

# Safety of Water Purification using Plastic PET Bottles Coated with TiO<sub>2</sub>

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Presented in partial fulfillment of the requirements for the degree of master of science





# Outline

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- Necessity of clean drinking water
- Disinfection options
- TiO<sub>2</sub> water disinfection advantages
- Safety of production and use
- Storage experiment
- Taste test experiment
- Dye indicator pill test
- Micro-enterprise development
- Conclusions & Recommendations



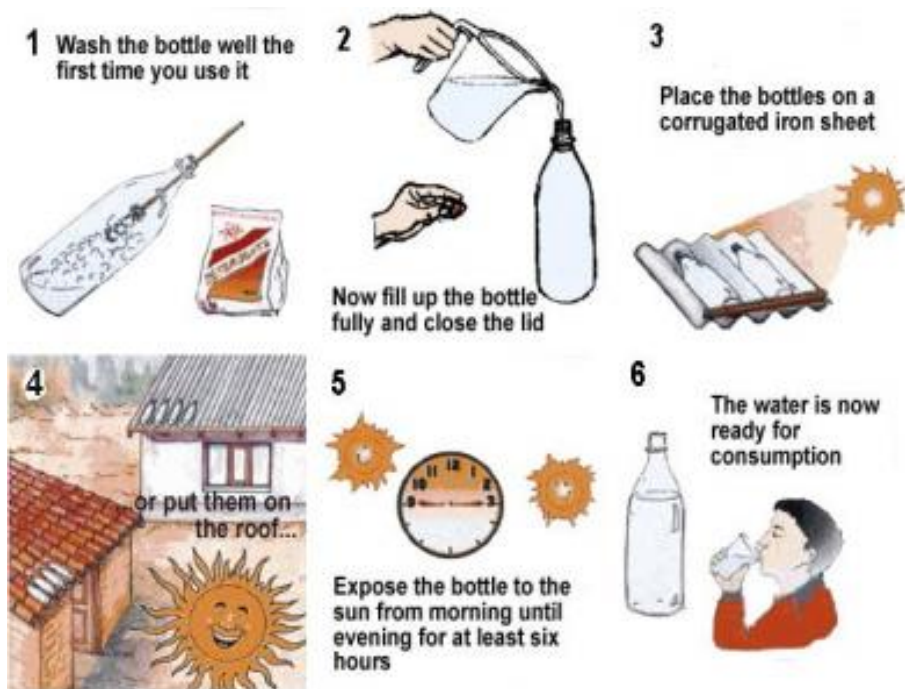
# Necessity for Clean Water in the Developing World

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- Over 1 billion people with no access to clean drinking water
- Estimated 2 to 5 million deaths each year
- Children particularly susceptible
- Decrease in life expectancy

# Water Disinfection Options Available to the Developing World

- Boiling
- Filtration
- Chlorination
- SODIS (Solar Disinfection)



# Development of TiO<sub>2</sub> Photo-Catalytic Method

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- Coating method
- Dye indicator pill
- Development of a safer substitute for perchloric acid





# Advantages of Water Disinfection using $\text{TiO}_2$ Mediated Photo-catalysis

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- More rapid disinfection time
- Storage length
- Degradation of organic molecules including pesticides
- Conversion of arsenite to arsenate and the precipitation of arsenic



# Production and Use Safety of TiO<sub>2</sub> Coated Bottles

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- Bottle coating procedure
- Dye indicator pill production
- Consumption of chemicals used (all are approved food additives)
  - Titanium Dioxide
  - Sodium Acetate
  - Indigo Carmine
  - Hypromellose



# Mean Lethal Dose Analysis

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- LD<sub>50</sub>: dose of a drug which causes mortality in 50% of the population

Chemical	Tested Population	Delivery method	LD <sub>50</sub> (mg/kg)	Max. ingested from one TiO <sub>2</sub> bottle (mg/kg)
Sodium Acetate	mouse	oral	> 6,800	0.32
Titanium Dioxide, P-25	mouse	oral	>10,000	0.8
Indigo Carmine	mouse	oral	> 2,500	0.14
Hypromellose	mammal	oral	>10,000	10.36



# Storage experiment

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- Purpose: to determine if bacteria regrow during storage
- Procedure: coated bottles inoculated with e. coli bacteria, exposed, stored, and tested using coliscan membrane filtration method

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Set	TiO <sub>2</sub> Coating	Dye Indicator Pill	Air space in bottle	Sun exposure	Re-growth anticipated
A	Y	Y	N	Full	N
B	Y	Y	N	Low – cloudy	N
C	Y	N	N	Full	N
D	N	N	N	Full (SODIS)	N < 3 days Y > 3 days
E	Y	Y	Y	Full	Y
F	Y	N	N	None	Y
G	N	N	N	None	Y
H	Y	Y	N	N	Y

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# Storage experiment results

- A few bacteria persist after one day of storage
- No bacteria survival after four days
- No bacteria survival in air bubble

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Storage Period (days)	E. Coli Concentration (cfu/100mL)						
	1	4	11	40	110	190	360
A	5	0	0	0	0	0	NA <sup>°</sup>
B	0	0	0	0	0	0	NA
C	9	0	0	0	0	0	NA
D	4	0	0	0	0	0	NA
E	7	0	0	0	0	0	NA
F	TMC*	TMC	TMC	TMC	0	0	NA
G	TMC	TMC	TMC	TMC	0	3	NA
H	TMC	TMC	TMC	TMC	0	0	NA

\*TMC = Too Many to Count

<sup>°</sup>NA = Data Not Yet Available



# Secondary Storage Test

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- Tested consistency of original results
- Confirmed the persistence of bacteria shortly following disinfection

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	E. Coli Concentration (cfu/100mL)				
Storage Period (days)	0	1	2	3	4
A	12	0	0	0	0
D	0	0	0	0	0

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## Taste test

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- Purpose: to determine if the method imparts a distinguishable taste on the disinfected water
- Tasters sampled from three cups
- Two cups contained spring water and one contained disinfected water
- Samplers were asked to choose the sample they felt was different from the other two



# Taste test results

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- Sample A contained the disinfected water
- 8 out of 15 tasters selected sample A
- Cumulative binomial distribution gives the probability that random guessing would produce greater than or equal to a certain number of successes

$$\sum_y^n \frac{n!}{y!(n-y)!} p^y (1-p)^{n-y}$$

- A commonly accepted probability for statistical significance is 5%



## Taste test results (cont.)

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- 8 samples has a cumulative probability of 8.8%
- The results suggest that tasters may have been able to distinguish the difference, but the results were not statistically significant
- 3 tasters preferred the taste of the disinfected water to the spring water
- None of the tasters found the taste of the disinfected water displeasing



# Dye Indicator Pill Testing

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- Current characteristics
  - Fragile
  - Dissolves incompletely in water
- Experimental pills tested
  - Pills created based on constituents found in common medicine such as aspirin

	Pill #1	Pill #2	Pill #3
Indigo Carmine	1.3%	1.3%	1.3%
Hypromellose	38.7%	48.7%	58.7%
Lactose	50%	40%	30%
Starch	10%	10%	10%

- Test pill results
  - Dissolved completely
  - Still fragile

# Micro-enterprise development

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- Bottle production instructional guide
  - English and Spanish versions
- Local interest
  - SODIS already practiced in some towns
- Partnership organizations
  - Puerto Saludable





# Conclusions & Recommendations

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- Bacteria do not regrow during storage, however some bacteria persists after 1 day
- Bottles should be stored for 2 days prior to consumption
- Degradation pathways and times to mineralization should be determined to ensure safety
- The method does adversely affect water taste



# Acknowledgements

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# Questions???

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