuit for vapourisation and for removal of the residual HPV at the end of the process (aeration). During the vapourisation phase the HPV recirculated back to the generator is not removed by a catalyst, but is simply reheated and additional solution vapourised. No HPV is removed during the vapourisation stage and no drying takes place. This is the 'so-called' wet process. This process is characterised by the following:

- The quantity of hydrogen peroxide required to achieve biological inactivation is reduced
- The dew point is reached more quickly because no moisture is removed
- The concentration of HPV is lower but the speed and rate of kill is higher
- The process can utilise a lower concentration of aqueous solution and still achieve rapid inactivation
- The dual loop configuration is a more efficient disinfection process

The detailed analysis of this process is described in the paper by Watling et al.²

Material Compatibility

An obvious concern is that saturated vapour may lead to material compatibility issues. However this is unfounded. Both types of generator described above reach saturated vapour conditions but the actual quantity of micro-condensation on surfaces is very small. Typically the degree of micro-condensation required to achieve microbial kill is less than one micron in thickness - well below the visible spectrum so it cannot be seen. It is generally unusual to witness visible condensation during the HPV process. Obviously gross condensation where hydrogen peroxide runs down walls will only occur if the process is out of control when too much hydrogen peroxide is used. Systems that reduce the amount of hydrogen peroxide clearly are advantageous.

Hydrogen peroxide is a strong oxidising agent and in the vapour phase some basic principles should be used:

- Materials should generally be chemically resistant to small quantities of H₂O₂
- Materials that are subject to rapid oxidation should be protected by a resistant coating
- Materials that act as catalysts to H₂O₂ should generally be avoided
- Surfaces should form a vapour barrier to avoid penetration of HPV into the substrate

Providing these guidelines are followed even material and equipment such as electrical components, electronics and computer equipment can be treated safely with HPV.

'Dry Fogging' Systems

Some manufacturers of fogging or nebulising systems often misrepresent these as HPV systems. There is a very big difference between the so-call 'dry fogging' systems and the HPV processes. Fogging systems generally use a cocktail of chemical disinfectants which may include H₂O₂, peracetic acid, silver nitrate or phosphoric acid. The quantity of H₂O₂ in the solution is normally about 3%. The main active ingredient that produces biological inactivation is peracetic acid. This is an extremely aggressive chemical and leaves residues of acetic acid on the surfaces that it comes in contact with.

Tiny droplets are produced by spraying the disinfectant solution at high pressure through a nozzle jet. These droplets will evaporate into the air due to the high ratio of surface area to weight until the dew point is reached. When the air becomes saturated the droplets cannot evaporate so remain as discrete particles of liquid subject to gravitational forces. The droplets tend to settle on horizontal surfaces making them physically wet. The process is very sensitive to the relative humidity at the start of the process. If it is above 50% the droplets cannot evaporate for long and the process becomes ineffective to reach all areas.

The fogging process is characterised by the following:

- Variable action
- Poor distribution
- Damage to sensitive materials
- Surface contamination with residues of other chemicals

Efficacy Data

There is much efficacy data that has been peer reviewed and published regarding the broad spectrum effect of HPV on a wide range of organisms. In fact there is more data available regarding the efficacy of HPV than any other fumigation chemical.

Test Organism	Liquid	Vapour
H2O2 Concentration	370 mg/L	1 - 2 mg/L
Temperature	24-25 C	24-25 C
<i>B. stearothermophilus</i>	1.5 minutes	1-2 minutes
<i>B. subtilis</i>	2 - 7.3	0.5 - 1
<i>C. sporogenes</i>	0.8	0.5 - 1

However there is some misleading marketing information on the relative effect of hydrogen peroxide in the liquid and vapour phases. It has been suggested that hydrogen peroxide is more effective in the vapour phase and the following data has been offered as evidence of this.

This data appears to suggest that the D value (time for a one-log reduction) for the spore for *B. subtilis* is faster for the vapour phase than when exposed to liquid peroxide of a much higher concentration. However what this data does not point out is that the liquid used to produce the vapour is actually 31% w/w solution which has a concentration of 310,000 mg/l or over 800 times more concentrated than the liquid used for comparison of efficacy.

As always in marketing many ploys are used to discredit the competition. For anyone considering the use of HPV for a room or chamber disinfection process it is recommended that they have a demonstration of the process performed or talk independently to users of the systems available to receive unbiased advice on the relative merits of the systems available.

References

1. Sterilization by vapour condensation. Marcos, Bardat, Schnitthaeusler and Beysans. Pharmaceutical Technology Europe. Feb 1996 Volume 8 No. 2
2. Theoretical Analysis of the Condensation of Hydrogen Peroxide Gas and water Vapour as Used in Surface Decontamination. Watling D, Ryle C, Parks M, Christopher M. PDA Journal of Science and Technology .November 2002, Volume 56 No.6.

Your local BIOQUELL distributor:

TDS-3-METVSDRY-V1

BIOQUELL (UK) Ltd
 34a Walworth Road
 Andover
 Hampshire SP10 5AA
 United Kingdom

Tel: +44 (0)1264 835 835

Fax: +44 (0)1264 835 836

Email: enquiries@bioquell.com

©BIOQUELL (UK) Ltd 2006 BIOQUELL reserves the right to make changes to specifications without notice and accepts no liability arising from the contents of this summary literature