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

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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
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April 16, 2016
Diarrheal Disease

Figure: Causes of death among children < 5 years old [4].
Each year there are 1.7 billion cases of diarrheal disease, killing 760,000 children under the age of 5 [5].

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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

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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 [2].
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Problems with Shared Sanitation

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- 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).
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\[
\text{Environmental} \quad + \quad \text{Human-to-human} = ?
\]
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.
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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.

\[ \text{effective coverage} = \frac{\text{average number of individuals compliant with shared sanitation}}{\text{total number of individuals in population}} \]

How can policy makers and epidemiologists increase?

- More money $$$
- Education
- Time
- More money $$$
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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

Effective Coverage
\[ \alpha = 0.04 \]

- black = non-compliant
- red = compliant
Population Stratification

- Effective Coverage
  \[ \alpha = 0.08 \]

- black = non-compliant
- red = compliant
Population Stratification

black = non-compliant
red = compliant

Effective Coverage
\[ \alpha = 0.12 \]
Population Stratification

Effective Coverage
\[ \alpha = 0.16 \]

black = non-compliant
red = compliant
Population Stratification

Effective Coverage
\[ \alpha = 0.20 \]

black = non-compliant
red = compliant
Population Stratification

- black = non-compliant
- red = compliant

Effective Coverage
\[ \alpha = 0.24 \]
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
Transmission

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

Environmental Transmission
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

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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.
Environmental Transmission

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

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

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


Individuals will eventually recover.
Human-to-Human Transmission

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

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

High pathogen concentration in environment, low contact rate.
Cluster 2

Low pathogen concentration in environment, high contact rate.

![Diagram showing intervention effectiveness 10 years after implementation, Cluster 2.](image)
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.
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- Can be effective as a ”first rung” strategy if implemented properly and under the right conditions.
- Though costly, more sanitation units guarantees safer conditions.
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