Cislunar Water Sterilization Using Gold Nanoparticles

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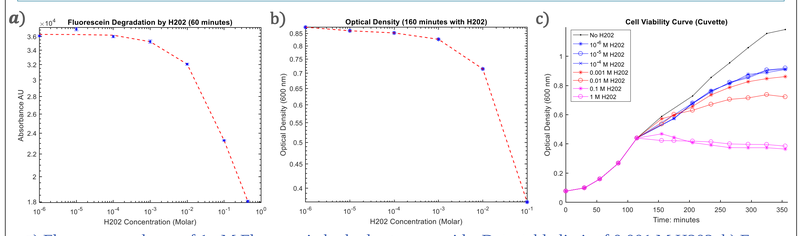
Background

As the largest material by mass needed to sustain life, clean water yields the highest potential cost for space travel. Previous efforts to sterilize water on earth have included water reclamation, filtration, and membrane reactors. However, it is more advantageous to enhance pre-existing systems in a limited environment such as space. A mixture between galactic and solar radiation, cislunar space provides a natural biocide through the production of reactive oxygen species (ROS) in water. Alone, this radiation does not produce a significant quantity for water sterilization, but its effects can be enhanced through radiocatalysts such as gold nanoparticles. Upon radiation exposure, gold and silver nanoparticles have been successfully shown to increase the oxidative pressure inside cells during chemotherapy treatment. The objective of this proposal is to optimize the use of gold catalysts to kill microbes in stagnant water using the shielded cislunar radiation environment on board a spacecraft in order to maintain water sterility for long-term spaceflight missions.

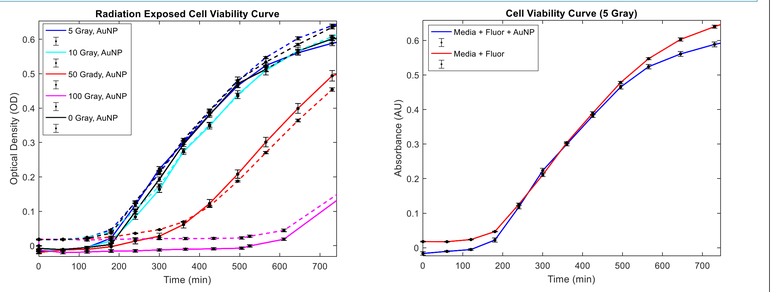
Results

Standardization Curves



a) Fluorescence decay of 1 nM Fluorescein by hydrogen peroxide. Detectable limit of 0.001 M H202. b) E. Coli cells (295 minutes total culture time, figure c) in 1 nM Fluorescein were exposed to hydrogen peroxide at an OD of 0.44. Cells did not grow with over 0.1 M H202 exposure. c) Cell viability curve of E. Coli, 1 nM Fluorescein, in hydrogen peroxide (cuvette culture). Peroxide is detectable even at 10^-6 Molar.

Radiation Exposed Data



A.) Radiation exposure cell viability curve from different radiation levels over time measuring optical density. We see an improvement in nanoparticle with 50Gy exposure. B.) Fluorescence measurement at 5 Gy exposure. We noticed an initial cell toxicity to AuNP exposure. As well as a delayed effect on cell viability due to radiation exposure.

Future Testing

Our proposal to expose the radiocatalysts to 25 KeV protons at the NASA Space Radiation Laboratory has recently been approved. Simulating the galactic cosmic rays found on board a shielded spacecraft, we plan on irradiating E. Coli cells containing Fluorescein and gold nanoparticles. By comparing our fluorescence measured to the Fluorescein-peroxide decay curve, we can estimate the ROS content produced. By additionally monitoring the optical density, we will be able to estimate the number of cells that survive. By comparing cell densities with ssssssradiation exposure, we will be able to determine the amount of ROS needed to sterilize stagnant water in space.

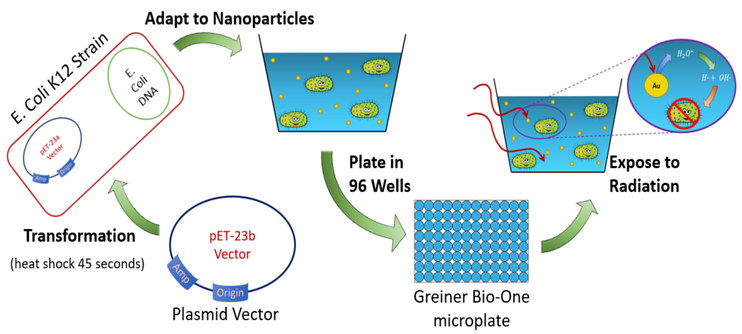
Conclusion

On top of nanocatalytic toxicity, we have found an additional decrease of 4.5-10.8% in cell viability due to radiation exposure. Based on the results, we have determined a significant improvement to cell toxicity for radiocatalyst exposures above 50 gray.

Experimental Methodology

Cellular Component

1. Add plasmid to E. coli suspension cells
2. Heat shock cells (45 seconds) to uptake plasmid
3. Grow cells in Luria-Bertani (LB) media at 37 °C
4. Add 500 ug of gold nanoparticles
5. Grow culture overnight in 1 nM Fluorescein (adapt)



Radiation Component

6. Plate 300 uL of cell solution into 96 well plate
7. Add hydrogen peroxide or
7. Irradiate the sample (0.1-100 Gy)
8. Incubate cells at 37 °C with an RPM of 180.
9. Measure fluorescence decay
10. Measure optical density for cell viability (600 nm)

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Acknowledgments

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Work Cited

1. Flynn, Michael, *et al* (2019). Planetary Water Recycling Systems Trade Study. 49th International Conference on Environmental Systems, Boston.
2. Gilles, M *et al.* (2018). Quantification of hydroxyl radicals and solvated electrons produced by irradiated gold nanoparticles suggests a crucial role of interfacial water. Journal of Colloid and Interface Science, 525, 31-38
3. Li, X, *et al.* (2014). Functional Gold Nanoparticles as Potent Antimicrobial Agents against Multi-Drug-Resistant Bacteria. ACS Nano, 8(10), 10682-10686.
4. Liu, Y, *et al.* (2015). The dependence of radiation enhancement effect on the concentration of gold nanoparticles exposed to low- and high-LET radiations. Physica Medica, 31(3), 210-218.
5. Zhao, Y, *et al.* (2010). Small Molecule-Capped Gold Nanoparticles as Potent Antibacterial Agents That Target Gram-Negative Bacteria. Journal of the American Chemical Society, 132(35), 12349-12356.