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Redox cell signalling triggered by radiofrequency electromagnetic fields and/or black carbon: influence on cell death

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The capacity of environmental pollutants to generate oxidative stress is known to affect the development and progression of chronic diseases. This scientific review aims to identify published articles reporting experimental studies using preclinical models of exposure to environmental stress agents, such as RF-EMF and/or black carbon, which produce cellular oxidative damage and can lead to different types of cell death. With this purpose, we summarize in vivo and in vitro studies, which are grouped according to the mechanisms and pathways of redox activation triggered by exposure to EMF and/or BC and leading to apoptosis, necrosis, necroptosis and pyroptosis. The possible mechanisms are considered in relation to the organ, cell type and cellular-subcellular interaction with the oxidative toxicity caused by BC and/or EMF at the molecular level. The actions of these environmental pollutants, which affect humans in daily life, are considered separately and together in experimental preclinical models. In accordance with expert researchers working in this field, we hypothesise that the physico-chemical properties of both environmental agents (EMF and BC) must be considered, as the joint or simultaneous interaction between both could modify the biological response of immune cells via different mechanisms: 1) By modifying the dielectric constant of the BC during RF exposure. The combined effects (electromagnetic and biological effects) of the interactions on cell metabolism would be different than if either of the agents acted separately [1,2]; and 2) By altering the characteristics of the cell membrane during exposure to non-ionizing radiation, thus amplifying the toxic action of the BC and modifying the response to cell death [3]. In our opinion, the high levels of cell death, apoptosis, necrosis and necroptosis and the dysfunctional immune response of macrophages or reticulocytes in the models of combined immunotoxicity caused by exposure to the environmental agents EMF and BC may indicate a relevant role in the mechanisms of oxidative damage in chronic diseases. However, for overall interpretation of the data, toxicological studies must first be conducted in humans, to enable possible risks to human health to be established in relation to the progression of chronic diseases.

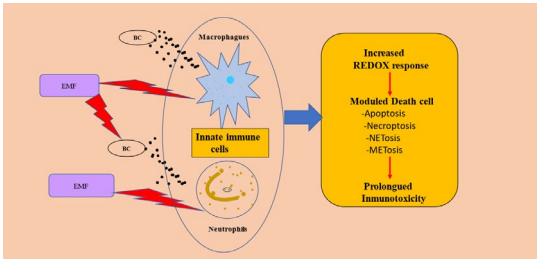

Figure 1. Cell death due to interaction between BC and EMF stress agents. The immune cell response increases REDOX stress, which acts by modulating cell death and prolonging the immunotoxic effects.

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2. A. H. Sihvola, "How strict are theorical bounds for dielectric properties of mixtures?," *IEEE Trans. Geoscience and Remote Science*, **45**, 4, April 2002, pp. 880-886,Doi: 10.1109/TGRS.2002.1006369.

3. L. Lin, M. R. McCraw, B. Uluutku, Y. Liu, D. Yan, V. Soni, A. Horkowitz, X. Yao, R. Limanowski, S.D. Solares, H. Beilis, and M. Keidar, "Cell Membrane Oscillations under Radiofrequency Electromagnetic Modulation". *Langmuir*, 7; **39**, 9, March 2023, pp. 3320-3331. doi: 10.1021/acs.langmuir.2c03181.