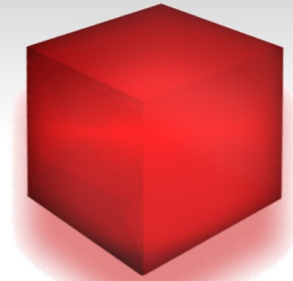


HYDROGEN PEROXIDE DECONTAMINATION

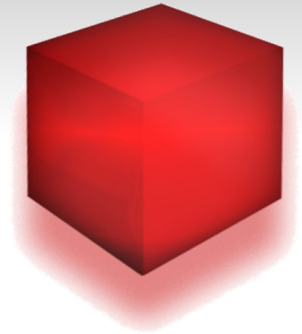
A CONCEPTUAL APPROACH TO





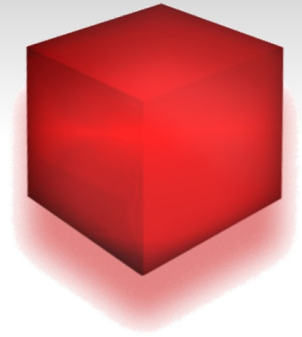
- **SOURCES OF KNOWLEDGE**

- Generally, nobody knows exactly the nature of living form contaminating a load
- Many publications has been done on the use of diluted liquid H_2O_2 , against specific living form
- Each of this publications highlights a contact time vs log reduction direct correlation
- Two publications:
 - Finnegan et alter in Journal of Antimicrobial Chemotherapy (2010) [research]
 - Linley and alter in Journal of Antimicrobial Chemotherapy (2012) [summarization]
reports the results of comparative study about efficiency of liquid and vaporized H_2O_2 in decontamination and about the decontamination mechanism
- **We based on this papers and on the basic chemistry knowledge our considerations (and comparison) about H_2O_2 application method**



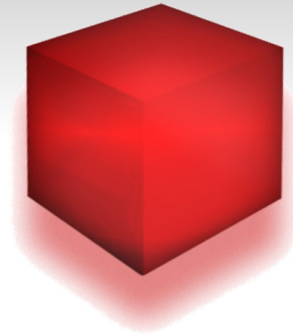
- **HYDROGEN PEROXIDE DECONTAMINATION MECHANISM**

- Generically, the mechanism with which H_2O_2 kills the living forms it is named as “oxidation”
- Currently, despite the many decades of use of the H_2O_2 , liquid or gaseous, as “disinfectant”, there are several hypothesis about the oxidation mechanism in decontaminating the several kind of living forms
- Three main oxidation reactions take place in decontaminating:
 - ✚ A Fenton reaction
 - ✚ A Haber - Weiss reaction
 - ✚ A catalase reaction



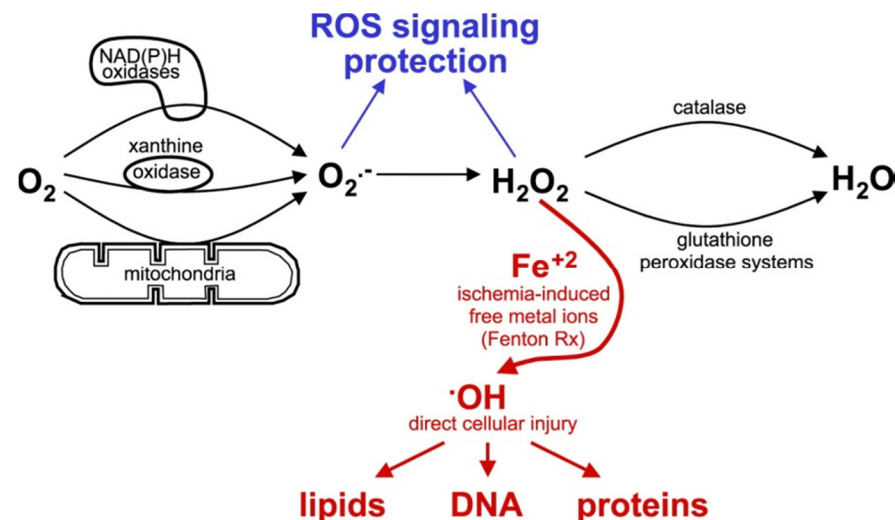
+ Fenton reaction

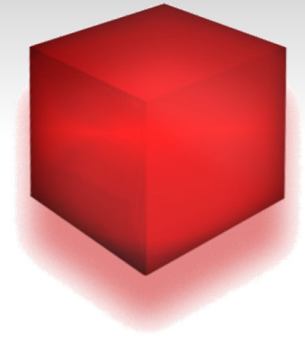
- + $\text{Fe(II)} + \text{H}_2\text{O}_2 \rightarrow \text{Fe(III)} + \text{OH}\bullet + \text{OH}^-$
- + This reaction takes place by the presence of Fe, contained in the biological structure of the living form
- + Due to the presence of the Superoxidant agent $\text{OH}\bullet$, the DNA of the living form is damaged, inhibiting the possibility of reproduction
- + It is promoted by the contiguity between membrane cell and H_2O_2 molecule
- + It is inhibited, or slowed down, by the presence of ROS (Reactive Oxygen Species), which are formed, also but not only, by the H_2O_2 decomposition under an highly concentrated energy form of activation
- + The ROS, for many kind of cells, are respiration substances and promote the cell immunity



Haber - Weiss reaction

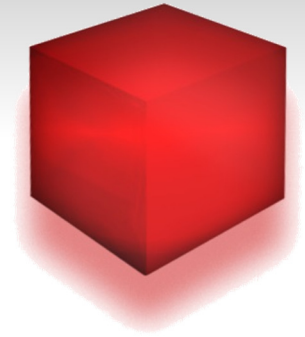
- $O_2^{\bullet-} + H_2O_2 \rightarrow O_2 + OH^{\bullet} + OH^-$
- This reaction takes place by the presence of Fe, contained in the biological structure of the living form and, through a Fenton reaction, generates the superoxidant $O_2^{\bullet-}$
- It is effective also on membrane cell disruption
- Moreover, finalize the DNA depletion promoted by the Fenton reaction





✚ Catalase reaction

- ✚ $2\text{H}_2\text{O}_2 \rightarrow \text{O}_2 + 2\text{H}_2\text{O}$
- ✚ It is the “typical” dissociation reaction of the H_2O_2
- ✚ It is promoted by the presence of catalase in the living forms
- ✚ Not all the living forms have got the same amount of catalase: for instance, E-coli, Streptococcus family and Pseudomonas family have got a low catalase and are less subject to this kind of reaction
- ✚ Each molecule of catalase requires, to be decomposed, about 5 millions of molecules of H_2O_2 per second
- ✚ Catalase reaction damages the structure of the living form and/or its membrane.



- CHEMISTRY BASICS

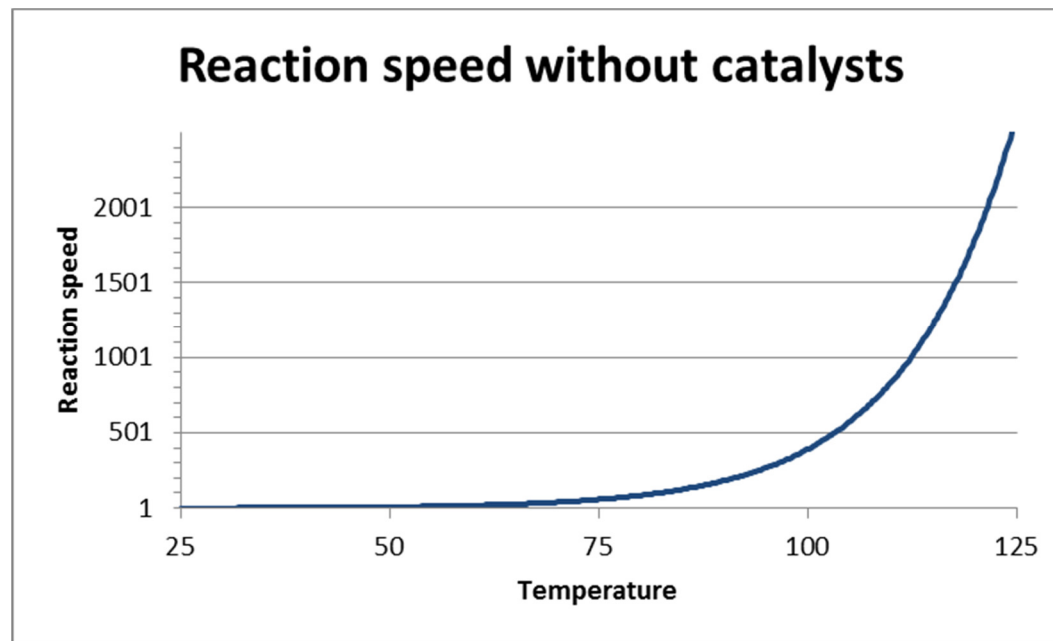
- ✚ Coefficient of diffusion

- ✚ H_2O_2 in gaseous form (vapors) has got a diffusivity in air of $0,188 \text{ cm}^2/\text{s}$ (Perry chemical handbook)
- ✚ H_2O_2 in liquid form has got a diffusivity in water of $0,148 \text{ cm}^2/\text{day}$ at about 20% of concentration and $0,78 \text{ cm}^2/\text{day}$ at about 6% of concentration (US Peroxide et alter)
- ✚ This means that H_2O_2 in gaseous form has got an easiest attitude to cover quickly large areas and volumes being faster available for the reactions (that need the contact between the oxidizing and the oxidizer)

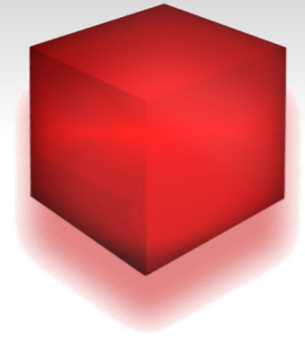
✚ Reaction speed



- ✚ H_2O_2 reactions need an activation energy E of 75 kJ/mol in the absence of catalysts
- ✚ Reaction speed, always in the absence of catalysts, follows an exponential law



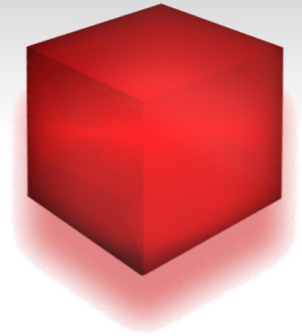
- ✚ The graph shows how works the exponential trend of the reaction speed: too high activation energy supplied to the H_2O_2 means a very low life of the molecule, that decompose itself very quickly without an oxidation effect



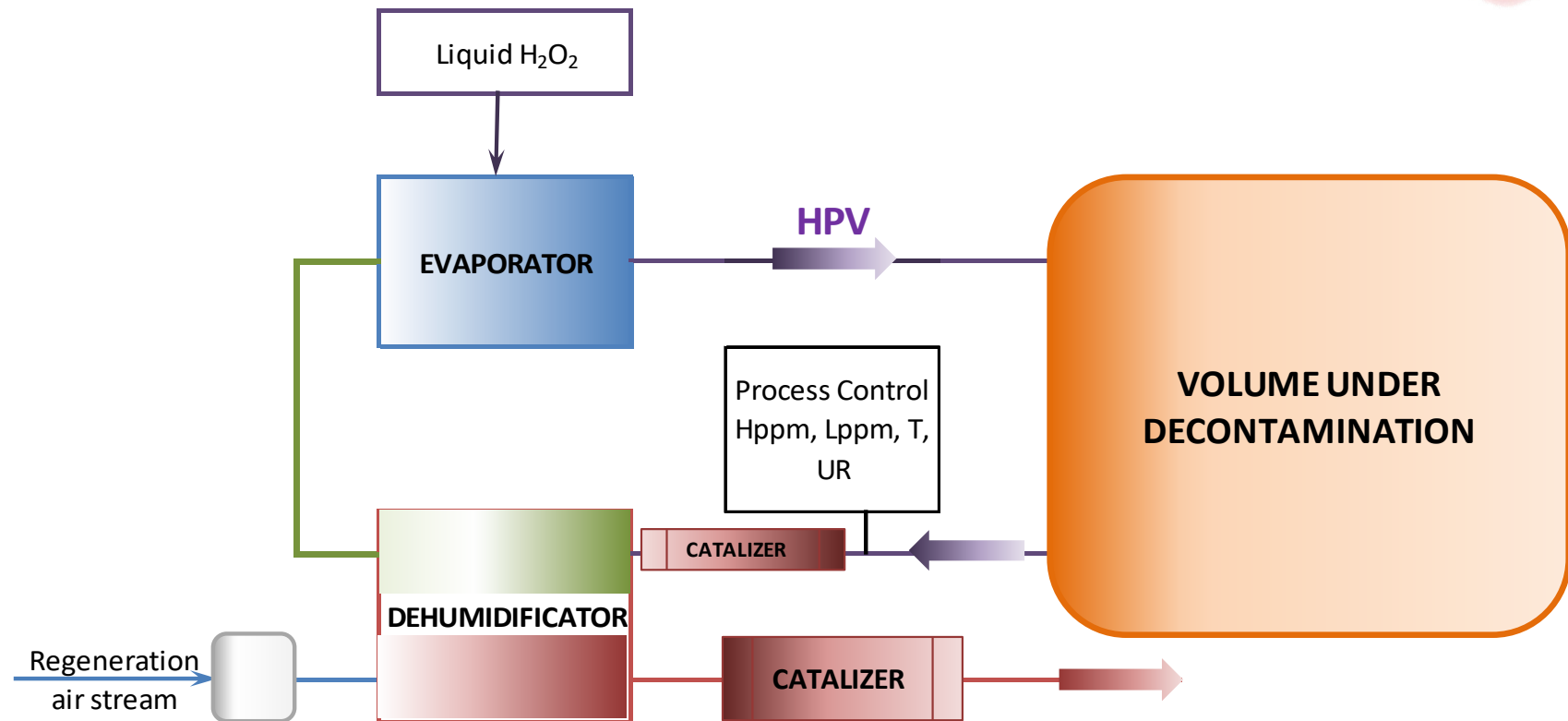
- FURTHER CONSIDERATIONS

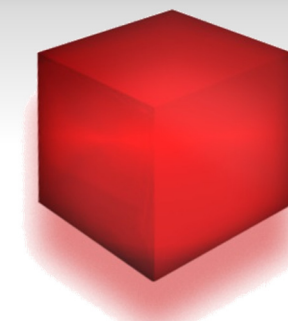
- ✚ Method efficiency

- ✚ Finnegan et al research, demonstrate the superior decontamination efficiency of H_2O_2 in vapor form on, at least, macromolecules decontamination
- ✚ H_2O_2 delivery method and air water content reduction are the most relevant parameters to let the H_2O_2 fully available for the cells and living forms oxidation, minimizing the catalase reaction of the H_2O_2 before its contact with the living forms
- ✚ Overall outcomes of the TDP generators H_2O_2 vaporizing method:
 - ✚ High decontamination efficiency over a wide range of living forms
 - ✚ No load or equipment stress for temperature or moisture



- THE TDP HPV GENERATOR PRINCIPLES

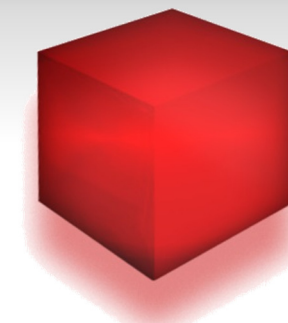




• METHODS COMPARISON - 1

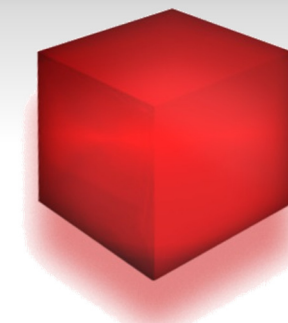
H₂O₂ Activation energy

Spray /Fog /Dry Fog	iH ₂ O ₂	TDP
H₂O₂ reaction activation energy is fully supplied by the load, in a not controlled way and is a one shot supply type. The load must heavily be pre heated (40°C) in order to transfer energy to the liquid H₂O₂ , generating the decontamination sequence: • water evaporation, • H₂O₂ availability, • decontamination by direct oxidation	Very high energy supply, delivered in one point (the spray gun nozzle) through a quasi - plasma arch. High rate of local decomposition of the H₂O₂ at the entrance of the system. Generation of ROS that helps cells to self immunize, reducing the decontamination efficiency. Activated H₂O₂ has got a very short oxidation lifetime. Not activated H₂O₂ is carried as liquid spray. Generate modest amount of UV frequency that are not influent in the decontamination process due to their localization, distribution and shadowing	Fully controlled in the dispensing unit by evaporation temperature control and carrier airstream temperature control. H₂O₂ vapor maintains a full capability to react with the living forms without an unfair, earlier decomposition



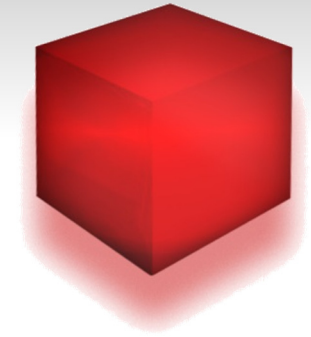
• METHODS COMPARISON - 2

	Spray /Fog /Dry Fog	iH ₂ O ₂	TDP
Air humidity control and H ₂ O ₂ amount introduction capability	None, during the decontamination process. Load pre heating generate an environment able to accept a fixed amount of water, and then of H ₂ O ₂ solution. Environment cool down during the decontamination cycle let unevaporated the most part of the sprayed solution	None during the decontamination process and nor in advance. Decontaminant solution amount introduced during the decontamination process is limited by the system geometry and the load geometry (available air volume).	Continuous along the whole decontamination cycle, except than during purge. It allows a virtually unlimited introduction of H ₂ O ₂
H ₂ O ₂ diffusivity	Very slow. H ₂ O ₂ availability for the decontamination process , and in the decontamination cycle duration, takes place only after water evaporation	Mixed, very slow for the fog phase, fast for the activated, short life, H ₂ O ₂	Fastest, as allowed by the H ₂ O ₂ vapors chemical physical features



- METHODS COMPARISON - 3

	Spray /Fog /Dry Fog	iH ₂ O ₂	TDP
Decontamination efficiency	Long term (hours) contact efficiency demonstrated by studies	Not demonstrated by studies	Demonstrated by studies, vapor H ₂ O ₂ is more faster and efficient than liquid phase H ₂ O ₂
H ₂ O ₂ distribution uniformity	Poor, heavily conditioned by load patterns and spraying devices pattern	Fair, atomization fill out the available space. Deeply conditioned by the load pattern complexity	Best, as any gas distribution
Purge efficiency (load adsorbing / desorbing action excluded)	Long term due to the evaporation of the residual water / H ₂ O ₂ solution and to the further H ₂ O ₂ removal	Long term due to the evaporation of the residual water / H ₂ O ₂ solution and to the further H ₂ O ₂ removal	Faster due to the H ₂ O ₂ vapor status and it high diffusivity speed



- **ONGOING**

TDP H₂O₂ vapors generators are ongoing to a continuous evolution to improve the knowledge of decontamination mechanisms, the systems affordability and the repeatability of the outcomes under different application cases.

Currently, an advanced decontamination control method, which promise to let the decontamination cycle ruled by measurable parameters instead than time exposure, is under investigation and development.

Customers using TDP generators will be able, also in the future, to up-to-date their TDP generators with the newest control technology, preventing the technological aging of their systems



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