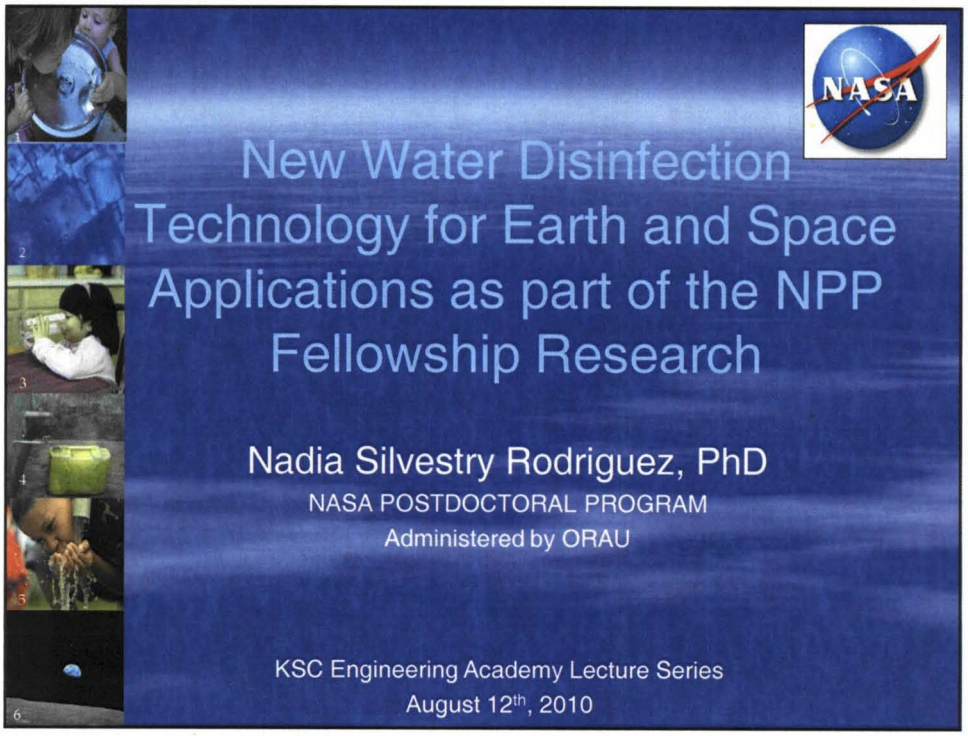
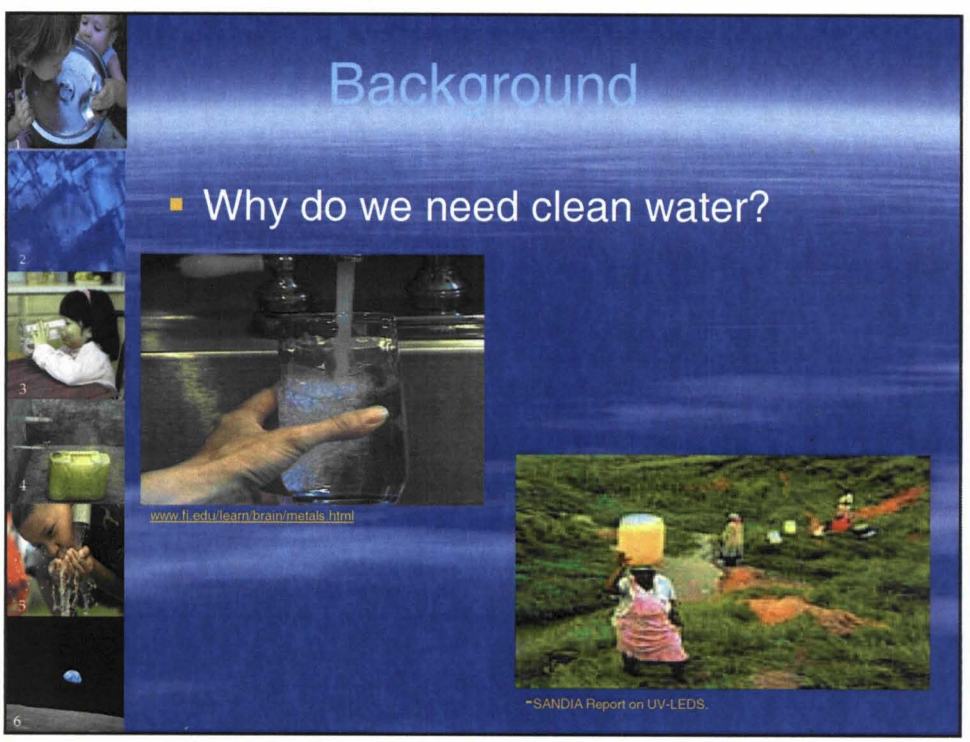
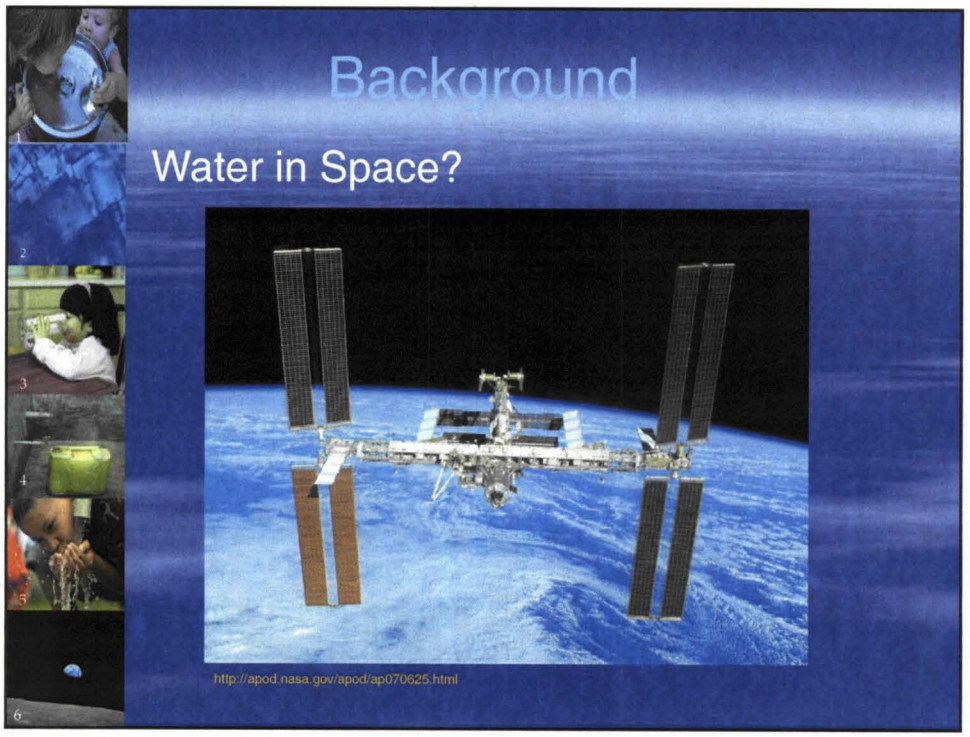
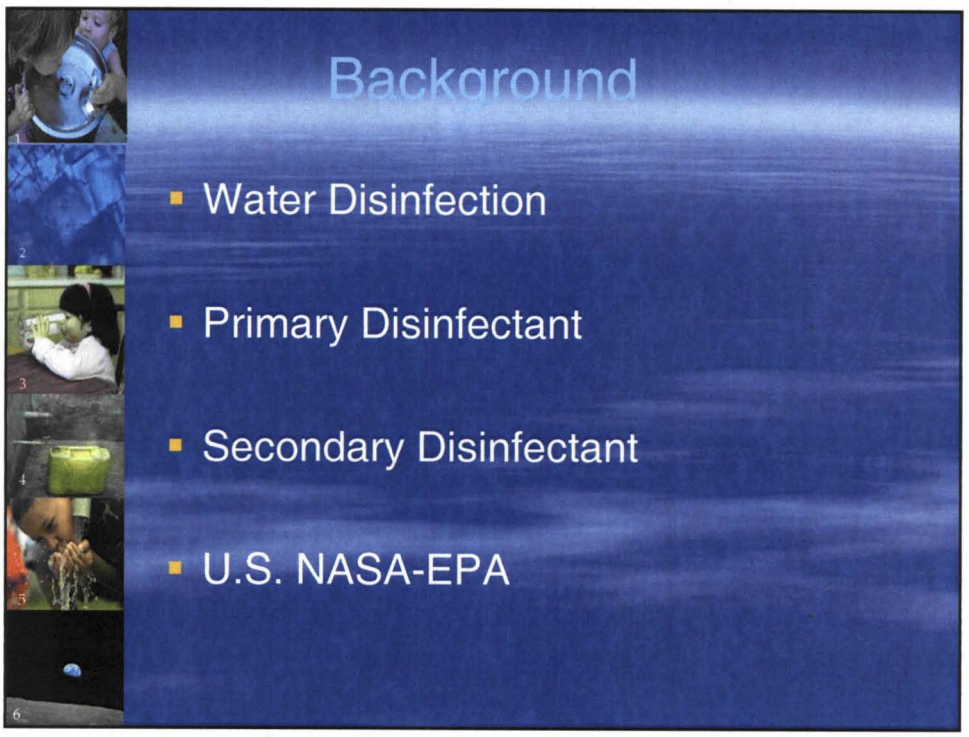

NASA
New Water Disinfection Technology for Earth and Space Applications as part of the NPP Fellowship Research
Nadia Silvestry Rodriguez, PhD
NASA POSTDOCTORAL PROGRAM
Administered by ORAU
KSC Engineering Academy Lecture Series
August 12th, 2010

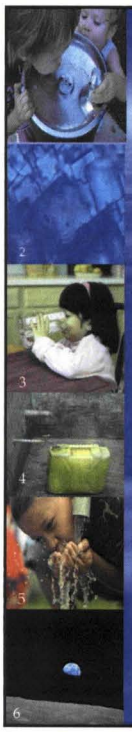

Background
Why do we need clean water?
www.fi.edu/learn/brain/metals.html
-SANDIA Report on UV-LEDS.


Background
Water in Space?
http://apod.nasa.gov/apod/ap070625.html


Background
Water Disinfection
Primary Disinfectant
Secondary Disinfectant
U.S. NASA-EPA

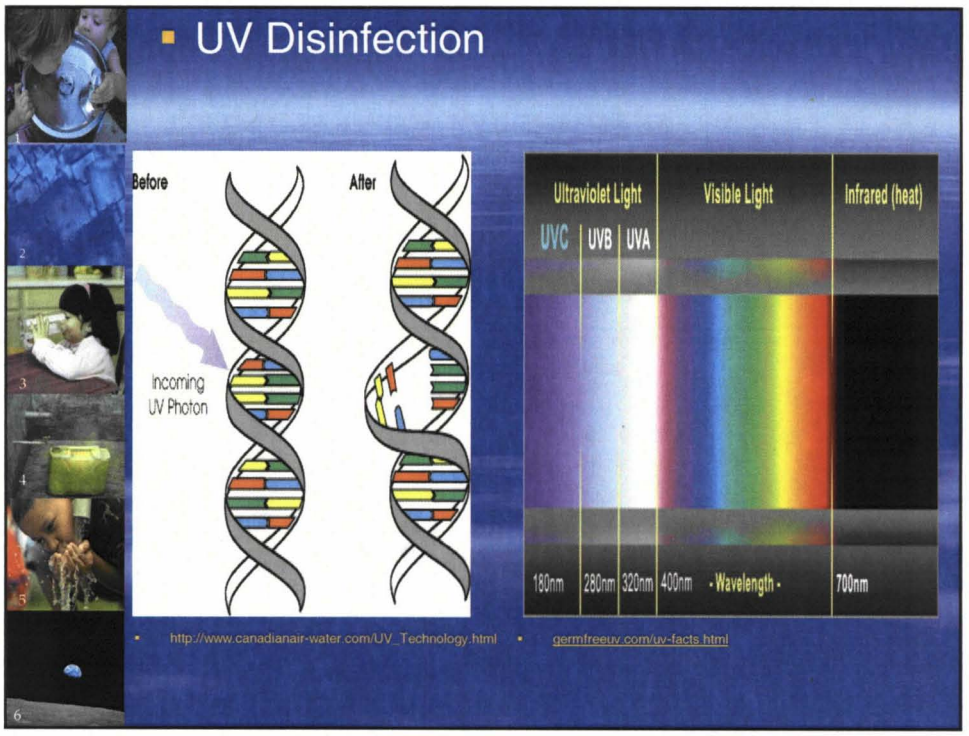
Problem Statement

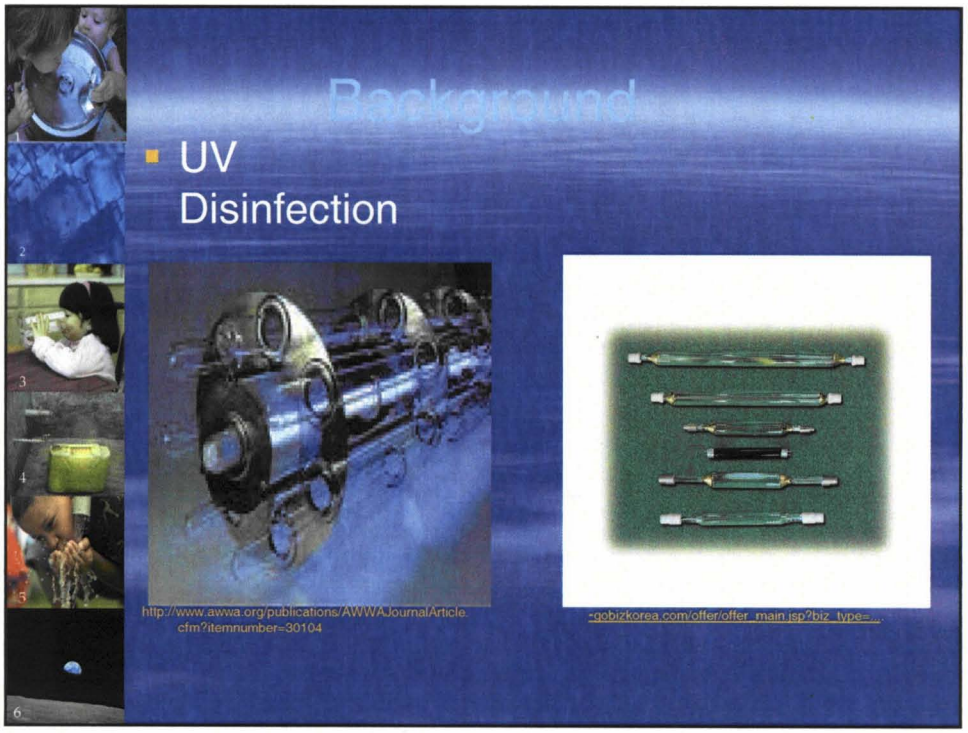
- There is the need for a safe, low energy consuming and compact water disinfection technology to maintain water quality for human consumption

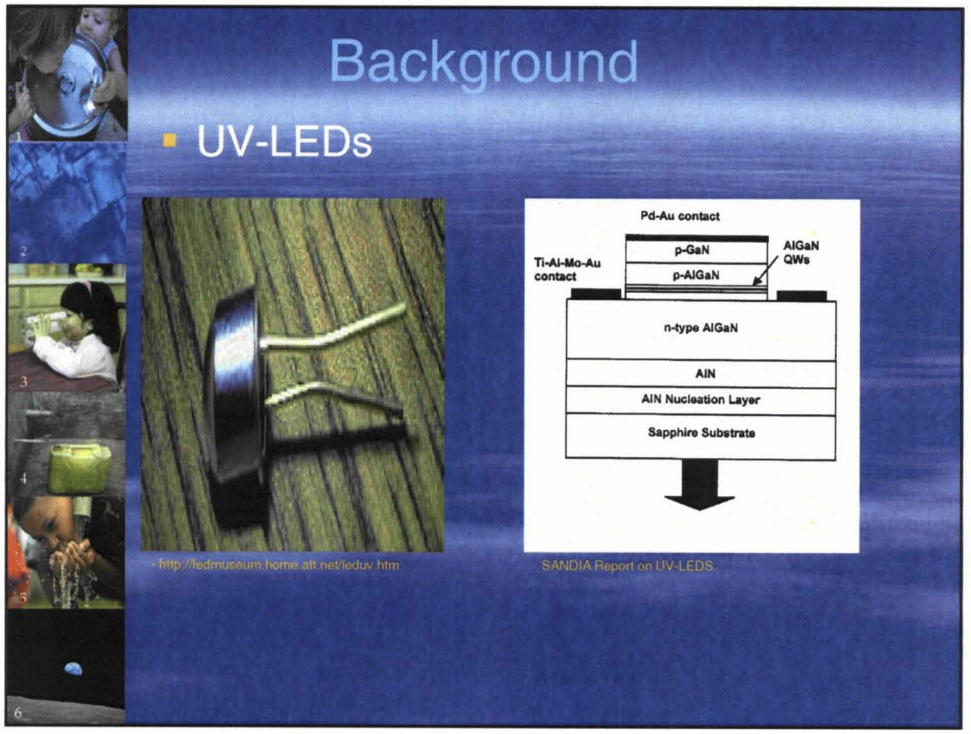


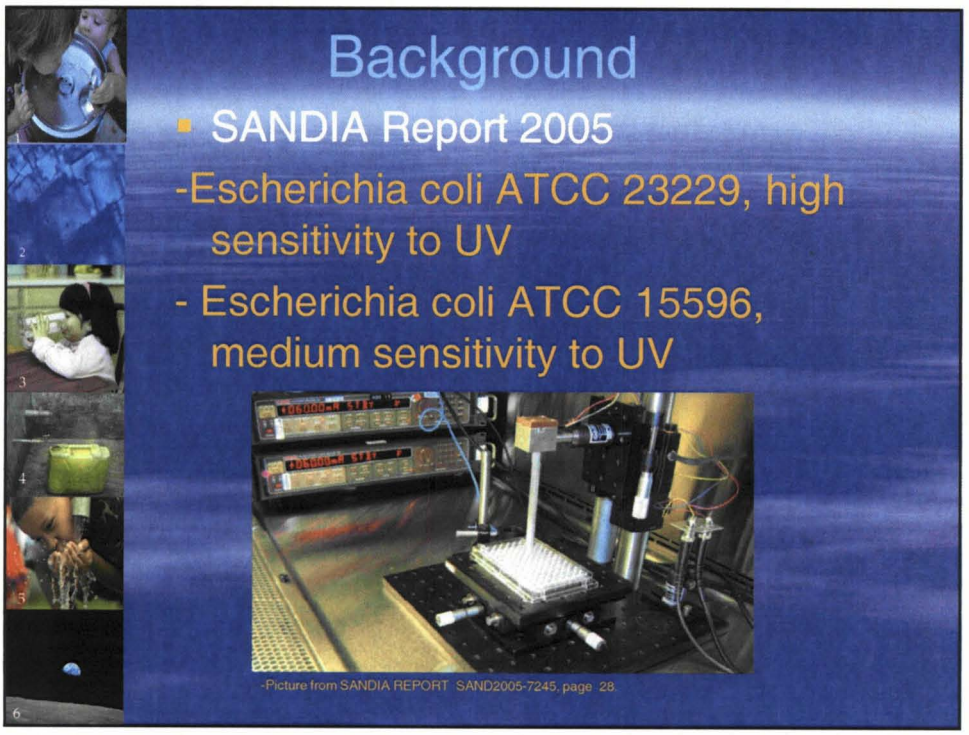
Background

- Chlorination YES or NO?
- Metals
- Other….Chloramines, Ozone
- Ultraviolet Radiation?


UV Disinfection
Before
After
Incoming
UV Photon
Ultraviolet Light
Visible Light
Infrared (heat)
UVC
UVB
UVA
180nm
280nm
320nm
400nm
- Wavelength -
700nm
http://www.canadianair-water.com/UV_Technology.html
germfreeuv.com/uv-facts.html


Background
UV
Disinfection
http://www.awwa.org/publications/AWWAJournalArticle.cfm?itemnumber=30104
-gobizkorea.com/offer/offer_main.jsp?biz_type=...


Background
UV-LEDs
- http://ledmuseum.home.att.net/leduv.htm
Pd-Au contact
p-GaN
AlGaN QWs
Ti-Al-Mo-Au contact
p-AlGaN
n-type AlGaN
AlN
AlN Nucleation Layer
Sapphire Substrate
SANDIA Report on UV-LEDS


Background
SANDIA Report 2005
-Escherichia coli ATCC 23229, high sensitivity to UV
- Escherichia coli ATCC 15596, medium sensitivity to UV
-Picture from SANDIA REPORT SAND2005-7245, page 28.

Background

- Vilhunen et al. 2008

-Escherichia coli (k12)

- Hammamoto et al. 2007, and Mori et al. 2007

-Vibrio parahaemolyticus

-enteropathogenic Escherichia coli,

-Staphylococcus aureus

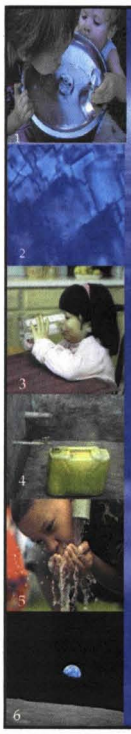
Background

-Escherichia coli DH5α

were reduced by greater than 5-log10 stages within 75 min at 315 J/cm^2 of UVA

-Salmonella enteritis

was reduced greater than 4-log10 stages within 160 min at 672 mJ/cm^2 of UVA

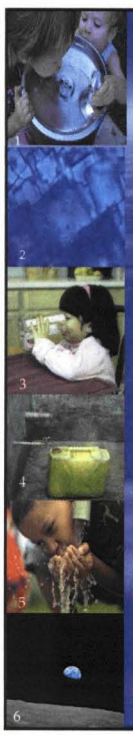


Background

Birmele et al., 2009

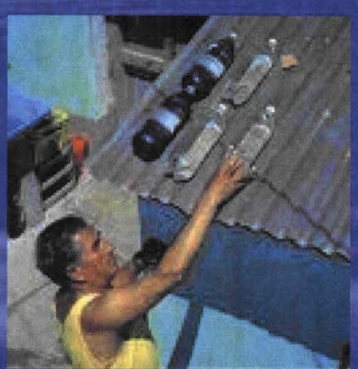
-*Sphingomonas paucimobilis, Pseudomonas aeruginosa, Burkholderia cepacia, Methylobacterium fujisawaense and Cupriavidus metallidurans*

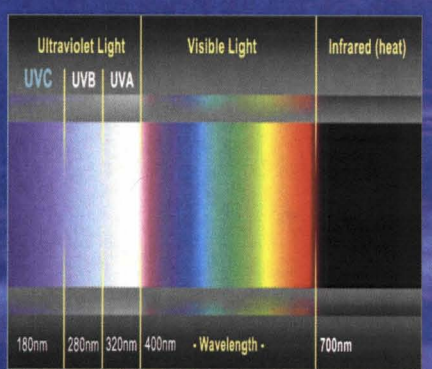
3-log reduction in one hour of UVC exposure in a static test



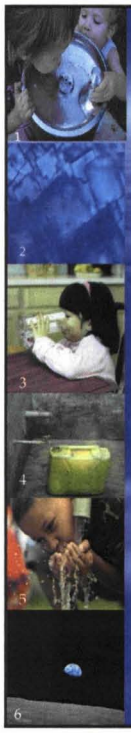
Background

- UVA Disinfection





- http://www.thescienceofcreativity.com/794
- germfreeuv.com/uv-facts.html



Background

- TiO_2

$$TiO_2 \xrightarrow{h\nu} TiO_2\,(h^+_{vb} + e^-_{eb})$$

$$O_2 + e^-_{eb} \rightarrow O_2^{\cdot -}$$

$$O_2^{\cdot -} + e^-_{eb} + 2H^+ \rightarrow H_2O_2$$

$$O_2^{\cdot -} + H_2O_2 \rightarrow {}^{\cdot}OH + OH^- + O_2$$

$$e^-_{eb} + H_2O_2 \rightarrow {}^{\cdot}OH + OH^-$$

$$h^+_{vb} + H_2O \rightarrow H^+ + {}^{\cdot}OH$$

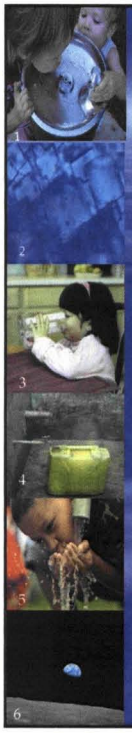
$$h^+_{vb} + H_2O \rightarrow H^+ + {}^{\cdot}OH$$

$$2\,h^+_{vb} + 2H_2O \rightarrow 2H^+ + H_2O_2$$

Silver, Ag

- Silver has been used in:

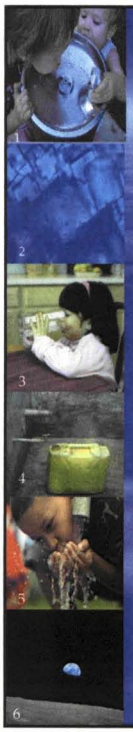
  –Water, vinegar, fruit juices, wine
  –Dental amalgams, composites
  –Topical creams, bandages, catheters, medical devices
  –Polymers, ceramics, synthetic fabrics



Silver, Ag

- Mechanisms of microorganism Inactivation:
- Accumulates inside cells
- Binds to:

- Cell wall/ membranes
- Proteins (-SH)
-DNA
-Electron donor groups



General Objective

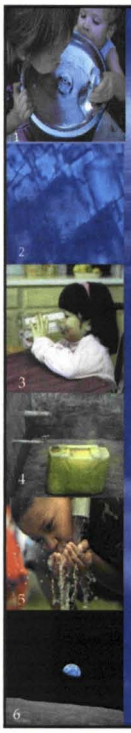
- Design and test a reactor to prove the efficacy of a UVA-LED, TiO_2, and nanosilver safe technology to sustain water quality for life support systems.

Microorganisms tested:

-MS2 Bacteriophage

-*Pseudomonas aeruginosa*

-*E. Coli*

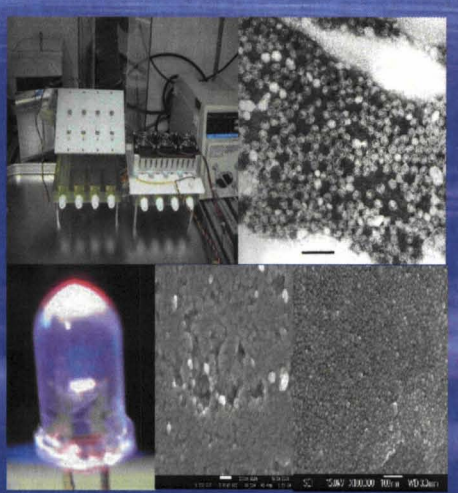


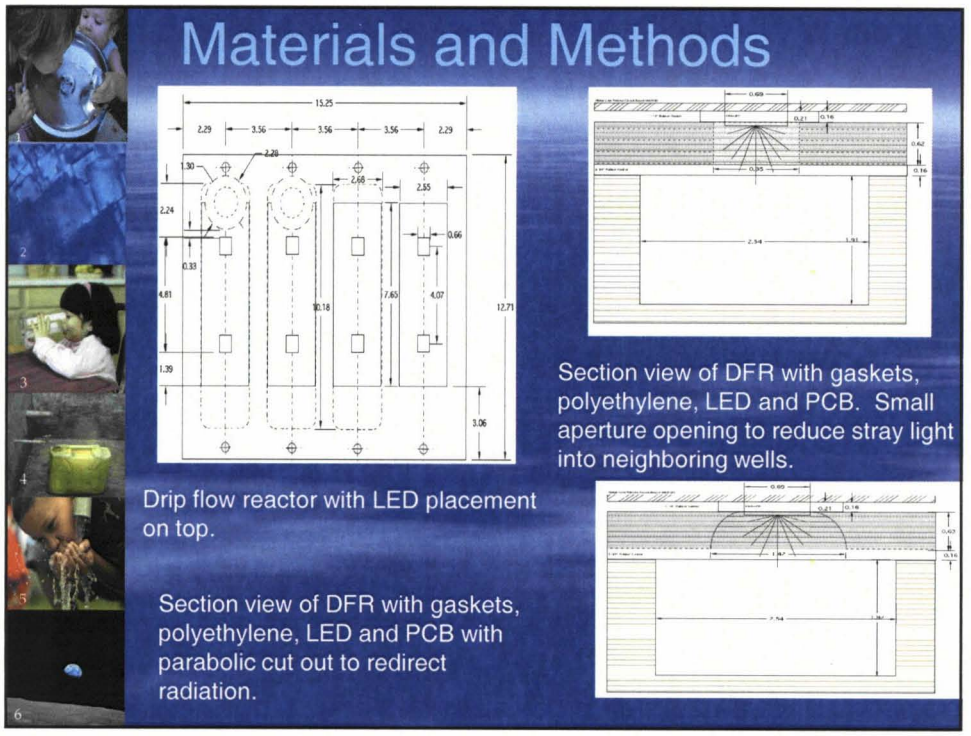
Experiment Design

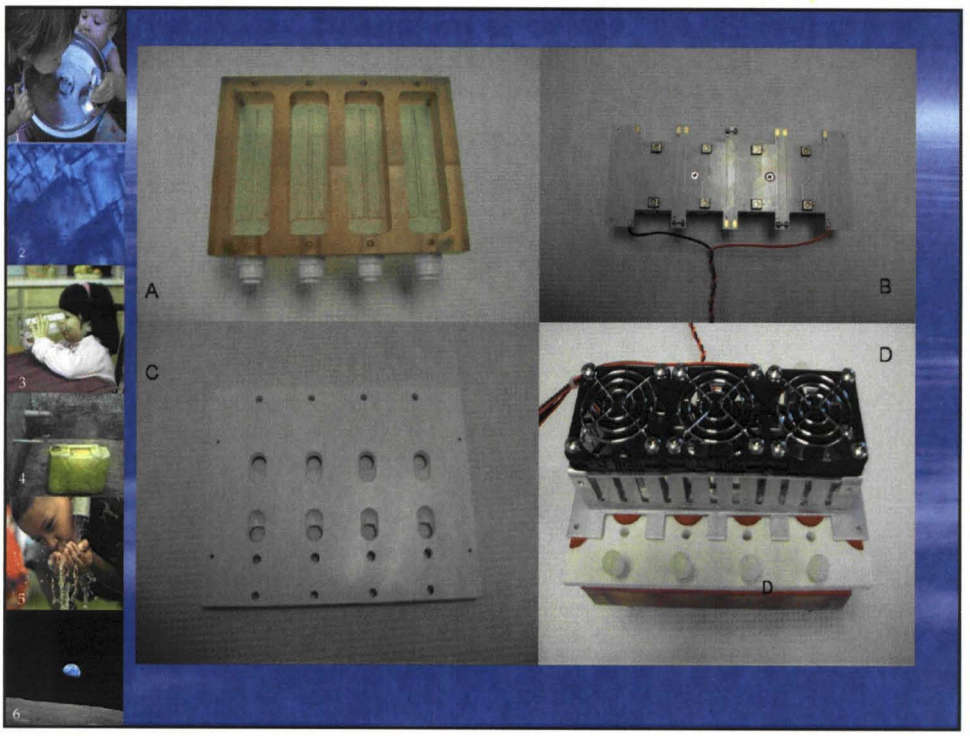
Experiment	UVA-LED	TiO2	Nanosilver
Treatment 1	X		
Treatment 2	X	X	
Treatment 3	X		X
Treatment 4	x	x	x

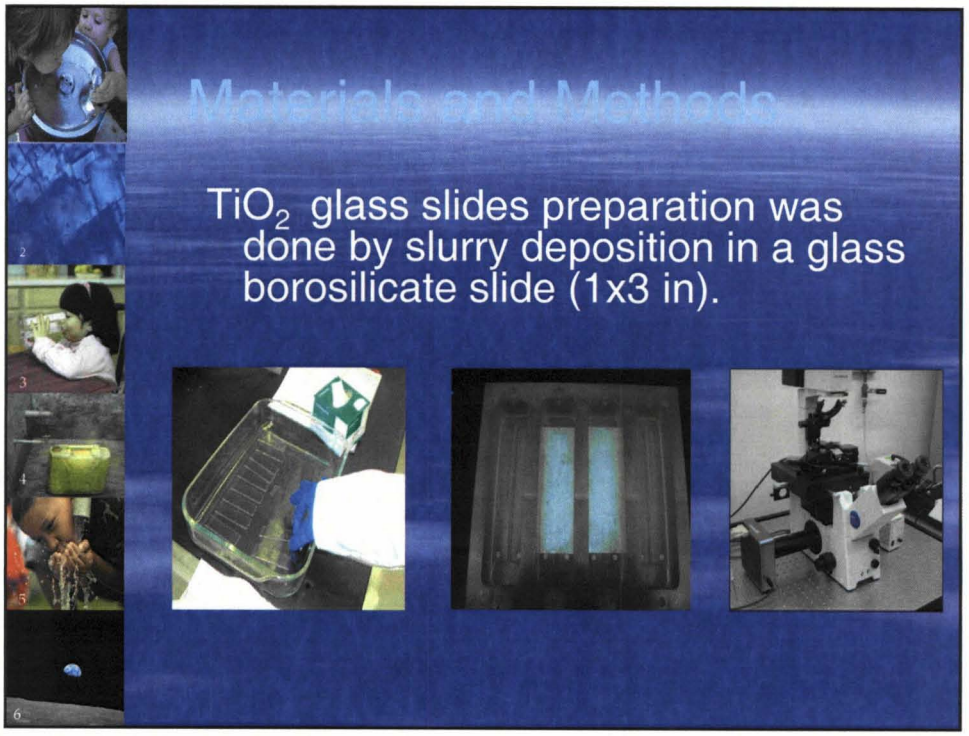
Materials and Methods

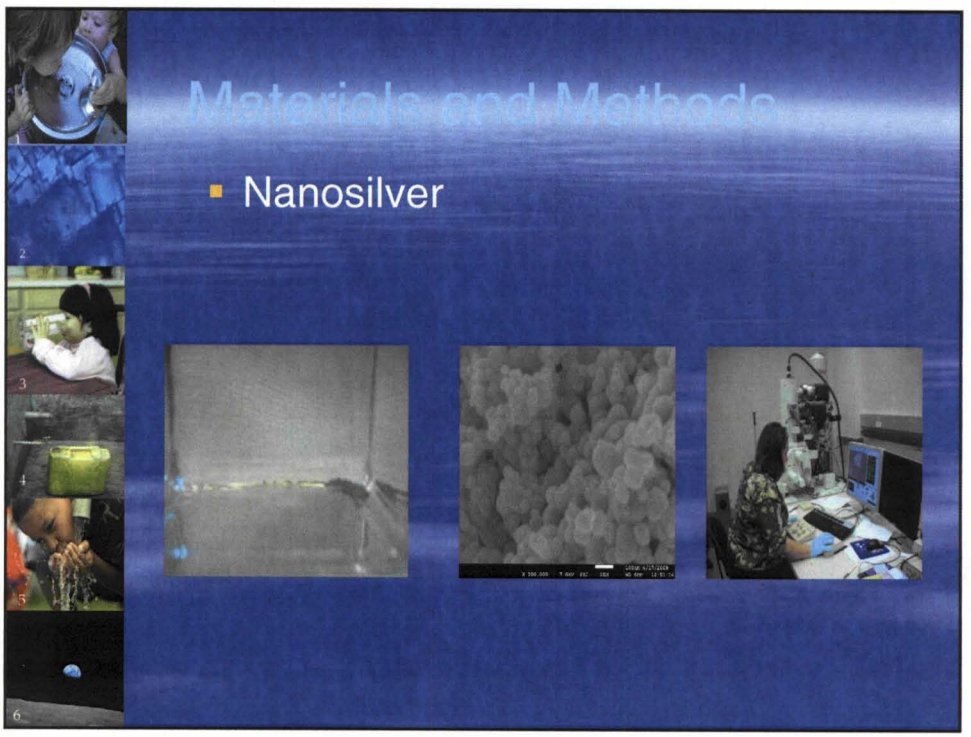
- Modified DFR
- UVA-LEDS
- TiO_2 coated glass slides
- Nanosilver

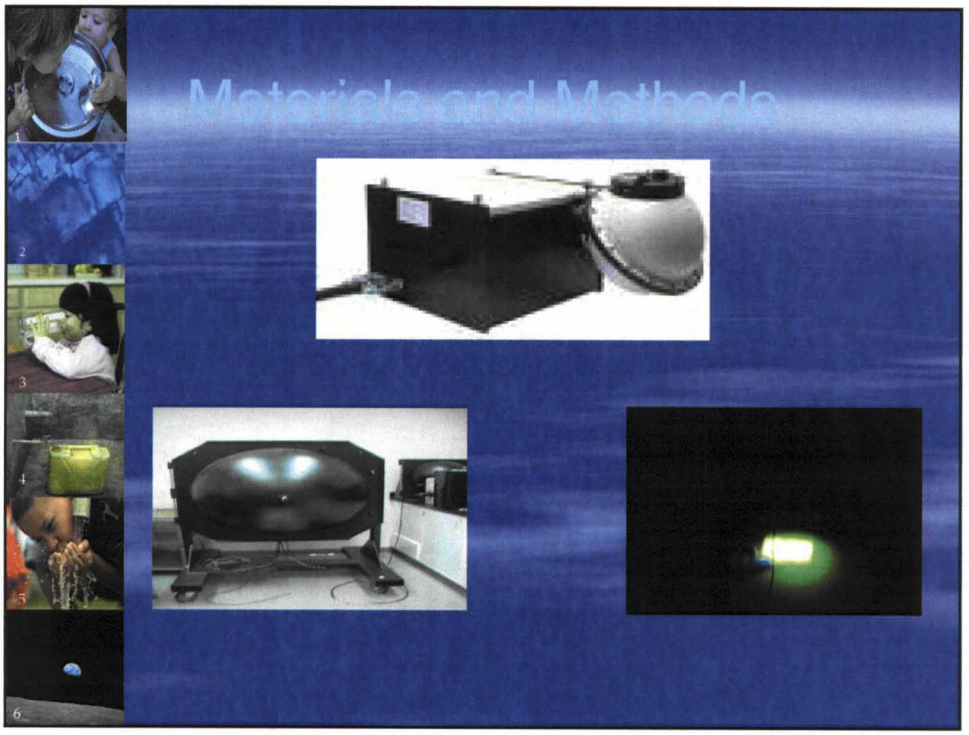


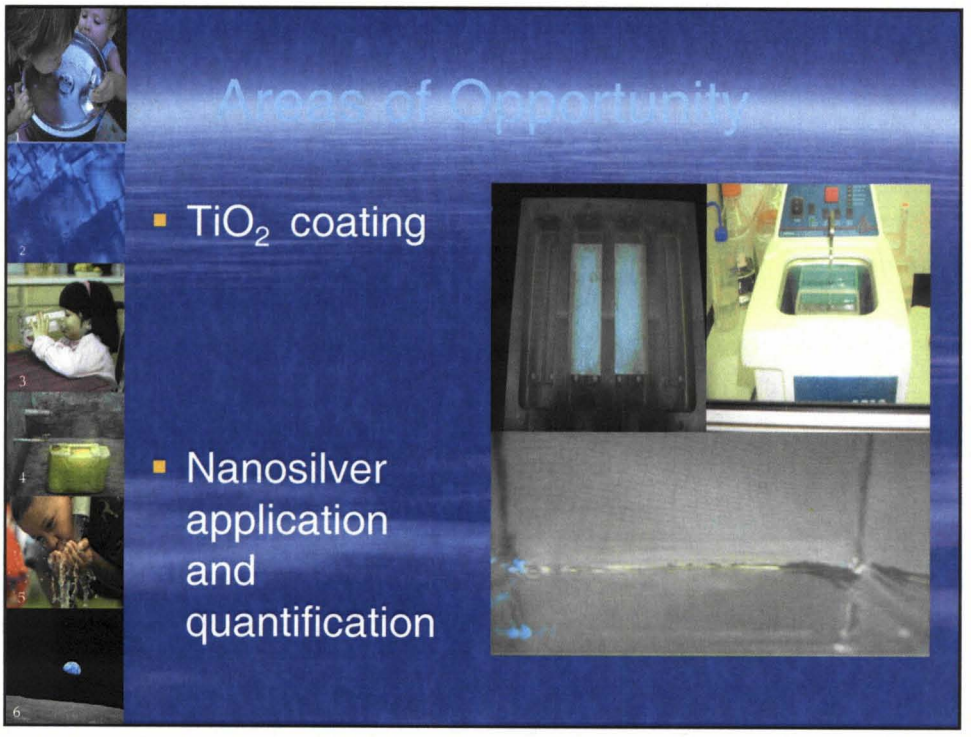

Materials and Methods
Drip flow reactor with LED placement on top.
Section view of DFR with gaskets, polyethylene, LED and PCB with parabolic cut out to redirect radiation.
Section view of DFR with gaskets, polyethylene, LED and PCB. Small aperture opening to reduce stray light into neighboring wells.

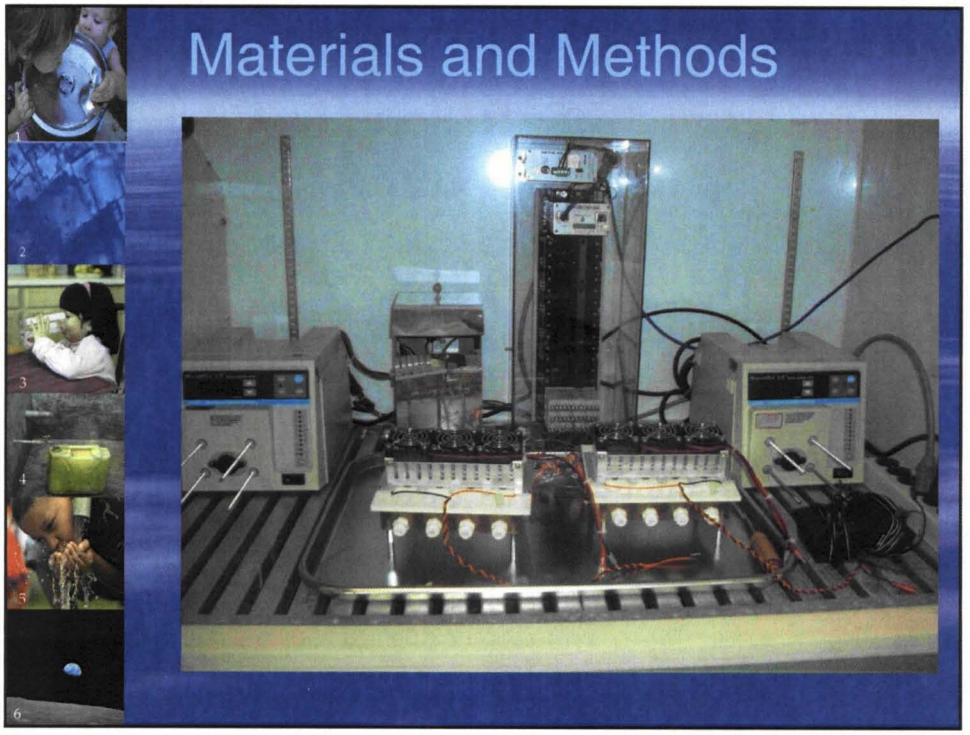

A
B
C
D

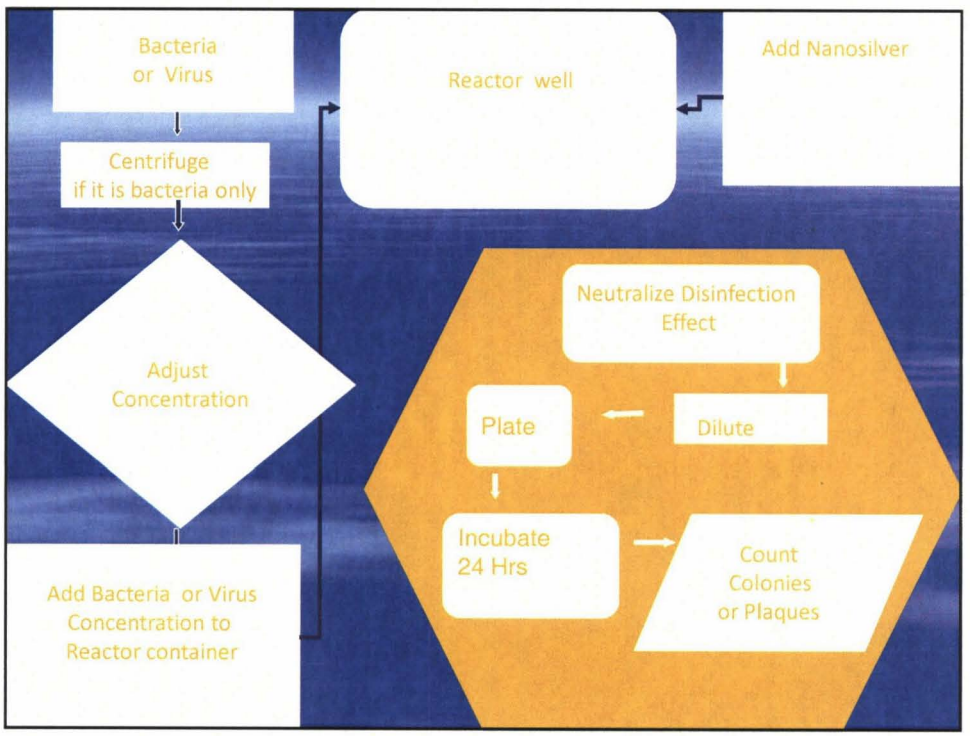

Materials and Methods
TiO_2 glass slides preparation was done by slurry deposition in a glass borosilicate slide (1x3 in).

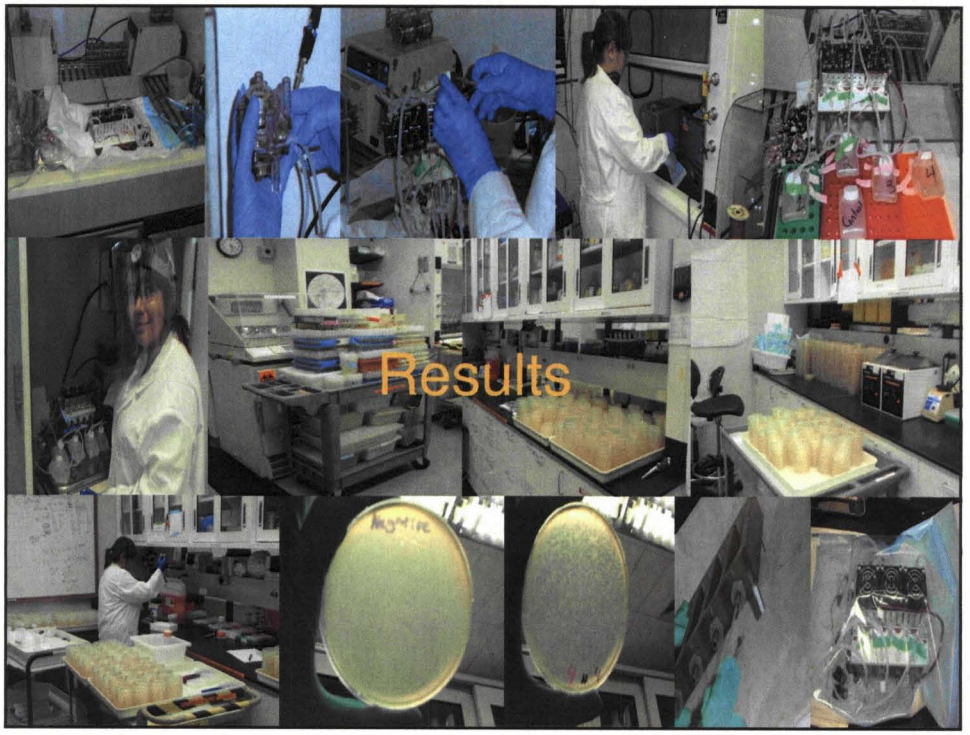

Materials and Methods
Nanosilver

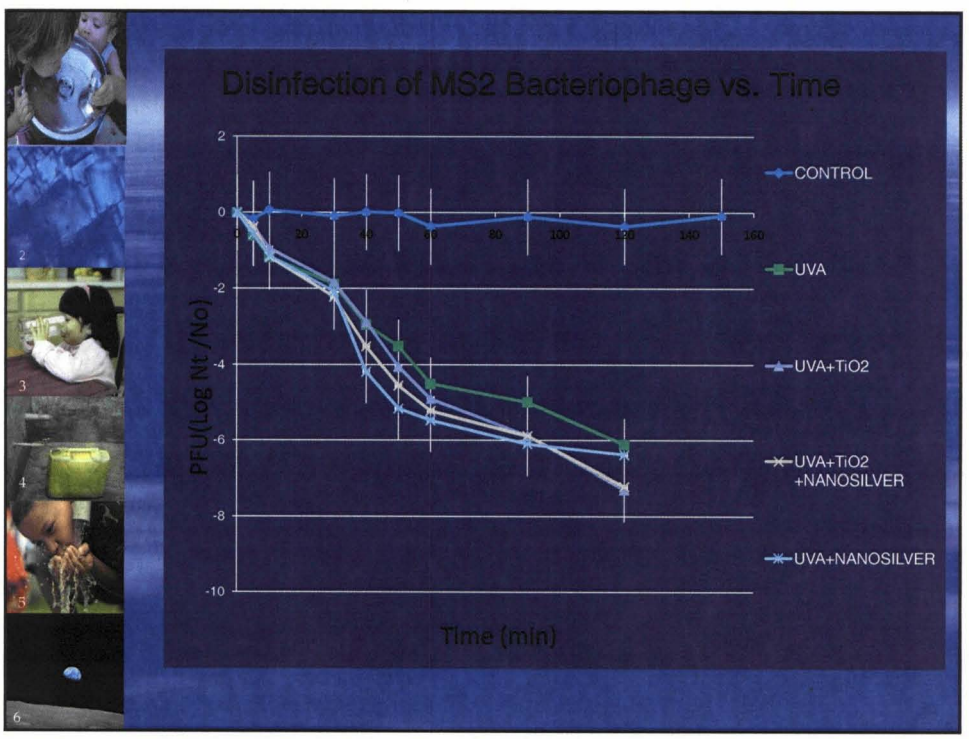

Materials and Methods

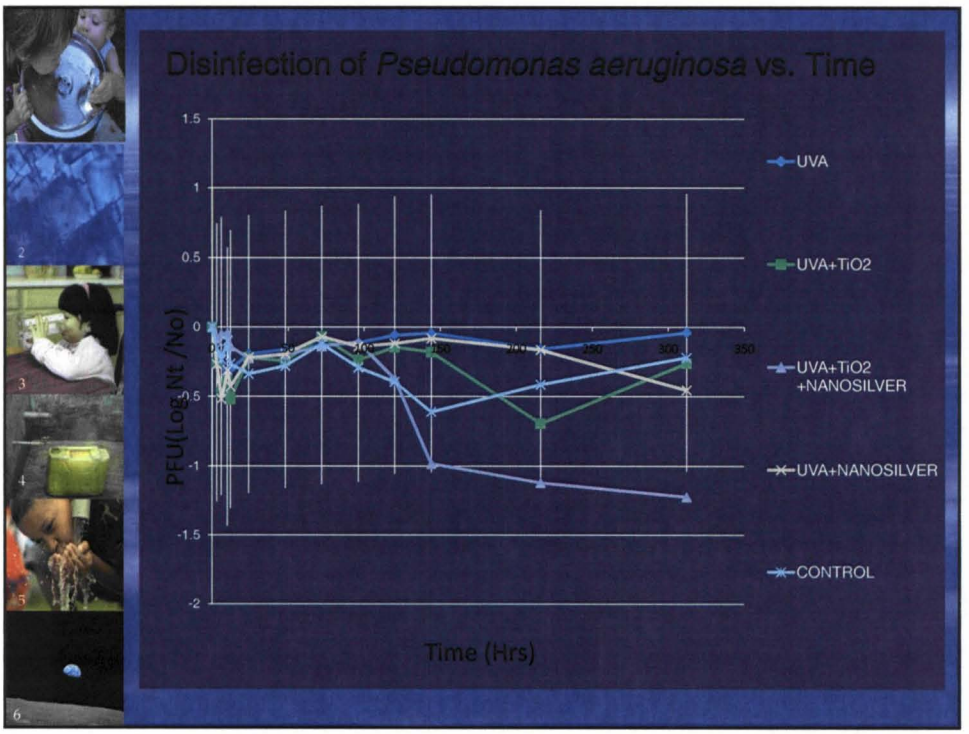

Areas of Opportunity
TiO_2 coating
Nanosilver application and quantification

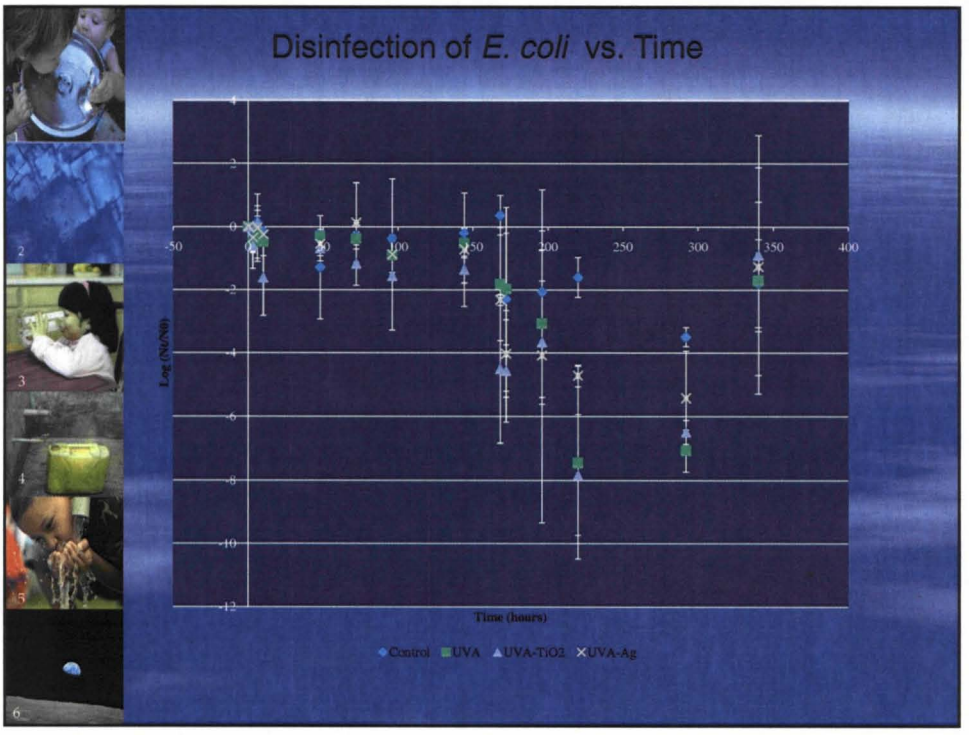

Materials and Methods


Bacteria
or Virus
Centrifuge
if it is bacteria only
Adjust
Concentration
Add Bacteria or Virus
Concentration to
Reactor container
Reactor well
Add Nanosilver
Neutralize Disinfection
Effect
Plate
Dilute
Incubate
24 Hrs
Count
Colonies
or Plaques


Results


Disinfection of MS2 Bacteriophage vs. Time
PFU(Log Nt /No)
Time (min)
CONTROL
UVA
UVA+TiO2
UVA+TiO2 +NANOSILVER
UVA+NANOSILVER


Disinfection of *Pseudomonas aeruginosa* vs. Time
PFU(Log Nt /No)
Time (Hrs)
UVA
UVA+TiO2
UVA+TiO2 +NANOSILVER
UVA+NANOSILVER
CONTROL

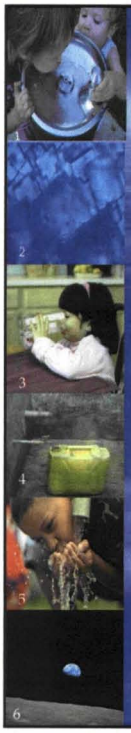

Disinfection of *E. coli* vs. Time
Log (Nt/No)
Time (hours)
Control
UVA
UVA-TiO2
UVA-Ag

Conclusions

- The design of the reactor presents no overheating and a constant temperature. A good electrical and optical performance for a UV water treatment system.
- The assessment of this study shows that UVA-LEDs can be used as a good disinfectant in water for MS2 Bacteriophage. The log reduction was sufficient to meet US EPA standards as a secondary disinfectant for maintaining water quality control.

Conclusions

- This study has shown that at the conditions tested there is no inactivation of *Pseudomonas aeruginosa* and *E. Coli* and further testing at different conditions (specifically contact area and time of exposure) have to be performed to use UVA-LED as a secondary disinfectant to maintain water quality.

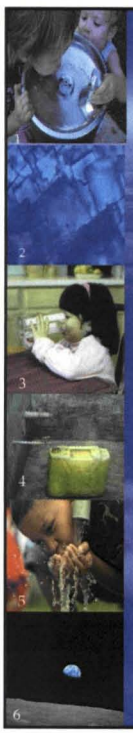


Further work recomended

- Other contact areas and longer times of exposure should be tested.
- Microorganisms:

-*Cryptosporidium parvum* oocyst

- Other research lines such as biocides and reactive oxygen species in the reactor.

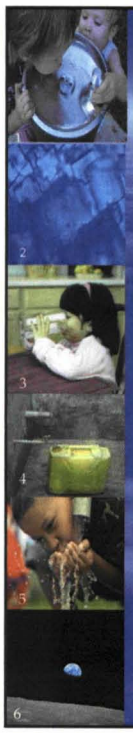


Key point

UVLEDS are a viable disinfectant in water that should be further investigated to develop an optimized Water Technology for Earth and Space Applications

References

- 1.- US SANDIA National Laboratories. Final LDRD Report: Ultraviolet Water Purification Systems for Rural Environments and Mobile Applications. November 2005.
- 2.-Hammamoto et al. 2007; Mori et al. 2007; Vilhunen et al. 2008.
- IMAGES ON LEFT SIDE:
- 2.- apod.nasa.gov/apod/image/9909/water_jsc.jpg
- 3.- coep.pharmacy.arizona.edu/water/drink2.jpg
- 4.- www.ryanswell.ca/projects/images/Photo5_Page1
- 5.- imthi.com/.../2009/09/charity-water-honduras.jpg
- 6.- NASA Image: Earthrise over the lunar horizon, December 1968.

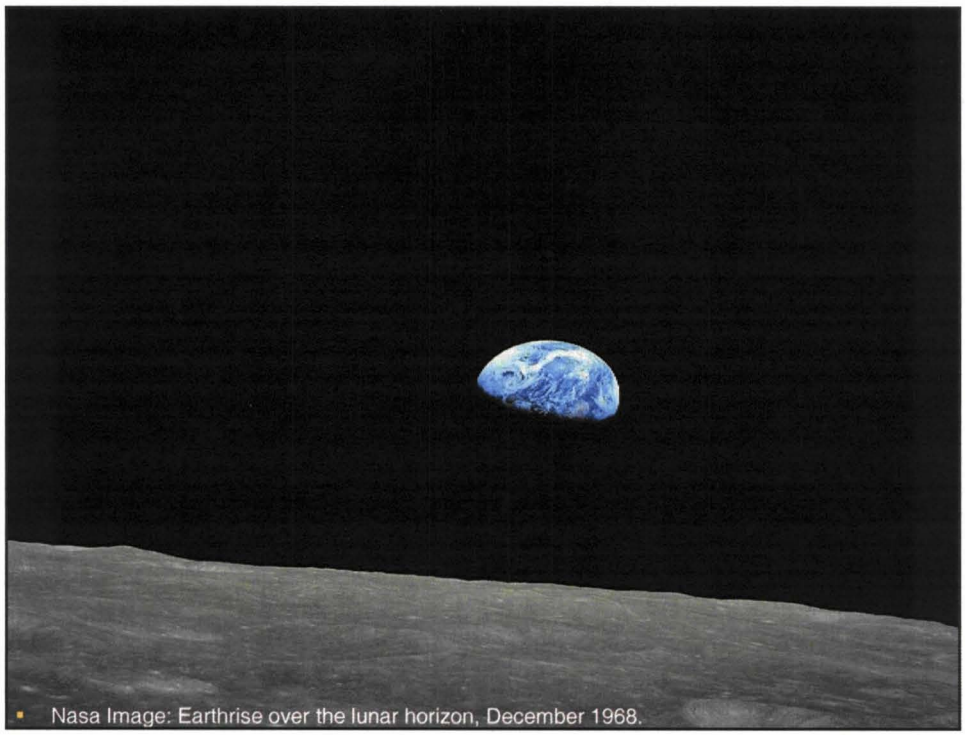


Acknowledgements

- NASA and NPP administered by ORAU.
- Michael S. Roberts, Raymond Wheeler, and Daniel Barta.
- KSC Education Office (Patricia Gillis, Lisa Valencia, Hortense Burt and Lesley Garner).
- Dynamac technical support staff and everybody in the LSSC contract.
- Paul Hintze, LaNetra Tate, Wenyan Li, Jackie Quinn, Lanfang Levine, Luz Maria Calle, Brenton Hicks, Kari Cezat and Carolina Ragolta.

Questions?

- earthfirst.com/tag/water/
- Nasa Image: Earthrise over the lunar horizon, December 1968.



- Nasa Image: Earthrise over the lunar horizon, December 1968.