SIMPLE AND RELIABLE TESTS THAT HOMEOWNERS CAN USE TO DETERMINE THE MICROBIAL DRINKING WATER QUALITY OF RAINWATER COLLECTED FROM ROOFS AND STORED IN CISTERN TANKS

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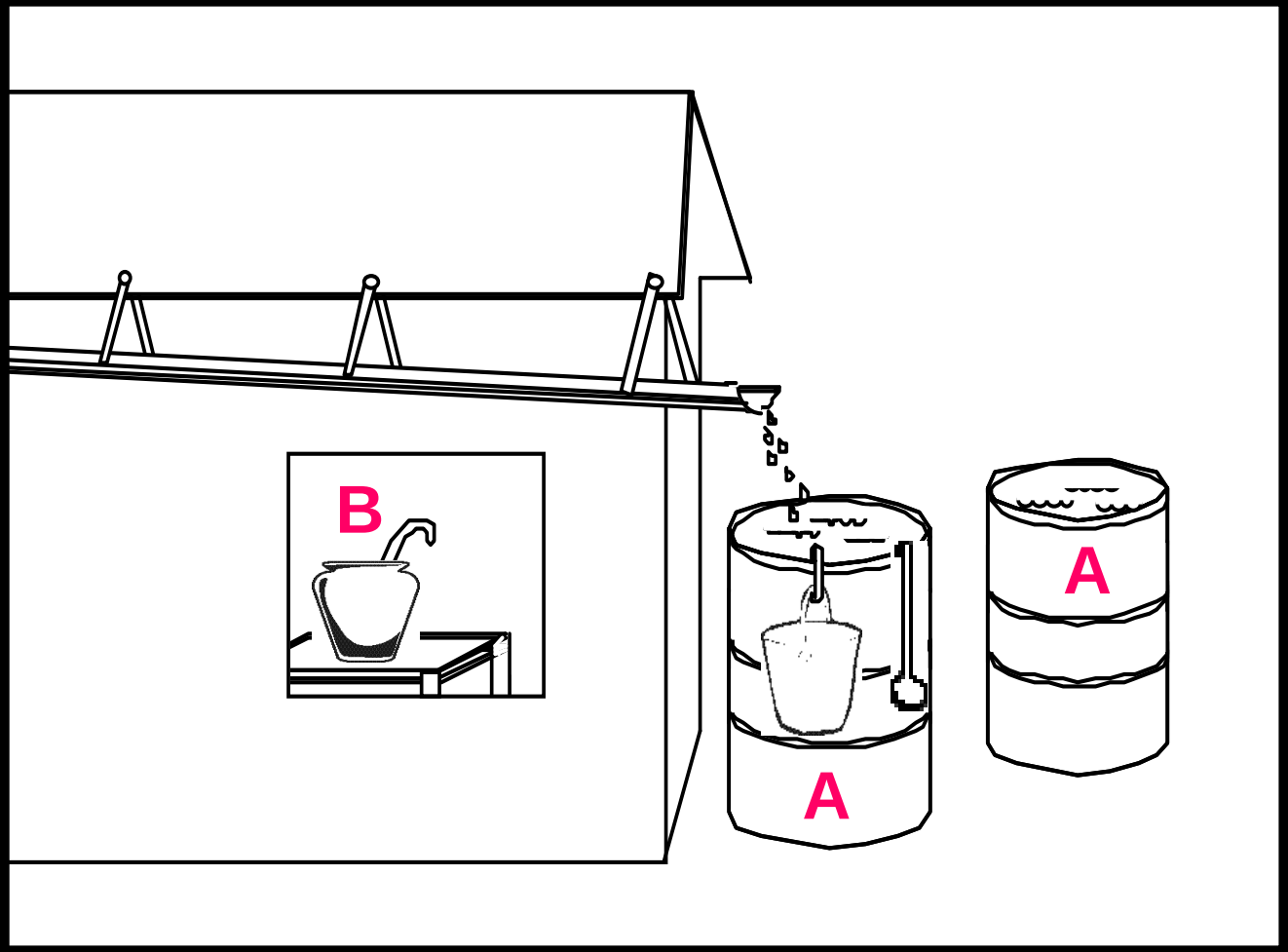
INTRODUCTION

- **For some households, collecting rainwater is the most feasible means of obtaining water for all their household needs.**
- **These households use roof rainwater catchment system (RRCS).**
  - **Roof: Catchment area to collect rain**
  - **Gutters/downpipes: To transport water**
  - **Cisterns or tanks: To store water**

WATER FROM RRCS

- A private source. Not regulated.
- Quality Not monitored. Not required.
- Susceptible to contamination:
  - Cannot meet drinking water standard of 0 coliform/100 ml.
  - May be contaminated with fecal borne pathogens.
- Degree of susceptibility due to design, construction and maintenance of RRCS.

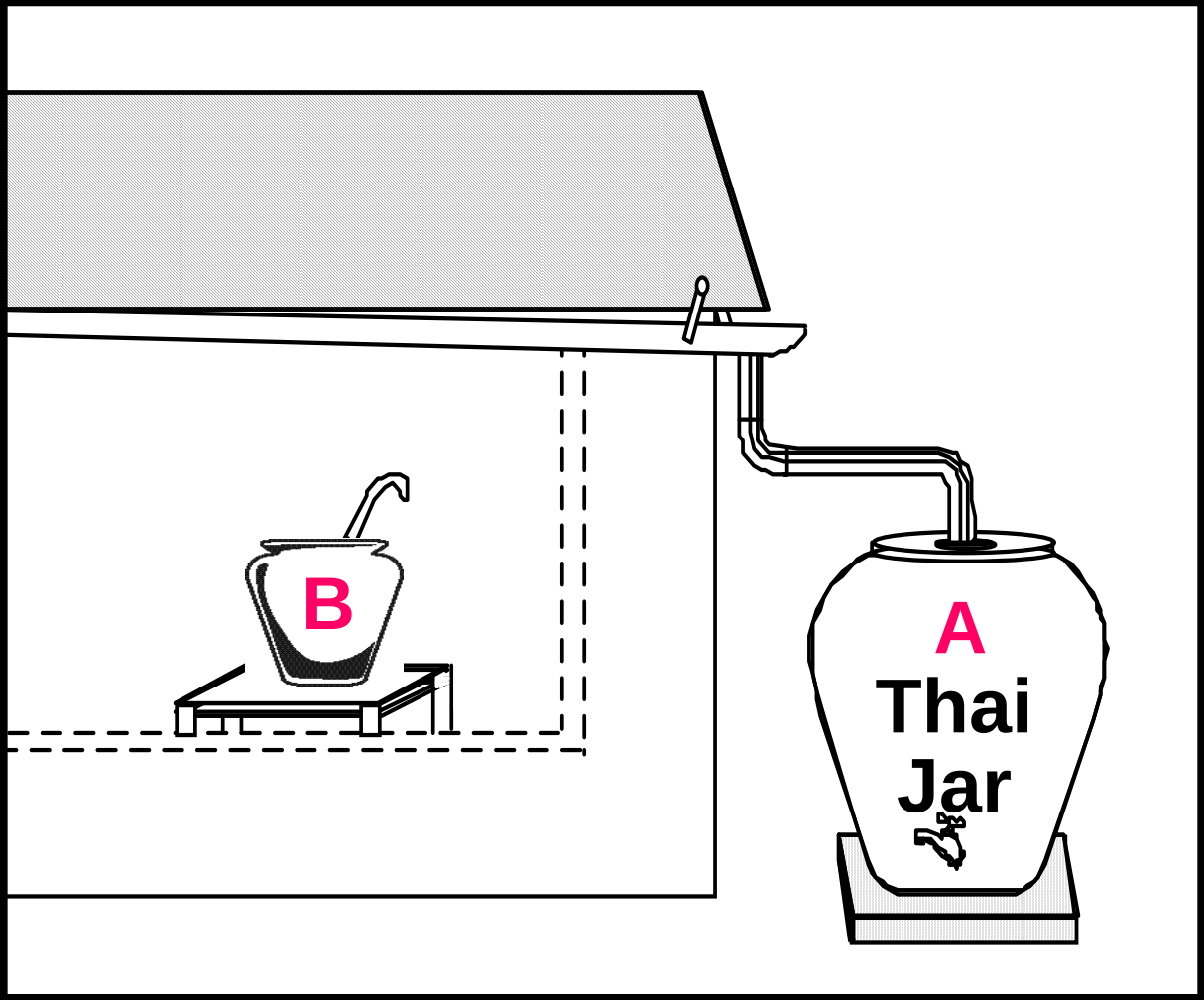
Minimally Designed RRCS in Under-Developed County: Highly Susceptible to Contamination



CHARACTERICIS OF MINIMALLY DESIGNED RRCS IN DEVELOPING COUNTRIES

- **Example: Very remote and poor area.**
- **Homeowners have limited resources: Money electricity, piped water, supplies, education.**
- **Hygienic conditions: Poor.**
- **Country environmental regulations: Not established/implemented.**

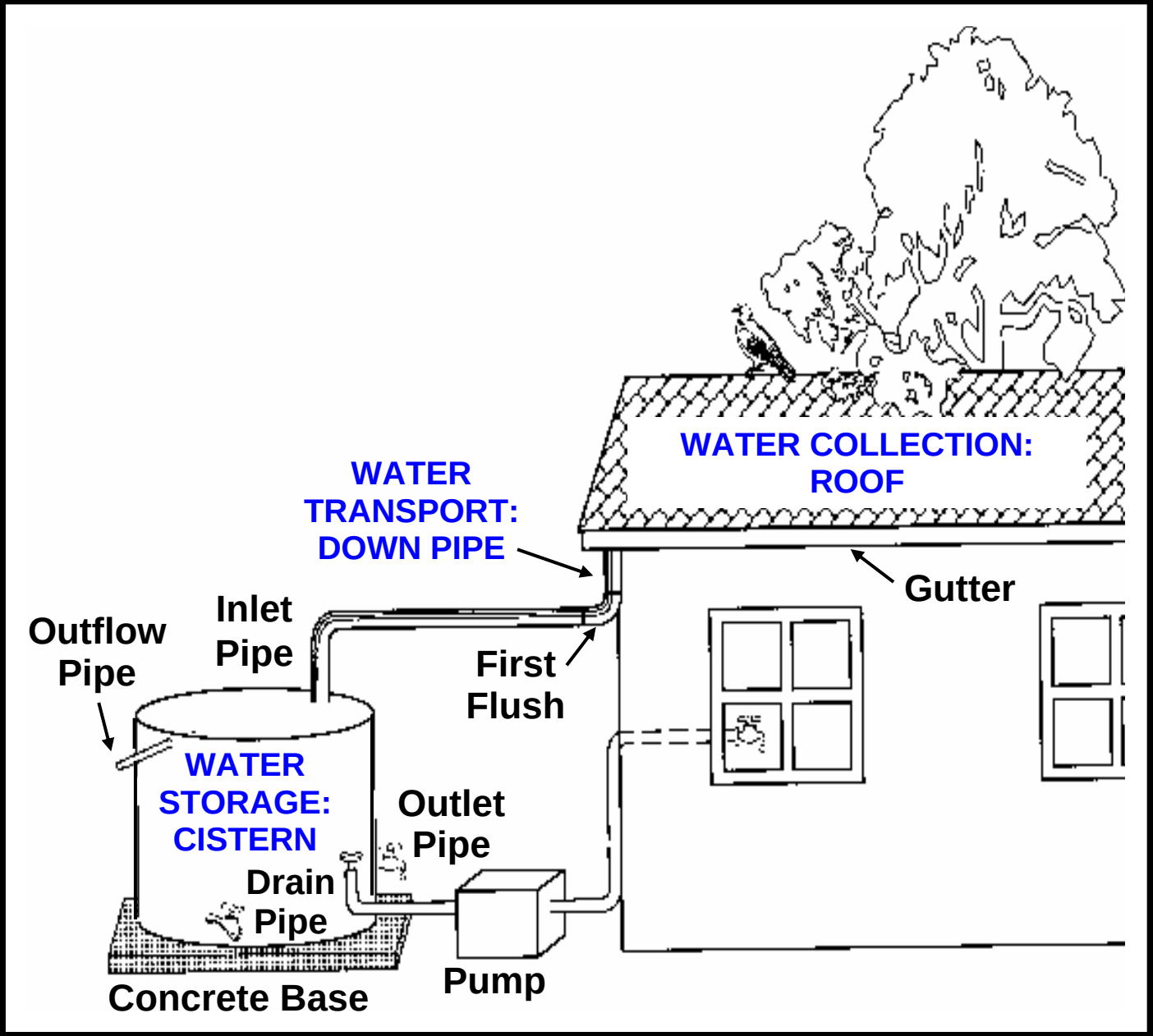
Well-Designed RRCS for Developing Countries: Moderately Susceptible to Contamination



RRCS (Thai jar) in Thailand

CHARACTERISTICS OF RRCS IN DEVELOPING COUNTRIES

- **Examples: Asia (Thailand), Africa.**
- **Homeowners have few resources: Money, electricity, piped water, supplies, education.**
- **Hygienic Conditions: Compromised.**
- **Country environmental regulations: Usually inadequate and not protective.**



Best designed RRCS: Minimally susceptible to fecal contamination. Few animals have access to roof.

CHARACTERISTICS OF RRCS IN DEVELOPED COUNTRIES

- **Examples: Virgin Island, Kentucky, Hawaii.**
- **Homeowners have resources: Money, electricity, piped water, supplies, education.**
- **Hygienic Conditions: Very good.**
- **Country environmental regulations: Established and protective.**

GOALS FOR TODAY'S PRESENTATION

1. **To review problems and solutions to improve microbial quality of water collected by well-designed RRCS at private homes and used for potable and other household needs.**
2. **To report on a new homeowners test for total coliform and *E. coli*, which meets EPA/WHO guidelines for drinking water quality standards.**

PROBLEM 1: Water From RRCS Contain High Concentrations of Fecal Indicator Bacteria (Coliform, *E. coli*)

1. All RRCS susceptible to contamination by fecal indicator bacteria.
2. Poorly designed and operated RRCS: Chance of water contamination by fecal borne pathogens is high.
3. Well designed RRCS: Water may exceed public drinking water standards, but relatively safe to consume and better than many surface and shallow well sources.

Fecal Coliform Contamination in Water From RRCS

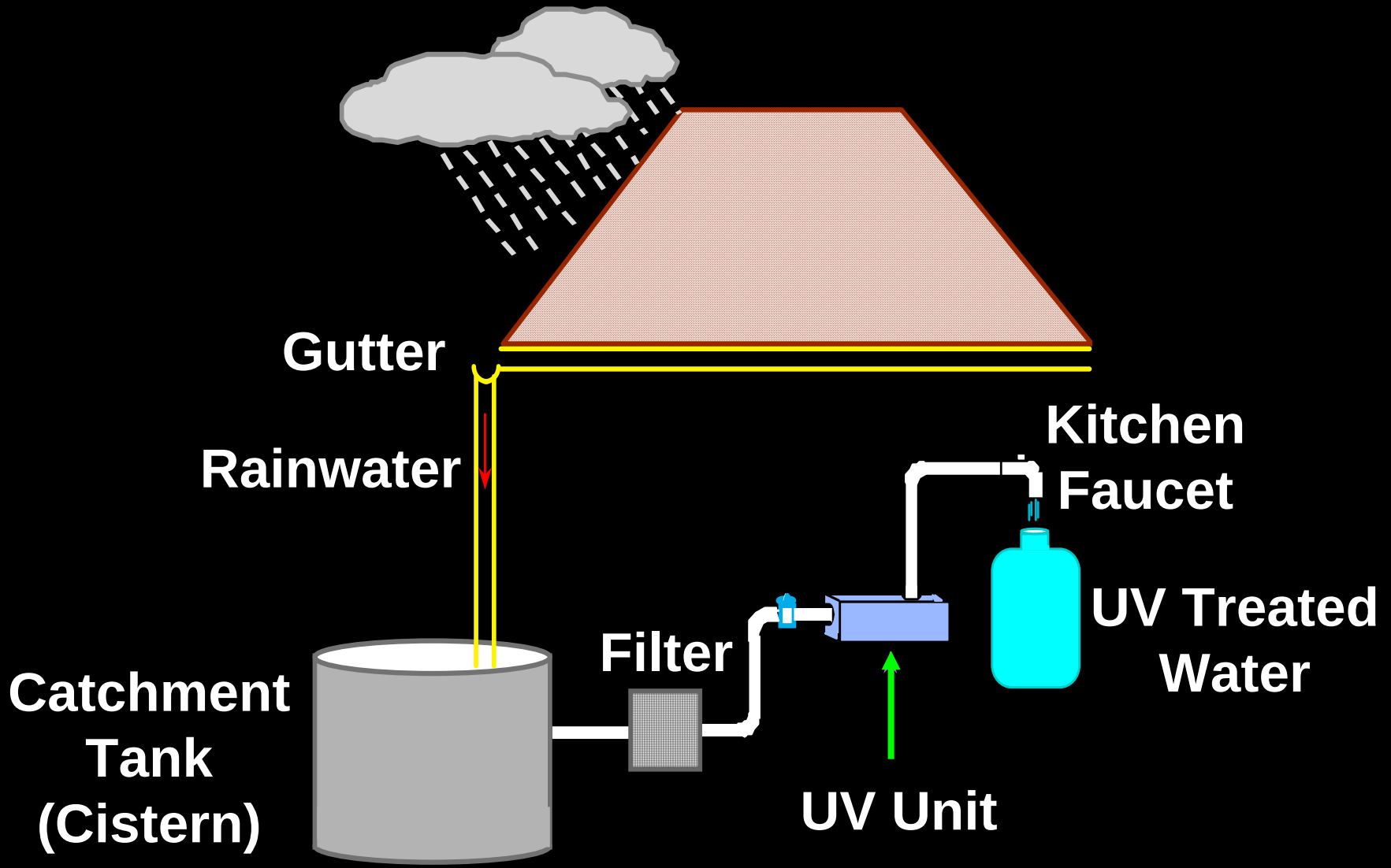
LOCATION	NO. OF SYSTEMS	% POSITIVE FECAL COLIFORM	FECAL COLIFORM CFU/100 ml
	— (CFU/100 ml in Household Tap Water) —		
Micronesia	203	29	0–100
Kentucky	30	3	0–20
U.S. Virgin Islands	17	59	0–40
Hawaii (Fujioka, 1991)	9	89	0–4800
Thailand	86	40	0–100
Australia	6	83	0–130
U.S. Virgin Islands	14	36	0–770

Modified from Lye, 2002.

SOLUTION: DISINFECT CISTERN WATER WITH UV TREATMENT SYSTEMS

- **Water from RRCS should be disinfected to kill pathogens, which may be present.**
- **Strategy to chlorinate water in cistern tank is not effective and taste unacceptable to homeowners.**
- **UV treatment of cistern waters, <u>especially water to be used for drinking</u>, can effectively reduce microbial load in water without affecting taste. Acceptable to homeowners.**

UV Treatment of RRCS Water: Kitchen Faucet (Rijal and Fujioka, 1992)



Ultraviolet treatment system installed in kitchen

Concentration of Indicator Microorganisms Recovered From Cistern 6 Water Sample Before UV Treatment (BUV) and After UV Treatment (AUV)

SAMPLES	CFU/100 ml									
	WEEK 1		WEEK 2		WEEK 3		WEEK 4		WEEK 5	
	BUV	AUV	BUV	AUV	BUV	AUV	BUV	AUV	BUV	AUV
Fecal coliform	476	0	140	0	272	0	216	0	328	0
E. coli	412	0	152	0	216	0	176	0	280	0
C. perfringens	0	0	0	0	0	0	0	0	0	0
Enterococci	20	0	126	0	126	0	69	0	123	0
TB (CFU/ml)	3400	3.04	4000	0.21	5200	2.6	536	4.32	22400	1.8

Data From Rijal and Fujioka, 1992.

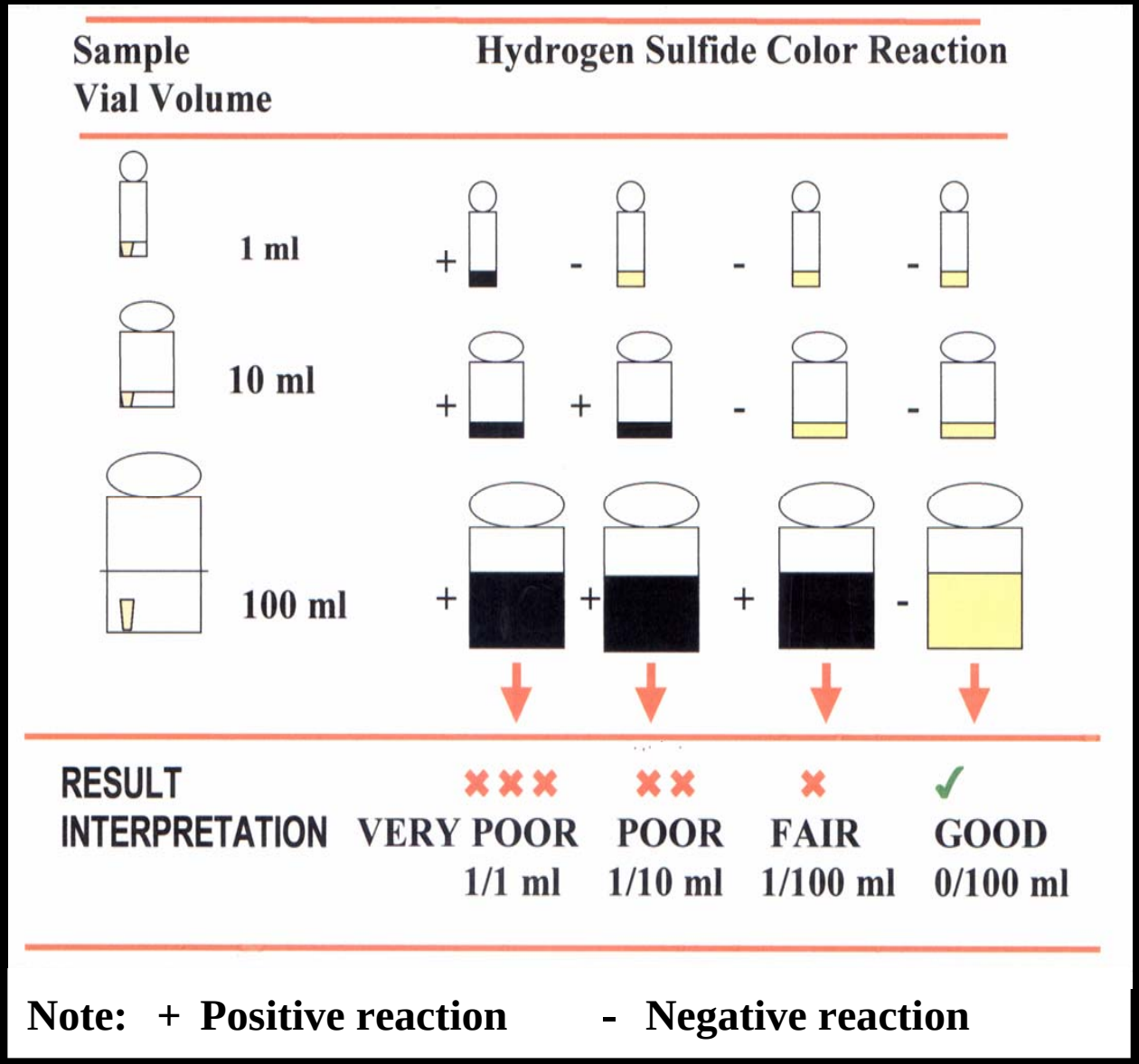
PROBLEM 2: NO FEASIBLE WATER QUALITY TEST FOR HOMEOWNER

- **EPA/WHO drinking water sources/guidelines do not include roof catchment systems.**
- **EPA/WHO standardized tests for total coliform, fecal coliform and *E. coli* are too demanding (skill, equipment) for homeowner.**
- **EPA/WHO drinking water standard (0 coliform 100 ml) is unrealistic for water from RRCS.**

INTERIM SOLUTION: HYDROGEN SULFIDE BACTERIA TEST

- **This test is simple, requires minimum supplies: Can be completed by homeowner.**
- **Measures for hydrogen sulfide bacteria, as surrogate for coliform and *E. coli* bacteria.**
- **Rijal & Fujioka (1995) study showed this test is reliable and feasible for homeowner.**
- **This test now commercially available.**
- **Although this test provides reliable data for water quality and effectiveness of disinfectant, this method was not approved by EPA/WHO.**

Study design for hydrogen sulfide test



Results of Hydrogen Sulfide Test at Cistern 4

Week	CFU/100 ml					24 hr (25°C) H_2S (MPN)			
	MI Agar		mTEC	H_2S Agar	mHPC				
	TC	EC	EC	H_2S	TB	1 ml	10 ml	100 ml	Quality
1	108	56	54	38	240000	–	–	+	Fair
2	172	28	30	48	183860	–	–	+	Fair
3	1560	520	252	218	4800000	–	+	+	Poor
4	5000	4400	1600	820	920000	–	+	+	Poor
5	3560	840	720	410	1560000	–	+	+	Poor
AVG	2080	1169	531.2	306.8	1540772	–	–/ +	+	Poor
GM	875.99	313.2	216.01	167.96	788080	–	– / +	+	Poor

CURRENT PROBLEM: HOMEOWNERS NEED AN EPA APPROVED TEST FOR WATER QUALITY

- **Test must be EPA/WHO approved for coliform and *E. coli*.**
- **Test must use reagents and incubator approved by EPA/WHO.**
- **Test must be commercially available, simple and standardized for use at home.**
- **Test must be safe and feasible for homeowner.**

SOLUTION: AQUASURE PRO 3000 (EPA Approved Test Designed for Homeowners for Total Coliform and *E. coli*)

- **Manufactured by OBIE International (Canada).**
- **Test uses EPA approved growth medium (Readycult) to detect total coliform and *E. coli*.**
- **Test uses EPA approved individual incubator, powered by battery or electricity.**
- **All components: Selective medium, sampling bottles UV light and incubator are available.**
- **Test and color reaction designed for homeowner to detect total coliforms and *E. coli* in water samples.**

Procedure for ReadyCult®/Aquasure Pro 3000

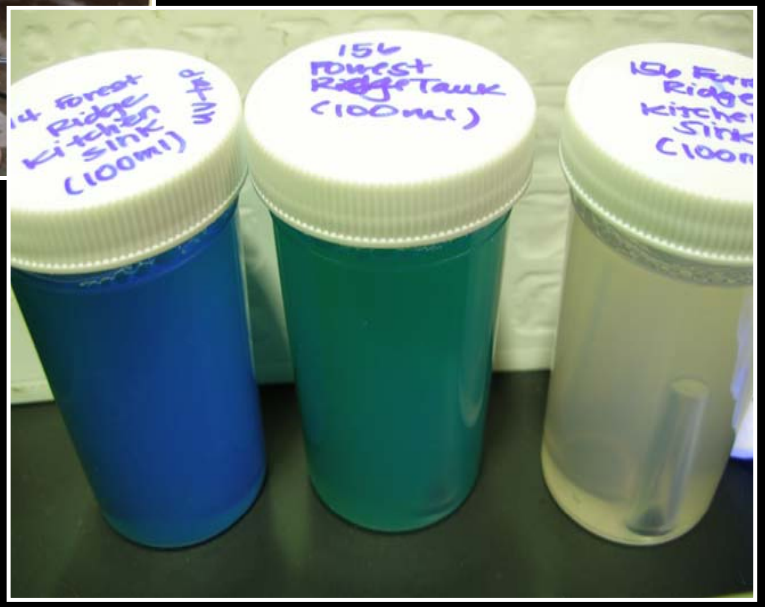
Add media to sample

Incubate sample 35ºC for 24 hr

Blue-Green reaction: Positive for coliform

Blue Fluorescence reaction: Positive for *E. coli*

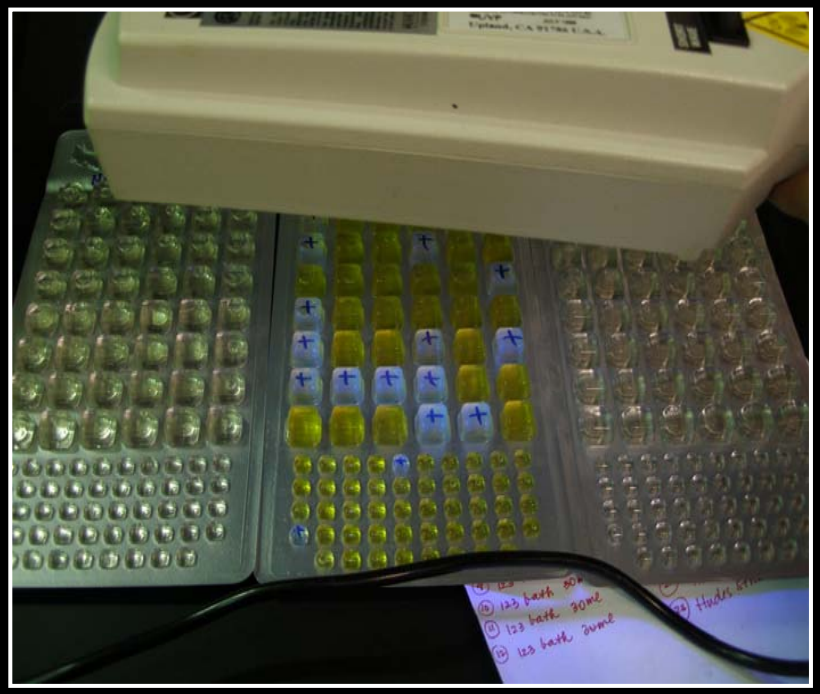
Aquasure Pro 3000: Sample, incubator, color reaction for coliform / *E. coli*



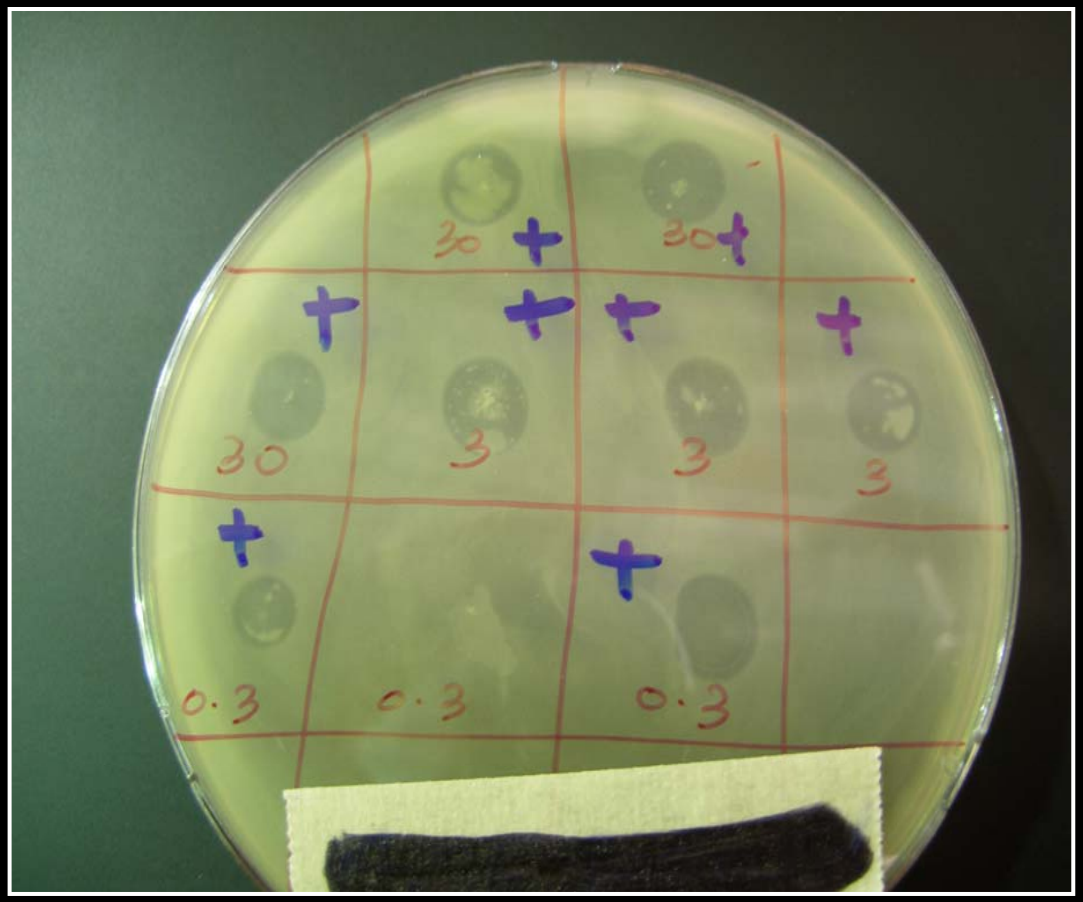
OBJECTIVES OF CURRENT STUDY

- **To evaluate reliability of Aquasure Pro 3000 and feasibility for homeowner use.**
- **To compare results of Aquasure Pro 3000 test with other EPA approved tests (Colilert) for coliform and *E. coli*.**
- **To characterize RRCS water samples based on additional tests for total bacteria (general quality) and for FRNA coliphage test (new test for fecal contamination).**

EPA approved Colilert test



FRNA plaque assay



Experimental Design to Evaluate Use of Aqua Pro 3000

- **Analyze water at 15 households using RRCS.**
- **Homeowner instructed in use of Aquasure Pro 3000.**
- **Sample incubated at owners home for 24 hrs. Then results read with homeowner.**
- **Aliquot samples taken to UH lab and assayed for total coliform, *E.coli*, FRNA coliphage, and total bacteria using EPA approved laboratory tests.**

Table 1. Concentrations of Fecal Indicator Microorganisms in Untreated Water from Cistern Tank and in Non-Disinfected (ND) Water From Household Faucets

HOUSEHOLD ID SAMPLE SITE	AQUASURE PRO 3000 +/– / 100 ml		COLILERT-18 MPN/100 ml		COLIPHAGE MPN/100 ml FRNA	MEMBRANE FILTRATION CFU/100 ml TOTAL BACTERIA
	Coliform	*E. coli*	Coliform	*E. coli*		
ND-1 Cistern Tank	+	–	345	<1	4	33,152
Bath Faucet (100 ml)	+	+	323	1	1	5,152
Bath Faucet (10 ml)	+	+	†	†	†	†
Kitchen Faucet	+	–	255	1	<1	5,088
ND-2 Cistern Tank	+	–	<1	<1	<1	396
Kitchen Faucet	+	+	<1	<1	<1	532
ND-3 Cistern Tank	+	+	39	3	1	3,936
Kitchen Faucet	+	+	<1	<1	4	2,592
Kitchen Faucet*	+	+	<1	<1	7	728
ND-4 Cistern Tank	+	–	3	<1	1	3,640
Kitchen Faucet	+	–	2	1	<1	5,120

* Special filter used at kitchen sink; † not assayed.

Table 1 (continued) — Concentrations of Fecal Indicator Microorganisms in Untreated Water from Cistern Tank and in Non-Disinfected (ND) Water From Household Faucets

HOUSEHOLD ID SAMPLE SITE	AQUASURE PRO 3000 +/– / 100 ml		COLILERT-18 MPN/100 ml		COLIPHAGE MPN/100 ml FRNA	MEMBRANE FILTRATION CFU/100 ml TOTAL BACTERIA
	Coliform	*E. coli*	Coliform	*E. coli*		
ND-5 Cistern Tank	+	–	>2,419	<1	<1	14,080
Kitchen Faucet	+	–	12	<1	<1	8,360
ND-6 Cistern Tank	+	+	>2,419	1,203	1	38,880
Kitchen Faucet	–	–	<1	<1	<1	440
ND-7 Cistern Tank	+	+	1,300	299	3	46,720
Kitchen Faucet	+	–	11	0	<1	6,920
ND-8 Cistern Tank	+	+	>2,419	1,203	<1	27,360
Kitchen Faucet	+	+	>2,419	1,203	50	13,120
ND-9 Cistern Tank	+	+	>2,419	< 2,419	<1	23,360
Kitchen Faucet	+	+	1,300	867	<1	9,280
Kitchen Faucet*	–	–	<1	<1	1	60,160

* Special filter used at kitchen sink.

Table 2. Concentrations of Fecal Indicator Microorganisms in Untreated Water from Cistern Tanks and in UV Disinfected (UVD) Water From Household Faucets

SAMPLE SITE HOUSEHOLD ID	AQUASURE PRO 3000 +/– / 100 ml		COLILERT-18 MPN/100 ml		COLIPHAGE MPN/100 ml FRNA	MEMBRANE FILTRATION CFU/100 ml TOTAL BACTERIA
	Coli-form	*E. coli*	Coli-form	*E. coli*		
Cistern Tank	+	+	>2,419	20	3	14,336
UVD-1 Kitchen Faucet	–	–	<1	<1	4	1,476
Cistern Tank	+	+	>2,419	6	1	27,040
UVD-2 Kitchen Faucet	+	+	16	<1	<1	5,840
Cistern Tank	+	+	>2,419	38	370	23,040
UVD-3 Kitchen Faucet	–	–	2	<1	4	<4
Cistern Tank	–	–	<1	<1	<1	524,160
UVD-4 Kitchen Faucet	–	–	2	<1	<1	4,560
Cistern Tank	+	+	378	64	3	16,280
UVD-5 Kitchen Faucet	–	–	<1	<1	<1	1,600
Cistern Tank	+	+	172	1	<1	53,760
UVD-6 Kitchen Faucet	–	–	<1	<1	<1	40

Table 3. Concentrations of Fecal Indicator Microorganisms from Possible Sources of Contamination

SAMPLE SITE	AQUASURE PRO 3000 +/– / 100 ml		COLILERT-18 MPN/100 ml or per 100 g		COLIPHAGE MPN/100 ml FRNA	MEMBRANE FILTRATION CFU/100 ml TOTAL BACTERIA
	Coliform	*E. coli*	Coliform	*E. coli*		
Rainwater flowing from roof of home	+	–	>2,419	2	<1	125,440
Rainwater flowing on driveway near home	+	+	>241,920	6,950	80	>525,160
Soil near home	not done	not done	>2,419,200	5,200	not done	not done

SUMMARY/CONCLUSION

- **Well-designed RRCS are good sources of alternative water supply and provide relatively safe water.**
- **Water from RRCS are susceptible to contamination and often contain concentrations of fecal indicator bacteria, which exceed EPA/WHO drinking water standards.**
- **Water from RRCS are at risk from contamination by disease causing pathogens. However, risk is relatively low because humans and large mammals that carry most pathogens do not have access to roofs of homes.**

CONCLUSION

- **Disinfection and monitoring of water from RRCS are needed to ensure safety of water used by homeowners.**
- **UV disinfectant systems effectively reduce microbial load in water collected by RRCS.**
- **Aquasure Pro 3000 is an EPA approved, commercially available and feasible homeowner test for coliform and *E. coli*. This test can determine effectiveness of treatments (special filters, UV systems) used by homeowner. Contact: www.OBIECorp.com**