Georgia Southern University
Digital Commons@Georgia Southern

Georgia Southern University Research Symposium

Apr 16th, 1:30 PM - 2:30 PM

The Implications of Shared Sanitation Facilities on the Transmission of Diarrheal Pathogens Transmitted via Environmental and Person-to-Person Routes: A Modeling Study

Matthew R. Just
Georgia Southern University, mj00788@georgiasouthern.edu

Follow this and additional works at: http://digitalcommons.georgiasouthern.edu/research_symposium

Recommended Citation
http://digitalcommons.georgiasouthern.edu/research_symposium/2016/2016/167

This presentation (open access) is brought to you for free and open access by the Programs and Conferences at Digital Commons@Georgia Southern. It has been accepted for inclusion in Georgia Southern University Research Symposium by an authorized administrator of Digital Commons@Georgia Southern. For more information, please contact digitalcommons@georgiasouthern.edu.
A Modeling Study

The Implications of Shared Sanitation Facilities on the Transmission of Diarrheal Pathogens Transmitted Via Environmental and Person-To-Person Routes

Matthew Just

Georgia Southern University
Department of Mathematical Sciences
April 16, 2016
Diarrheal Disease

Each year there are 1.7 billion cases of diarrheal disease, killing 760,000 children under the age of 5 [5]. A great majority of these cases could be prevented through WASH (water, sanitation, and hygiene) interventions.

Figure: Causes of death among children < 5 years old [4].
Diarrheal Disease

- Each year there are 1.7 billion cases of diarrheal disease, killing 760,000 children under the age of 5 [5].

Figure: Causes of death among children < 5 years old [4].
Diarrheal Disease

- Each year there are 1.7 billion cases of diarrheal disease, killing 760,000 children under the age of 5 [5].
- A great majority of these cases could be prevented through WASH (water, sanitation, and hygiene) interventions.

Figure: Causes of death among children < 5 years old [4].
Nearly 1 billion people have no access to any sanitation (open defecation) [7]. Shared sanitation prevents environmental shedding, eventually reducing transmission of environmentally spread pathogens (Cholera).
Shared Sanitation

- Nearly 1 billion people have no access to any sanitation (open defecation) [7].
Shared Sanitation

- Nearly 1 billion people have no access to any sanitation (open defecation) [7].
- Shared sanitation prevents environmental shedding, eventually reducing transmission of environmentally spread pathogens (Cholera).
Problems with Shared Sanitation

Shared sanitation is not considered to be improved sanitation. There is evidence that shared sanitation units can increase prevalence of diarrheal disease.
Problems with Shared Sanitation

- Shared sanitation is not considered to be *improved* sanitation.
Problems with Shared Sanitation

- Shared sanitation is not considered to be *improved* sanitation.
- There is evidence that shared sanitation units can increase prevalence of diarrheal disease [2].
Hypothesis

- Shared sanitation can decrease environmental transmission (Cholera).
- Increased human-to-human transmission among compliant individuals (Norovirus).
Hypothesis

- Shared sanitation can decrease environmental transmission (Cholera).
Hypothesis

- Shared sanitation can decrease environmental transmission (Cholera).
- Increased human-to-human transmission among compliant individuals (Norovirus).
Hypothesis

- Shared sanitation can decrease environmental transmission (Cholera).
- Increased human-to-human transmission among compliant individuals (Norovirus).
The Model

A mathematical model is constructed to shed light on if and when a shared sanitation intervention can be effective. Mathematical models do not predict the future, merely give a spectrum of possibilities.
The Model

- A mathematical model is constructed to shed light on *if* and *when* a shared sanitation intervention can be effective.
The Model

- A mathematical model is constructed to shed light on *if* and *when* a shared sanitation intervention can be effective.
- Mathematical models do not predict the future, merely give a spectrum of possibilities.
The Model

- A mathematical model is constructed to shed light on *if* and *when* a shared sanitation intervention can be effective.
- Mathematical models do not predict the future, merely give a *spectrum* of possibilities.
The Model
The Model

1 Population Stratification
The Model

1. Population Stratification
2. Environmental transmission component
The Model

1. Population Stratification
2. Environmental transmission component
3. Human-to-human transmission component
The Model

1. Population Stratification
2. Environmental transmission component
3. Human-to-human transmission component
4. Outbreak Scenarios
Effective Coverage of Shared Sanitation

The variable represents effective coverage of shared sanitation. It is calculated as the average number of individuals compliant with shared sanitation divided by the total number of individuals in the population.

How can policy makers and epidemiologists increase effective coverage? They could consider:

- Money $$$
- Education
- Time
Effective Coverage of Shared Sanitation

The variable $\alpha$ represents effective coverage of shared sanitation.
Effective Coverage of Shared Sanitation

The variable $\alpha$ represents effective coverage of shared sanitation.

$$\alpha = \frac{\text{average \# of individuals compliant with shared sanitation}}{\text{total \# of individuals in population}}$$
Effective Coverage of Shared Sanitation

The variable $\alpha$ represents effective coverage of shared sanitation.

$$\alpha = \frac{\text{average } \# \text{ of individuals compliant with shared sanitation}}{\text{total } \# \text{ of individuals in population}}$$

How can policy makers and epidemiologists increase $\alpha$?
Effective Coverage of Shared Sanitation

The variable $\alpha$ represents effective coverage of shared sanitation.

$$\alpha = \frac{\text{average } \# \text{ of individuals compliant with shared sanitation}}{\text{total } \# \text{ of individuals in population}}$$

How can policy makers and epidemiologists increase $\alpha$?

- Money
The variable $\alpha$ represents effective coverage of shared sanitation.

\[ \alpha = \frac{\text{average \# of individuals compliant with shared sanitation}}{\text{total \# of individuals in population}} \]

How can policy makers and epidemiologists increase $\alpha$?

- Money
- Education
Effective Coverage of Shared Sanitation

The variable $\alpha$ represents effective coverage of shared sanitation.

$$\alpha = \frac{\text{average } \# \text{ of individuals compliant with shared sanitation}}{\text{total } \# \text{ of individuals in population}}$$

How can policy makers and epidemiologists increase $\alpha$?

- Money
- Education
- Time
Effective Coverage of Shared Sanitation

The variable $\alpha$ represents effective coverage of shared sanitation.

$$\alpha = \frac{\text{average # of individuals compliant with shared sanitation}}{\text{total # of individuals in population}}$$

How can policy makers and epidemiologists increase $\alpha$?

- Money
- Education
- Time
- More money $$$
Population Stratification

black = non-compliant
red = compliant

Effective Coverage
$\alpha = 0.00$
**Population Stratification**

- Black = non-compliant
- Red = compliant

Effective Coverage

\[ \alpha = 0.04 \]
Population Stratification

black = non-compliant
red = compliant

Effective Coverage
\( \alpha = 0.08 \)
Population Stratification

black = non-compliant
red = compliant

Effective Coverage
$\alpha = 0.12$
Population Stratification

black = non-compliant
red = compliant

Effective Coverage
\( \alpha = 0.16 \)
Population Stratification

Effectice Coverage

\[ \alpha = 0.20 \]

Black = non-compliant
Red = compliant
Population Stratification

black = non-compliant
red = compliant

Effective Coverage
\[ \alpha = 0.24 \]
Population Stratification

Effective Coverage
\[ \alpha = 0.24 \]

Observed values of \( \alpha \) in rural India are between 0.03-0.19 [8].

black=non-compliant
red=compliant
Transmission
Transmission

Population Stratification
Environmental Transmission Component
Human-to-Human Transmission Component
Outbreak Scenarios
Transmission
Transmission

Environmental Transmission

Outbreak Scenarios
Transmission

Environmental Transmission

Human-to-human Transmission
Environmental Transmission

S (Susceptible) – I (Infected) – R (Recovered) – W (Environment)

Ordinary Differential Equation (ODE) Model [1, 3]
Environmental Transmission

S (Susceptible) – I (Infected) – R (Recovered) – W (Environment)
Ordinary Differential Equation (ODE) Model [1, 3]

Everyone in the population starts out being susceptible.
Environmental Transmission

S (Susceptible) – I (Infected) – R (Recovered) – W (Environment)
Ordinary Differential Equation (ODE) Model [1, 3]

Everyone in the population starts out being susceptible.
Environmental Transmission

S (Susceptible) – I (Infected) – R (Recovered) – W (Environment)
Ordinary Differential Equation (ODE) Model [1, 3]

The environment starts out contaminated.
S (Susceptible) – I (Infected) – R (Recovered) – W (Environment)

Ordinary Differential Equation (ODE) Model [1, 3]

Susceptible individuals contact environment, causing them to become infected.
Environmental Transmission

S (Susceptible) – I (Infected) – R (Recovered) – W (Environment)

Ordinary Differential Equation (ODE) Model [1, 3]

Infected individuals shed into environment, making it more contaminated.
Environmental Transmission

S (Susceptible) – I (Infected) – R (Recovered) – W (Environment)

Ordinary Differential Equation (ODE) Model [1, 3]

Compliant individuals do not shed into the environment.
Environmental Transmission

\[ S \text{ (Susceptible)} \rightarrow I \text{ (Infected)} \rightarrow R \text{ (Recovered)} \rightarrow W \text{ (Environment)} \]

Ordinary Differential Equation (ODE) Model \([1, 3]\)

Infected individuals will eventually become recovered.
Environmental Transmission

S (Susceptible) – I (Infected) – R (Recovered) – W (Environment)
Ordinary Differential Equation (ODE) Model [1, 3]

Pathogen decays from environment over time.
Environmental Transmission

S (Susceptible) – I (Infected) – R (Recovered) – W (Environment)

Ordinary Differential Equation (ODE) Model [1, 3]
Human-to-Human Transmission

S (Susceptible) – E (Exposed) – I (Infected) – A (Asymptomatic) – R (Recovered)

Ordinary Differential Equation (ODE) Model [6]
Human-to-Human Transmission

S (Susceptible) – E (Exposed) – I (Infected) – A (Asymptomatic) – R (Recovered)
Ordinary Differential Equation (ODE) Model \([6]\)

Almost everyone in the population starts out being susceptible.
Human-to-Human Transmission

S (Susceptible) – E (Exposed) – I (Infected) – A (Asymptomatic) – R (Recovered)
Ordinary Differential Equation (ODE) Model [6]

Almost everyone in the population starts out being susceptible.
Human-to-Human Transmission

S (Susceptible) – E (Exposed) – I (Infected) – A (Asymptomatic) – R (Recovered)
Ordinary Differential Equation (ODE) Model [6]

Individuals are exposed, will become infected, slightly infectious.
Human-to-Human Transmission

S (Susceptible) – E (Exposed) – I (Infected) – A (Asymptomatic) – R (Recovered)
Ordinary Differential Equation (ODE) Model [6]

Individuals are infected and fully infectious.
Human-to-Human Transmission

\[ S \rightarrow E \rightarrow I \rightarrow A \rightarrow R \]

Ordinary Differential Equation (ODE) Model [6]

Individuals are no longer symptomatic, still slightly infectious.
Human-to-Human Transmission

S (Susceptible) – E (Exposed) – I (Infected) – A (Asymptomatic) – R (Recovered)

Ordinary Differential Equation (ODE) Model [6]

Individuals are completely recovered.
Human-to-Human Transmission

S (Susceptible) – E (Exposed) – I (Infected) – A (Asymptomatic) – R (Recovered)

Ordinary Differential Equation (ODE) Model [6]

Infected individuals will eventually become recovered.
Human-to-Human Transmission

S (Susceptible) – E (Exposed) – I (Infected) – A (Asymptomatic) – R (Recovered)

Ordinary Differential Equation (ODE) Model [6]

Compliant individuals have increased transmission.
Human-to-Human Transmission

S (Susceptible) – E (Exposed) – I (Infected) – A (Asymptomatic) – R (Recovered)
Ordinary Differential Equation (ODE) Model [6]

Individuals will eventually recover.
Human-to-Human Transmission

S (Susceptible) – E (Exposed) – I (Infected) – A (Asymptomatic) – R (Recovered)
Ordinary Differential Equation (ODE) Model [6]
Each square represents a unique cultural and environmental setting.
Sampling the Parameter Space

Each square represents a unique cultural and environmental setting.
Sampling the Parameter Space

Each square represents a unique cultural and environmental setting.
Sampling the Parameter Space

Each square represents a unique cultural and environmental setting.
Cluster 1

High pathogen concentration in environment, low contact rate.

![Graph showing intervention effectiveness 10 years after implementation for Cluster 1, with prevalence of diarrhea over effective coverage of shared sanitation. The graph includes lines for total, human-to-human, and environmental transmission.]
Cluster 2

Low pathogen concentration in environment, high contact rate.
Cluster 3

Low pathogen concentration in environment, low contact rate.
Discussion

Shared sanitation is a long-term strategy. Can be effective as a "first rung" strategy if implemented properly and under the right conditions. Though costly, more sanitation units guarantees safer conditions.
• Shared sanitation is a long-term strategy.
Discussion

- Shared sanitation is a long-term strategy.
- Can be effective as a "first rung" strategy if implemented properly and under the right conditions.
Discussion

- Shared sanitation is a long-term strategy.
- Can be effective as a “first rung” strategy if implemented properly and under the right conditions.
- Though costly, more sanitation units guarantees safer conditions.
References

- C. T. Codeço. 
  Endemic and epidemic dynamics of cholera: the role of the aquatic reservoir.  

- J. Fuller, T. Clasen, M. Heijnen, and J. Eisenberg.  

- Y. H. Grad, J. C. Miller, and M. Lipsitch.  
  Cholera modeling: challenges to quantitative analysis and predicting the impact of interventions.  

  Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000.  

- W. H. Organization.  
  Diarrhoeal disease.  

- K. Simmons, M. Gambhir, J. Leon, and B. Lopman.  
  Duration of immunity to norovirus gastroenteritis.  

- USAID.  
  Why do we talk about toilets on world water day?  

  Risk map of cholera infection for vaccine deployment: the eastern kolkata case.  
THANK YOU!