Impact of a Water Quality Intervention on Typhoid Incidence in Urban India

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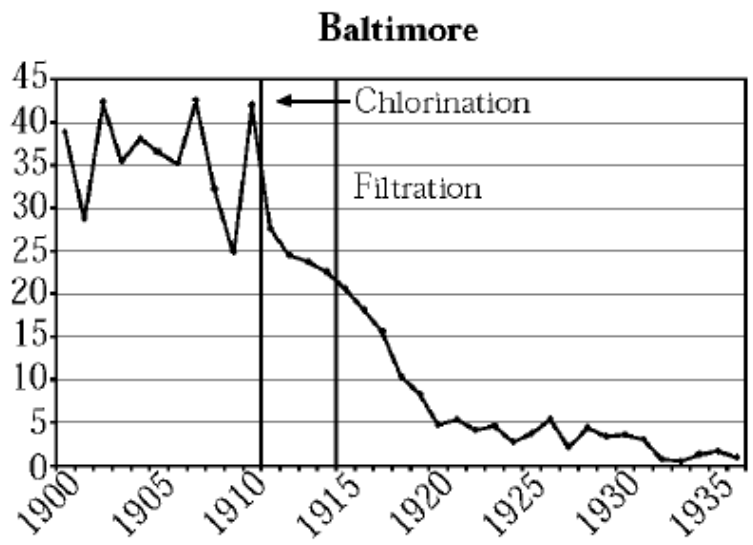
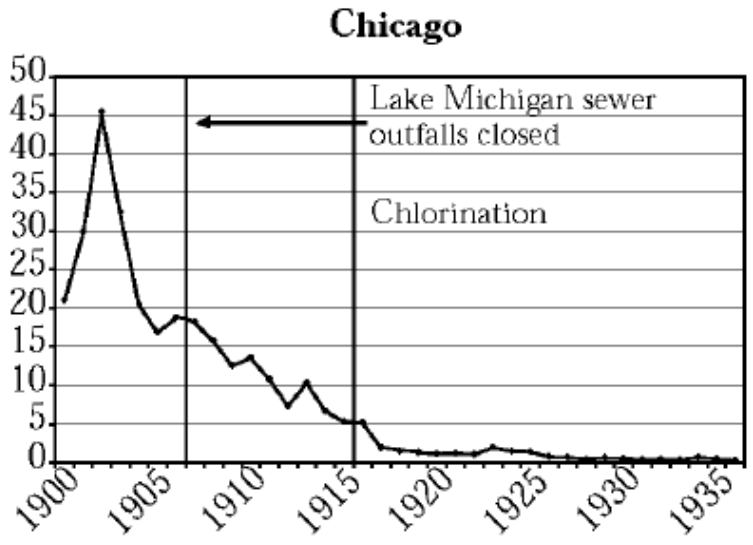
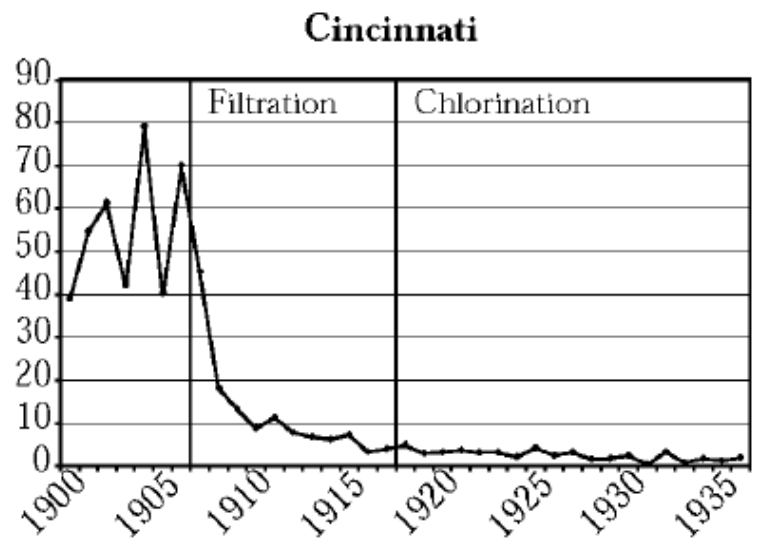
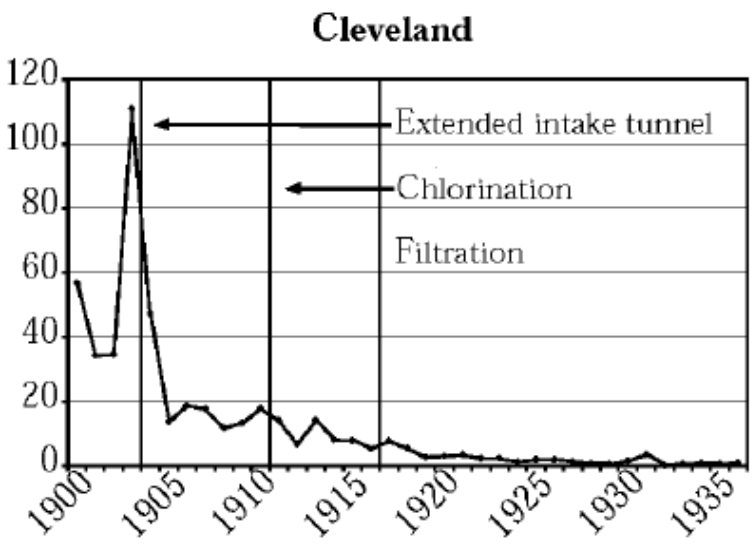
Typhoid Fever Trends (Mortality per 100,000) and Sanitary Interventions, 1900-1936 [Source: Cutler and Miller 2005]



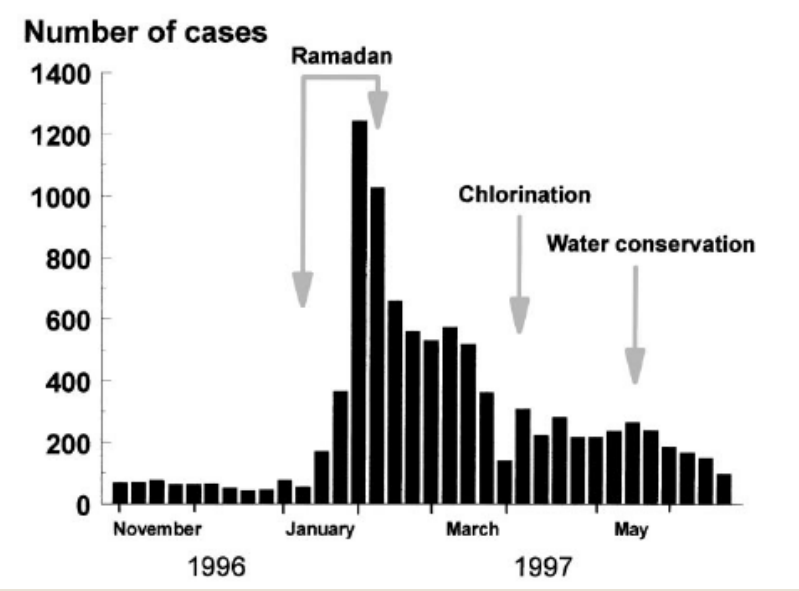






Typhoid Fever and Municipal Water Supply

Typhoid outbreak associated with municipal water consumption in Tajikistan
(Mermin et al. 1999)



[Source: Mermin et al. 1999]

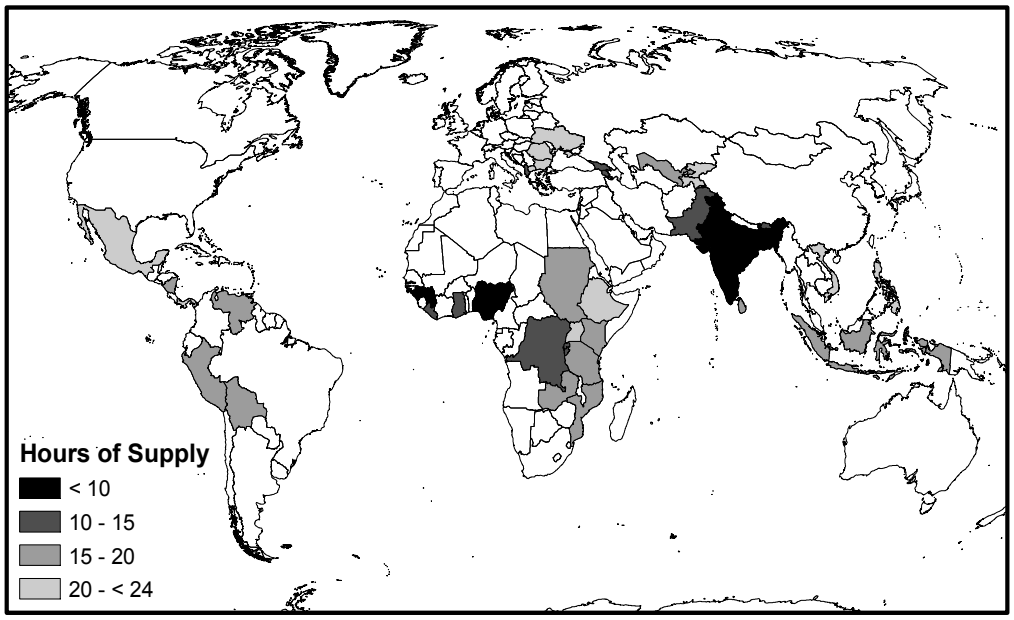
Typhoid fever associated with consumption of unboiled water from municipal supply in slum in Dhaka, Bangladesh
(Ram et al. 2007)

Typhoid outbreak molecularly traced to municipal water supply in Nepal
(Lewis et al. 2005)

Water systems characterized by inadequate chlorination, cross-connections with sewer lines and inadequate/ intermittent water pressure in distribution pipelines

Intermittent Delivery of Municipal Water

- Many municipal piped water systems in low-income countries operate intermittently
- Sub-segments of distribution system receive water service on rotating basis



[Source: van den Berg and Danilenko 2011]

Health Impact of Intermittent Water Supply

- Contamination of water in pipelines
- Contamination during household storage
- Reliance on unsafe water sources
- Limited water availability for hygiene

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Health Impact of Intermittent Water Supply

- **Short-term intermittencies in continuous systems associated with diarrhea**
  (Huang et al. 2011; Hunter et al. 2005; Nygard et al. 2007; Özkan et al. 2007)

- **Chronic intermittent supply in low-income countries associated with increased waterborne illness**
  (Abu Amr and Yassin 2008; Abu Mourad 2004; Cifuentes et al. 2002; Yassin et al. 2006)

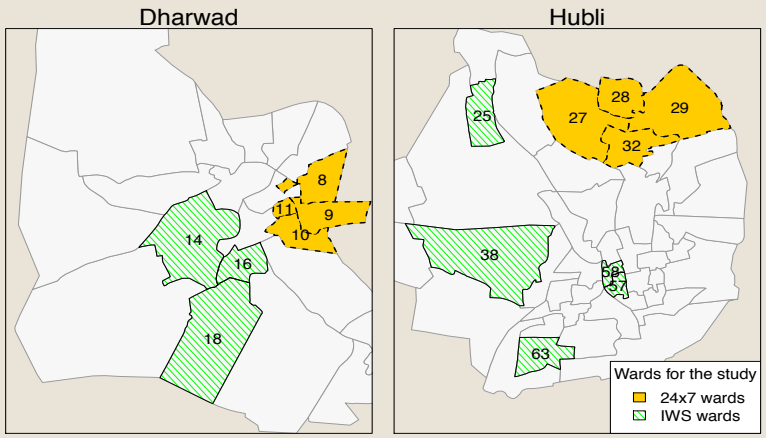
- **Longer intermittencies lead to higher risk**
  (Ercumen et al. 2014)

Continuous Water Supply (24x7) in Hubli-Dharwad, India

- Twin cities in northern Karnataka with population of 1 million
- Over 80% of the population has access to municipal piped water
- 10% of city's connections (~14,000 households) upgraded in 2007-2008
  - 24x7 water supply
  - Complete pipe replacement
  - Removal of public standpipes
- Rest of city continued to receive intermittent supply (every ~5 days)

Health Impact Evaluation of 24x7 Supply: Matched Cohort Study

- Pre-existing, non-randomized intervention
- Multivariate matching to identify comparable intermittent supply areas (Diamond and Sekhon 2013)
- Enrolled 3,922 households with children <5 years
- Longitudinal follow-up with quarterly visits over one year



24x7 Supply Wards and Selected Intermittent Supply Wards in Hubli-Dharwad (Ward: Administrative Unit)

Caregiver-Reported Health Outcomes

- Typhoid fever, cholera and hepatitis
  - Incidence in any household member since onset of 24x7
  - Diagnosis for these typically made in local informal clinics
  - Often symptom-based, with or without laboratory confirmation
- Child death
  - In children <2 yrs since onset of 24x7
- Diarrhea and blood/mucus in stool
  - Prevalence in children <5 yrs in week before interview
  - Diarrhea defined as ≥3 loose stools in any 24-hour period
- Cough/cold and scrapes/bruises
  - Prevalence in children <5 yrs in week before interview
  - Negative control outcomes - symptoms with no plausible association with 24x7 supply

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Groups Well Balanced in Socioeconomics and Demographics

Characteristics	24x7 Participants	Intermittent Participants
Mean number of persons per household	6.5	6.5
Mean number of children <5 yrs per household	1.4	1.4
Mean age of primary caregiver of children < 5 yrs	27	27
Mean number of rooms in household	2	2
% of households with *pakka* roof	44	45
% of households with illiterate mother	9	10

Groups Well Balanced in Hygiene and Sanitation Indicators

Characteristics	24x7 Participants	Intermittent Participants
% of households with handwashing facility:		
Inside the household	74	74
In yard	25	25
No specific place	2	1
% of households with sanitation access:		
Private latrine	91	92
Public latrine	6	4
No latrine	3	5
% of households with sewerage in vicinity:		
Underground piped sewer	78	74
Open drain	72	75

Impact on Severe Waterborne Illness

Symptom	Intermittent Incidence [a]	24x7 Incidence [a]	Cumulative Incidence Ratio (Adjusted)
Typhoid fever	61	34	0.58 (0.41, 0.78)
Hepatitis	27	34	1.13 (0.76, 1.73)
Cholera	2	4	1.48 (0.37, 6.92) [b]
<2 Child death	12	7	0.51 (0.22, 1.07)

[a] Incidence defined as number of households (per 1000) with at least one case since implementation of 24x7.

[b] Adjusted analysis not possible due to sparse data.

Impact on Typhoid Fever: Subgroup Analysis by Wealth

Symptom	Intermittent Incidence	24x7 Incidence	Cumulative Incidence Ratio (Adjusted)
Typhoid Fever			
Below median	60	32	0.53 (0.32, 0.83)
Above median	61	36	0.60 (0.38, 0.91)

Below vs. above median wealth determined based on quartiles of asset index calculated with principal component analysis.

Impact on Child Diarrheal Illness

Symptom	Intermittent Prev %	24x7 Prev %	Prevalence Ratio (Adjusted)
Diarrhea			
Main analysis	8.4	7.9	0.93 (0.83, 1.04)
Below median	9.8	8.8	0.89 (0.76, 1.04)
Above median	7.0	6.9	0.98 (0.84, 1.16)
Blood/Mucus in Stool			
Main analysis	1.9	1.5	0.78 (0.60, 1.01)
Below median *	2.5	1.6	0.63 (0.46, 0.87)
Above median *	1.2	1.4	1.08 (0.73, 1.63)

* Significant interaction (p=0.03)

No Impact on Negative Control Outcomes

Symptom	Intermittent Prev %	24x7 Prev %	Prevalence Ratio (Adjusted)
Cough/cold			
Main analysis	41.5	41.1	1.00 (0.96, 1.05)
Below median	43.5	43.7	1.02 (0.95, 1.08)
Above median	39.4	38.4	0.98 (0.92, 1.05)
Scrape/bruise			
Main analysis	5.0	5.6	1.12 (0.97, 1.29)
Below median	5.5	6.1	1.12 (0.92, 1.35)
Above median	4.4	5.1	1.13 (0.91, 1.38)

Study Limitations

- Potential confounding from unobserved covariates
  - Observational study (randomization not feasible)
  - Exceptionally good balance between groups in observed covariates
  - No impact on negative control outcomes
- Non-differential measurement bias
  - Self-reported outcomes with no laboratory confirmation
  - Non-differential misdiagnosis with respect to study group would bias results towards null
- Differential measurement bias
  - Courtesy bias by recipients of 24x7 supply
  - No impact on least specific outcome (i.e., overall diarrhea) that is most vulnerable to biased recall
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Conclusions

- Intermittent delivery of municipal water through piped networks associated with severe waterborne illness in this urban population

- 24x7 water supply associated with:
  - 42% reduction in typhoid fever incidence in study population
  - 37% reduction in bloody diarrhea prevalence in <5 children in low-income households
  - No overall impact on diarrhea in <5 children

- Scale up of 24x7
  - Ongoing effort to scale up to all of Hubli-Dharwad
  - Increased municipal water consumption per capita under 24x7

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- SDM College of Engineering, Dharwad, India
- Northern Karnataka Urban Water Supply and Drainage Board

EXTRA SLIDES

Differential Impact of 24x7 by Socioeconomic Status

High Income Areas

67% have open drains
39% treat drinking water
61% use overhead tanks

Low Income Areas

80% have open drains
14% treat drinking water
8% use overhead tanks

Water Handling Practices

Characteristics	% of 24x7 Participants	% of Intermittent Participants
Obtains municipal water from:		
Own connection	67	58
Shared connection	33	35
Public connection	<1	6
Obtains water from borewell (public or private)	5	38
Treats drinking water	27	27
Has handwashing facility with water	96	93
Retrieves drinking water from:		
From tap	10	2
From overhead tank	<1	<1
From storage container	77	83

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Impact on Water Quality

- Both tap and stored water quality improved under 24x7
- However, contamination during storage was common
- Difference between 24x7 and intermittent supply was less pronounced in stored water than in tap water

	% of samples positive for *E. coli*	
	24x7	Intermittent
Tap water	<1	32
Stored water	13	34

Kumpel, E., & Nelson, K. L. (2013). Comparing microbial water quality in an intermittent and continuous piped water supply. Water research, 47(14), 5176-5188.