Enhancing solar disinfection of water for application in developing regions

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FAPESP, IOP and RSC Workshop:
Physics and Chemistry of Climate Change and Entrepreneurship
Sao Paulo, Brazil

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Presentation overview

- University of Ulster and NIBEC
- Water and Climate Change
- Solar Disinfection
- Enhancing Solar Disinfection

We seek collaborations with countries with lovely sunlight!

University of ULSTER

Largest university on the island of Ireland

Jordanstown campus:

Engineering, Health Science and Sports

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Nanotechnology and Integrated BioEngineering Centre (NIBEC)

£10M purpose-built multi-disciplinary research centre

working at the interface of bioengineering and nanotechnology

Successful track record in commercialisation of research

Photocatalysis research

Areas of research include:

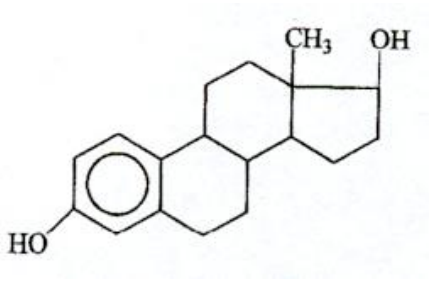
- Catalyst development
- Immobilisation
- Thin film characterisation
- Commercialisation

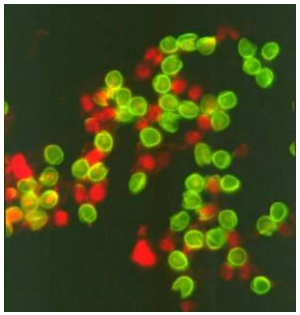
Photopure

Photocatalysis research

Applications:

- Water purification; estrogens, POP's, organics
- Disinfection; water and medical devices
- Biosensors; glucose and DNA
- Solar hydrogen, solar cells





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Self aligned nanoporous TiO_2

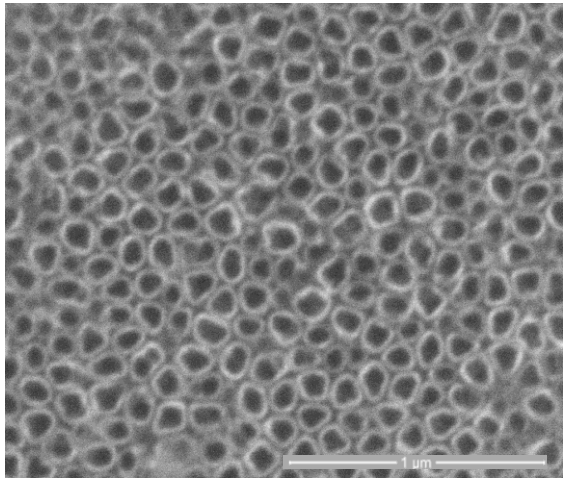
Room temperature, low energy input method to TiO_2 nanotubes

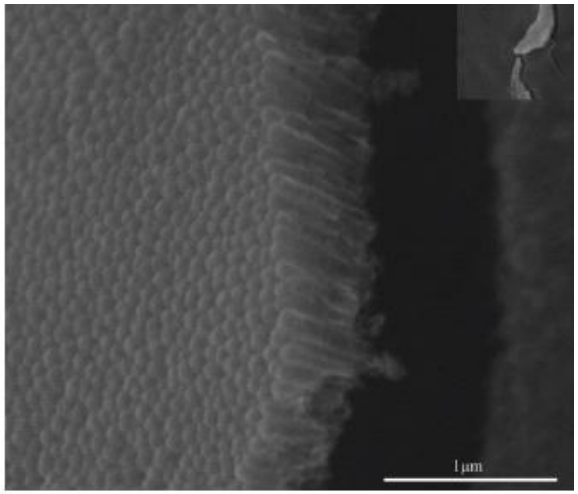
- Regular pore diameters
- Controllable pore size

Environmental catalysis

Photo-reduction of CO_2

Hydrogen storage





Climate change and water

- Increased precipitation intensity
- Longer periods of low flows exacerbate water pollution
- Impacts on ecosystems and human health
- Increased water system operating costs

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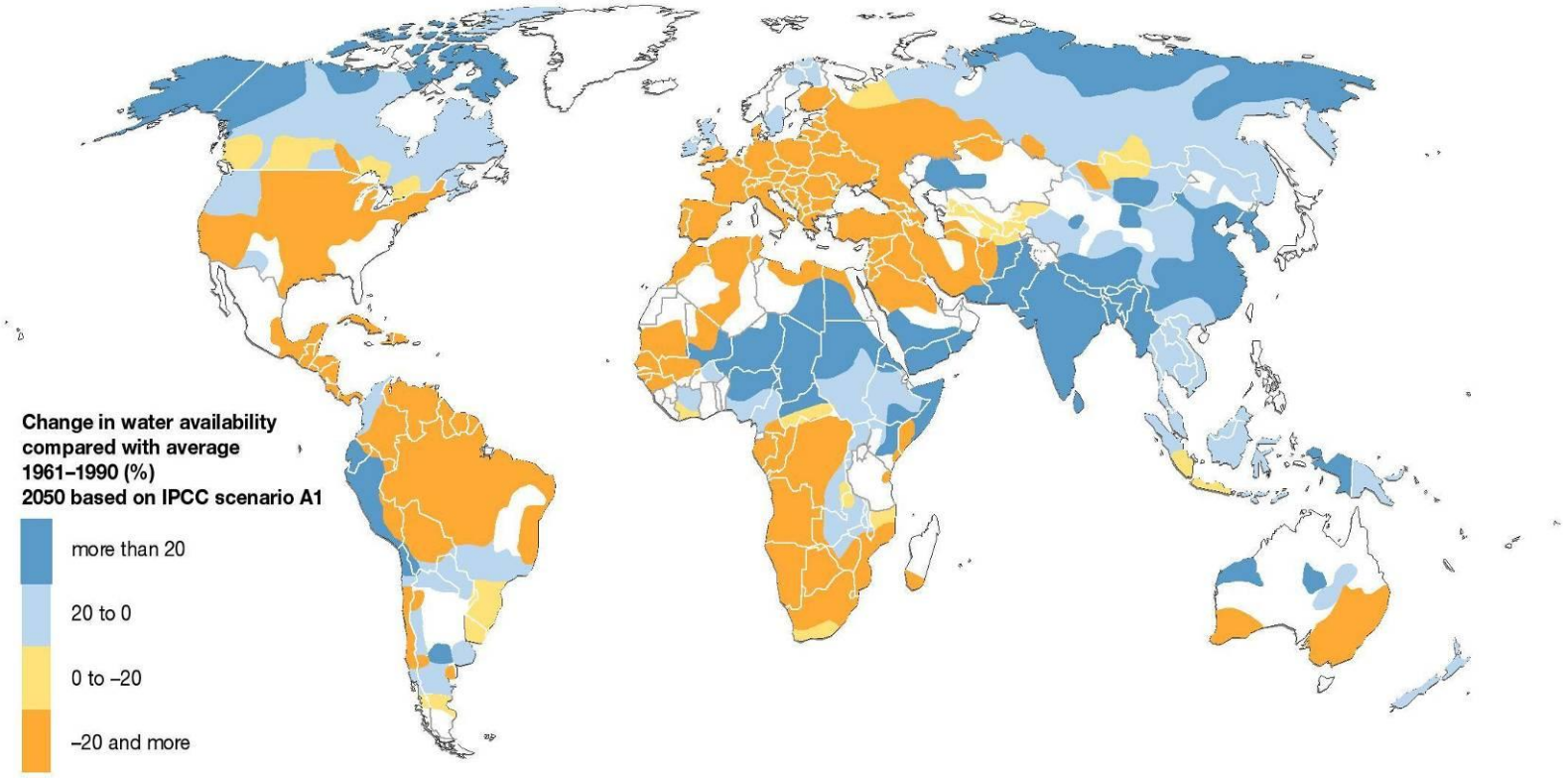
Climate change and water



http://www.grida.no

Climate change and water

US citizens use 500 litres per day, the British average is 200
Only 1% of treated water is consumed as potable water!

Importance for food production (litres required / kilo):

Potatoes	1,000
Maize	1,400
Wheat	1,450
Beef	42,500

"The West" can afford to waste water, however,

- 1.1 Billion people without access to safe water
- 4 Billion cases of diarrhoea (88% due to unsafe water)
- 1.8 Million die each year (majority under 5 yrs)

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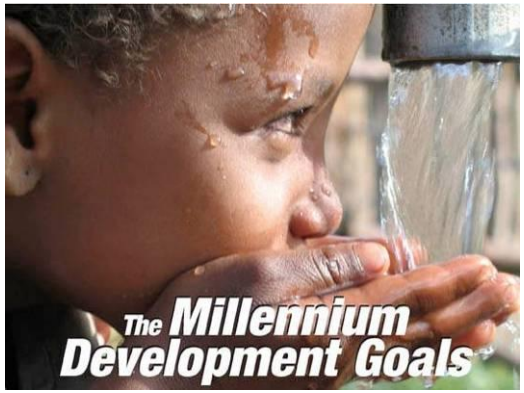
Millennium Development Goal Target 10:

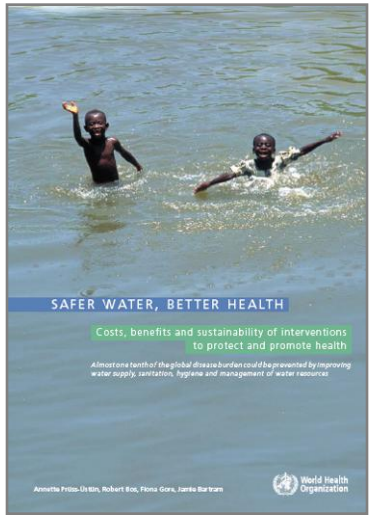
"by 2015, reduce by half, the 1.1 billion people lacking access to safe drinking water and basic sanitation".

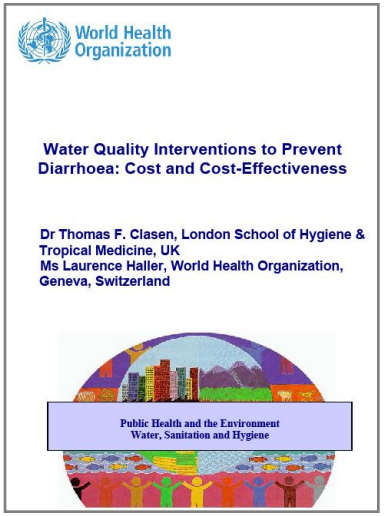


WHO / UNICEF reports:

Water: $4 billion required per year

Lower-cost, point-of-use (POU) water purification





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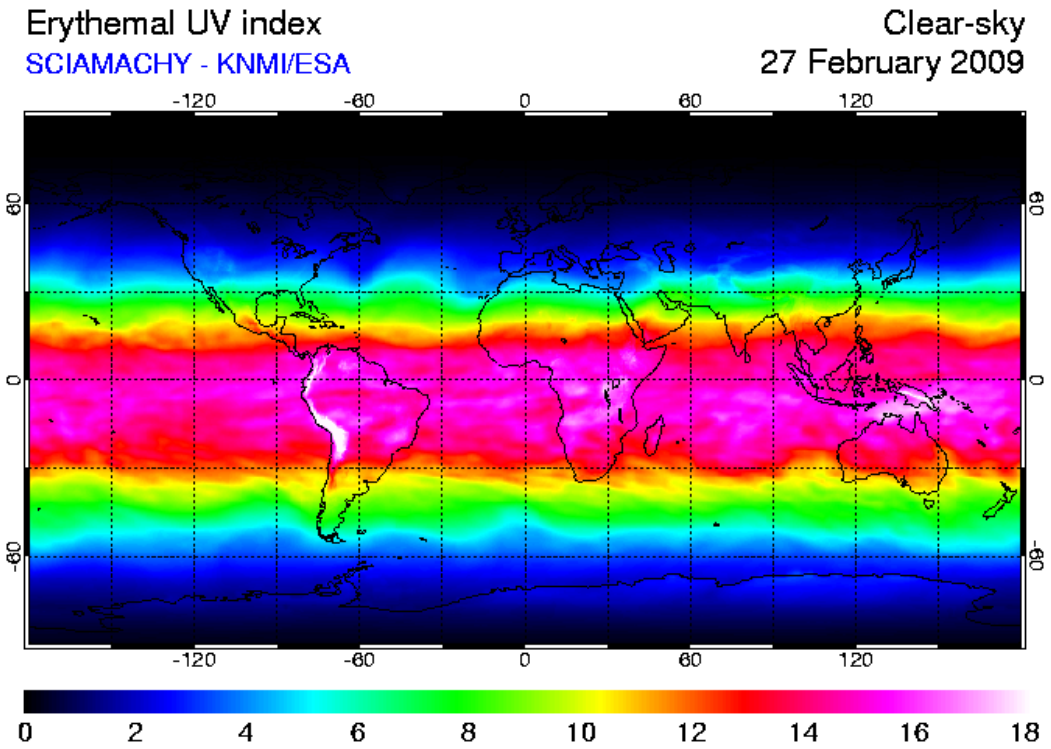
Household water treatment intervention options:

- Boiling
- Filtration
- Chlorination
- Solar Disinfection



Solar Disinfection (SODIS)

1 Wash the bottle well the first time you use it

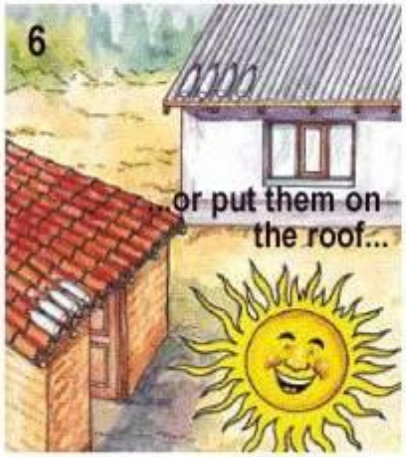
Fill the bottle 3/4 full with water

Shake the bottle for 20 secondes

4

Now fill up the bottle fully and close the lid

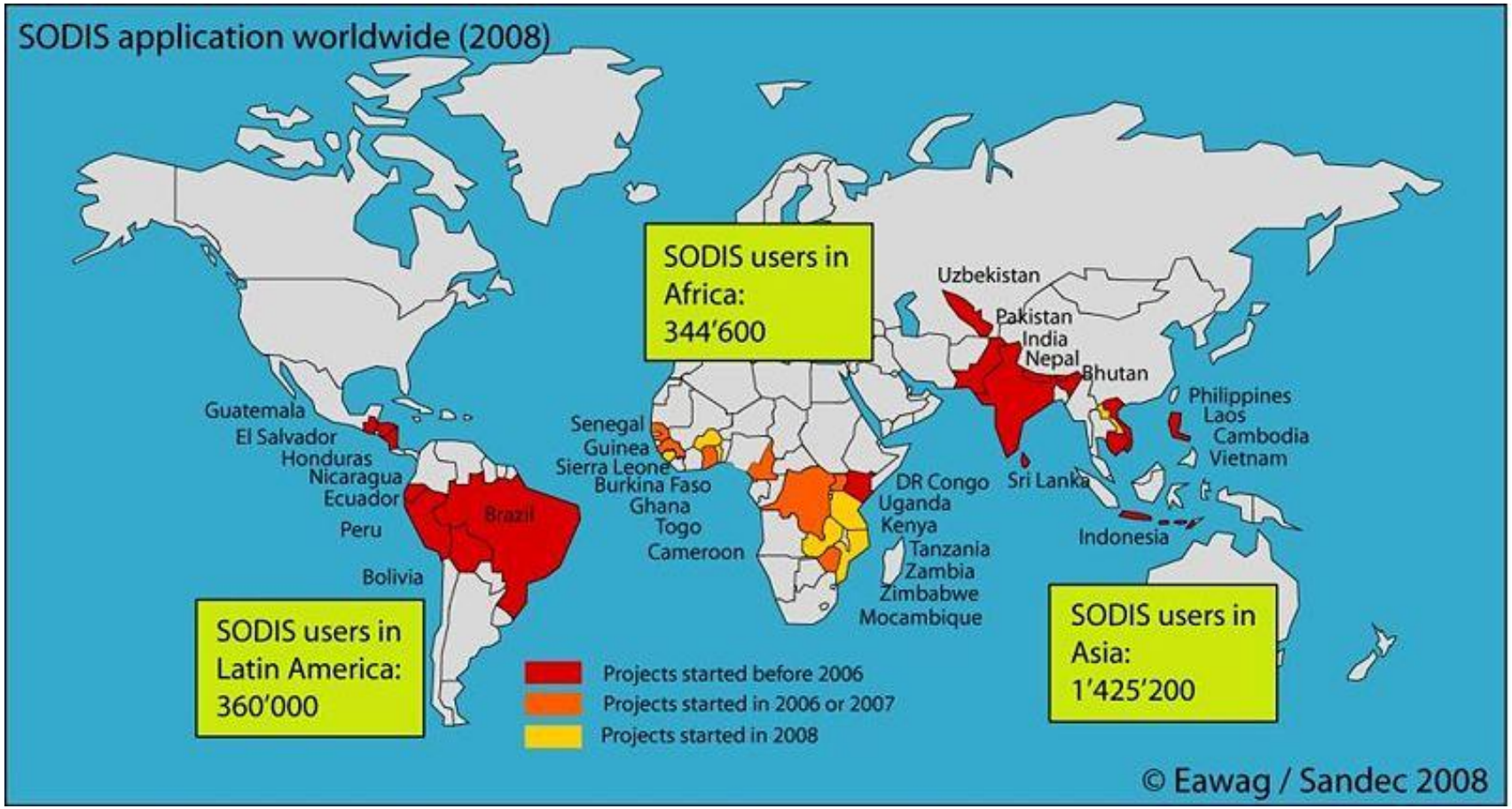
Place the bottles on a black iron sheet



Expose the bottle to the sun from morning until evening for at least six hours

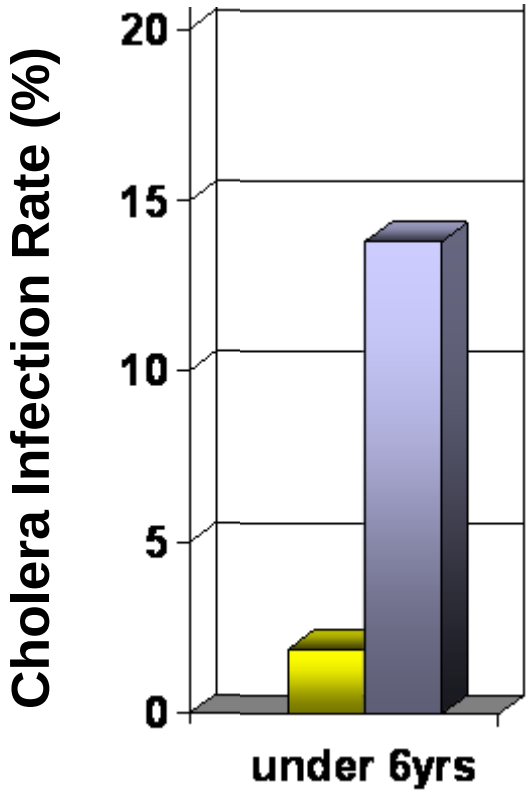
The water is now ready for consumption

Solar Disinfection (SODIS)



In Brazil: Prainha do Canto Verde north of Fortaleza

Health Impact Assessment



Children under age 6 who used SODIS were 7 times less likely than non-SODIS users to contract cholera.

Conroy RM, McGuigan KG, *et al.* (2001) *Arch. Dis. Child.* **85**, 293-295.

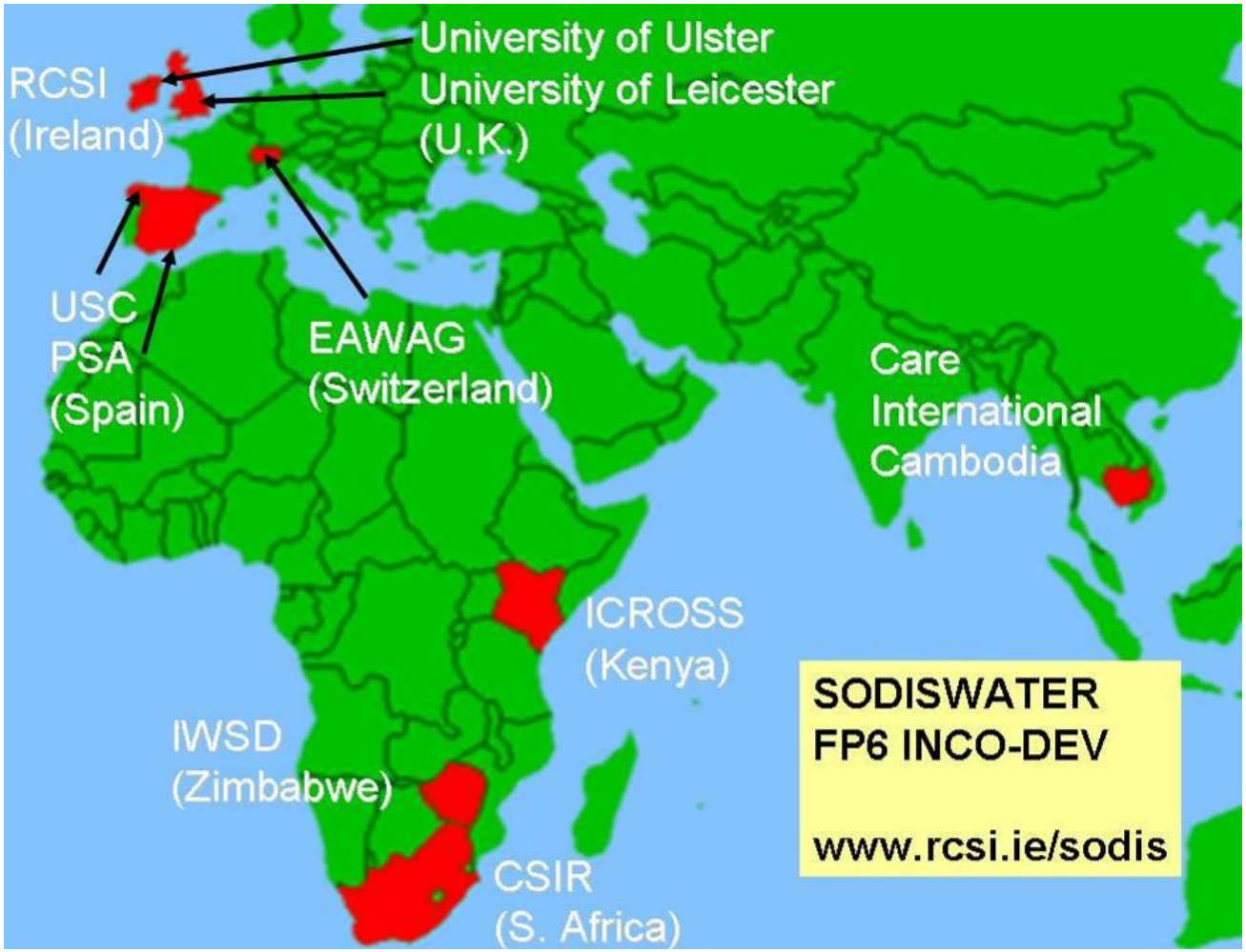
Positives for SODIS:

Effective against a wide range of pathogens
Low cost (effectively zero)
Simple to use

Negatives for SODIS:

Some pathogens are resistant to SODIS
Rate of kill depends upon environmental factors
No quality assurance
Cultural / societical / political factors
Education is required

SODISwater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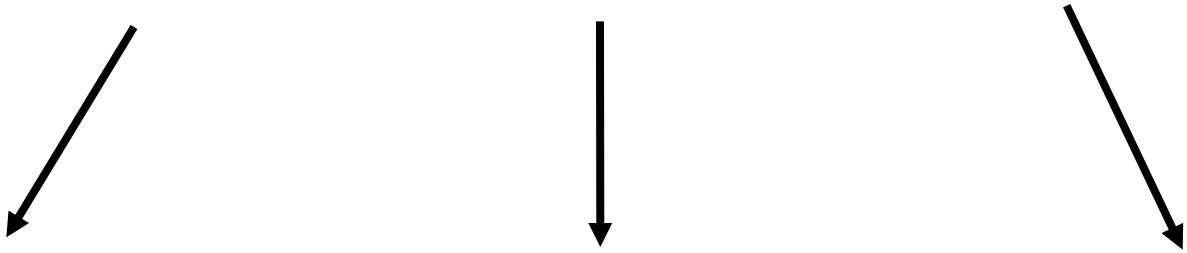
EAWAG
(Switzerland)
Care
International
Cambodia
ICROSS
(Kenya)
IWSD
(Zimbabwe)
CSIR
(S. Africa)
SODISWATER
FP6 INCO-DEV
www.rcsi.ie/sodis

SODISwater

To demonstrate that SODIS is an appropriate, effective and acceptable intervention against waterborne disease in developing countries without reliable access to safe water.



Efficacy of SODIS against resistant pathogens

Increasing SODIS uptake within communities

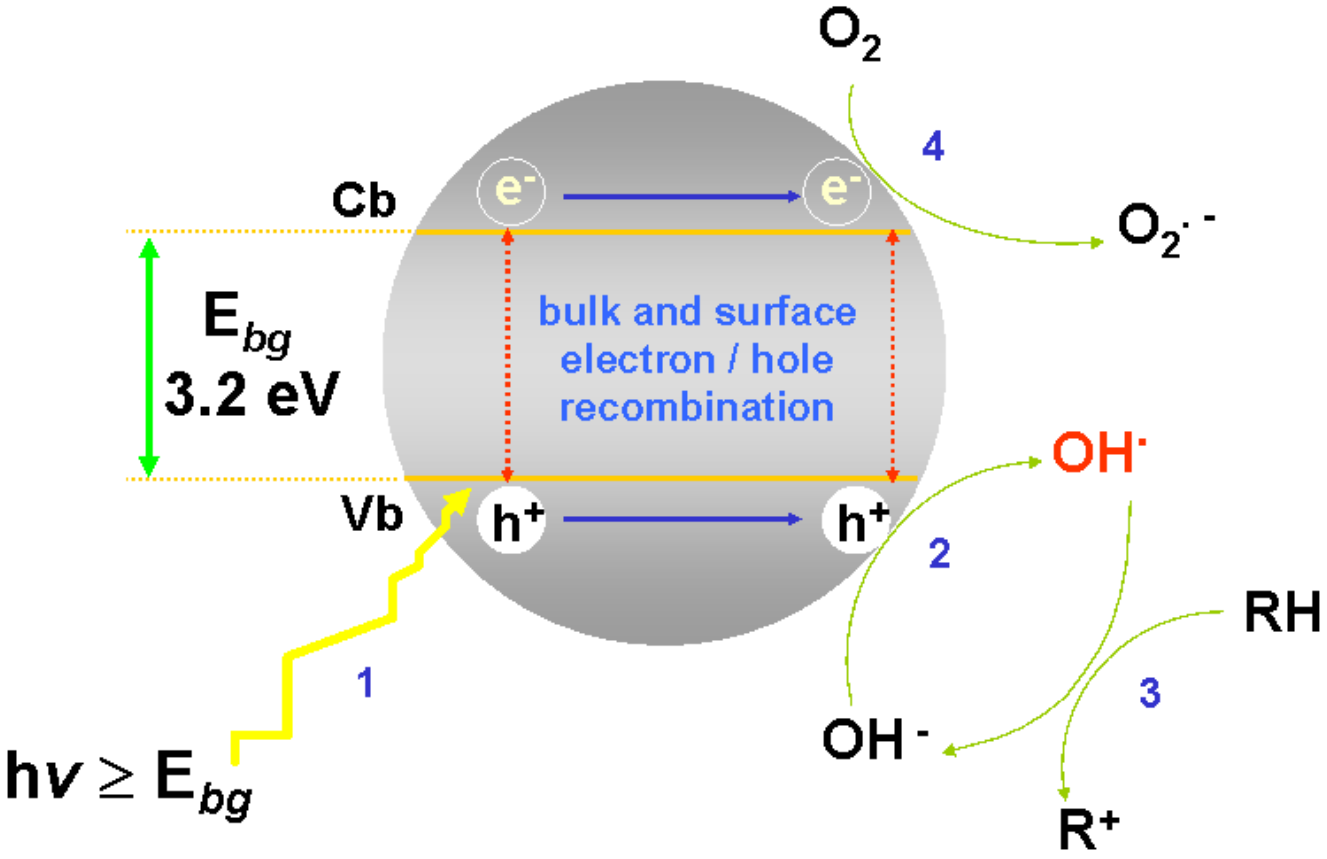
Enhancing SODIS

Enhancing SODIS

1. Continuous flow photocatalytic SODIS
2. Batch photocatalytic SODIS reactor
3. Photocatalytic SODIS bag
4. “Quality control” indicators for SODIS

Pro poor, i.e. LOW cost !

Photocatalysis



Cb= *Conduction band;* **Vb**= *Valance band;* **e**$^-$ = *promoted electron;* **h**$^+$= *remaining hole;*

OH· = Hydroxyl radical; RH= *Organic pollutant;* **R**$^+$= *Oxidised organic pollutant*

1. Continuous flow photocatalytic SODIS reactor

TiO_2 coated borosilicate glass tubes (0.4 mg/cm^2) were incorporated into the CPC-SODIS reactors used at PSA and used as a 7L re-circulating batch system using *E. coli* K12 in saline (1x10^6 CFU/mL) as a model test organism.

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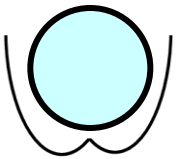
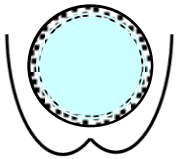
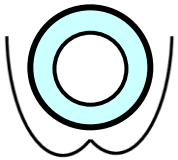
Recirculating Batch



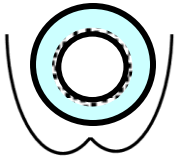
Uncoated external



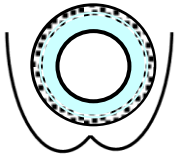
TiO_2 coated external



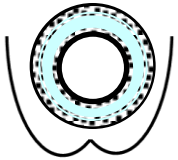
Uncoated external, uncoated internal



Uncoated external, TiO_2 coated internal



TiO_2 coated external, uncoated internal



TiO_2 coated external, TiO_2 coated internal

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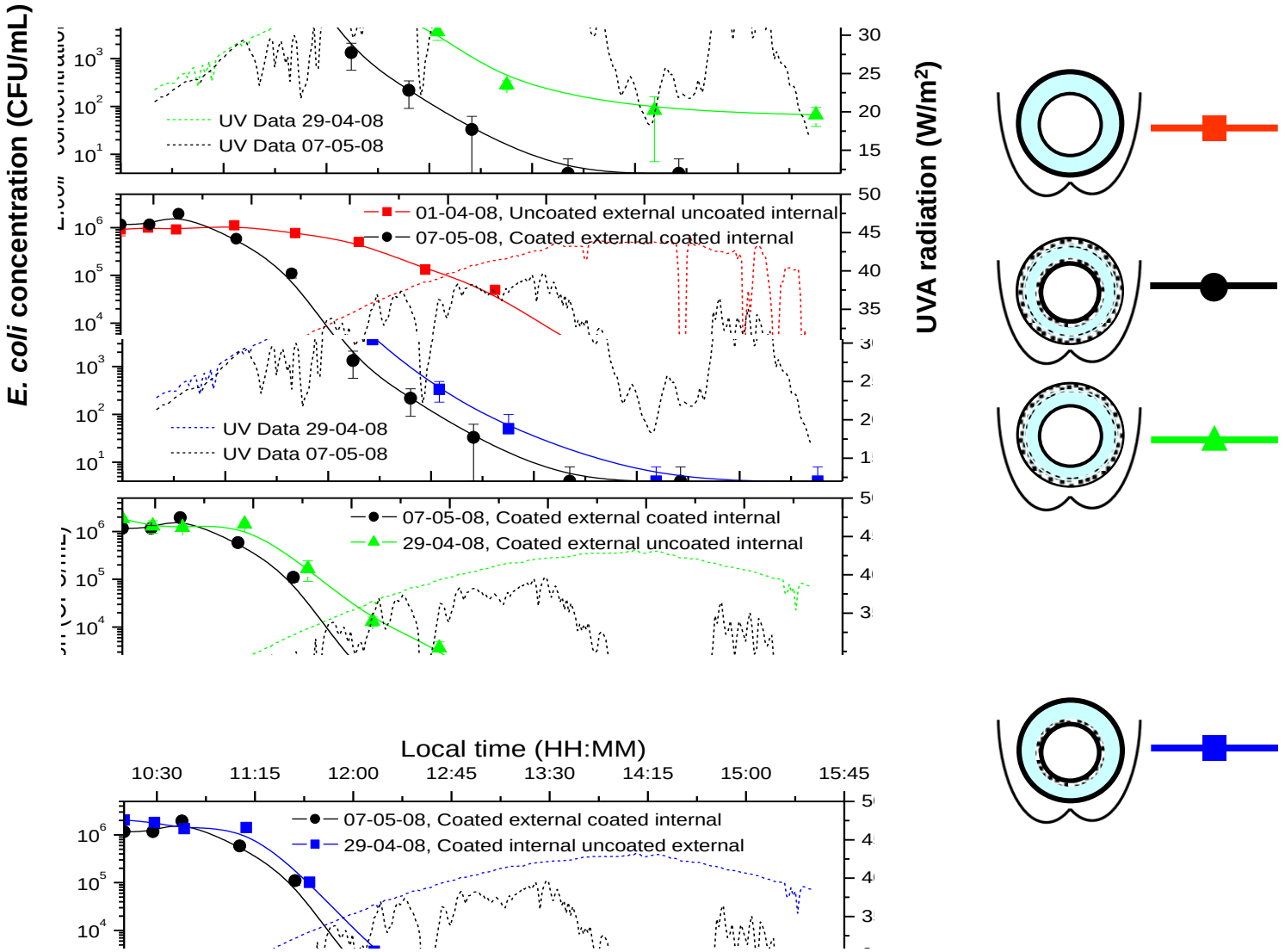

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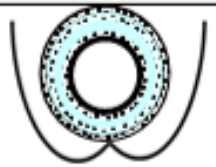
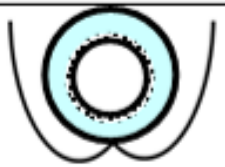
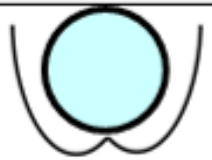
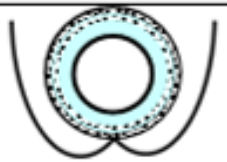
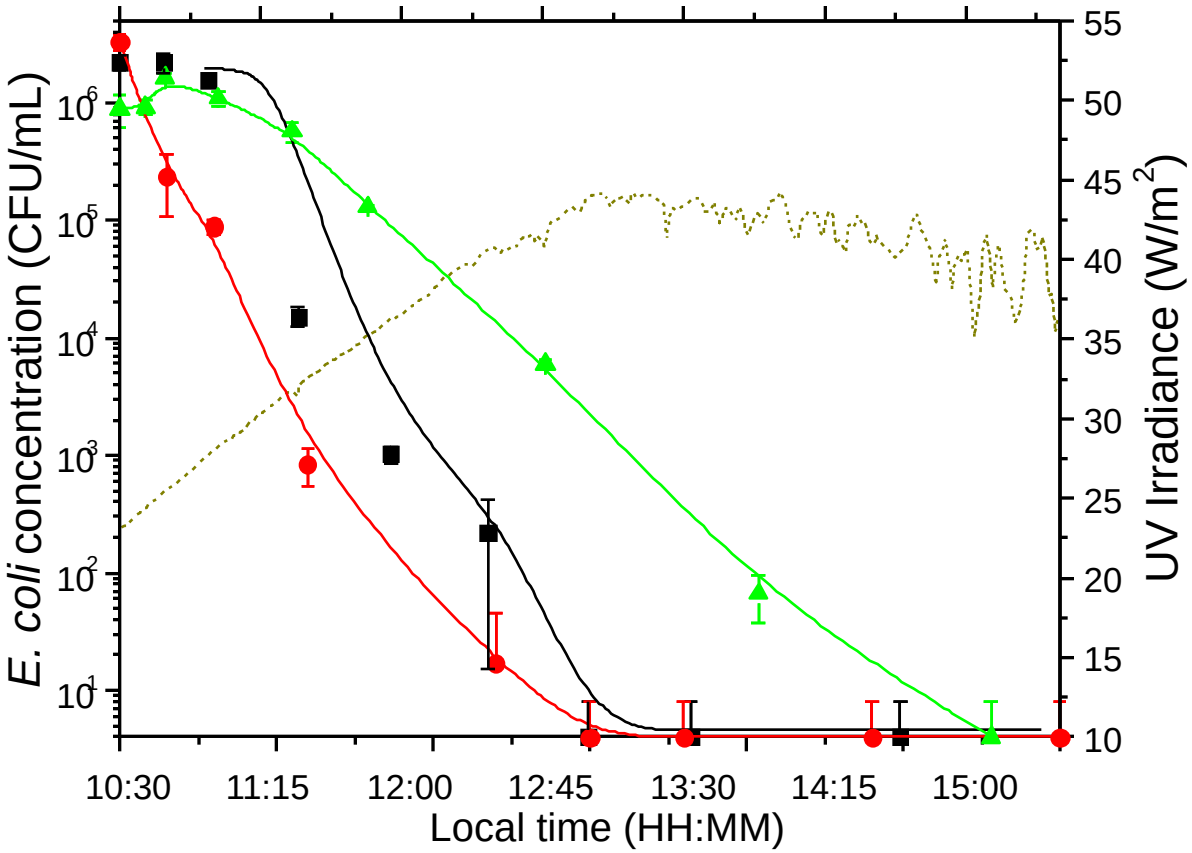
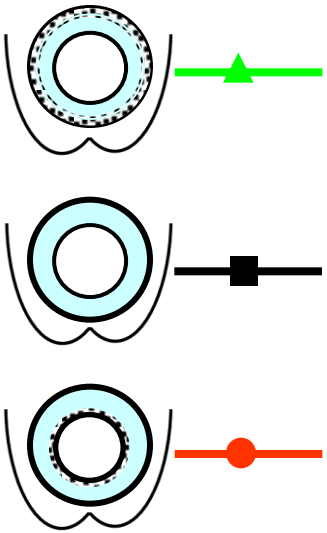
Summary of results:

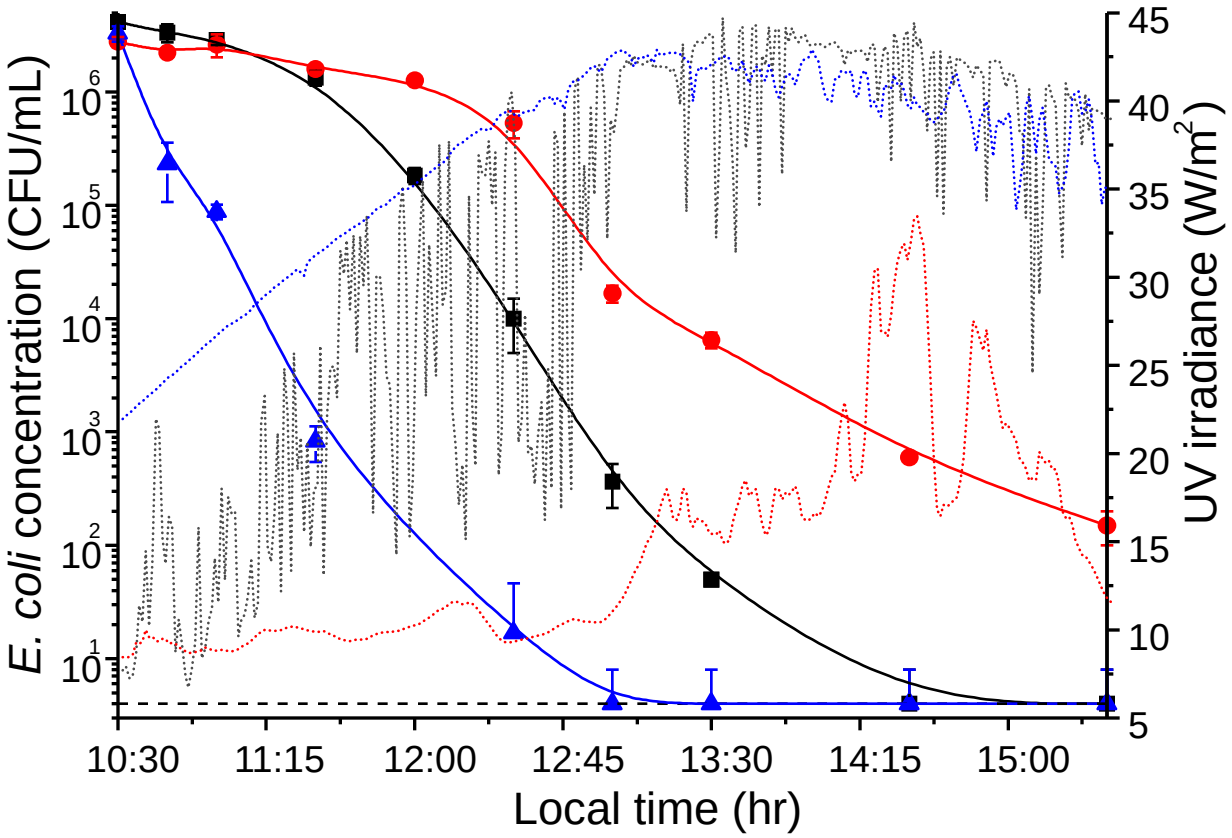
TiO_2-coated internal–TiO_2-coated external	>	TiO_2-coated internal–uncoated external	>	Uncoated external	>	TiO_2-coated external-uncoated internal	>	Uncoated internal–uncoated external
	>		>		>		>	

2. Batch photocatalytic SODIS reactor





Effect weather photocatalytic SODIS:

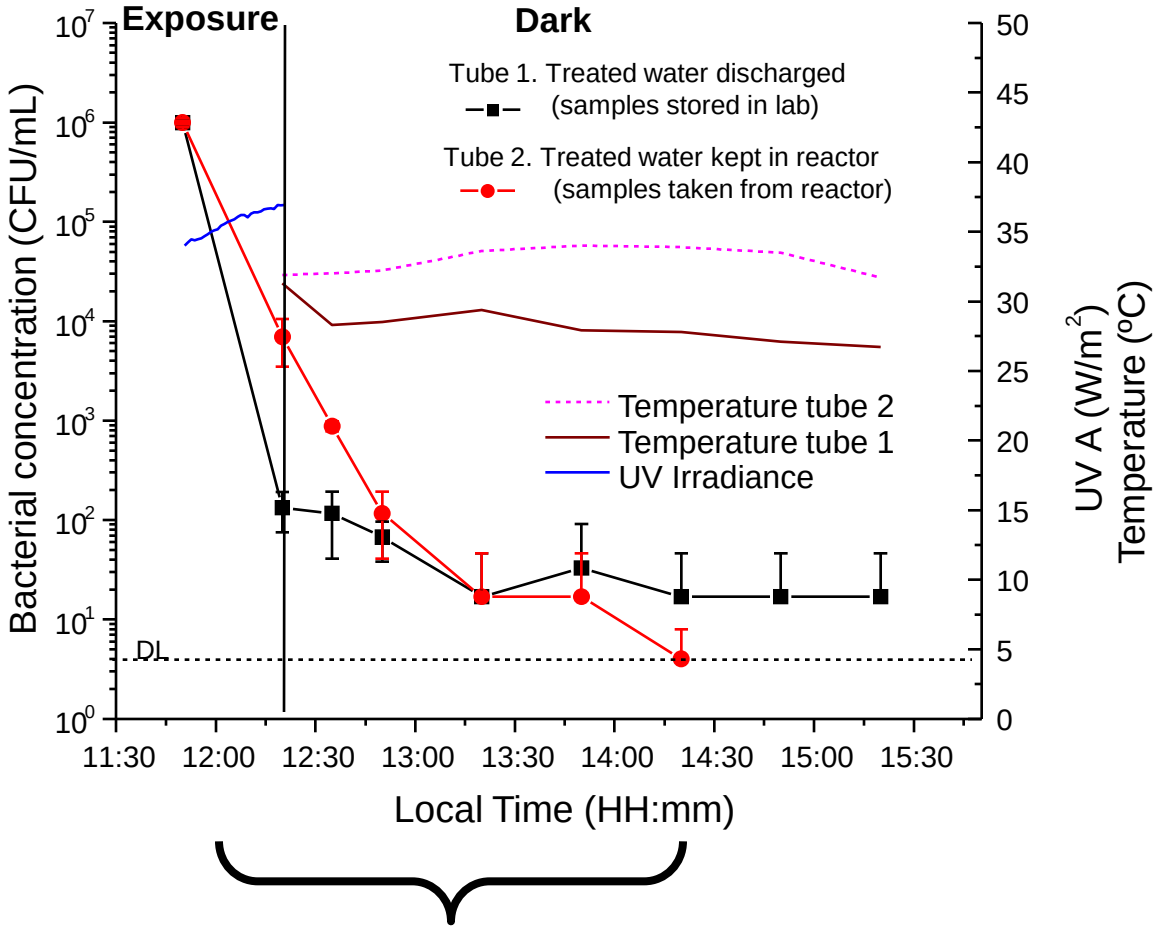


Sequential batch reactor

Experiments using *E. coli* in natural well water ($1x10^6$ CFU/mL) were carried out to assess the total treatment time required for sequential batch SODIS. Effect of UVA dose on total treatment time investigated using 20, 30, 40, 60, 70 and 80 Wh m^2.

Sequential batch reactor

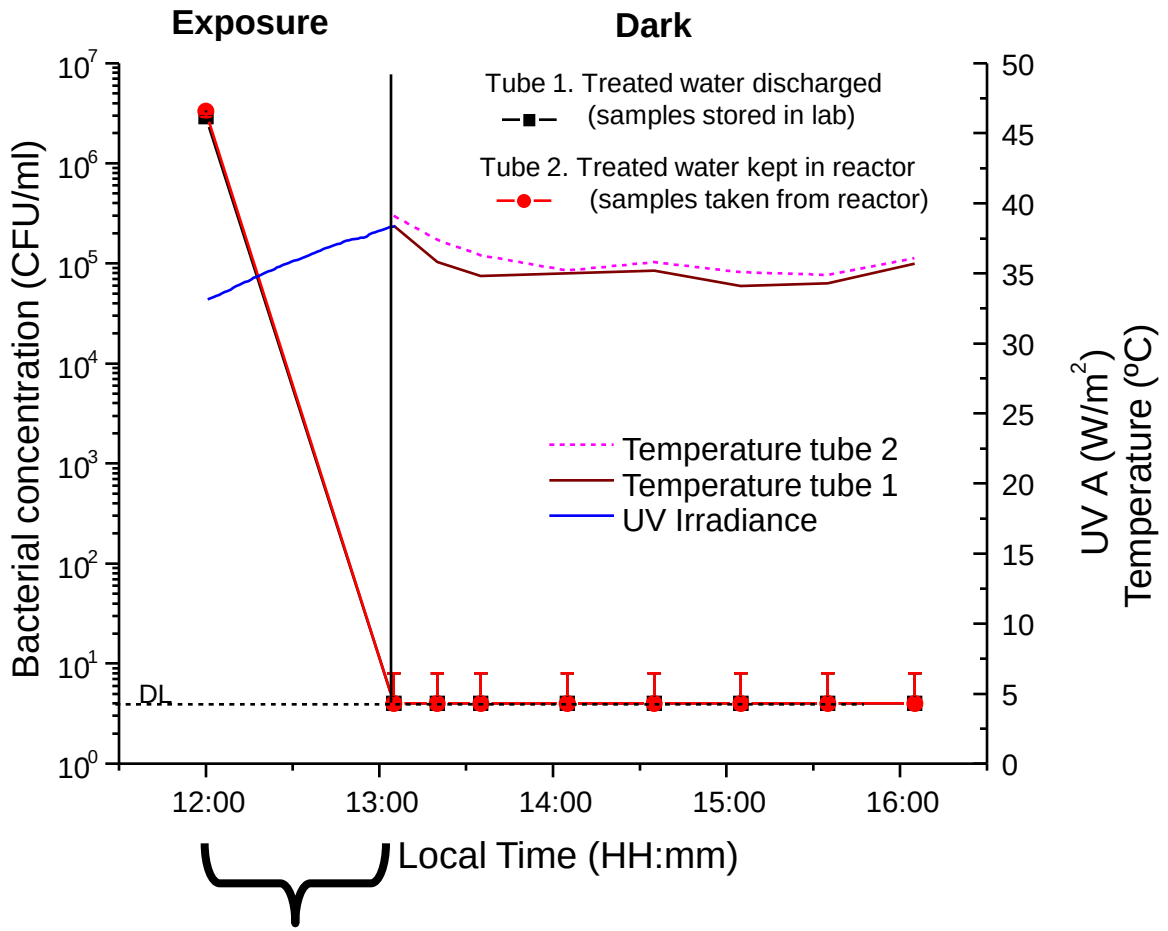
Accumulated UVA dose = **33.7 W·h/m²**



Total treatment time 2.5 hours … water must be kept in SODIS reactor!

Sequential batch reactor

Accumulated UVA dose = **68.0 W·h/m²**

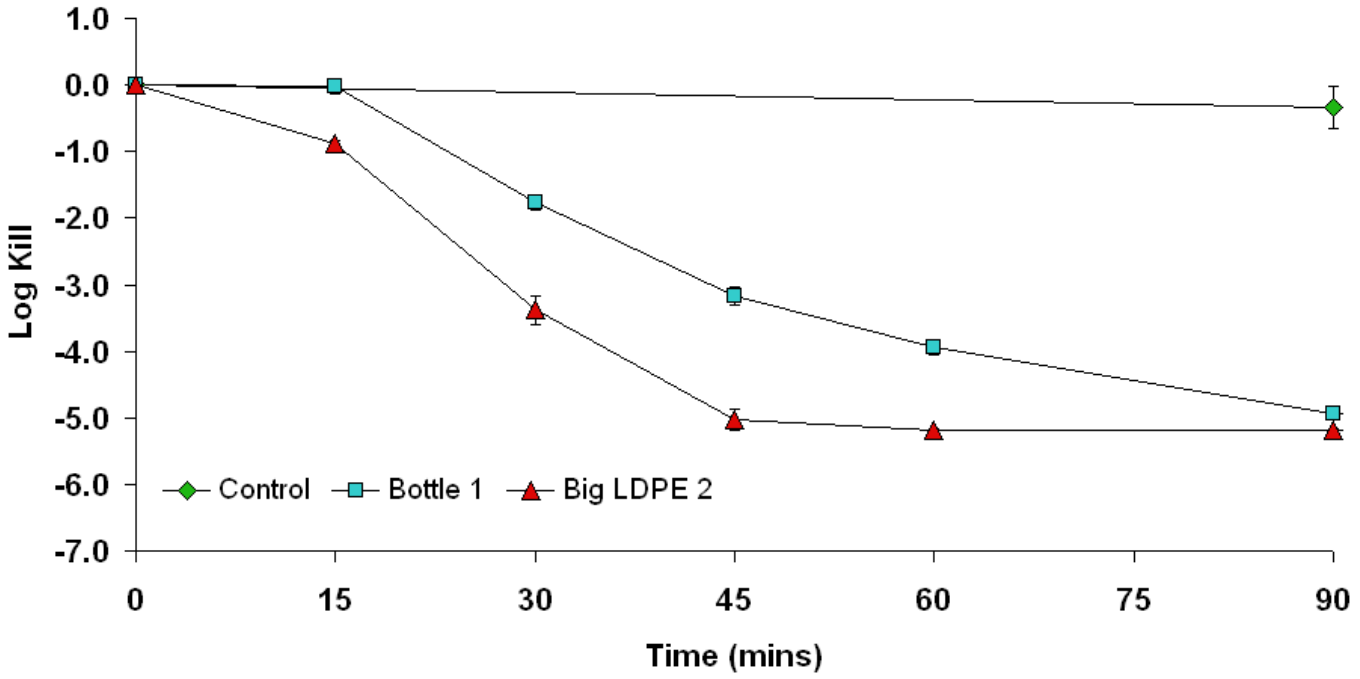


Total treatment time 1.0 hour … in SODIS reactor

Photocatalytic SODIS Bag

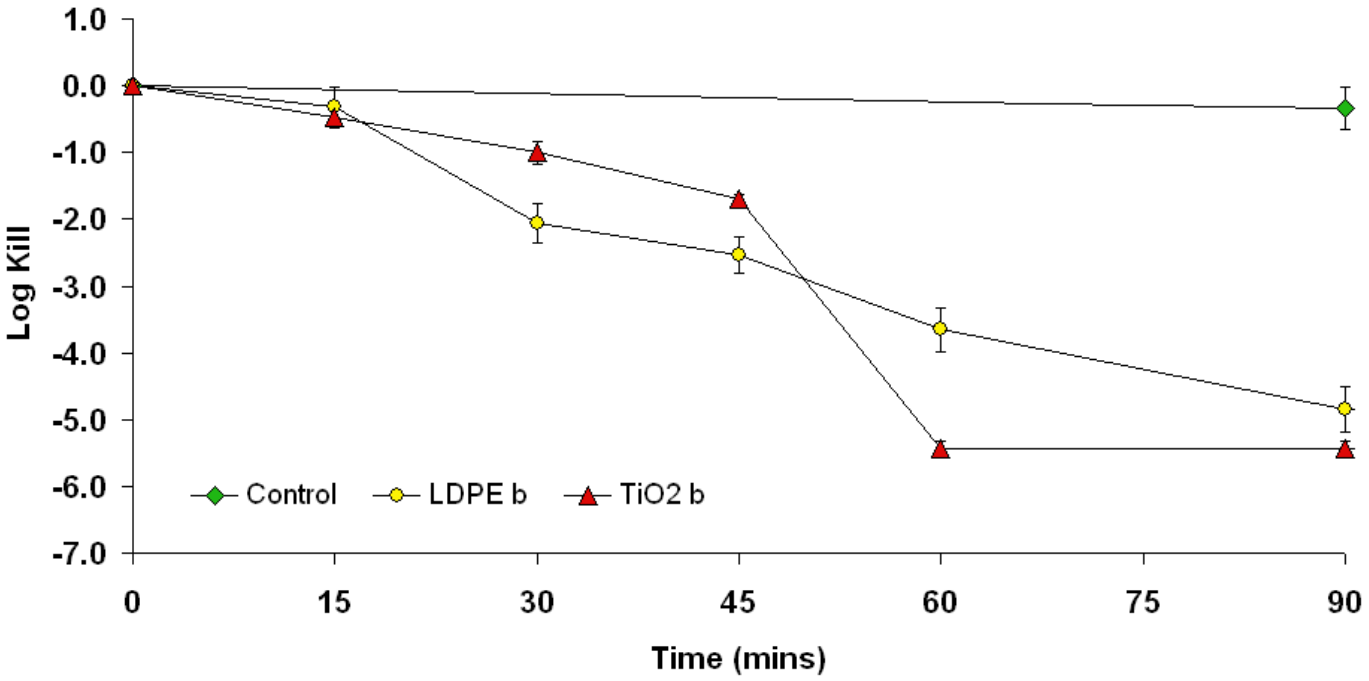
Polymer bags were made from FEP, PET, PVC and LDPE (500mL and 1500mL). Photocatalytic polymer bags were prepared in LDPE. Bags used as static batch system with *E. coli* K12 in distilled water ($1x10^6$ CFU/mL) as a model test organism.

Photocatalytic SODIS Bag



SODIS bag faster than SODIS bottle

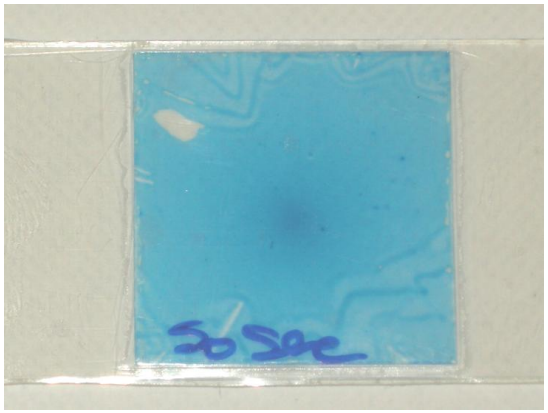
Photocatalytic SODIS Bag



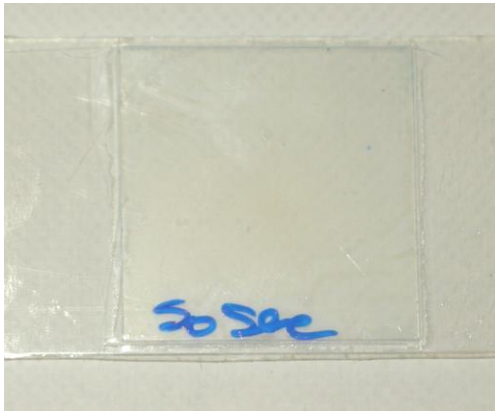
Photocatalysis again increases rate of disinfection

“Quality control” indicators for SODIS

Dosimetric sensors ensure “lethal solar radiation dose” has been received, confirming water is safe for consumption.

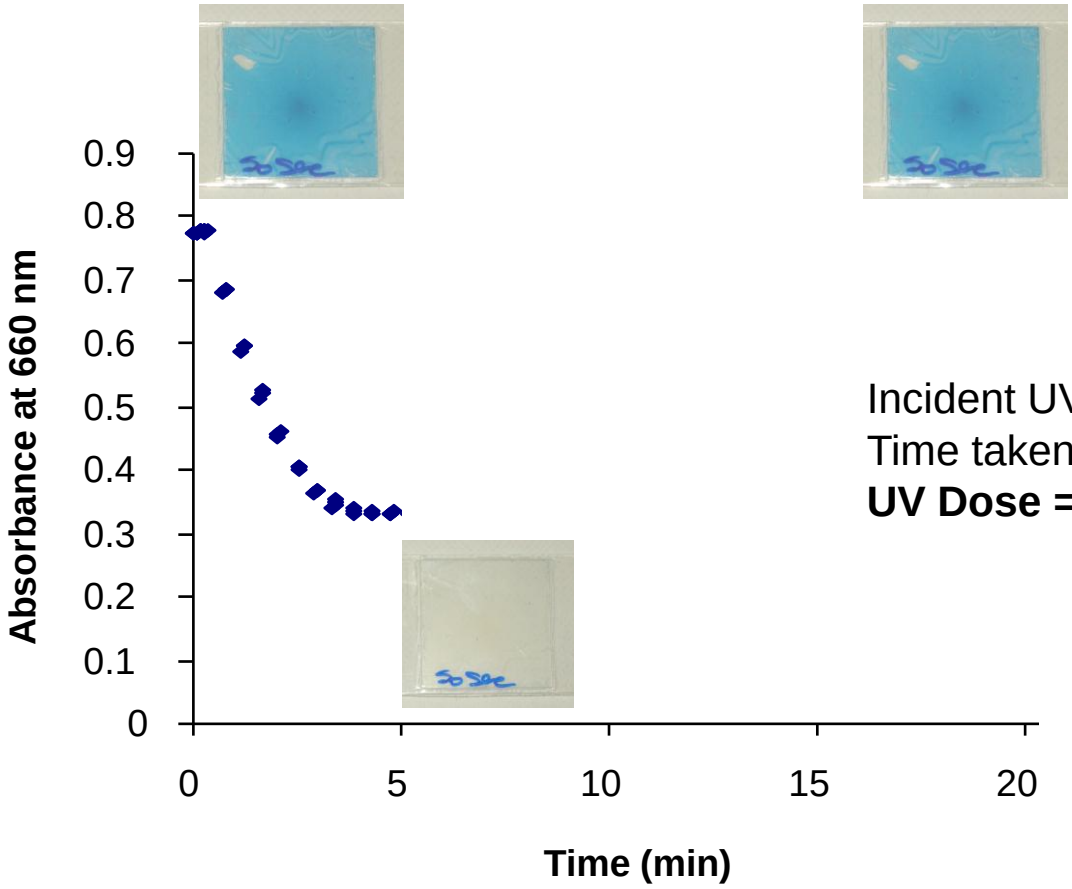


Time 0
before exposure



Time x
Following receipt of
“lethal dose”

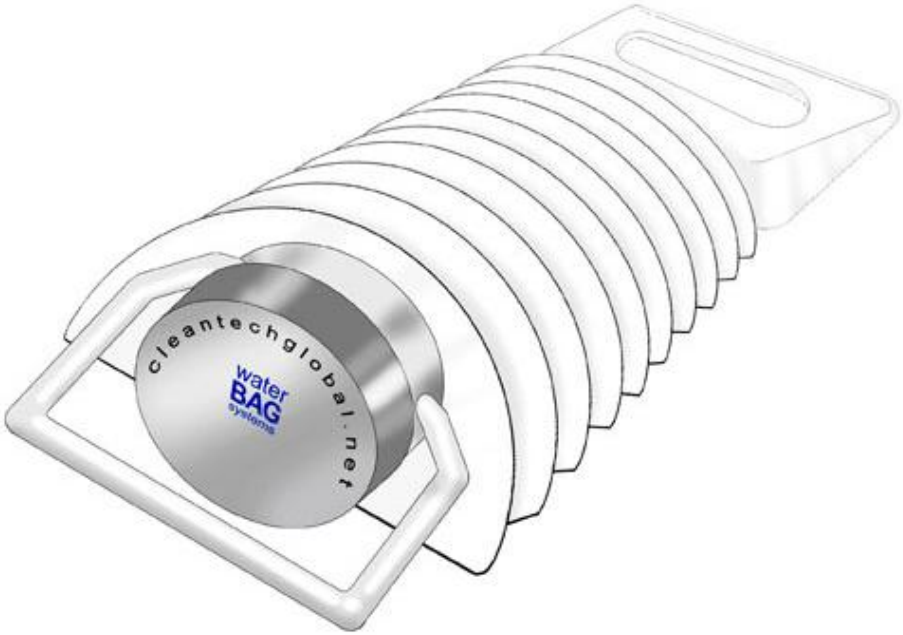
“Quality control” indicators for SODIS



Incident UVA intensity = 30 Wm^2
Time taken for colour change = 5 min
UV Dose = 2.5 $Wh.m^2$

Single use and repeat use sensors for 30, 45, 60 and 80 $Wh.m^2$

Enhanced “emergency” SODIS



Low cost (25p) Large surface area:volume ratio Easy to fill

Desirable? Quality control (peace of mind) built it

Summary

SODIS is a simple, user friendly approach to reducing mortality where access to safe drinking water supplies is lacking

Nanotechnology (photocatalysis and sensor technology) can enhance the efficiency and provide some quality assurance to the end user

Cost based analysis will be undertaken to determine which technologies will be deployed for pilot testing in Africa

Just a thought … If we inactivate the microorganisms, but they remain in the water, could SODIS treatment act as an oral dose vaccine?

Acknowledgements

European Commission for funding under FP6 INCO-DEV

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