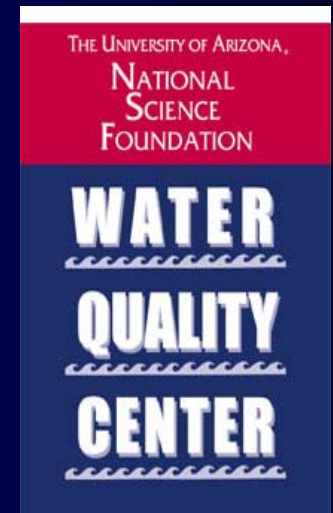


Graywater Systems and Use

Charles P. Gerba

Department of Soil, Water,
and Environmental Science

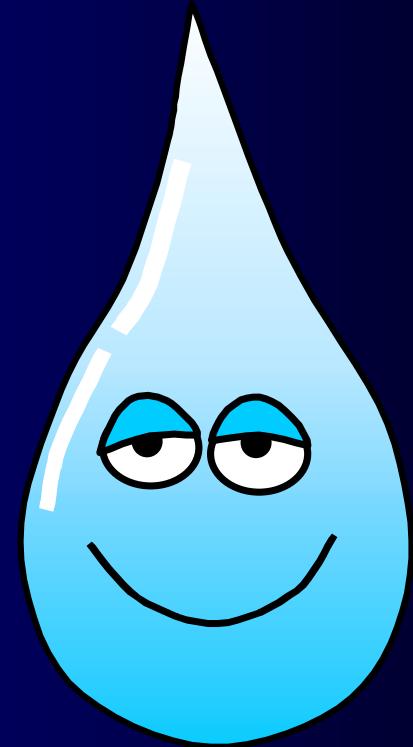
University of Arizona



What is Graywater?

Water collected from:

- ❖ **Bathroom sinks**
- ❖ **Kitchen sink**
- ❖ **Bathtubs and showers**
- ❖ **Washing machine**



State of Arizona Standards for Graywater Reuse for Irrigation

Fecal coliforms

Geometric mean
of 25, single
sample not to
exceed 75

Chlorine residual

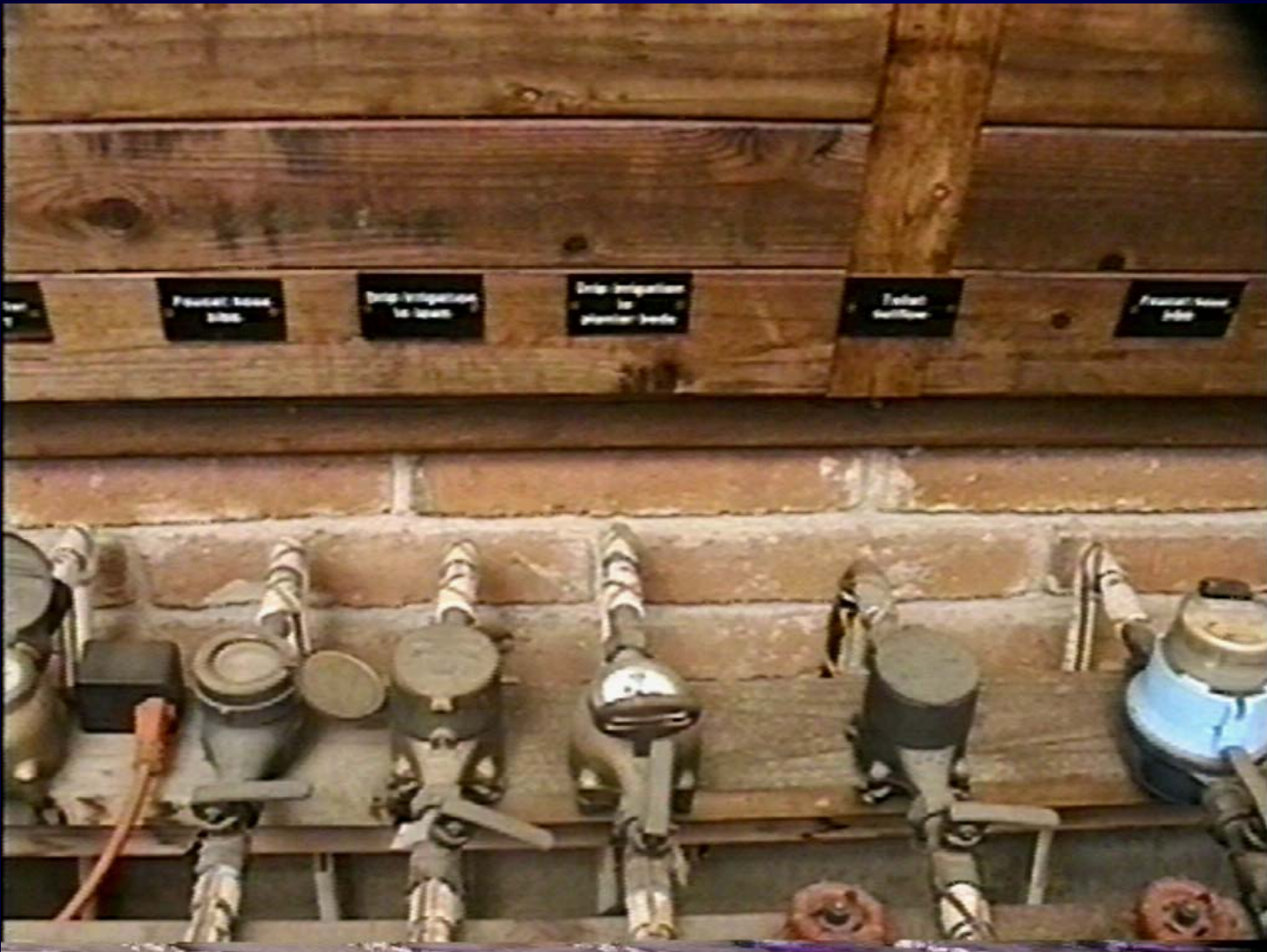
20 mg/L

Samples required

Series of 5 in one
calendar month;
one sample
series per year



The Casa del Agua



Graywater is piped from the household drains...



and goes into a holding tank.

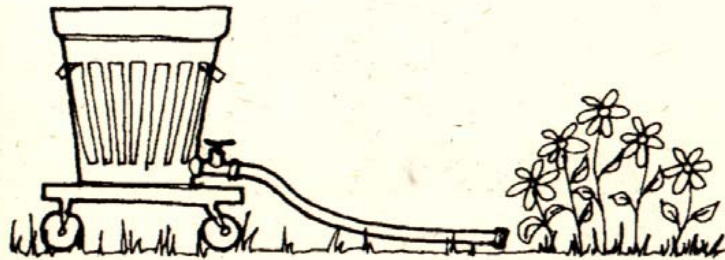
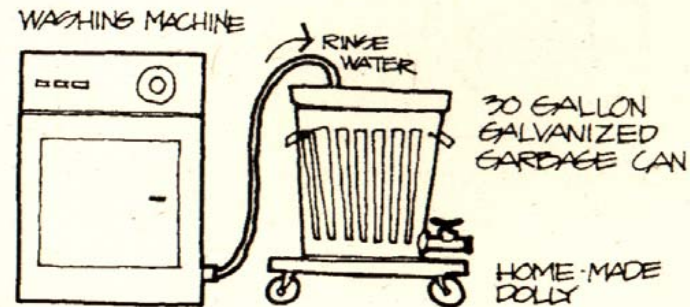


It is reused to water the landscaping.

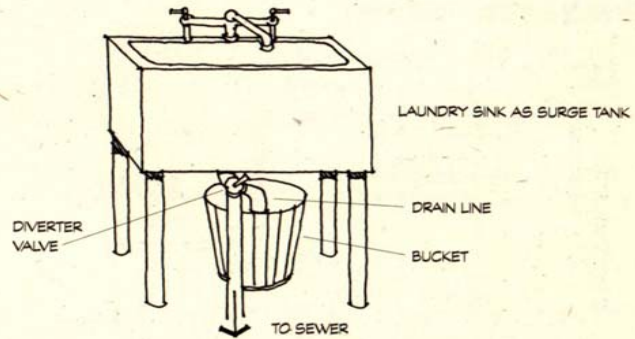
SAMPLE SYSTEMS

The following graphics are provided to convey the wide variety of systems that can be designed for retrofitting a home and to help you design and install your own system.

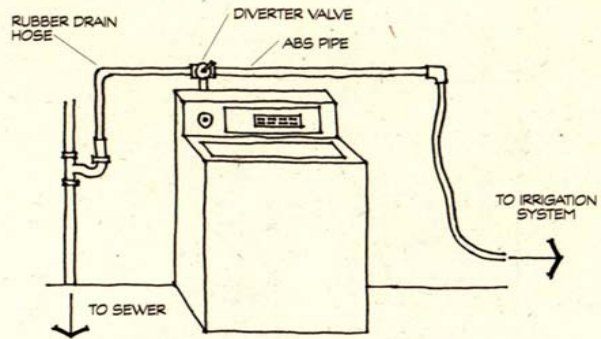
Gravity System



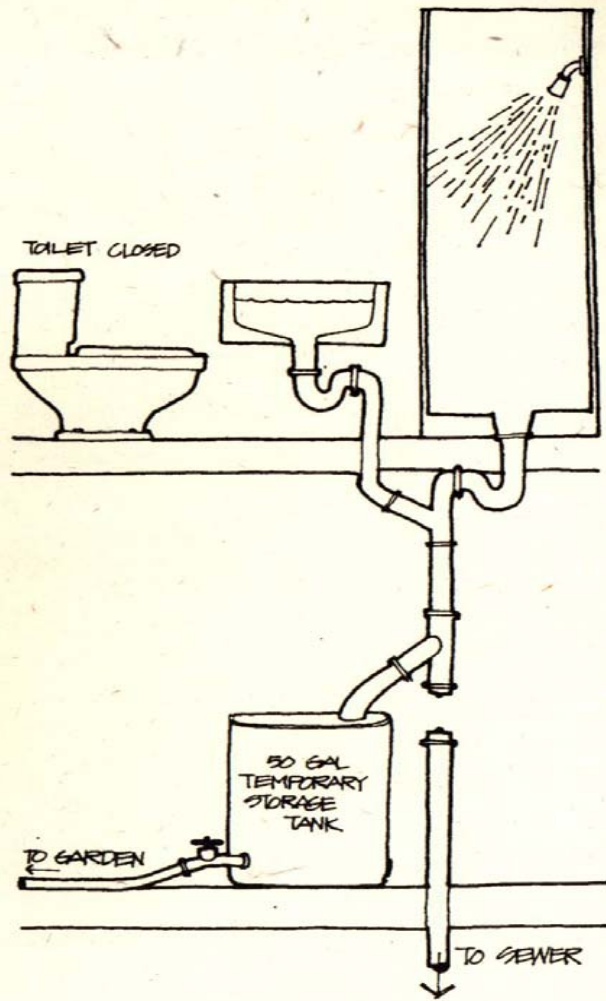
Gravity System with Portable Tank



Bucket Graywater System



Hose Attachment Graywater System



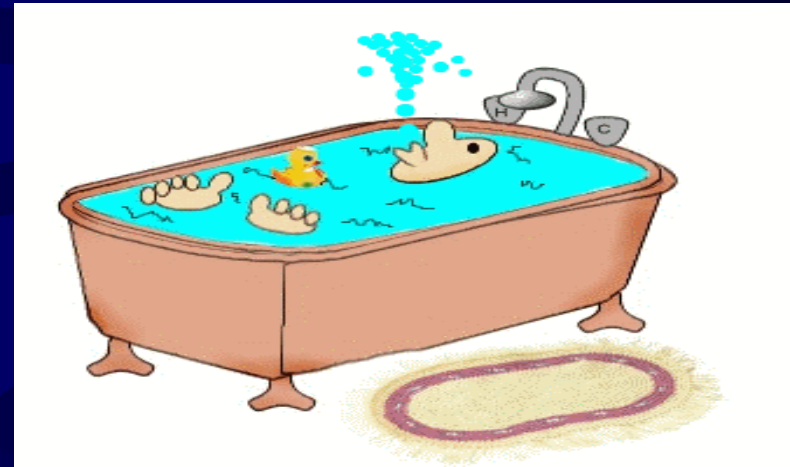
Graywater Collection from Second Story

Graywater Use In Pima County, Arizona

- 20,000 to 30,000 households may be using graywater
- These households involve 50,000 to 80,000 persons (Tucson, AZ - population of 900,000)

Sources of Graywater/Pima County, AZ

- Bathroom tubs / showers - 15%



- Bathroom sinks - 5%



Sources of Graywater/Pima County, AZ

Kitchen sinks - 10%



Clothes washer - 66%



Other - 4%

Occurrence of Coliforms and Fecal Coliforms in Wash Water After Laundering

Type of Clothing	Coliform Arithmetic Average		Fecal Coliform Arithmetic Average	
	Washer Load	Per Item	Washer Load	Per Item
Underwear	5.2×10^6	4.5×10^5	5.6×10^5	7.4×10^4
Jeans	7.2×10^5	1.07×10^5	1.5×10^4	2.24×10^3
Bath Towels	1.2×10^6	1.77×10^3	$<1.6 \times 10^4$	ND

How Graywater is used in Pima County ,AZ



- **Ornamental trees – 32%**
- **Shrubs - 19%**
- **Grass - 14%**

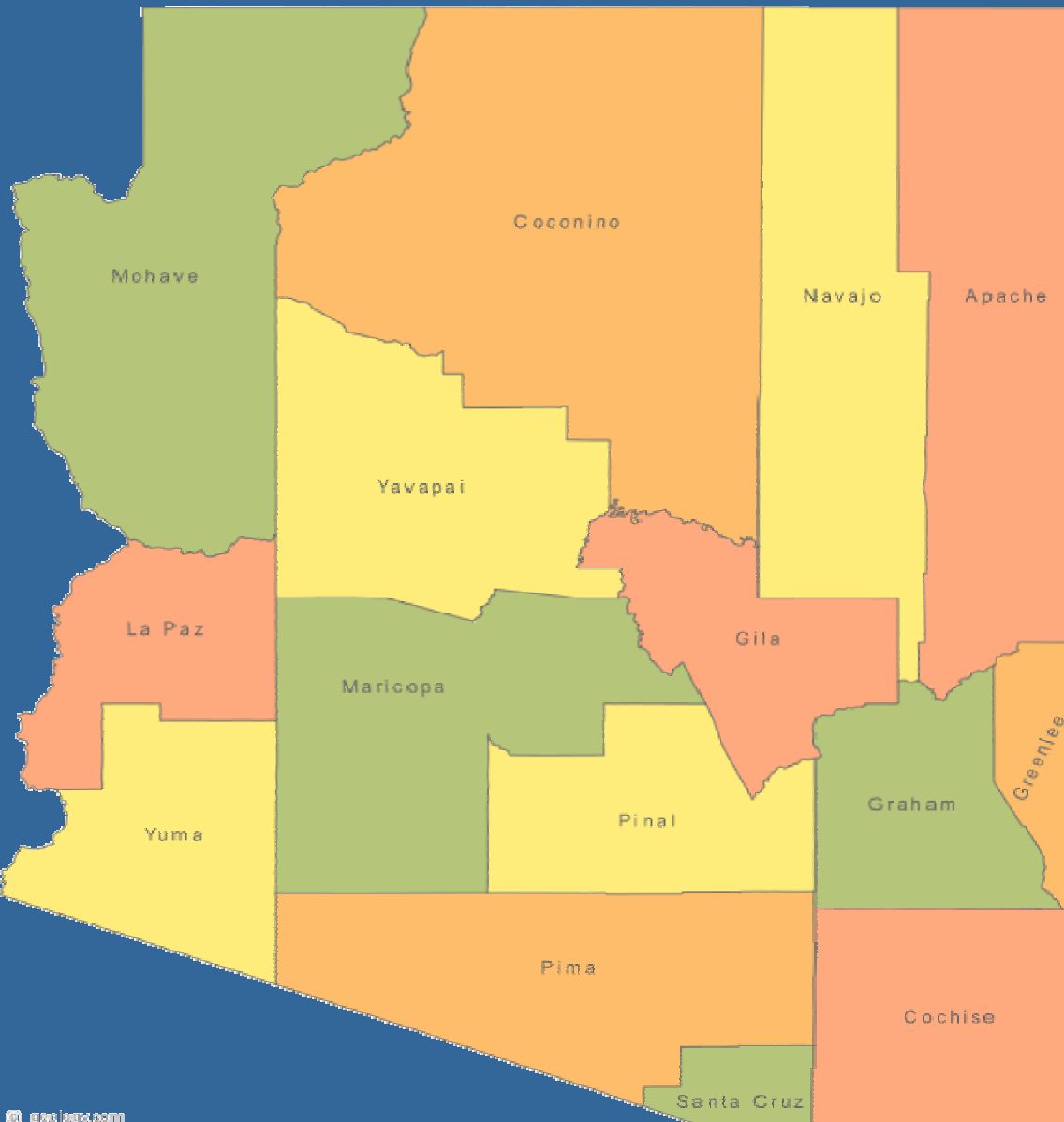
Factors that Motivate People to Use Graywater

- Environmental sensitivity
- Water conservation ethic
- Desire to reduce water bill
- Desire to reduce sewer bill or prolong life of septic tank

Factors that Increase the Likelihood of Graywater Use

- Older homes
- Lower value homes
- Manufactured homes
- Lower income levels
- Septic tanks

Survey of Microbial Quality of Graywater



Location:

Pima
County, AZ

Number of
Homes:

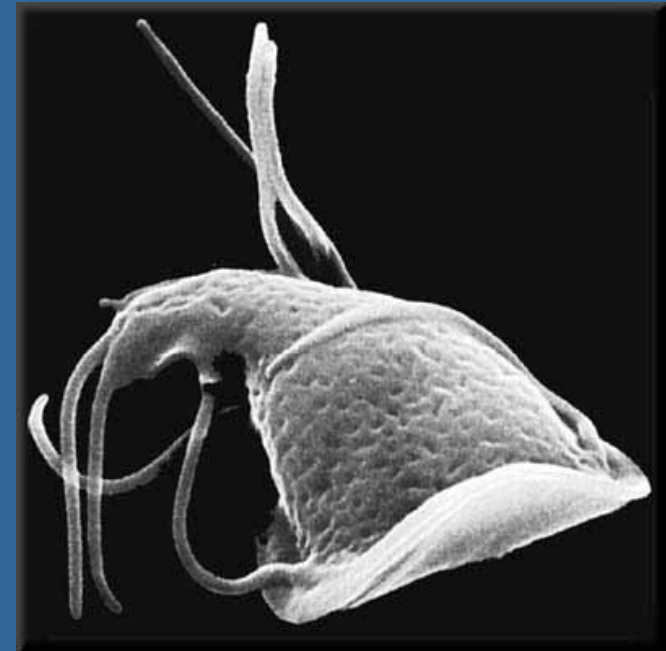
12

Length of
Study:

12 months

Microbial Parameters Evaluated

- Coliforms
- Fecal coliforms
- *E. coli*
- *Enterococci*
- *Giardia* cysts
- *Cryptosporidium* oocysts



Household Demographics

7 Adults only

4 With children (age 0 - 19)

Study of Household Graywater – Application Methods



- Drip – 3 households



- Flood - 8 households

Sources of Graywater in Study Households

Washing machine only	5
Washing machine + kitchen sink	3
Kitchen sink only	1
Washing machine + kitchen sink + bathroom	3

Geometric Averages of Fecal Coliforms

Household Demographic	Fecal Coliforms per Gram of Irrigated Soil
Adults only	1,260
With children	32

Geometric Averages of Fecal Coliforms

Source of Graywater	Graywater*	Irrigated Soil**
Kitchen sink	88,400	1,300
Washing machine and/or bathroom sink	822	27

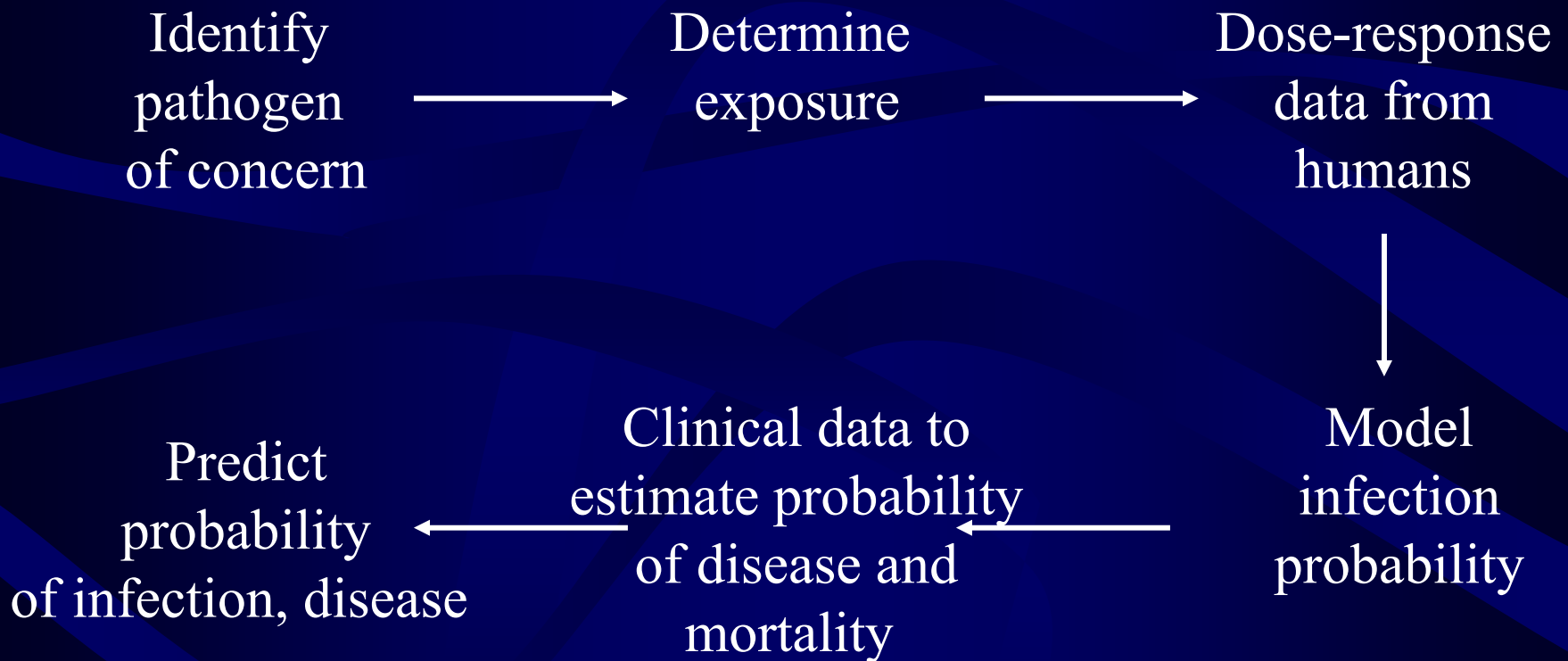
* per 100 ml

** per gram

Geometric Averages of Fecal Coliforms

Type of Application	Fecal Coliforms per Gram of Soil
Drip	11 ± 22
Flood	$469 \pm 716,000$

Quantitative Microbial Risk Assessment



Risk Assessment Assumptions

- All fecal coliforms are *E. coli* 0157:H7
- $P = 1 - (1 + N/\beta)^{-\alpha}$
- $\alpha = 0.1705$ $\beta = 1.61 \times 10^6$
- Child 6 ingests 200 mg.
- Child over 6 ingests 100 mg.
- Acceptable risk of infection 1:10,000/year

Risk of Infection from One Time Exposure

Source of Graywater

Child under 6

Child over 6

Kitchen

4.1×10^{-2} to
 4.3×10^{-4}

2.2×10^{-2} to
 2.1×10^{-4}

Sink or washing
machine

1.2×10^{-5} to
 7.5×10^{-8}

10^{-6} to 10^{-8}

**Risk of Infection from
360 days of Exposure**

**Source of
Graywater**

Child under 6

Child over 6

Kitchen

1.4×10^{-1}

7.5×10^{-2}

Sink or washing
machine

10^{-4} to 10^{-5}

10^{-4} to 10^{-5}

Conclusions Pima County Study

- Levels of fecal coliforms in graywater are influence by
 - source of graywater
 - children in household
- Levels of fecal bacteria in soil are
 - greater in graywater irrigated soil
 - influenced by method of application
- Animals in household had no effect
- No *Giardia* or *Cryptosporidium* detected

Arizona Dept. of Environmental Quality

Residential Graywater Reuse Rules

(effective January 2001)

Type 1 Permit

- Allows private residential direct graywater reuse of less than 400 gallons per day
- Must not leave property
- No irrigation of food crops
- Minimization of standing water
- No spray irrigation
- No kitchen source
- No irrigation of surface if diapers are washed

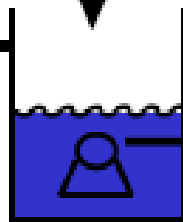
Graywater Study in the United Kingdom –

Environ. Mont. Assessment - 2007



GREYWATER COLLECTED FROM BATHS, SHOWERS AND WASHBASINS IN THE HALLS OF RESIDENCE
GREYWATER FLOW = approx. 14l/h

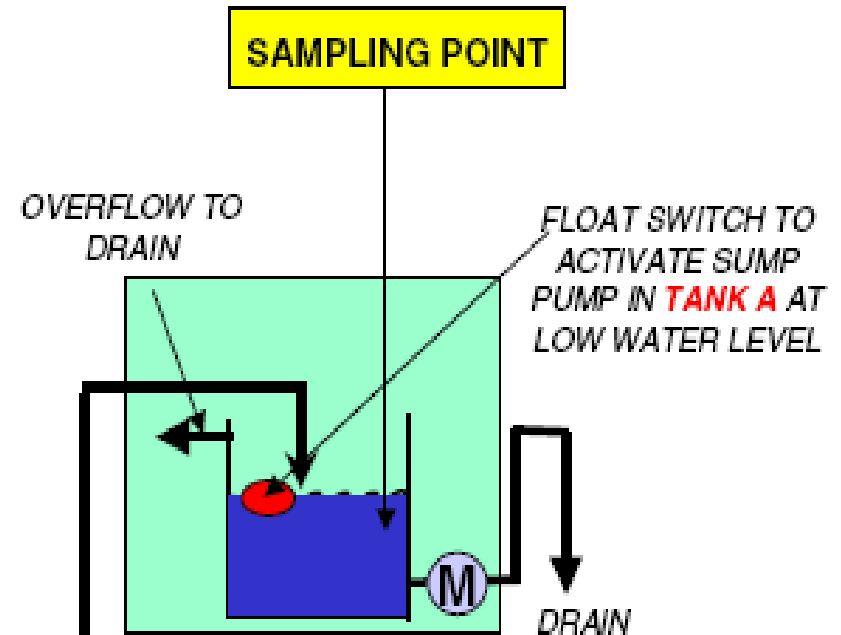
OVERFLOW TO DRAIN



PUMP

TANK A

150 LITRE SUBSURFACE SUMP TANK IN THE GROUNDS OF THE HALLS OF RESIDENCE



TANK B

1m³ COLLECTION TANK IN PORTACABIN ADJACENT TO THE HALLS OF RESIDENCE

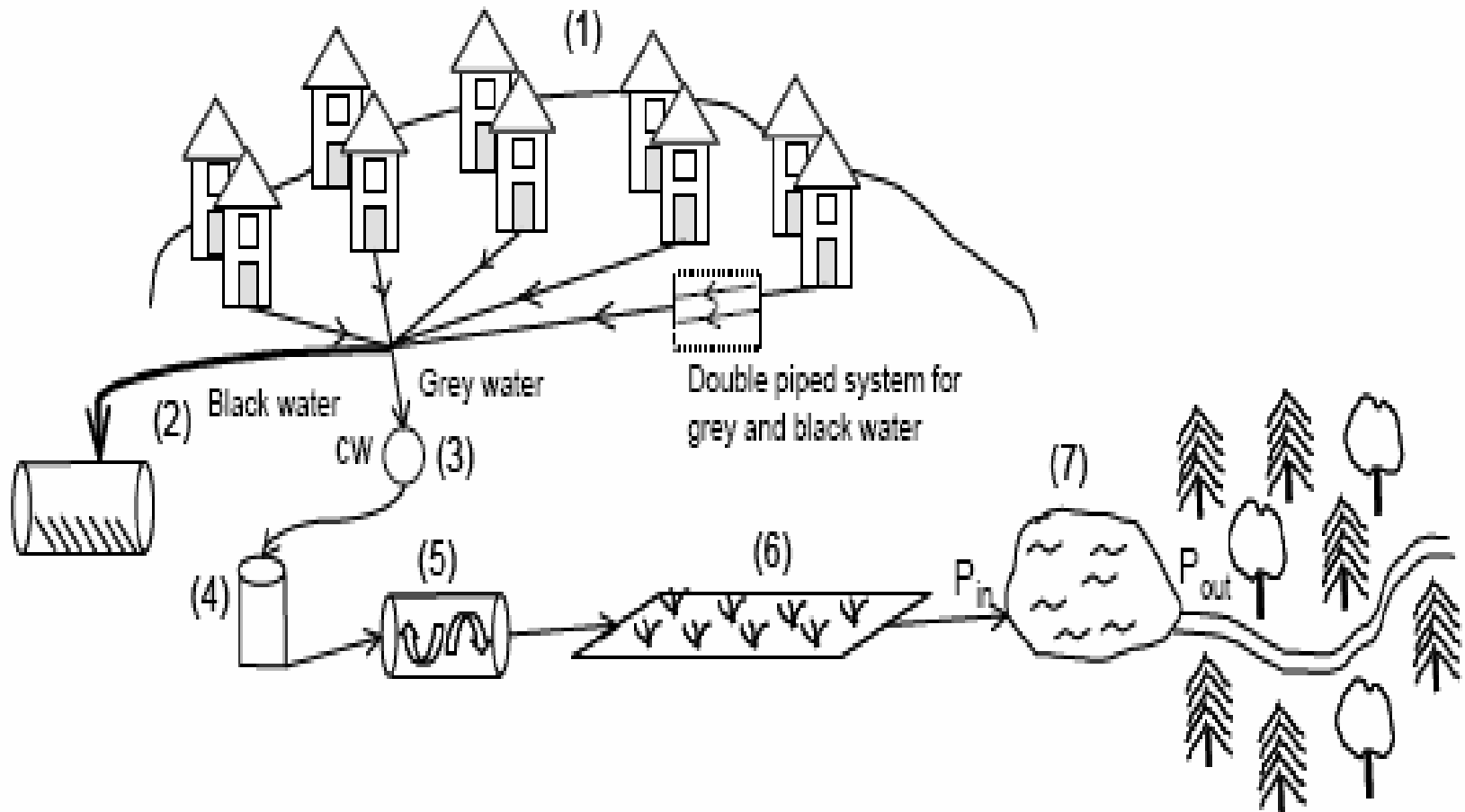
Graywater Study in the United Kingdom

– Environ. Mont. Assessment - 2007

- Giardia – 63% of samples - Range 0.5-1.5/liter
- Salmonella - 13% of samples
- Not detected *Cryptosporidium*, *Campylobacter*, enteroviruses, *E. coli* 0157:H7

Graywater Study Sweden

Water Research 2003



Graywater Study Sweden

Water Research 2003

- **Risk Assessment Assumptions**
 - Accidental ingestion of one mL of irrigation water for 26 days of irrigation
 - -used likely concentration of pathogens based on excretion rates in sewage
 - Monitoring study showed that 0.04 grams feces per person per day

Graywater Study Sweden

Yearly Risks (26 days of exposure) from Irrigation

- Rotavirus = $10^{-0.2}$
- Salmonella = $10^{-5.0}$
- Giardia = $10^{-4.5}$
- Safe level of exposure is considered 10^{-4}
- Conclusions : viruses present the greatest risk; Salmonella and Giardia did not present a significant risk

Graywater - Observations

- Fecal coliforms, coliforms and *E. coli* can grow in graywater – thus they can not be used as indicator of pathogen risk
- Greatest risks are from viruses
- Risks are reduced by
 - No surface ponding
 - No lawn irrigation

Disease Risks are Reduced by

- Prevention of surface ponding
- No lawn irrigation
- Restriction to washing machine, bath, and bathroom sink
- No off site runoff
- Irrigation confined to ornamental plants and trees
- Limited to individual residences
- Limited to rural areas