The Chemistry of Hydroxyl Radical Air Cleaning

1. Allergens

Allergens usually enter the respiratory system through the nose. Mast cells in the airways release mediators, which trigger the allergy attack. This attack is an overreaction of the body's immune system to the invading allergens that have bonded with antibodies. Mast cells are one of the human body's principal defences against allergens and are found in connective tissue and mucous membranes. One of its biological functions is innate immunity including involvement in host defence mechanisms against parasitic infestations, tissue repair, etc.

Mast cells, contain pockets of granules rich in histamine and heparin that cause allergy if triggered by invading allergens. In allergy sufferers Immunoglobulin E (IgE) antibodies present on the surface of mast cells trigger the release of histamine when allergens stick to these IgE antibodies. This irritates the mucous membrane in the upper airways, which manifests itself for example through coughs and sneezes.

1.1 Pollens & Non-Vegetative Spores, Pet Dander and Cat Saliva

Hydroxyl radicals have been shown to modify the IgE-binding capacity in pollens, spores and pet dander through the degradation and modification of the tertiary structure and/or the induction of protein denaturation and/or aggregation. This modified allergen structure is no longer recognised by the body's immune system and therefore histamine and other chemical mediators are not released.

While the references below refer in their titles to cluster ions, the text makes it clear that the recorded effects are achieved by hydroxyl radicals which result from the chemical interactions between cluster ions.

References:

1. S.Kawamoto et al. Decrease in the Allergenicity of Japanese Cedar Pollen Allergen by Treatment with Positive and Negative Cluster Ions, International Archive of Allergy and Immunology, 2006, Vol.141, No. 4
2. K. Nishikawa et al. Exposure to positively and negatively charged plasma cluster ions impairs IgE binding capacity of indoor cat and fungal allergens, World Allergy Organization Journal 2016
3. K. Nishikawa et al. Exposure to positively and negatively charged plasma cluster ions impairs IgE binding capacity of indoor cat and fungal allergens, World Allergy Organization Journal 2016

1.2 House Dust Mites

Hydroxyl radicals instantly denature the allergen Der p1 and Der f1 found in house dust.

Hydroxyls radicals oxidise their protein structures, for example causing protein backbone damage due primarily to a hydrogen atom abstraction at the alpha carbon. This process leads to backbone fragmentation.

Side-chain damage is another protein oxidation mechanism and can occur through hydrogen abstraction or oxygen addition. Both hydroxyl radical initiated oxidation mechanisms result in a modified allergen structure. This allergen structure is no longer recognised by the body's immune system and therefore histamine and other chemical mediators are not released.

References:

1. W.M. Garrison, Reaction mechanisms in the radiolysis of peptides, polypeptides, and proteins. Chem Rev 1987:381-398 -9920.
2. Singh J & Thornton J M. Atlas of Protein Side-Chain Interactions, Vols. I & II, 1992 IRL press, Oxford.

2. Ozone and Carbon Monoxide

Hydroxyl radicals have a strong tendency to remove (abstract) a hydrogen atom from organic species (RH) whenever possible. The organic radical (R) then reacts with oxygen (O2) to form organic peroxides (RO2).

On a global scale, OH reacts primarily with carbon monoxide (40%) to form carbon dioxide, around 30% of the OH produced is removed from the atmosphere in reactions with organic compounds and 15% reacts with methane (CH4). The remaining 15% reacts with ozone (O3), hydroperoxy radicals (HO2) and hydrogen gas (H2).

OH reacts with ozone according to the following reaction mechanism:

$OH\bullet + O_3 \rightarrow HO_4\bullet$

$HO_4\bullet \rightarrow O_2 + HO_2\bullet$

OH reacts with CO according to the following reaction mechanism:

$CO + OH\bullet \rightarrow CO_2 + H$

3. Pollutants & Volatile Organic Compounds (VOCs)

Including Odours, Formaldehyde, Carbon Monoxide, Ammonia and Ultra-fine Particles

Hydroxyl radicals react in 20-60 milliseconds with VOCs and initiate a series of fast, free radical chains reactions that continuously decompose VOCs and their byproducts, keeping air safe to breath.

Hydroxyl radicals oxidise and decompose VOCs by a series of free radical chain reactions which are very fast and efficient – thousands of times faster than ionic reactions that characterise ionisation and plasma systems and a million times faster than ozone.

The cascade of secondary oxidants formed is more stable, and circulate throughout the treatment area to complete the purification process. Oxidant and byproduct concentrations are diluted to the safe levels found in nature, which range from 10-40 ppb.

Bi-products recirculate until they are fully oxidised – a process which “clips” off carbon atoms one at a time, forming carbon dioxide and water.

Smaller VOCs react faster, so oxidation byproducts like formaldehyde or acetaldehyde don’t accumulate.

Ultra-fine particles (less than 0.1 microns) are known to be potentially harmful to health and make up around 90% of all airborne particles. While scientists are certain that both organic and inorganic ultra-fine particles are oxidised by hydroxyl radicals, typically about a half of ultra-fine particles are particle-phase organic carbon where the reactions are best understood. These organic carbon particles are subject to heterogeneous oxidation by the gas-phase hydroxyl radical. The amount of particle-phase carbon decreases with oxidation, due to fragmentation (C - C scission) reactions that form small, volatile products that escape to the gas-phase.

References:

1. D. E. Heard, “Analytical Techniques for Atmospheric Measurement”, Blackwell Publishing, 2006 – Professor at the University of Leeds, UK).
2. B. J. Finlayson-Pitts and J. N. Pitts, Jr., The Chemistry of the Upper and Lower Atmosphere, Academic Press, San Diego, 1999.
3. J. A. Logan et al. Atmospheric Chemistry: Response to Human Influence, Phil. Trans. Roy. Soc. (London) 290, 187 (1978).
4. W. J. Moore, Physical Chemistry, 4th Edition, Prentice-Hall, Princeton, 1972.

5. C. J. Weschler and H. C. Shields, Production of the Hydroxyl Radical in Indoor Air, Environ. Sci. Tech. 30, 3250 (1996).

6. Heterogeneous oxidation of atmospheric aerosol particles by gas-phase radicals. I.J.George and J.P.D Abbatt. Nature Chemistry. Vol 2. September 2010.

4. Bacteria, Viruses and Vegetative Spores (Mould)

Hydroxyl radicals are lethal to both pathogenic viruses and bacteria (gram –ve & +ve), for example MRSA, C.difficile, Salmonella, Norovirus, and Flu Virus both in the air and on surfaces.

The cascade process created by Airora is a condensing process, in that it has zero vapour pressure, therefore particles, other molecules and surfaces in general will be “coated” at a molecular level by the reactants, and the hydroxyl radical yielded will oxidise the targets.

In general terms hydroxyls kill bacteria, viruses and mould by reacting with the lipids and proteins in their thin, delicate cell wall causing lysing.

Pathogenic bacteria succumb to hydroxyls because they are infinitely small (just one atom of hydrogen and one atom of oxygen), and able to pass through the outer cell wall structures of the bacteria where they can oxidise the third membrane responsible for electron transport. This membrane is highly sensitive to oxidation, and minor disruption will render the whole organism non-viable.

Pathogenic viruses suffer from oxidation of cell surface structures, losing their receptors and thus being rendered inactive.

The hydroxyl radical is infinitely small in comparison to a bacteria or even a small virus. They are incredibly reactive and as the Airora process produces a never ending supply, even clumps of cells, thick layers and heavy cell walls (such as TB and spores) will eventually succumb.

The process kills the target organisms in such a way as to maintain their antigen “signature” without viability, which is important to maintaining “passive immunity”.

Free-living and commensal organisms such as normal skin flora are by definition non-pathogenic, sharing our environment, and are therefore largely immune to hydroxyl radicals, and are not significantly affected by the process.

Tests at the UK Government’s Health Protection Agency’s Centre for Emergency Preparedness & Response at Porton Down have shown that exposure to hydroxyl radicals created by our technology:

• Killed 99.9999% of airborne test virus (MS2 Coliphage) in less than 5 minutes

• Killed 99.999% of airborne Staphylococcus epidermidis in less than 2 minutes

• Killed 99.9999% of surface concentration of MRSA on glass over a 24 hour period

References:

1. Digel et al. Bactericidal effects of plasma-generated cluster ions, Medical and Biological Engineering and Computing November 2005, Volume 43, Issue 6, pp 800–807
2. R. Bailey et al. Effect of ozone and open air factor against aerosolized Micrococcus luteus. J Food Prot. 2007 Dec;70(12):2769-73

5. Find out more

You can find out much more about our scientific journey, how we used internationally renowned testing organisations to demonstrate our claims and the science behind hydroxyls on the Resources page of our web site.