There are two questions difficult to answer. One is the tailing phenomenon of survivor curve of plasma sterilization and the other is whether plasma clusters can inactivate bacteria and virus.

Tailing is the phenomenon illustrated in Figure 1 [1]. Many physicists interpreted it as being done by Moison [2], which several different kinetics may co-exist. The author deny their interpretation and considers it is due to clumping phenomenon of biological indicator (BI, Figure 2) [3] because penetration depth of gas plasma is less than 1 μm and the thickness of each bacterial spore of BI is around 1 μm. Therefore if clumped, the second layer of BI by plasma exposure will be protected with the first layer. First layer will be inactivated with first order equation as straight line of survivor curve (Figure 2), but the second or third layer delayed inactivation by protection of the first layer, so the survivor curve tailed and as a whole it is not straight line (Figure 1) [4].

The next question is whether plasma cluster, nano-e and so on can inactivate bacteria and virus.

The major component of plasma exposure is OH radical. The life period of OH radical is 10^-6 second and the flight distance is 30 cm/0.01 second, so only 0.003 cm can fly during life period. It is hard to analyze OH radical even though the use of radical trapping agent such as DMPO (Figure 3) because the life period of OH radical is quite short and additionally it is quite hard to set DMPO within the equipment because plasma reaction will interfere with the presence of DMPO.

OH radical can react another OH radical at the kinetics rate of 5×10^9/M/second and produce hydrogen peroxide (H_2O_2). The re-produced H_2O_2 (OH + OH → H_2O_2) can then be exposed Fenton Reaction as follows:

Fe^{3+} + H_2O_2 → Fe^{2+} + OH + OH → K=76/M/second
Cu^{+} + H_2O_2 → Cu^{2+} + OH + OH + K=4.7×10^7/M/second

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So, the produced H$_2$O$_2$ is changed to OH$^·$ by Fenton reaction and produced OH$^·$ may react once again with OH$^·$ to produce H$_2$O$_2$ again. As this reaction continuously occurs, OH radical is quite reactive to microorganisms (Table 1). As bacteria have Cu and Fe in their body, Fenton reaction can easily occur. On the contrary, virus has not, so Fenton reaction does not occur. This means virus is not inactivated by Fenton reaction. To confirm this, it is necessary to determine Cu and Fe in the virus body by using ICP or ion chromatography-MS.

HEPA filter may trap virus with carrier, but not sure virus without carrier.

Bacteria charged with minus, so by charging minus, bacteria cannot into the interior of minus charged protection. On the contrary, enveloped and non-enveloped virus charged plus and minus, so hard to protect with charging [5].

As cluster, nano-e$^·$ and so on promote PR of virus inactivation, but it is not always correct from the standpoint of science.

**References**


<table>
<thead>
<tr>
<th>Radical</th>
<th>Spore Log Reduction</th>
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<tbody>
<tr>
<td>O</td>
<td>2.2</td>
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<td>1.9</td>
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<tr>
<td>OH</td>
<td>3.8</td>
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<tr>
<td>H</td>
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*Table 1: Comparison of sterility strength among O, OOH, OH, and H.*