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Benefits Trickling Away: The Health Impact of extending access to piped Water and Sanitation in urban Yemen

(published in Journal of Development Effectiveness) with some further analyses

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Manchester Impact Evaluation Workshop

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What do we know about …

…Drinking water ?

- 1.1 billion people without safe drinking water — UNICEF 2010
- Water pollution causes nearly 90% of all diarrheal diseases — WHO 2004

…Diarrhea?

- causes 20% of child mortality in developing countries (<5 yrs) — Kosek et al 2003
- causes 8% of total lost life years in dev. countries — Smith et al 1999
- also affects health outcomes, education, (future) income — Zwane & Kremer 2007

…Impact of Piped Water on Child Diarrhea?

- World Bank IEG (2010): Evaluation of World Bank water projects (worth >$3 billion)

”Evidence of improved water quality is rare, as are indications of the improved health of project beneficiaries.”

Study Setting: Urban Yemen

Key Message

Conditions in Yemen are similar to many other countries in the Middle East and (North) Africa

MENA Region

Water Stress

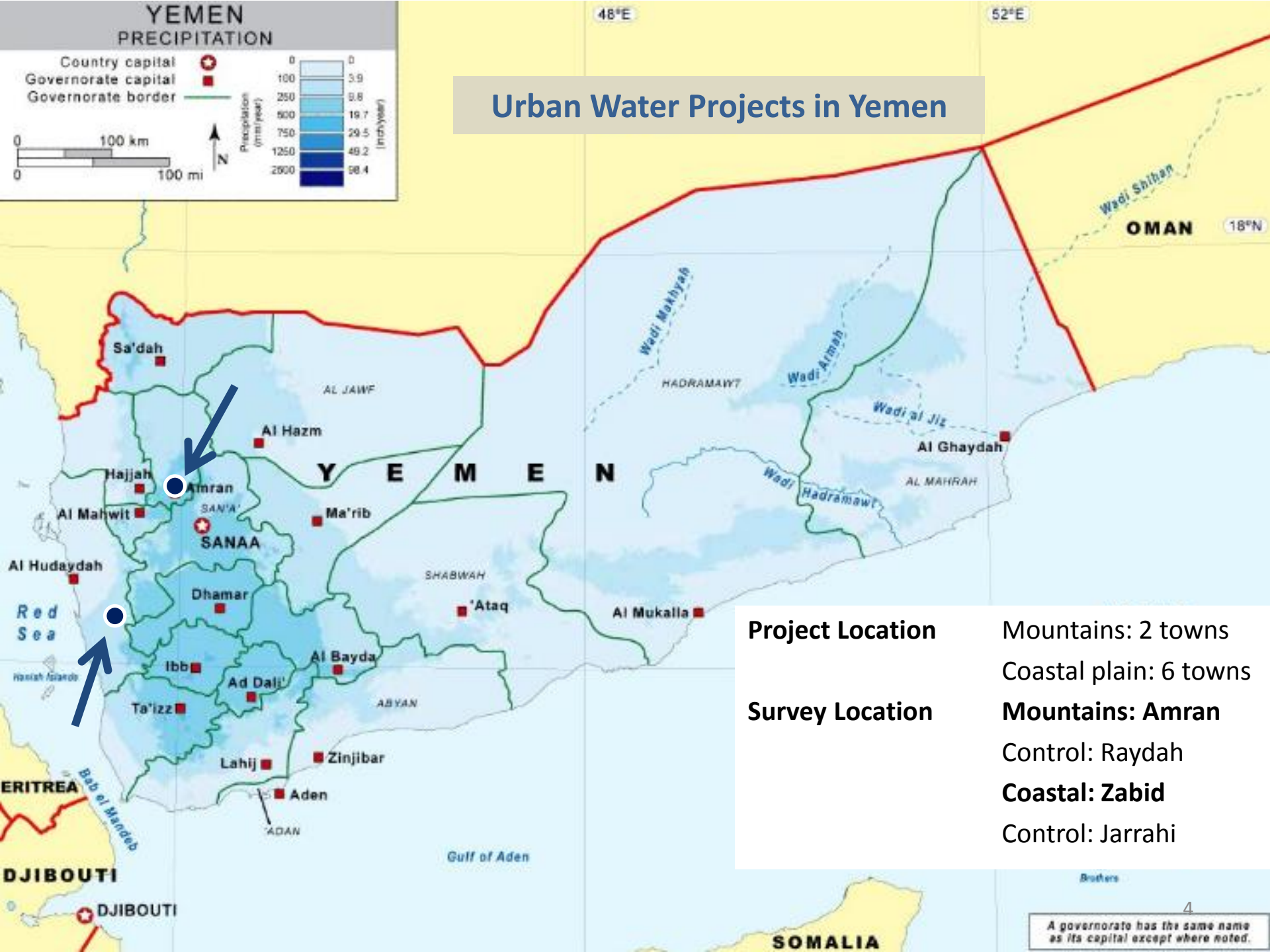
- over-use of ground-water
- sizable country: 24 million
- urban population growth very high: 4.7%

Low Human Capital

- low adult literacy rate: 40% women (77 % men)
- health knowledge is even more limited
- HDI: 150 (out of 177)

Weak Government

- governance structures are weak;
- frequent social conflicts on land & water rights



Project Location	Mountains: 2 towns
	Coastal plain: 6 towns
Survey Location	**Mountains: Amran**
	Control: Raydah
	Coastal: Zabid
	Control: Jarrahi

Main Evaluation Results

Intervention

Piped water and sanitation in provincial towns in Yemen

Mountain: water and sanitation access

Coastal: Additional sanitation access

Evaluation

Mix of quasi-experimental methods to quantify health impact using in-town and out-of-town control groups:

- Matching
- Instrumental Variable Regression
- Diff-in-Diff
- Panel Analysis from health facilities

Results

1. Access to piped water ***increases*** diarrhea among children and adults

2. Negative health impact linked to interruptions of piped water supply

3. Limited impact of piped sanitation; requires running water to function well

Treatment & Instruments

Treatment

- Project includes new wells, treatment plants and piped network
- Effectively replaces water bought from trucks by piped water
- Continued storage of water at household level (tanks and containers)

Selection Effects

- House connections were installed without choice
- Construction always started in the city center / Old City
- Manual labor used: streets with hard rocky ground were avoided

Instruments

1. Distance from City Center
2. Rocky Ground
3. Age of House

Water Source in Control Areas

- Truck water from agricultural wells
- Truck water is available in project towns

Data

Survey Data

- 2500 households in 4 provincial towns
- 2 types of control groups: project town and control towns
- Covers: health, water handling and storage, education, socio-economic charact.

Secondary Data

- Baseline data for 1 town (no panel), useful for diff-in-diff
- Coliform tests data on pollution in wells, pipes and households
- Health facility data on diarrheal diseases
- GPS data of household location (neighborhoods and streets)

Descriptives

3. Descriptive Statistics

Main Source of Drinking Water

		Source	Drinking Water Sources *Percent*	 *N*
Mountain	Water	Pipe	74.6	449
		Tanker	20.2	124
		Other	5.2	36*
		Total	**100.0**	**609**
	Not Connected	Tanker	91.7	386
		Other	8.3	40*
		Total	**100.0**	**426**
	Control Town	Tanker	95.7	261
		Other	4.3	12*
		Total	**100.0**	**273**
Coastal	Water	Pipe	99.2	849
		Other	0.8	11*
		Total	**100.0**	**860**
	Control Town	Tanker	40.9	150
		Other	59.1	245
		Total	**100.0**	**395**
Total				**2563**

In Amran the main source of drinking water is still the tanker truck for every fifth <u>connected</u> household

Descriptive Statistics

Problems with piped and tanker water

			Unreliable Supply	*Poor Quality*	*Too expensive*	*No Problems*	*Sources*
		Source	*Percent*	*Percent*	*Percent*	*Percent*	*N*
Mountain	Water	Pipe	26.0	9.3	21.3	43.4	389
		Tanker	16.0	8.0	29.6	46.5	213
	None	Tanker	3.1	8.8	40.1	48.0	354
	Control Town	Tanker	3.2	5.5	43.9	47.4	253
Coastal	Water	Pipe	8.7	2.5	29.3	59.5	827
		Tanker	0.0	0.0	33.3	66.7	6
	Control Town	Tanker	8.7	9.4	35.6	46.3	149
Sample			**10.9**	**6.1**	**31.8**	**51.3**	**2191**

Note: Households use multiple drinking water sources

Lack of reliability of pipe water supply is perceived to be the most important problem in Amran
Water supply and sanitation in Zabid is perceived to as reliable and of good quality (but as ‚expensive')

Diarrheal diseases among children and adults (past 30 days)

Main Results

- Children are widely affected by diarrheal diseases
- Incidence much higher in treatment group

Indicator		Diarrhea		Waterborne Diseases		Disease Severity		Days missed		HH
		Child	All Ages	Child	All Ages	Child	All Ages	School	Work	N
Mountain										
Water		13.8	5.3	30.2	9.9	34.8	7.6	0.3	0.9	201
Water	Sanitation	15.9	5.8	46.8	11.2	44.3	8	1.4	6.4	270
Control	Area	9.8	3.4	25.8	8.2	27.6	6.1	0.2	1.8	374
Control	Town	4.9	3.3	20.5	6	21.8	5	0.1	2.3	298
Coastal										
Water		11.8	5.1	37.1	11.2	37.6	6.6	5.4	1.3	127
Water	Sanitation	10.6	3.5	26.1	7.2	29.1	4.7	1.4	1.6	714
Control	Town	8.2	3.3	21.9	6.4	17.9	4.3	1.2	1.8	434
Total		10.2	3.9	28	7.9	28.7	5.6	1.2	2.2	2418

Note: Symptoms of water borne diseases include diarrhoea, dysentery, vomiting, abdominal pain, and fever

Double Difference Results for Water and Sanitation

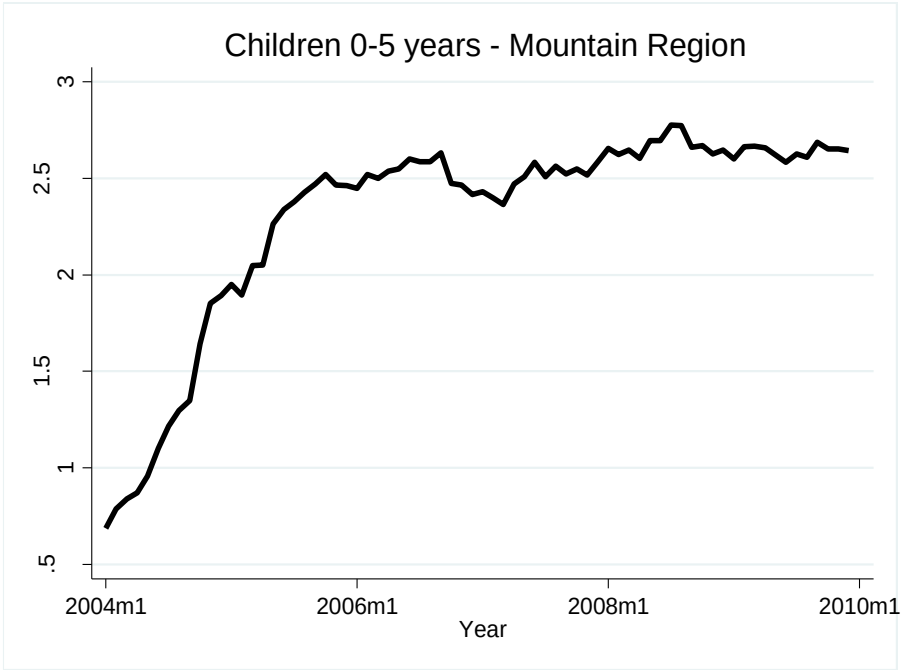
Main Results

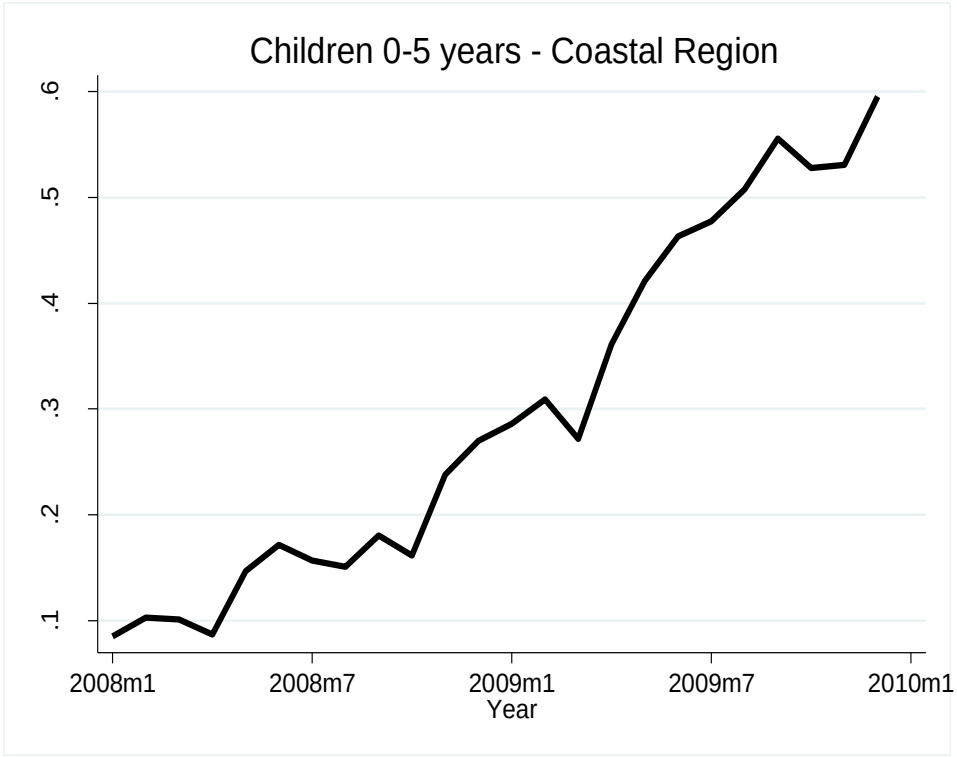
- Piped Water leads to increased diarrhea when water rationing is frequent
- Sanitation seems to further increase diarrhea incidence

Outcome	Diarrhoea *pct points*	Baseline *Individuals*	Endline *Individuals*
First Difference: change over time			
Water	3.44*	1744	1832
Sanitation	4.35*	1744	2256
Control	2.07	1118	2922
Double Difference: treatment – control			
Water	1.37**	Impact of Water	
Sanitation	2.27**		
Treatment Difference: sanitation – water			
Sanitation	0.91*	Impact of Sanitation	

Results only for project town with frequent water rationing
Improved sanitation is conditional on access to piped water
Differences between point estimates

Figure 2: Differences in Diarrhoea Incidence between Treatment and Control Towns (Health Facility Data)





Econometric Results on Health Impact

Health Impact of Water: Propensity Score Matching

Main Results

- Increased disease burden in mountains, where water rationing is frequent
- Child Diarrhea (Incidence + severity)
- Water borne diseases (adults + children)

Outcome		Coastal Region		Mountain Region			
		out-of-town control		out-of-town control		in-town control	
		ATT	N	ATT	N	ATT	N
Diarrhoea	Child	0.0151	338	0.0954***	361	0.0412	409
	All Ages	0.0111	560	0.0193	488	0.0195*	567
Waterborne Diseases	Child	0.1328	338	0.1078*	361	0.0631	409
	All Ages	0.0399**	560	0.0455***	488	0.0268*	567
Severity	Child	0.1879	338	0.1347*	361	0.1041	409
	All Ages	0.0184	560	0.0329**	488	0.0239*	567
Days missed	School	0.0441*	560	0.0018	496	0.0018	573
	Work	-0.0074	560	-0.0076	496	-0.003	573

Note: Radius matching, calliper=0.05

Treatment & Instruments

IV First Stage Regression

Instruments	(1)	(2)	(3)	(4)	(5)
	Access to Piped Water				
Distance to center, 100m	-0.0273***			-0.0269***	-0.0258***
	(0.003)			(0.003)	(0.003)
Rocky ground		-0.1652***		-0.1013***	-0.1014***
		(0.035)		(0.037)	(0.038)
Age of house, 100yrs			0.1434***		0.0913***
			(0.019)		(0.017)
Observations	2,372	2,438	2,438	2,372	2,372
Model FTest	109.035	22.342	54.850	65.309	70.610
Model pval	0.000	0.000	0.000	0.000	0.000
adj R2	0.149	0.008	0.023	0.152	0.161

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Health Impact of Water: Instrumental Variables

Main Results

- Increase in child diarrhea
- Increase in other water related symptoms for all age groups
- Increase in illness severity

Outcome		Mountain Region			
		Impact	F-test Stage 1	Hansen p-value	N
Diarrhoea	Child	0.155***	57.76	0.645	784
	All Ages	0.035	78.71	0.38	1072
Waterborne Diseases	Child	0.213*	57.76	0.795	784
	All Ages	0.0723**	78.71	0.561	1072
Disease Severity	Child	0.307**	57.76	0.557	784
	All Ages	0.0669**	78.71	0.294	1072

Results only for project town with frequent water rationing
Instruments: Distance from center, rocky ground, age of house, control town

Health Impact of Sanitation: Propensity Score Matching

Main Result

- Few health improvements: only when no water rationing occurs
- Increase in water related symptoms among children: if rationing occurs

Outcome		Coastal Region		Mountain Region	
		In-town control		In-town control	
		ATT	N	ATT	N
Diarrhoea	Child	-0.0223	418	0.015	327
	All Ages	-0.0207	841	0.0087	458
Waterborne Diseases	Child	-0.1172	418	0.1382*	327
	All Ages	-0.0373*	841	0.0187	458
Disease Severity	Child	-0.0899	418	0.0684	327
	All Ages	-0.0244	841	0.0077	458

Radius matching, calliper=0.05
Improved sanitation is conditional on access to piped water

Health Impact of Sanitation: Instrumental Variables

Main Results

- No significant health improvements for children or adults

Outcome		Mountains				Coastal			
		Impact	F-test First Stage	Hansen p-value	N	Impact	F-test First Stage	Hansen p-value	N
Diarrhoea	Child	0.001	34.38	0.632	311	-0.187	4.938	0.496	411
	All Ages	0.011	46.91	0.335	436	-0.071	3.16	0.42	826
Waterborne Diseases	Child	0.103	34.38	0.907	311	-0.552	4.938	0.703	411
	All Ages	0.008	46.91	0.887	436	-0.152	3.16	0.33	826
Disease Severity	Child	0.024	46.91	0.518	436	-0.079	3.16	0.792	826
	All Ages	0.158	34.38	0.667	311	-0.626	4.938	0.793	411

Instruments: Distance from center, rocky ground, age of house, control town
Improved sanitation is conditional on access to piped water

Robustness

Matching

Same results with more extreme techniques

- Kernel Matching (improved common support)
- Nearest-Neighbor Matching (reduced common support)

Instrumental Variables

Same results with different instrument set (but weaker first stage)

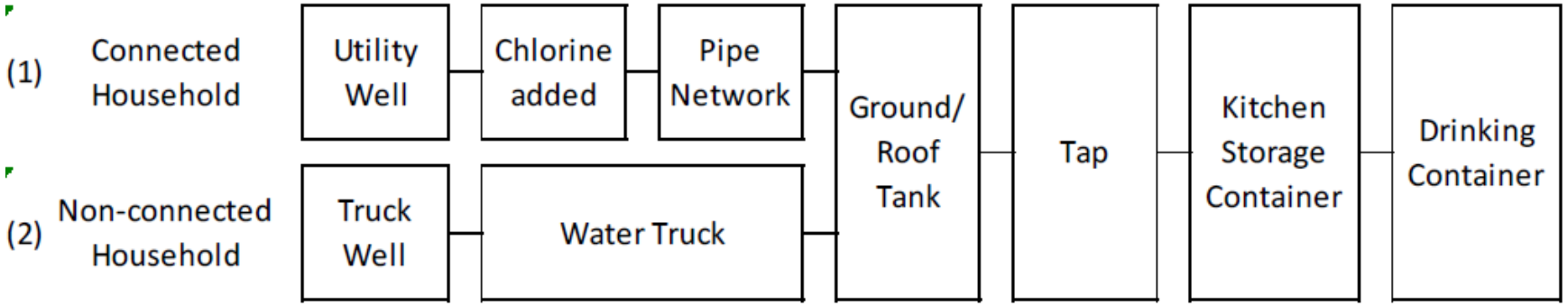
- without binary control town indicator (potential violation of exclusion restriction)
- without age of house (potentially endogenous)

Measurement

Same results with

- diseases at individual level
- exclusion of richest quintile

Transmission Mechanism 1: Technical design



Appendix 3: Contamination of Drinking Cup

		E.coli	HH
		%	*N*
Mountain			
Water	Pipewells	20.0	70.0
Sanitation		38.4	73.0
None	Truckwells	20.3	64.0
Control	Truckwells	40.0	65.0
Coastal			
Water	Pipewells	46.4	69.0
Water & Sanit.		36.6	71.0
Control	Truckwells	61.4	88.0
Total		38.6	500.0

Table 1. Pollution at Point-of-use and Diarrhea (Dysentery)

Dysentery	(1)	(2)	(3)	(4)	(5)	(6)
	Illness		Severity		Duration	
Total Coliform	0.0020**	0.0029**	0.0014*	0.0020*	0.0070**	0.0098**
at Drinking Cup	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.004)
Observations	499	499	499	499	499	499
Controls	NO	YES	NO	YES	NO	YES

Robust standard errors in parentheses

Significance levels *** p<0.01, ** p<0.05, * p<0.1

Controls include age, gender, education, hygiene behavior, improved water and sanitation, location fixed effects

Source: Lechtenfeld (2012).

Table 3. Water pipe pollution: Total Coliform, low threshold

Total Coliform Low Pollution Threshold	(1) OLS	(2) Probit	(3) IV	(4) BL	(5) BP	(6) BP	(7) BP	(8) BP
Piped Water	0.0228	0.0202	0.2009	0.0586	0.0111	0.0118	0.0198	0.0328
	(0.050)	(0.046)	(0.131)	(0.137)	(0.030)	(0.030)	(0.041)	(0.052)
Roof Tank	-0.0948	-0.0953	-0.0760	-0.0910		-0.1910***	-0.1947***	-0.1544***
	(0.064)	(0.064)	(0.069)	(0.066)		(0.066)	(0.064)	(0.058)
Tank Size (100L)	0.0009	0.0007	0.0011	0.0009		0.0002	-0.0007	-0.0003
	(0.001)	(0.001)	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)
Water Rationing	-0.0505	-0.0336	-0.1427	-0.0690			1.4169***	0.8881***
	(0.075)	(0.053)	(0.100)	(0.102)			(0.108)	(0.079)
Household Size (Neighborhood mean)	0.0327*	0.0360*	0.0417**	0.0345*				-0.0154
	(0.019)	(0.022)	(0.020)	(0.020)				(0.024)
Housing Index (Neighborhood Mean)	0.3903	0.4585	0.4750	0.4073				-0.3143
	(0.308)	(0.335)	(0.313)	(0.314)				(0.316)
Mother Education (Neighborhood Mean)	-0.1756	-0.2342*	-0.3889**	-0.2185				0.4547***
	(0.128)	(0.126)	(0.190)	(0.205)				(0.142)
Income per capita (Neighborhood Mean)	-0.0662	-0.0736	-0.1032*	-0.0736				0.0955**
	(0.050)	(0.052)	(0.055)	(0.053)				(0.044)
Mountain Region	-0.2561***	-0.2597***	-0.3134***	-0.2676***	0.2654***	0.4058***	0.3609***	0.2818***
	(0.074)	(0.073)	(0.086)	(0.084)	(0.036)	(0.067)	(0.071)	(0.069)
Observations	446	446	446	446	481	464	446	446
Model F-Test	5.680		6.376					
Model Chi2		39.38		53.23	4158.8	1297.4	2393.0	5288.3
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Probit rho chi2				0.098	2.546	2.715	2.201	0.283
Probit rho p-value				0.952	0.111	0.099	0.138	0.595
ATE water	0.023	0.020	0.201	0.040	0.020	0.022	0.036	0.061
ATT water	0.023	0.024	0.201	0.033	0.021	0.025	0.041	0.070

Robust standard errors in parentheses; Significance *** p<0.01, ** p<0.05, * p<0.1
Probit, BL and BP in average marginal effects

Source: Lechtenfeld (2012)

5. Sources of Water Pollution

Hypothesis 1: The source well is polluted

			Source Well Polluted		Sample Size
		Water Source	E.coli *percent*	TDS *percent*	Wells *N*
Mountain	Water Water & Sanit	Pipewells	0.0	20.0	5
	None	Truckwells	0.0	66.7	3
	ControlTown	Truckwells	0.0	0.0	3
Coast	Water Water & Sanit	Pipewells	0.0	100.0	3
	ControlTown	Truckwells	85.7	57.1	7
Total			**28.6**	**47.6**	**21**

- Ecoli Clean
- TDS Some signs of pollution

5. Sources of Water Pollution

Hypothesis 2: The main feed pipes are polluted

	Water pipe polluted			Sample Size
	E.coli	Total Coliform	TDS	Pipes
	percent	*percent*	*percent*	*N*
Mountain	0.00	0.00	0.00	4
Coastal	50.00	100.00	100.00	2
Total	**16.66**	**33.32**	**0.00**	**6**

- Ecoli Pollution in Zabid
- Total Coli Pollution in Zabid
- TDS Pollution in Zabid

5. Sources of Water Pollution

Hypothesis: Water tanks are a source of pollution

a. **Existence of a Tank:** point-of-use water not cleaner without tank

- Tanks are not a general problem

b. **Location of a tank**: roof vs. ground tanks make no difference

- tank pollution seems to have external source

c. **Storage time in tanks:** no difference in tank pollution by time

- Tanks are not the source of pollution

But why are tanks polluted?

- **Rationing of piped water:** can cause storage tank pollution by pipe flushing
- Epidemiological literature suggests pollution through pipe flushing
- Caveat: Not enough variance in water-rationing data to analyze

Hypothesis 6: **Rationing of piped water causes storage tank pollution by mixing**

		Storage Tank Polluted			
	Water Source	E.coli	Total Coliform	TDS	Households
		percent	*percent*	*percent*	*N*
Mountain	Pipe	15.8	61.1	2.1	95
	Mixed	34.9	65.1	18.6	43
Coast	Pipe	36.7	88.5	98.6	139
	Mixed	na	na	na	0
Total		**29.2**	**75.5**	**53.1**	**277**

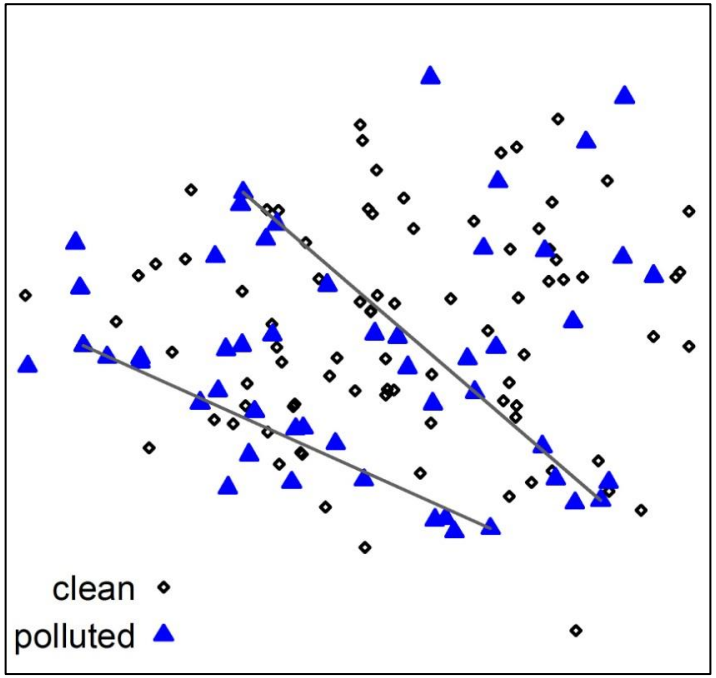
Analysis possible for Amran (very few tanks in Zabid):

- Ecoli Significant increase
- Total Coli No significant differences
- TDS Significant increase

Hypothesis 8: **Leaks in the small feed pipes cause pollution of the drinking water**

Spatial analysis: E.coli pollution in water tanks
Shows some spatial correlation
Indication for pollution from piped network

Zabid (coastal):



5. Sources of Water Pollution

Hypothesis 9: **Household members cause the water pollution at the point-of-use**

Changes in Pollution Prevalence

		E.coli *percentage points*	Total Coliform *percentage points*	TDS *percentage points*	HH *N*
Mountain	Water	23.3	17.2	0.9	116
	No Connection	16.0	10.0	0.0	50
	Control Town	22.0	36.0	0.0	50
Coast	Water	25.6	7.7	-20.5	117
	Control Town	31.0	4.2	-35.2	71
Total		**24.1**	**13.5**	**-11.8**	**407**

Change of pollution between tank and point-of-use:

- Ecoli — Significant increase
- Total Coli — Significant increase
- TDS — No change

Table III.3: Probability of drinking water treatment, connections compared, selected specifications

Specification	(1)	(2)	(3)	(4)	(5)	(6)
Estimator	Probit	Probit	Probit	Probit	Probit	Probit
Piped Water	0.054**	0.033**	0.060***	0.040***	0.061***	0.041***
	(0.012)	(0.015)	(0.013)	(0.015)	(0.014)	(0.015)
Sewerage		0.036**		0.042***		0.042***
		(0.015)		(0.015)		(0.015)
HH Member trained	0.102***	0.096***	0.105***	0.099***	0.106***	0.100***
	(0.020)	(0.020)	(0.021)	(0.021)	(0.021)	(0.021)
Web Access	0.069**	0.066**	0.073**	0.068**	0.073**	0.068**
	(0.033)	(0.033)	(0.033)	(0.034)	(0.033)	(0.033)
Primary Edu	0.044***	0.044***	0.043***	0.044***		
	(0.014)	(0.014)	(0.014)	(0.014)		
Intermediate Edu	0.010	0.008	0.010	0.009		
	(0.023)	(0.022)	(0.022)	(0.022)		
Secondary Edu	0.045**	0.044**	0.050***	0.049***		
	(0.018)	(0.018)	(0.018)	(0.018)		
Tertiary Edu	0.043**	0.042**	0.047**	0.047**		
	(0.021)	(0.020)	(0.021)	(0.021)		
Edu. Durat° HH Head					0.003***	0.003***
					(0.001)	(0.001)
Age HH Head	-0.000	-0.000	-0.000	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Gender HH Head	-0.044*	-0.042*	-0.047*	-0.045*	-0.042*	-0.040*
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
Marital Status HH Head	0.012	0.010	0.011	0.009	0.017	0.015
	(0.021)	(0.021)	(0.020)	(0.021)	(0.021)	(0.021)
Disease Awareness	0.006	0.006	0.006	0.006	0.004	0.004
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Asset Index	0.039***	0.038***	0.037***	0.036***	0.038***	0.038***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Dependency Ratio	-0.000	0.004	-0.006	-0.002	-0.010	-0.006
	(0.027)	(0.028)	(0.027)	(0.027)	(0.027)	(0.027)
Water Tank present	-0.021	-0.020	-0.026	-0.026	-0.027	-0.027
	(0.019)	(0.019)	(0.018)	(0.018)	(0.018)	(0.018)
Region	0.154***	0.161***				
	(0.016)	(0.017)				
Mountain Treatment			0.035**	0.027	0.036**	0.027
			(0.016)	(0.017)	(0.016)	(0.017)
Coastal Treatment			-0.149***	-0.168***	-0.152***	-0.172***
			(0.024)	(0.025)	(0.024)	(0.025)
Coastal Control			-0.071***	-0.074***	-0.074***	-0.077***
			(0.024)	(0.024)	(0.024)	(0.024)
Sample Size	2459	2459	2459	2459	2459	2459
Pseudo R^2	0.175	0.179	0.186	0.191	0.181	0.186

Source: Rieckmann (2014).

Table 5: Intra-household water pollution: changes in total coliform, low threshold

Total Coliform Low Pollution Threshold	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS
Improved water storage	-0.0610**				-0.0583*	-0.0582*	-0.0683**
	(0.031)				(0.031)	(0.031)	(0.031)
Water boiling		-0.1156			-0.1050	-0.1049	-0.1261
		(0.112)			(0.109)	(0.109)	(0.117)
Soap use			0.0084			0.0069	0.0091
			(0.042)			(0.041)	(0.045)
Health Knowledge				0.0114			-0.0010
				(0.038)			(0.041)
Dependency Ratio	0.0292	0.0265	0.0260	0.0212	0.0304	0.0313	0.0286
	(0.062)	(0.062)	(0.062)	(0.063)	(0.062)	(0.062)	(0.063)
Income per capita	0.0023	0.0031	0.0022	0.0014	0.0031	0.0031	0.0025
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
House rented	-0.0099	-0.0151	-0.0141	0.0066	-0.0109	-0.0108	0.0113
	(0.044)	(0.044)	(0.044)	(0.043)	(0.044)	(0.044)	(0.042)
Household Size (Neighborhood mean)	0.0041	0.0050	0.0055	0.0015	0.0038	0.0039	-0.0006
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Housing Index (Neighborhood Mean)	-0.0249	-0.0498	-0.0358	-0.0526	-0.0364	-0.0349	-0.0468
	(0.236)	(0.235)	(0.238)	(0.235)	(0.236)	(0.240)	(0.240)
Mother Education (Neighborhood Mean)	0.1977**	0.2259**	0.2147**	0.1905**	0.2082**	0.2077**	0.1840*
	(0.096)	(0.095)	(0.097)	(0.097)	(0.095)	(0.096)	(0.096)
Mountain Region	-0.0674	-0.0379	-0.0442	-0.0356	-0.0610	-0.0613	-0.0552
	(0.058)	(0.055)	(0.056)	(0.057)	(0.057)	(0.057)	(0.058)
Control town mountains	0.1335***	0.1247***	0.1302***	0.1160***	0.1294***	0.1303***	0.1185***
	(0.042)	(0.042)	(0.043)	(0.042)	(0.042)	(0.044)	(0.044)
Control town coast	0.0441	0.0522	0.0513	0.0465	0.0456	0.0458	0.0418
	(0.043)	(0.043)	(0.042)	(0.043)	(0.043)	(0.043)	(0.043)
Tank Pollution	-0.866***	-0.868***	-0.868***	-0.880***	-0.865***	-0.864***	-0.875***
	(0.046)	(0.046)	(0.046)	(0.047)	(0.046)	(0.046)	(0.047)
Constant	0.708***	0.641***	0.634***	0.692***	0.704***	0.696***	0.760***
	(0.140)	(0.137)	(0.137)	(0.138)	(0.140)	(0.140)	(0.141)
Observations	480	480	480	472	480	480	472
adj R2	0.550	0.549	0.547	0.556	0.550	0.550	0.560
Model F-Test	40.883	41.336	40.762	44.086	37.872	34.857	35.208
Model p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Robust standard errors in parentheses
Significance *** p<0.01, ** p<0.05, * p<0.1

Source: Lechtenfeld (2012)

Conclusions

Conclusions

Key Results

- No positive health impact of piped water and sanitation
- Impact worst in areas with frequent water rationing, which causes pollution in pipes
- Extended rationing forces households to use unimproved water sources
- Widespread water pollution at point-of-use
- No signs of water purification at point of use

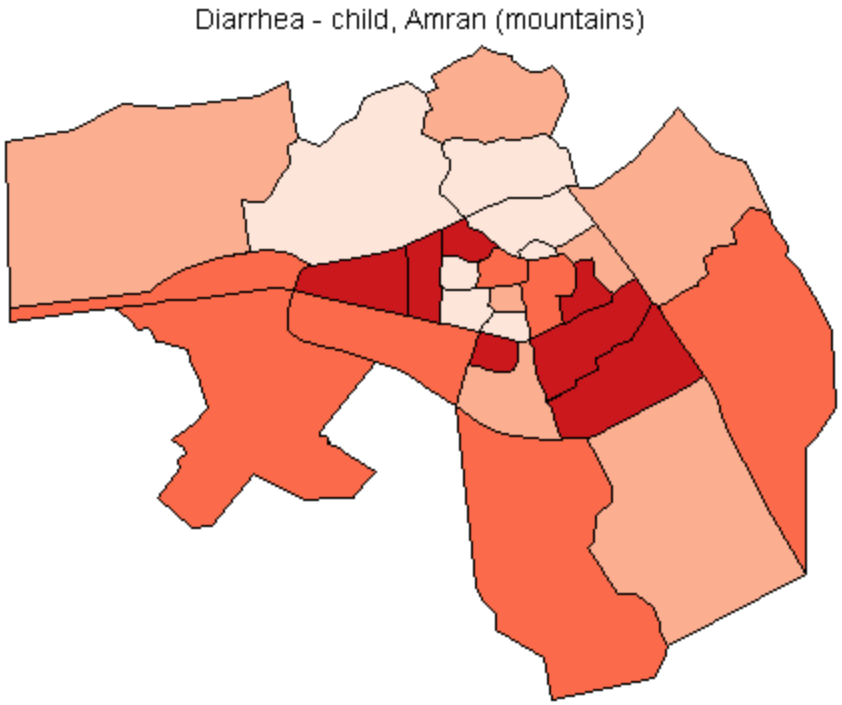
Policy Implication

- Investment in piped water supply should not be made when reliable water supply cannot be guaranteed
- Instead, alternatives should be tested to get better health outcomes at lower cost:
  1. engage with existing truck water vendors
  2. public standpipes with chlorinated water
  3. point-of-use water treatment
  4. hygiene education

Additional Details

Spatial Distribution of Water Pollution

Waterborne diseases also vary across space:



Data

Household Survey

		HHs	*Population*
Mountains	Water	201	1777
	Water & Sanitation	270	2257
	None	374	2977
	Control Town	298	2508
Coast	Water	127	859
	Water & Sanitation	714	4746
	Control Town	434	3101
Total		**2418**	**18225**

Identification

1. Matching

Only compares similar HHs between treatment and control groups, where similarity is defined by the predicted propensity of receiving treatment

Pro: Works with ex-post data

No functional form assumptions

Con: Biased if treatment selection driven by unobservables (conditional independence assumption)

Biased if used covariates are affected by treatment

Sensitive to specification of treatment model

2. Instrumental Variables Analysis

Measure the impact of predicted treatment by an instrument

Pro: Works with ex-post data

Avoids problem of unobserved treatment selection

Con: Biased if instrument directly affects outcome (exclusion restriction)

Biased if instrument only weakly predicts treatment

3. Double Differencing

Differencing between treatment and control group and over time

Pro: Removes systematic bias from ex-ante differences between treatment and control group

Con: Biased if time-variant differences exist (e.g. other interventions)

Biased if unobserved treatment selection

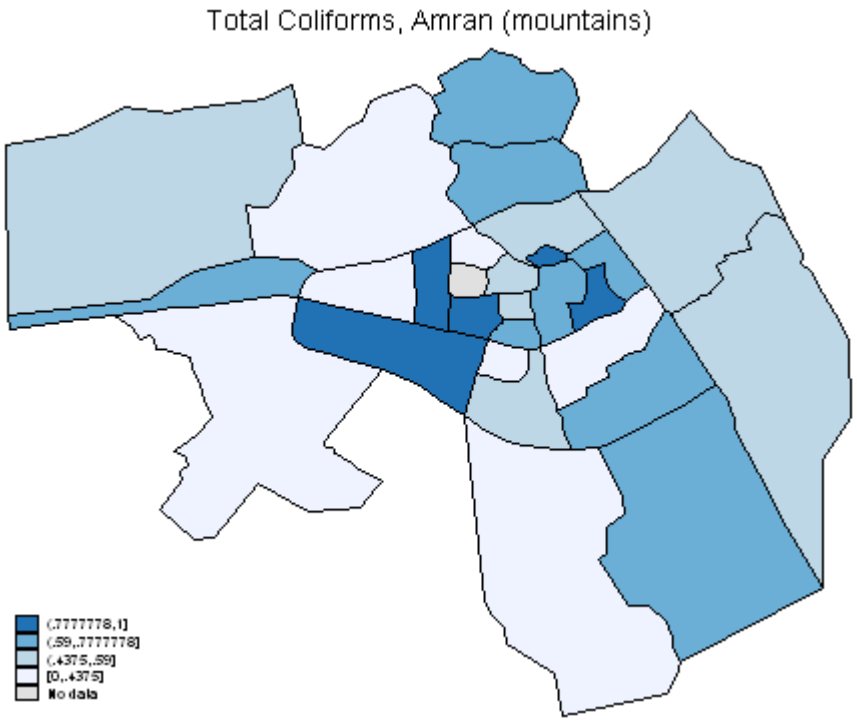
Identification

Controls:

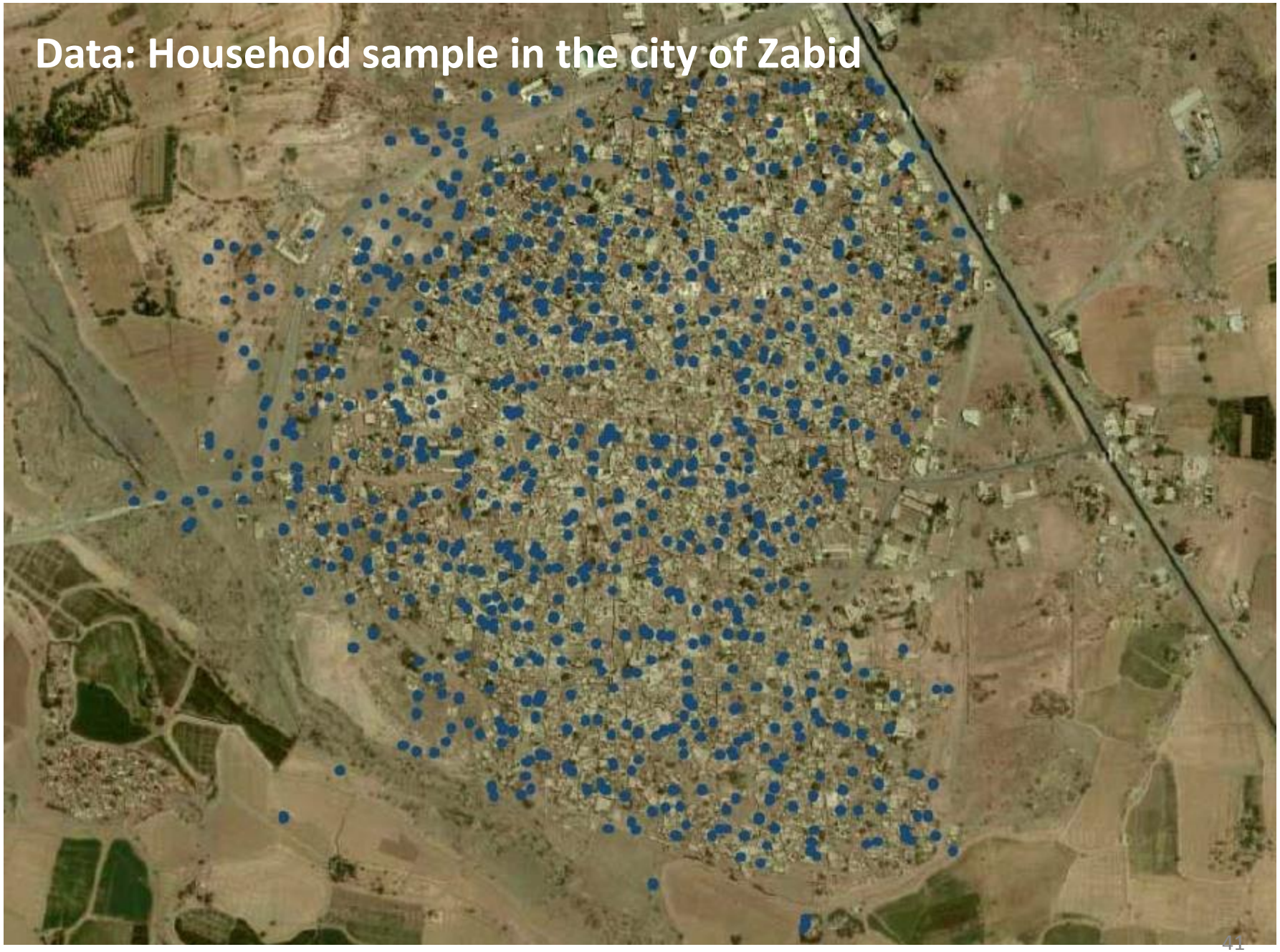
Education Level Parents, Disease knowledge, Soap, Purification, Bad water quality, Sewerage clogging, Dependency ratio, House ownership, Wealth (Asset Index), Truck Water Use

Spatial Distribution of Water Pollution

Water pollution varies across space:



Data: Household sample in the city of Zabid



Data

Illnesses 30 days prior to survey

		Diarrhea	Abdominal Pain / Vomiting	Fever	People in subsample
		Percent	*Percent*	*Percent*	*N*
Mountains	Water	4.47	4.24	4.87	1744
	Water & Sanit.	5.38	4.66	6.14	2361
	Control Area	3.32	3.72	4.70	2981
	Control Town	2.90	3.07	2.38	2479
Coast	Water	4.77	4.54	6.52	859
	Water & Sanit.	3.29	2.70	3.52	4746
	Control Town	2.71	2.61	3.87	3100
Total		**3.60**	**2.98**	**3.76**	**18270**

Data

Water purification at household level

		Boil	*Water filter*	*Other*	*No Treatment*	*HHs*
		%	*%*	*%*	*%*	*N*
Mountains	Water	4.9	18.0	2.0	74.3	490
	Control Area	2.4	7.2	1.9	87.2	374
	Control Town	2.3	4.7	0.7	91.6	299
Coast	Water	1.9	0.4	0.7	97.0	841
	Control Town	0.9	0.5	1.2	97.5	434
Total		**2.5**	**5.4**	**1.3**	**90.4**	**2476**

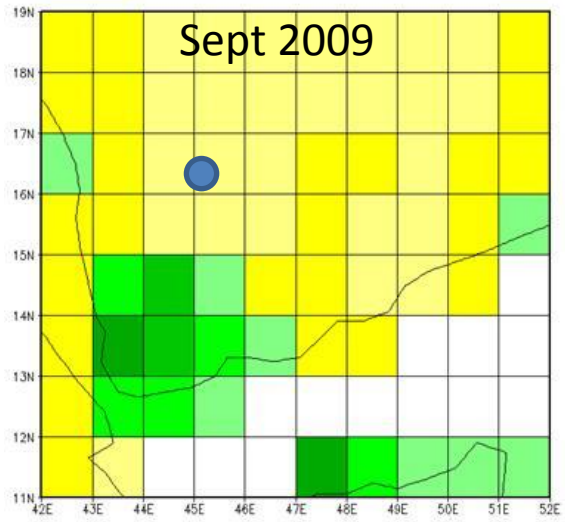
Data

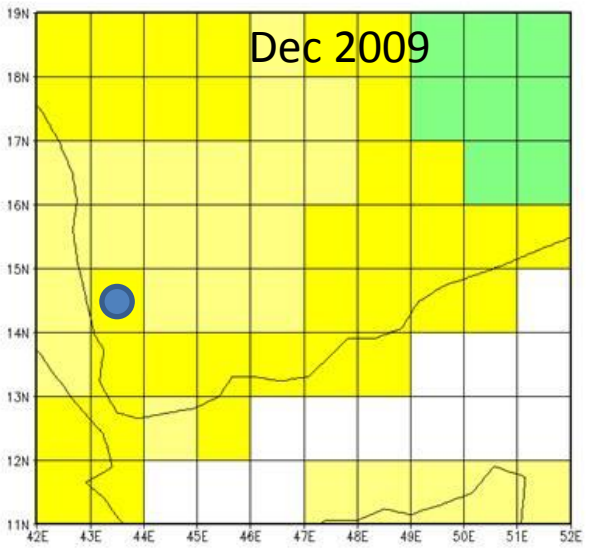
Water pollution: E.coli and Total Dissolved Solids

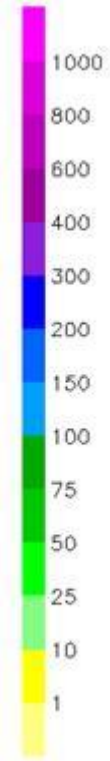
			Households		Sample Size
		Water Source	Drinking Cup Polluted		HH
			E.coli	TDS	
			percent	*percent*	*N*
Mountains	Water	Pipe	20.0	10.0	70
	Water & Sanit		38.4	5.5	73
	Control Area	Truck	20.3	12.5	64
	Control Town	Truck	40.0	0.0	65
Coast	Water	Pipe	46.4	75.4	69
	Water & Sanit		36.6	84.5	71
	Control Town	Truck	61.4	29.5	88
Total			38.6	31.4	500

Robustness: **Rainfall** (GPCC Data 2011)

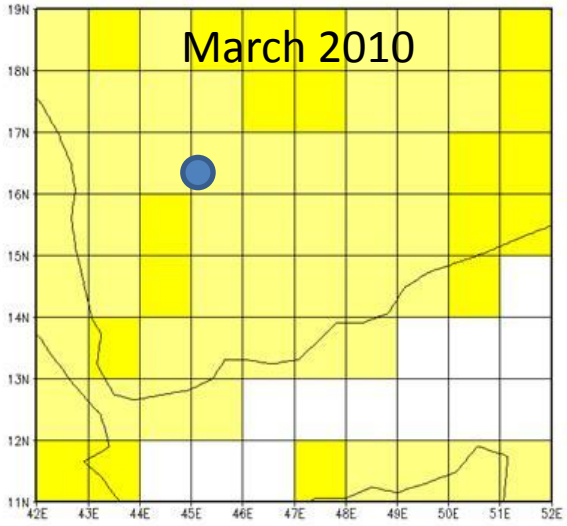
SURVEY: Mountains Coast mm rain

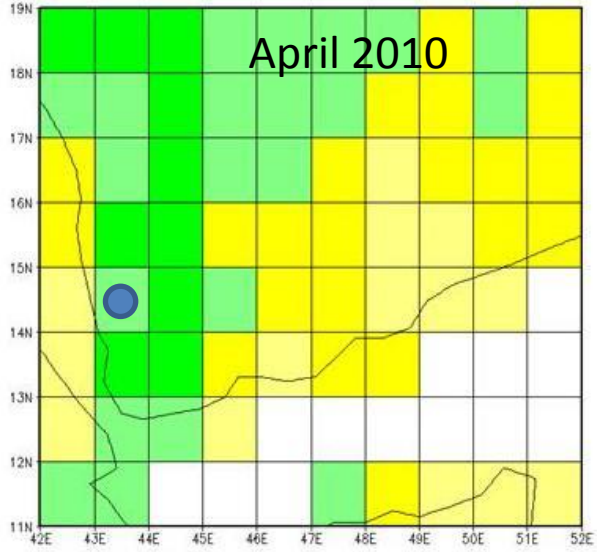






WATER TESTS: Mountains Coast





Background Middle East & North Africa

MENA	21 countries
Population	432 mio (2007)
Urban	65%

Urb. population increase: 60% till 2020

General problems across the region

- unclear land rights, incl. access to wells (surface property vs. land property)
- over-exploitation of groundwater
- unlicensed well drilling
- growing urban populations

Drinking water per person

Liters per day (drinking, cooking, bathing)

WHO	20-40 L	WHO 2005
MENA	38.6 L	
Yemen	4.4 L	
Germany	193 L	

Background Yemen

• Population	23.6 Mio	World Bank 2009
• Size	530.000 km²	1.5x Germany
• GNI per cap	2,330 USD PPP	2nd lowest in Arab world
• HDI	rank 133 (of 169)	lowest in Arab world
• Child Mortality	66/1000	under 5
main cause	diarrheal diseases	
• Adult illiteracy	29.6% male	UNDP 2004
	61.6% female	

Annual Rainfall

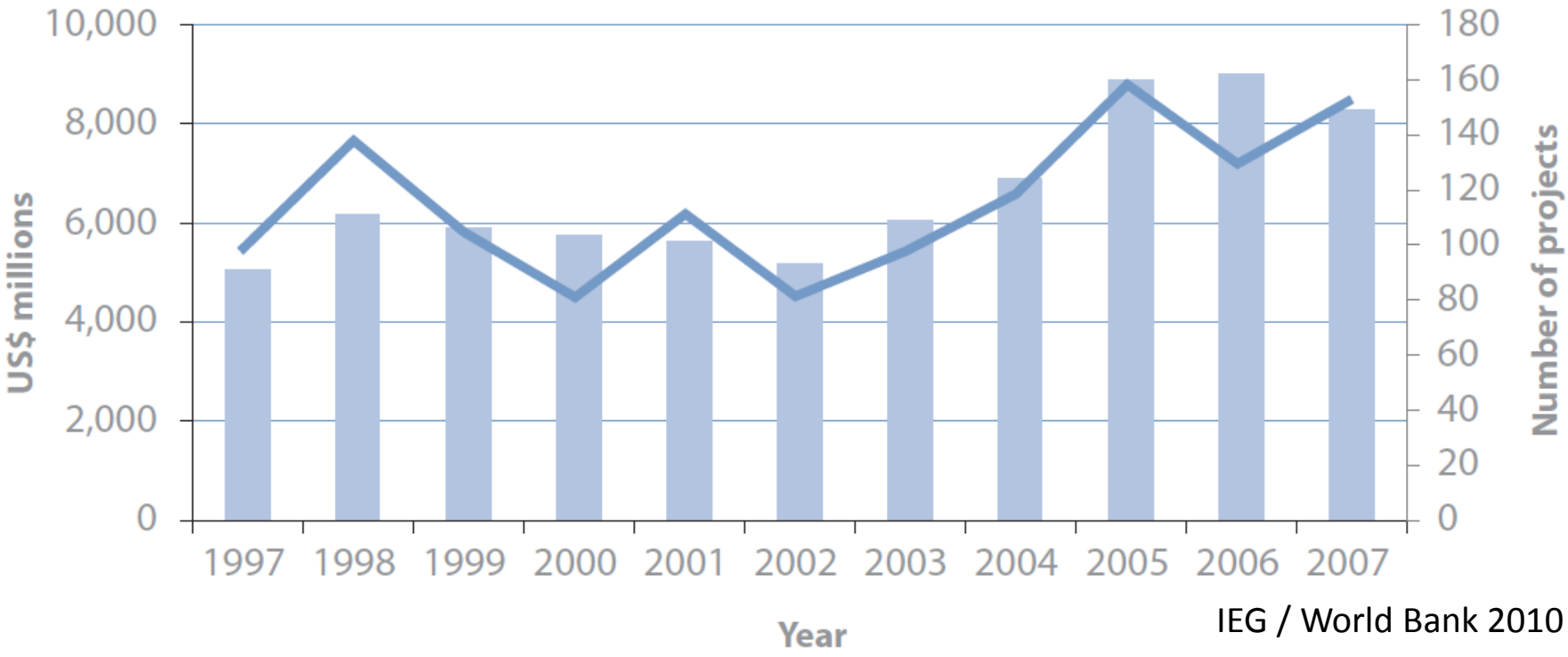
Mountains	250 mm
Coast	39 mm
Göttingen	649 mm

Total Renewable Freshwater Supply

Available	4.10 km³
Withdrawal	6.63 km³
Overuse	61.2 %

Motivation

World Bank lending in the water sector, 1997-2007:



IEG / World Bank 2010

Literature Why only limited health impacts?

Jalan and Ravallion (2003) *Journal of Econometrics*

- Treatment: -Piped water to each household in village
- Analysis: -Propensity score matching
- Results: - Diarrhea significantly lower among treated children (<5yrs)
  - BUT conditional on **mother's education**

Semenza et al (1998) *American Journal of Tropical Medicine and Hygiene*

- Epidemiological analysis of pollution sources in urban Uzbekistan
- Randomized Control Trial: chlorination of drinking water at home (N=240)
- Results: - Home treatment more important than piped water
  - No detectable levels of chlorine residues in 30% of pipes
  - Clear sign of **pipe pollution**
  - Chlorination and water pressure matters

Literature Meta Studies

Gundry et al (2004) *Journal of Water and Health*

- Focus: health outcomes related to household water quality
- Literature review: 16 studies on diarrhea and cholera
- Results: improved drinking water reduces cholera
  no clear impact on diarrhea

Wright et al (2004) *Tropical Medicine and International Health*

- Focus: microbiological contamination between source and point-of-use
- Literature review: 57 studies on pollution at source and point-of-use
- Results: negligible effects of source improvements on drinking quality
  storage and treatment at household level key to pollution

6 March 2012 Last updated at 11:28 GMT

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By David Loyn
Development correspondent, BBC News

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