



Non-equilibrium Plasma Applications for Water Purification supporting Human Spaceflight and Terrestrial Point-of-Use

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Why is NASA Interested in Water Purification/Recycling

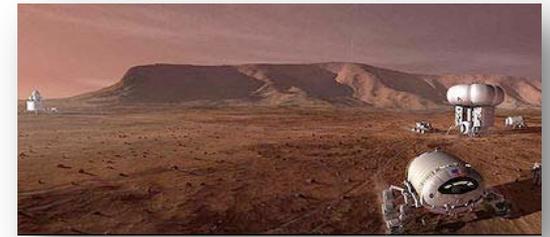
- Water is the essential ingredient to human survival. Since people cannot live without water, the ability to convert contaminated water—particularly in resource limited, remote locations—to pure drinking water is an incredibly important scientific achievement
- Most purification processes are based on filtration and direct chemical injection (eg. Cl, F)—approach under study is a paradigm shift—uses high voltage, nanosecond pulsed non-equilibrium plasma to treat water

– Treatment applications

- Water resources use and re-use on ISS,
- Long duration manned missions-eg. Mars
- Environment (“Green”)-Great Lakes, Ship Ballast Water
- Point-of-use water treatment on Earth (nice article in National Geographic April 2010)
 - Only 3 percent of earth’s water is fresh water and an even smaller fraction of this is accessible
 - Billions go without access to clean drinking water (80% of childhood deaths worldwide is due to disease from water born illness!)

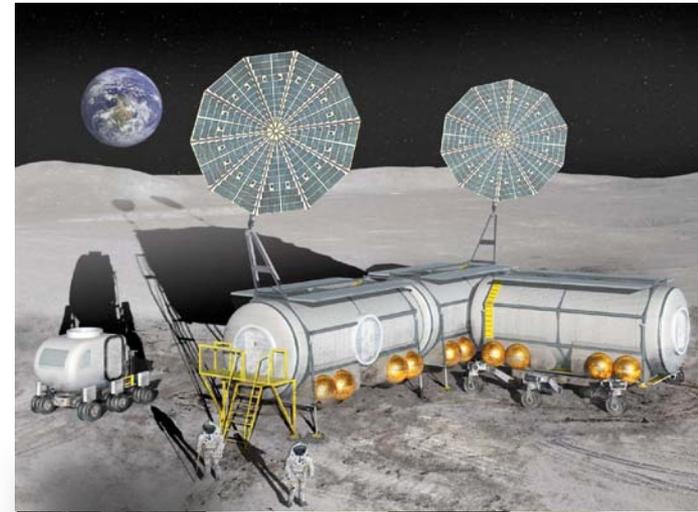
NASA water purification technologies are making a difference

- Advanced water purification technologies can enable **Point of Use** water treatment in remote areas as well as those areas where there is little or no water treatment infrastructure



The Promise of (Direct) Plasma-based Water Treatment Technologies: Technical Approach

- Plasma production in liquid water results in the the formation of advanced oxidation specie such as OH, H, O, Ozone, electrons, ions, excited species, shock waves, hydrogen peroxide and UV
 - Products violently attack organic toxins, reducing it to CO₂, water, and benign organic acids!
 - Highly antiseptic-treats bacteria and viral particles
 - Plasma oxidation also destroys any trace pharmaceuticals water
 - Amenable to point-of-use applications
- Not subject to fouling as typical of filter based systems; no toxic chemical injection (Cl, F) required
- **Technical approach** involves implementing an underwater plasma applicator powered by ns pulse power modulator with gas-bubbling (regular air) **for high volume, high throughput treatment applications**
 - Fast rise time combined with bubbling allows for plasma breakdown at reduced voltages and at atmospheric pressure
 - Plasma remains non-equilibrium—fast pulse prevents transition to arc mode via thermal instability
- Bubbling yields reactive components in addition to OH derived from disassociation of liquid water
 - Ozone, peroxides, UV atomic oxygen, excited nitrogen
 - Plasma pharmacy/cocktails are possible by changing injected gas composition so that specific species can be targeted
 - Plain air works well too
 - Ozone, excited nitrogen, atomic oxygen, lots of UV
 - Low cost and simple implementation in existing systems!



Myriad of Applications



Process is not
Electrolysis!!!!

Accomplishments

- Underwater plasma applicator designed and tested
- Plasma discharge evolution with air bubbling characterized
 - Highly reactive streamer mode well documented
 - Reactive species such as OH, excited nitrogen, and atomic oxygen in emission spectra of plume documented
- Discharge used to treat simulated effluent from textile mill (methylene blue dye-water solution)
 - Dye oxidation driven by plasma cleared water~ 100% transparency
 - Rapid treatment time
- **Recommendations**
 - Follow-on treatment and post test analysis studies of plasma-treated contaminated water (eg. samples from rivers, lakes)
 - Development of higher throughput reactor to investigate process efficiency

