Low cost water purification for developing countries and humanitarian assistance

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Motivation

Providing a consistent and reliable supply of potable water in the aftermath of a disaster is a challenge

Background Information

- After a natural disaster strikes an area:
  - quick response from national and international government
  - non-government organizations
  - humanitarian assistance
- Low-cost technologies are:
  - designated to improve water quality
  - able to meet the requirement that the World Health Organization (WHO) has identified for sustainable access to improved drinking water in the developing world
- Point-of-use device

Objective

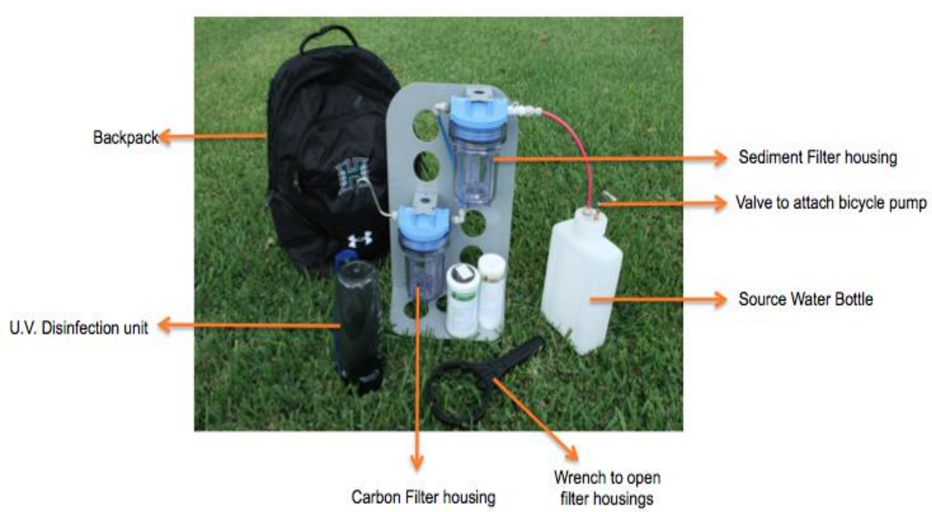
Evaluate the ability of three low cost water purification technologies

1. ***Backpack filter unit*** *(spun polypropylene filter → carbon block filter → UV),*
2. ***UV*** *disinfection unit powered by a* ***solar panel****,*
3. ***Water purifier*** *containing* ***sand*** *impregnated with* ***silver nanoparticles (TATA Swach)***

to enhance the quality of the feed water in the presence of emergency as well as in rural areas

Low cost water purification technologies

Backpack filter unit

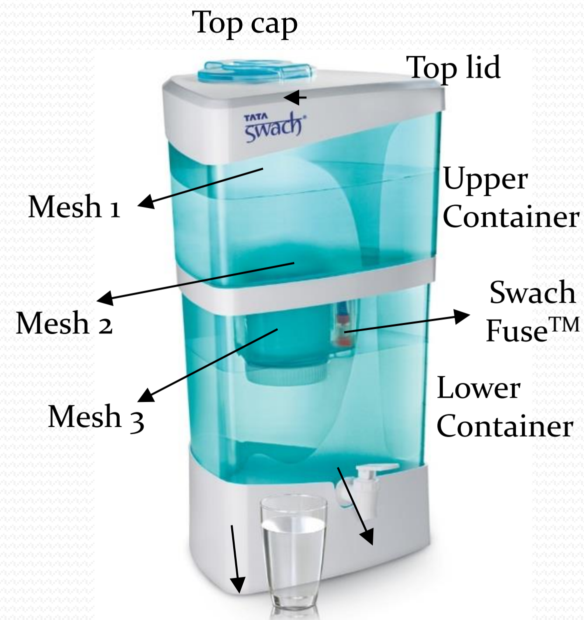


UV - Unit

4" diameter x 20" long PVC pipe
15 W 18" germicidal lamp

Developed at the University of Hawaii

TATA Swach



30 x 57.2 x 28 cm

Commercially available

www.tataswach.com/

Basic disinfection concepts…. (1)

UV…

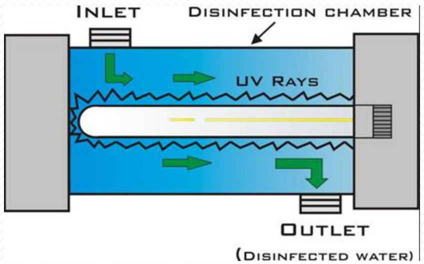
- involves the flow of water through a vessel containing a UV lamp.

- As the water passes through this vessel → microorganisms are exposed to intense UV light energy which causes damage to genetic material (i.e. nucleic acids: DNA or RNA) needed for reproductive functions → prevents the microorganism from multiplying or replicating in a human or animal host.

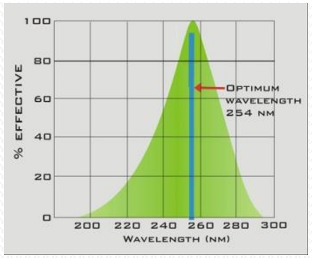
- UV light, λ: 200 to 390 nanometers (nm).

- λ = 254 nm is the most effective l from low-pressure Hg UH lamps for disinfection.

- Disinfection depends on:
  - UV dose
  - Water quality
  - Type of organism



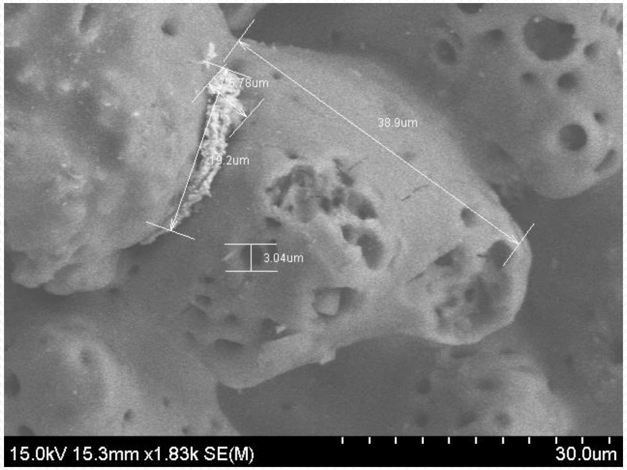
http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1241475412160&lang=eng



Basic disinfection concepts…. (2)

Sand impregnated with Silver nanoparticles …

- involves the flow of water through filters packed with sand impregnated with silver nanoparticles
- It is primarily due to the presence of silver nanoparticles
- It is based on the direct contact between silver nanoparticles and the cell wall of an organism
- The inhibition depends on:
  - Concentration } of silver nanoparticles
  - Shape and size } of silver nanoparticles
  - Initial bacterial number



Preliminary Information

Low cost water treatment	Field – Laboratory study	Location	Type of water
Backpack filter	Field	Thailand	Pond water
			Lake water
UV disinfection powered by a solar panel	Laboratory	Hawaii, USA	Stream water
			Stream water w primary effluent
TATA Swach	Laboratory	Hawaii, USA	Stream water*

*Higher turbidity and higher microbial content compared to typical sources of water recommended by TATA Swach. However, in India…

- the municipal water can be turbid during the monsoon seasons,
- in village areas, pond water may be the source of drinking water,
- stream water may be the only source of water after a disaster

Materials and Methods

- Turbidity
- Total Coliforms (TC) and *E.coli* (EC)

using Colilert 18 with Quanty-Tray 2000

from IDEXX industries

http://www.idexx.com/view/xhtml/en_us/water/colilert-18.jsf?SSOTOKEN=0

- Structure of the filtering media and evaluation of the movement of silver nanoparticles

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Hitachi S-4800 Field Emission Scanning Electron Microscope (SEM) with Oxford INCA X-Act EDX System

Backpack

Parameters	**Feed water**	**Output**	**Thai military standards**
POND WATER			
Turbidity (NTU)	13.4	3.32	< 5
Total coliforms (MPN/100 mL)	2420	45	< 2.2
E. Coli (MPN/100 mL)	2	< 1 (detection limit)	None
LAKE WATER			
Turbidity (NTU)	12	1.75	< 5
Total coliforms (MPN/100 mL)	> 2.420	1	< 2.2
E. Coli (MPN/100 mL)	46	< 1 (detection limit)	None

UV + Solar panel

SOURCE: Manoa Stream

Flow rate (mL/min)	Feed water (MPN/100 mL)	Output (MPN/100 mL)	Reduction (%)
TOTAL COLIFORMS			
55	15800	< 1	100%
170	15800	< 1	100%
285	15800	< 1	100%
E. Coli			
55	1310	< 1	100%
170	1310	< 1	100%
285	1310	< 1	100%

UV + Solar panel

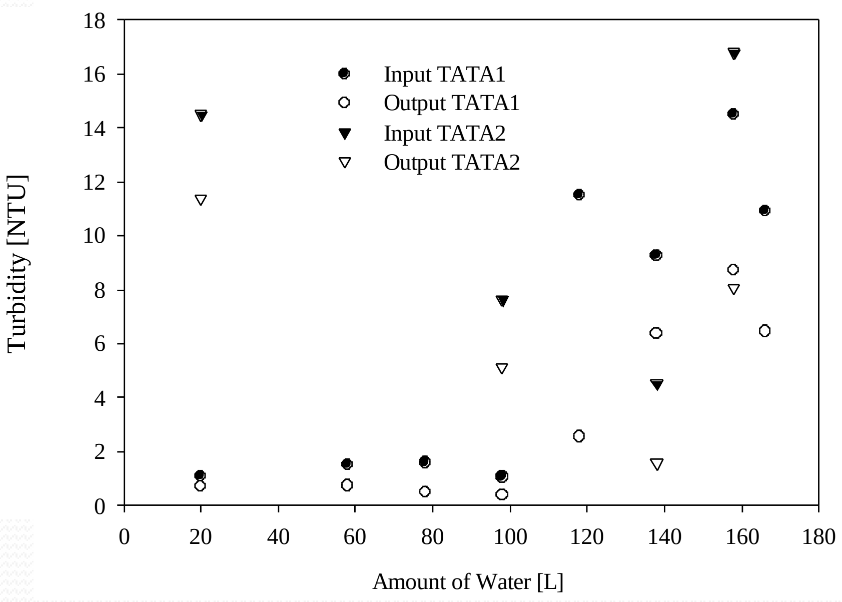
SOURCE: Manoa Stream + 10 % Primary effluent

Flow rate (mL/min)	Feed water (MPN/100 mL)	Output (MPN/100 mL)	Reduction (%)
TOTAL COLIFORMS			
55	82900	< 1	100%
170	82900	< 1	100%
285	82900	1	100%
E. Coli			
55	33600	< 1	100%
170	33600	< 1	100%
285	33600	1	100%

TATA Swach

Operating Conditions

ID	**1st TATA Swach**	**2nd TATA Swach**
Name	TATA1	TATA2
Type of water	Settled	Unsettled
Water added/batch	6L	4L
Starting turbidity	1.3 NTU	14.5 NTU
Range of turbidity	1 – 15 NTU	4 – 17.5 NTU
Operating/ resting time	1/1 hr	1/2 hr



Overall Reduction

- TATA1: 51%
- TATA2: 43%

Removal Efficiency of Total Coliforms

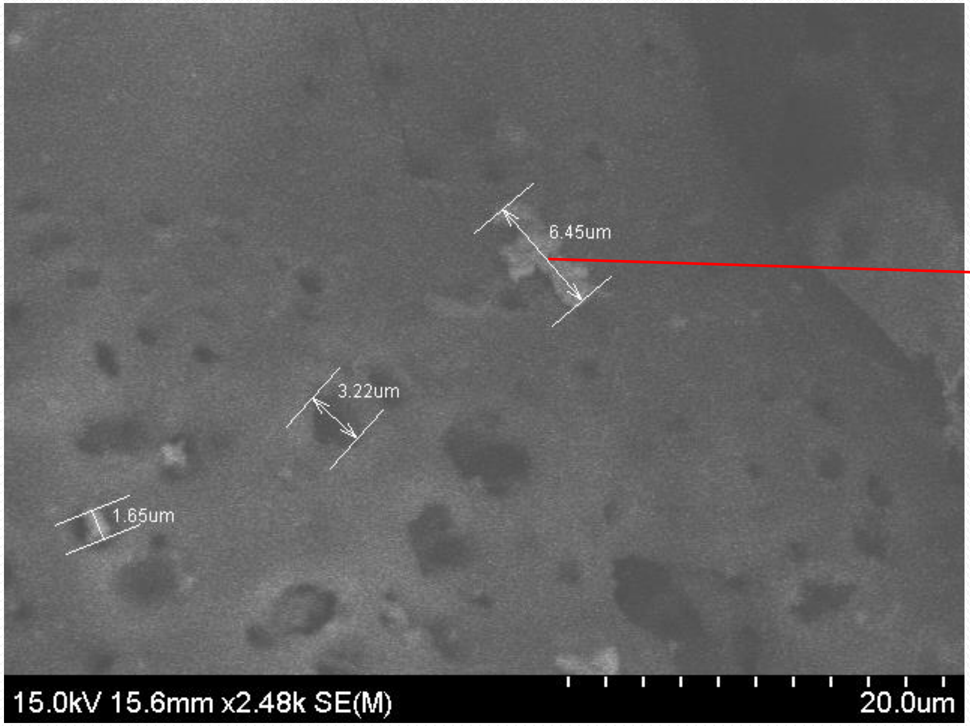
Batch of water (L)	Total Coliforms					
	TATA1			TATA2		
	Input (MPN/ 100 mL)	Output (MPN/100 mL)	Reduction (%)	Input (MPN/100 mL)	Output (MPN/100 mL)	Reduction (%)
20	1050	50.4	95.2	48392	257	99.5
40				28615	1583	94.5
60	908	23.1	97.5	26060	365.7	98.6
80	262	3.1	98.8	6350	224.8	94.5
100				2730	256.7	90.6
120	2934	259.8	91.2	8845	81.45	99.1
140	20224	478.7	97.6	1565	14.9	98.6
160	34465	774.1	97.8			

Removal Efficiency of *E.coli*

Batch of water (L)	*E. coli*					
	TATA1			TATA2		
	Input (MPN/ 100 mL)	**Output** (MPN/100 mL)	**Reduction** (%)	**Input** (MPN/100 mL)	**Output** (MPN/100 mL)	**Reduction** (%)
20	2	2	0	2734	182.7	93.3
40				1800	361.3	79.9
60	10	1	90	1255	90.8	92.8
80	0	0		315	71	77.5
100				342.5	35.8	89.6
120	349	70.4	79.8	398	22.8	94.2
140	2734	267.3	97.6	50	2.55	94.9
160	1800	238.4	97.8			

Impact of Silver nanoparticles

TOP LAYER

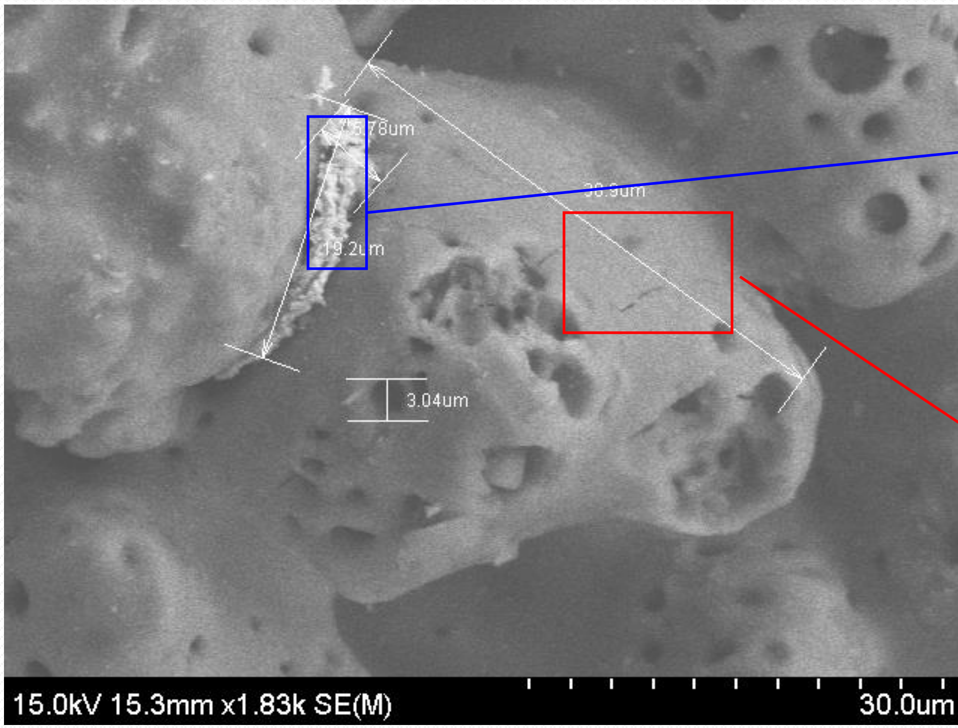


Element	Weight %	Atomic %
C	4.46	10.84
O	33.23	60.59
Si	15.81	16.42
Ag	42.69	11.55
W	3.81	0.61

- Mostly carbon and silica → presence of husk ash and silica sand
- Very few micro- and nano-particles of silver are present

Impact of Silver nanoparticles

Bottom Layer



Element	Weight%	Atomic%
C	10.23	21.65
O	36.06	57.29
Si	12.87	11.65
Ag	38.64	9.11
W	2.19	0.30

Element	Weight%	Atomic%
C	19.89	28.19
O	53.57	57.00
Si	23.74	14.39
K	0.34	0.15
Ag	0.66	0.10
W	1.79	0.17

- Micro- and nano-particles of silver are distributed on the surface of each grain.

Conclusions ....

- Regardless of the feed water, the backpack unit was able to meet the Thai military drinking water standards in terms of turbidity and *E. coli*. In one occasion, the level of Total coliforms exceeded the standards.

- The homemade UV unit was able to treat larger volume of water compared to the other 2 technologies and achieved at least 99% removal of total coliforms, while *E. coli* were constantly removed.

- Local atmospheric conditions highly impacted the bacterial removal.

- The solar panel was not able to provide consistent and adequate power to the UV unit.

- The efficiency of the TATA was limited by the quality and amount of water that passed through it.

Conclusions ....

- Limited amounts of water (140 to 166L) represents only 5.5% and 3.3% of the maximum amount of water* that this POU device should be able to provide.

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The source of water should be settled for a longer period of time prior to use in order to achieve < 1.5NTU.

- The SEM-micrographs showed a decreasing of silver nanoparticles between the top and bottom layer of the filtering unit → wash out

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Due to the specific location of the silver nanoparticles compared to the grains of husk ash

** According to TATA Swach*

Acknowledgments

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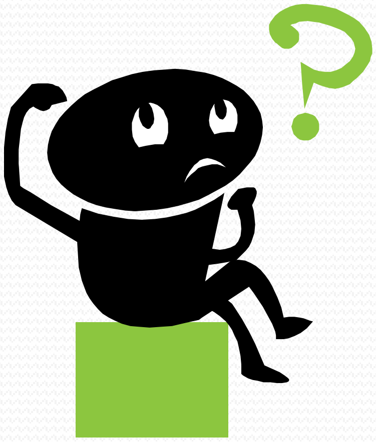
  - National Institute for Water Resources

- We would like to acknowledge Ren Ishii



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