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Supplemental Material

Boiled or Bottled: Regional and Seasonal Exposures to Drinking Water Contamination and Household Air Pollution in Rural China

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Additional File- Excel Document

Table S1: Person/s in the household who usually boils drinking water (any method) by gender, age, and province

	Guangxi	Henan	Total
Females age<5	0 (0%)	2 (0%)	2 (0.4%)
Females age>15	101 (46.8%)	156 (47.1%)	257 (47.0%)
Males age<5	1 (0.5%)	1 (0.3%)	2 (0.4%)
Males age 5-14	2 (0.9%)	0 (0%)	2 (0.4%)
Males age>15	26 (12.0%)	41 (12.4%)	67 (12.3%)
Females age>15 & Males age>15	37 (17.1%)	3 (0.9%)	40 (7.3%)
Not fixed (varies)	48 (22.2%)	127 (38.4%)	175 (32.0%)
Don't know	0 (0%)	1 (0.3%)	1 (0.2%)
Other	1 (0.5%)	0 (0%)	1 (0.2%)
Total	216 (100%)	331 (100%)	547 (100%)

Table S2: Mean Thermotolerant Coliform concentrations (MPN) by household water treatment method: Summer data alone and with Guangxi winter data

		Arithmetic mean		Geometric mean*	
	n	Mean (95% CI)	% lower than ref.	Mean (95% CI)	% lower than ref.
Guangxi & Henan Summer Data					
Boil: Electric Kettle	240	7.37 (3.24-11.50)	86%	1.55 (1.33-1.80)	83%
Boil: Pot	316	6.98 (3.31-10.65)	87%	1.47 (1.29-1.67)	84%
Bottled Water	267	16.38 (9.54-23.22)	69%	3.32 (2.78-3.97)	63%
Untreated Water	81	53.48 (33.41-73.55)	*reference*	8.94 (5.56-14.39)	*reference*
Summer Data & Guangxi Winter Data					
Boil: Electric Kettle	309	6.58 (3.03-10.13)	85%	1.47 (1.30-1.66)	77%
Boil: Pot	329	6.71 (3.18-10.24)	85%	1.45 (1.28-1.64)	77%
Bottled Water	278	15.76 (9.18-22.34)	64%	3.20 (2.69-3.80)	50%
Untreated Water	99	44.00 (27.12-60.88)	*reference*	6.41 (4.22-9.74)	*reference*

*Note: 1 (one) was added to the variables prior to calculation.

Table S3: Log_{10} Thermotolerant Coliform coefficients from the adjusted model for Guangxi & Henan (summer data) with bottled water cost data included

	Adjusted Model
Fixed part	
Boil with electric kettle (vs. no)	-0.58 (0.10)***
Boil with pot (vs. no)	-0.46 (0.10)***
Drink bottled water (vs. no)	-0.31 (0.10)**
"Improved" water source (vs. no)	-0.00 (0.06)
Safe water storage (vs. no)	0.03 (0.09)
HH is literate (vs. no)	-0.05 (0.08)
HH head's age (10 year steps)	0.02 (0.02)
TVs by HH population	-0.02 (0.07)
Village mean cost for bottled water (RMB)	*0.04 (0.02)**
Wash post defecation (vs. no)	-0.07 (0.12)
Soap likely used (vs. no)	-0.08 (0.05)
Wash before meals (vs. no)	-0.15 (0.12)
Province (Guangxi=0 Henan=1)	-0.10 (0.10)
Intercept	0.73 (0.24)**
Random part	
Between-level $\sqrt{\psi}$	0.11 (0.04)
Within-level $\sqrt{\theta}$	0.61 (0.02)
Model comparison	
Log-likelihood	-537.9
N	555

Notes: HH = household | * p<0.05; ** p<0.01; *** p<0.001 | Values are Log_{10}TTC β coefficients with standard errors (SE) in parentheses. $\sqrt{\psi}$ and $\sqrt{\theta}$ are the between-cluster and within-cluster standard deviation, with SE in parentheses. As model fit improves, log-likelihood tends to decrease. The large bottled water price SE is because village means were used for all households in a village. "Improved" water source classifications were based on JMP definitions at the time of the study (WHO/UNICEF, 2014).

Table S4: Log_{10} Thermotolerant Coliform coefficients from the adjusted model for Guangxi & Henan (summer data) using Maximum Likelihood Estimation

	Adjusted Model
Fixed part	
Boil with electric kettle (vs. no)	-0.66 (0.08)***
Boil with pot (vs. no)	-0.58 (0.09)***
Drink bottled water (vs. no)	-0.39 (0.08)***
"Improved" water source (vs. no)	0.01 (0.05)
Safe water storage (vs. no)	0.03 (0.07)
HH is literate (vs. no)	-0.03 (0.06)
HH head's age (10 year steps)	0.00 (0.00)
TVs by HH population	-0.02 (0.06)
Wash post defecation (vs. no)	-0.05 (0.10)
Soap likely used (vs. no)	-0.06 (0.04)
Wash before meals (vs. no)	-0.10 (0.10)
Province (Guangxi=0 Henan=1)	-0.29 (0.07)***
Intercept	1.07 (0.17)***
Random part	
Between-level $\sqrt{\psi}$	0.12 (0.03)
Within-level $\sqrt{\theta}$	0.55 (0.01)
Model comparison	
Log-likelihood	-609.4
N	732

Notes: HH = household | * p<0.05; ** p<0.01; *** p<0.001 | Values are Log_{10}TTC β coefficients with standard errors (SE) in parentheses. $\sqrt{\psi}$ and $\sqrt{\theta}$ are the between-cluster and within-cluster standard deviation, with SE in parentheses. As model fit improves, log-likelihood tends to decrease. The large bottled water price SE is because village means were used for all households in a village. "Improved" water source classifications were based on JMP definitions at the time of the study (WHO/UNICEF, 2014).

Table S5: Mean temperature and SUMS iButtons data for Guangxi summer and winter study villages

		Publicly available weather data [a]			**SUMS iButtons data (our study)**
		August, 2013	**December, 2013**	**January, 2014**	**December 2013 to January 2014** Mean of median temperatures (n)
County A	Mean low	25°C	9°C	10°C	Village #3 = 11.4°C (15)
	Mean high	33°C	17°C	19°C	Village #6 = 15.4°C (8)
County B	Mean low	25°C	8°C	9°C	Village #9 = 14.3°C (10)
	Mean high	32°C	17°C	19°C	Village #10 = 16.5°C (14)

[a] Publicly available weather data from http://tianqi.2345.com (WK, 2019)

Table S6: Data used to calculate risk ratios for detected Thermotolerant Coliforms and reported diarrhea by household water treatment method: Summer data alone and with Guangxi winter data

	TTC Contamination Detected		Diarrhea Reported	
	No	**Yes**	**No**	**Yes**
Guangxi & Henan Summer Data				
Untreated Water	33	48	76	5
Bottled Water	131	136	252	14
Boil: Electric Kettle	205	35	230	12
Boil: Pot	279	37	300	17
Summer Data & Guangxi Winter Data				
Untreated Water	48	51	96	5
Bottled Water	141	137	263	14
Boil: Electric Kettle	267	42	302	12
Boil: Pot	291	38	314	17

Table S7: Modeled air pollution concentrations by province and season.

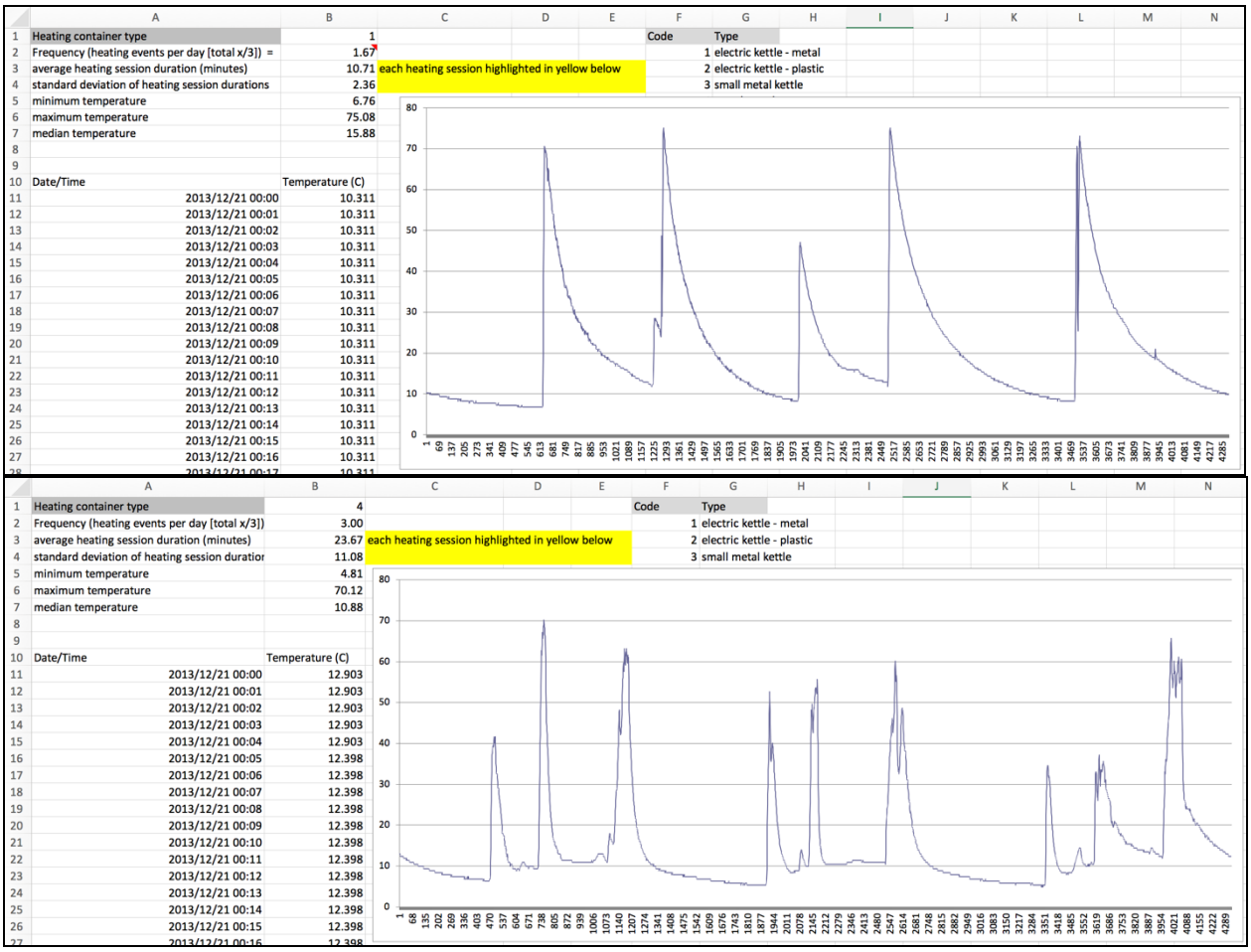
Province	**Season**	**Mean (μg/m^3)**	**SD**	**N**
Guangxi	Winter	87	12	5
Guangxi	Summer	66	95	60
Henan	Summer	84	24	146

Table S8: Estimated indoor PM2.5 concentrations from boiling water with biomass by province, season, ventilation category, and fuel type.[a]

Province	Season	Ventilation category[b]	Fuel Type	Estimated Concentration (µg/m^3)	SD	N
Guangxi	Summer	good	crops	53	81	4
Guangxi	Summer	avg	twigs	73	88	18
Guangxi	Summer	good	logs	61	84	3
Guangxi	Summer	avg	logs	100	145	5
Guangxi	Summer	good	twigs	47	55	26
Guangxi	Summer	poor	logs	143	213	2
Guangxi	Summer	poor	twigs	124	154	2
Henan	Summer	good	twigs	66	75	110
Henan	Summer	good	logs	94	137	17
Henan	Summer	good	crops	196	700	15
Henan	Summer	avg	twigs	84	110	3
Henan	Summer	poor	twigs	178	240	1
Guangxi	Winter	good	twigs	71	93	2
Guangxi	Winter	avg	twigs	95	108	1
Guangxi	Winter	avg	logs	116	163	1
Guangxi	Winter	good	logs	86	113	1

[a] PM2.5 estimates were modeled using a Monte Carlo single compartment box model, as described in the methods.
[b] We created a qualitative ventilation index based on survey questions related to ventilation: cooking location (attached to the house versus separate) and enumerator-based observations of household ventilation status. Ventilation index results (1-9 scale) were binned into three categories to represent good (1-3), average (4-6), and poor (7-9) ventilation. Houses were then assigned to these three categories, with category 1 being the most ventilated and category 3 being the least ventilated.

Figure S1: Electric kettle and pot with SUMS iButtons affixed with heat-resistant tape in study village #3 (SUMS units #3 and #5, respectively). Photo credit: Alasdair Cohen.



	A	B	C	D	E	F	G	H
1	Heating container type	1				Code	Type	
2	Frequency (heating events per day [total x/3]) =	1.67				1	electric kettle - metal	
3	average heating session duration (minutes)	10.71	each heating session highlighted in yellow below			2	electric kettle - plastic	
4	standard deviation of heating session durations	2.36				3	small metal kettle	
5	minimum temperature	6.76						
6	maximum temperature	75.08						
7	median temperature	15.88						
8								
9								
10	Date/Time	Temperature (C)						
11	2013/12/21 00:00	10.311						
12	2013/12/21 00:01	10.311						
13	2013/12/21 00:02	10.311						
14	2013/12/21 00:03	10.311						
15	2013/12/21 00:04	10.311						
16	2013/12/21 00:05	10.311						
17	2013/12/21 00:06	10.311						
18	2013/12/21 00:07	10.311						
19	2013/12/21 00:08	10.311						
20	2013/12/21 00:09	10.311						
21	2013/12/21 00:10	10.311						
22	2013/12/21 00:11	10.311						
23	2013/12/21 00:12	10.311						
24	2013/12/21 00:13	10.311						
25	2013/12/21 00:14	10.311						
26	2013/12/21 00:15	10.311						
27	2013/12/21 00:16	10.311						

	A	B	C	D	E	F	G	H
1	Heating container type	4				Code	Type	
2	Frequency (heating events per day [total x/3])	3.00				1	electric kettle - metal	
3	average heating session duration (minutes)	23.67	each heating session highlighted in yellow below			2	electric kettle - plastic	
4	standard deviation of heating session duratior	11.08				3	small metal kettle	
5	minimum temperature	4.81						
6	maximum temperature	70.12						
7	median temperature	10.88						
8								
9								
10	Date/Time	Temperature (C)						
11	2013/12/21 00:00	12.903						
12	2013/12/21 00:01	12.903						
13	2013/12/21 00:02	12.903						
14	2013/12/21 00:03	12.903						
15	2013/12/21 00:04	12.903						
16	2013/12/21 00:05	12.398						
17	2013/12/21 00:06	12.398						
18	2013/12/21 00:07	12.398						
19	2013/12/21 00:08	12.398						
20	2013/12/21 00:09	12.398						
21	2013/12/21 00:10	12.398						
22	2013/12/21 00:11	12.398						
23	2013/12/21 00:12	12.398						
24	2013/12/21 00:13	12.398						
25	2013/12/21 00:14	12.398						
26	2013/12/21 00:15	12.398						

Figure S2: Screenshots showing examples of SUMS iButtons data from household using an electric kettle in village #3 (a: SUMS unit #3 – top) and from household using a pot in village #3 (b: SUMS unit #5 - bottom)

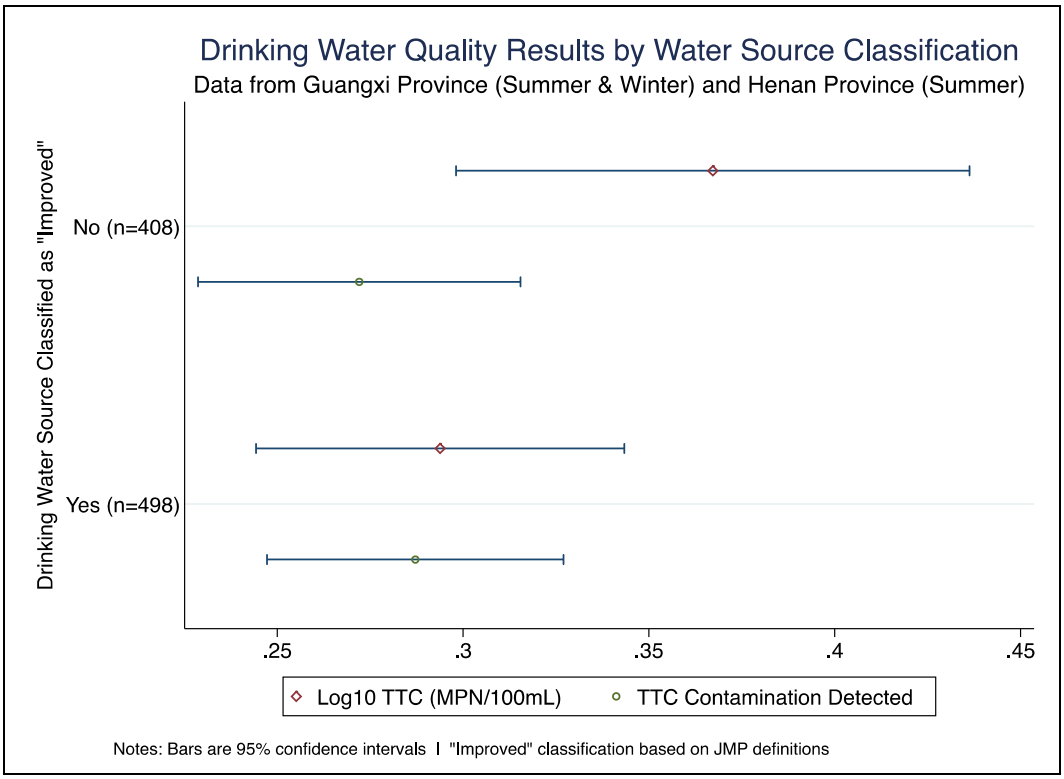
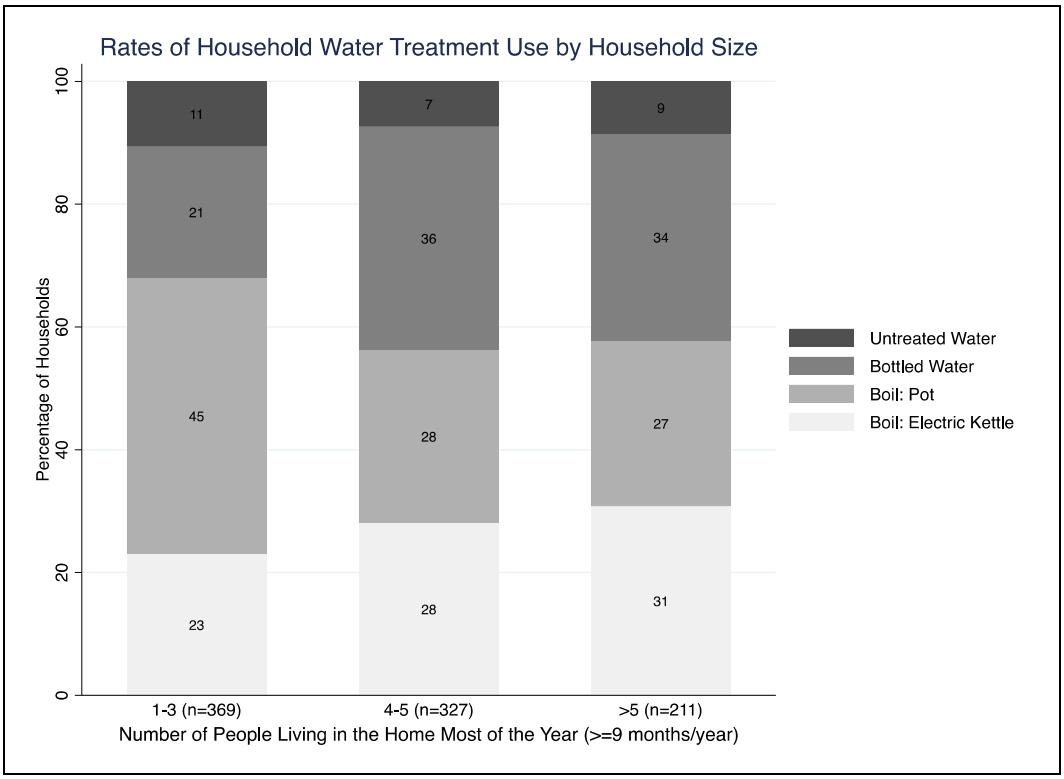


Figure S3: Geometric mean of Log_{10} concentrations as well as counts for Thermotolerant Coliforms (TTC) by JMP-defined [a] source water classifications. The summary data are reported in Table S15.

[a] The Joint Monitoring Programme (JMP) defined "improved sources" as public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, rainwater collection, and piped household water connections (WHO/UNICEF, 2014).



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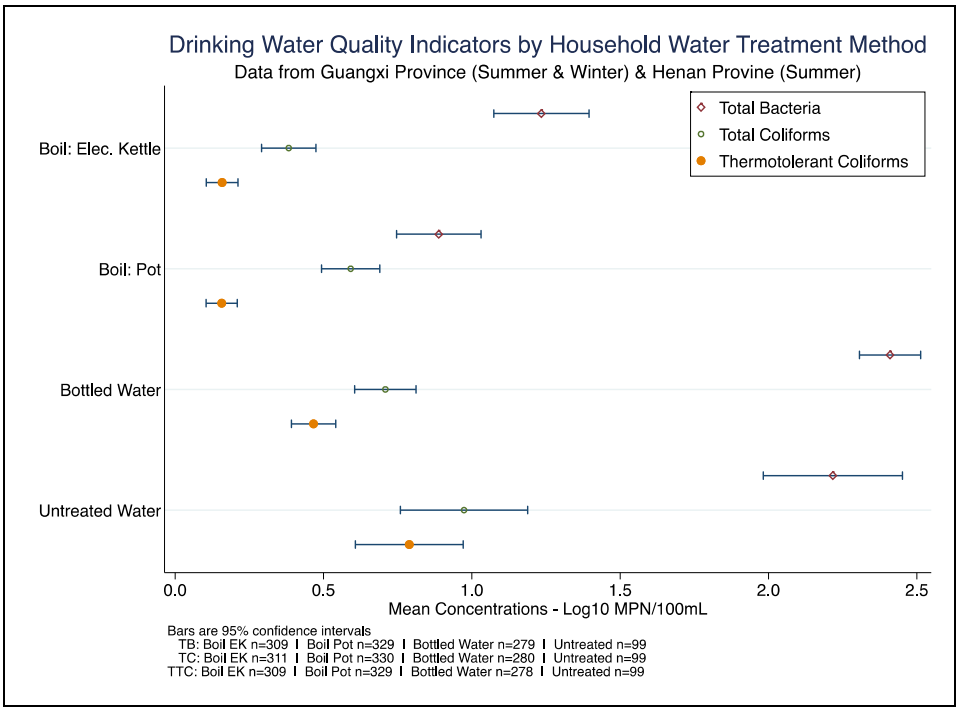

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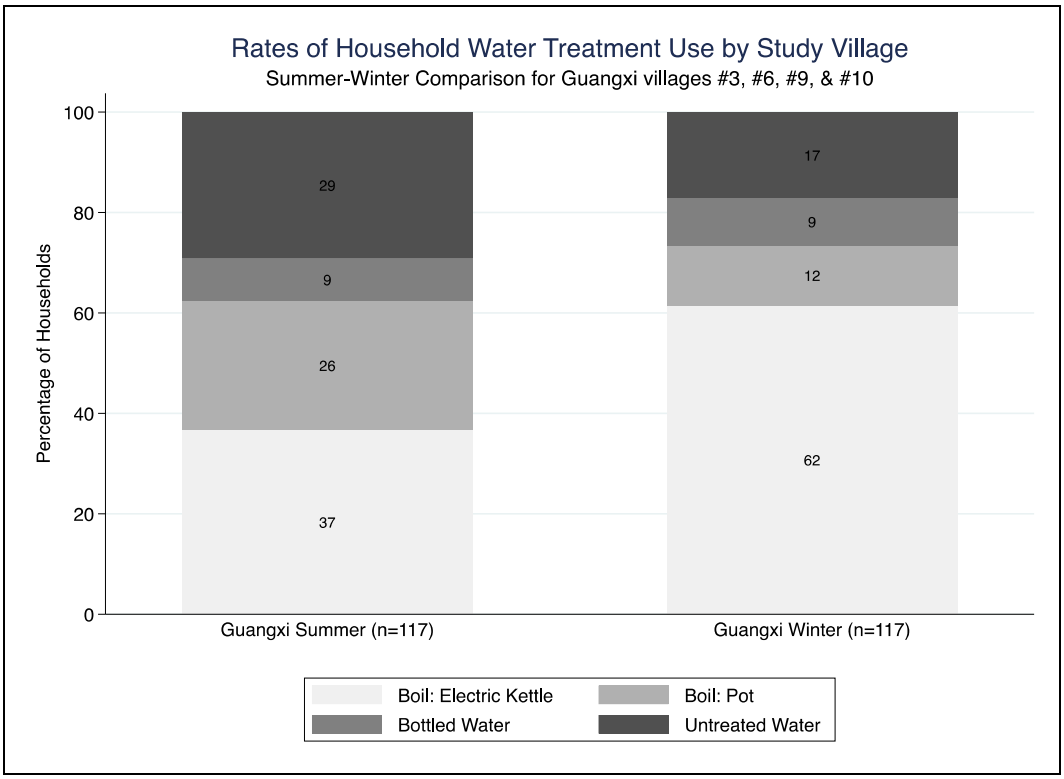

Figure S6: Household water treatment rates during the summer and winter in four Guangxi villages. The source data are reported in Table S18.

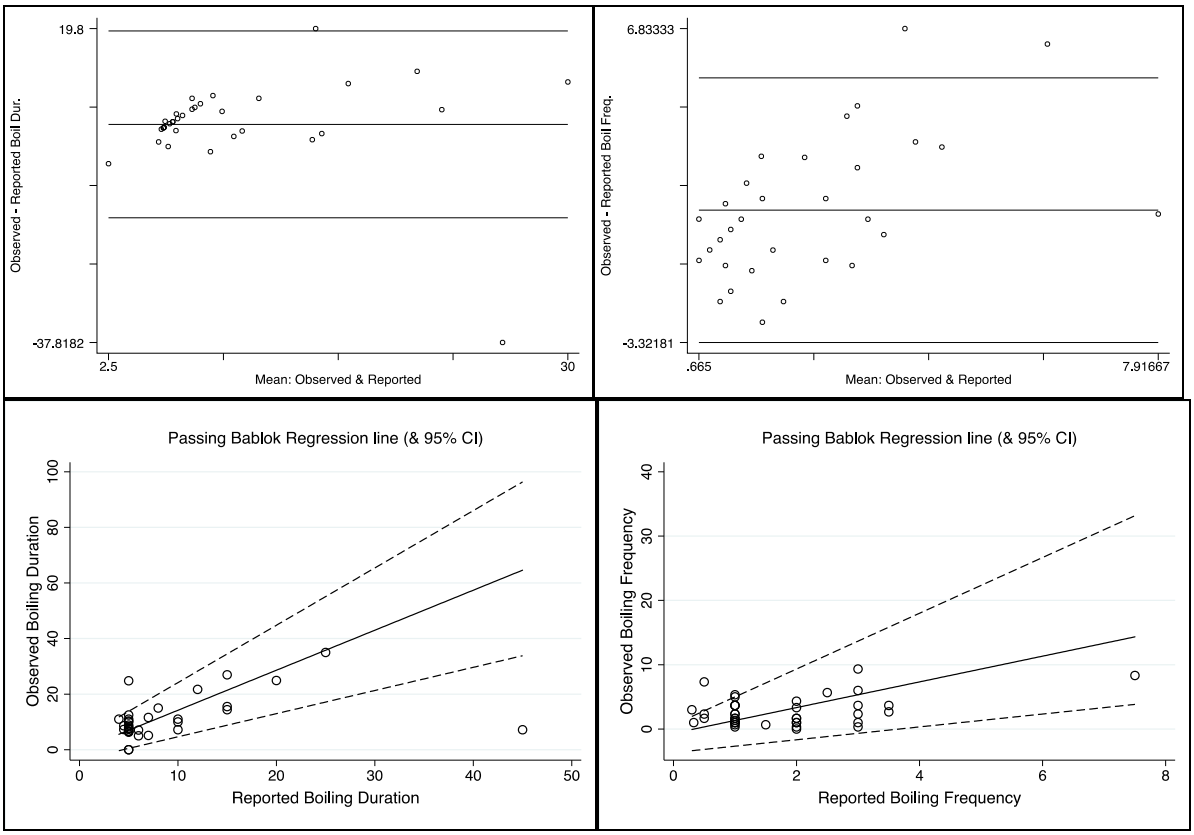

Figure S7: Bland-Altman (top) and Passing-Bablok (bottom) plots comparing observed (measured via the use of SUMS iButtons) and self-report (collected via survey) data on boiling durations (left) and frequencies (right) for Guangxi Province households during winter data collection

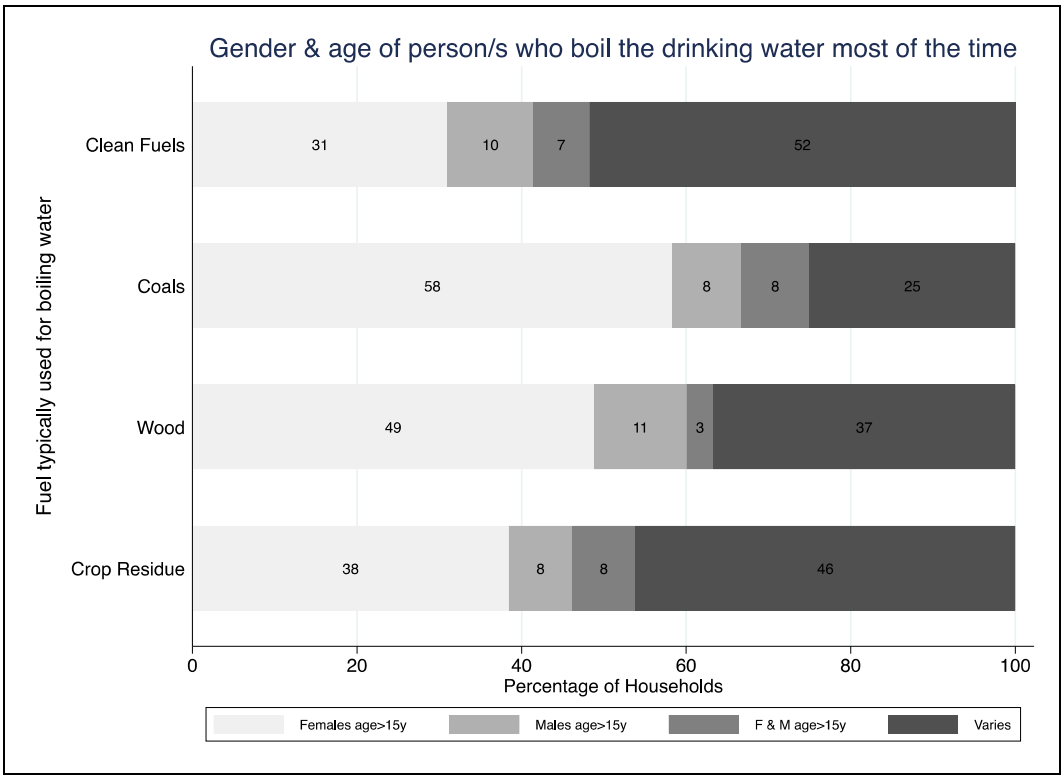

Figure S8: Gender and age of person/s who boiling drinking water by fuel type. The source data (number of households) are reported in Table S19.

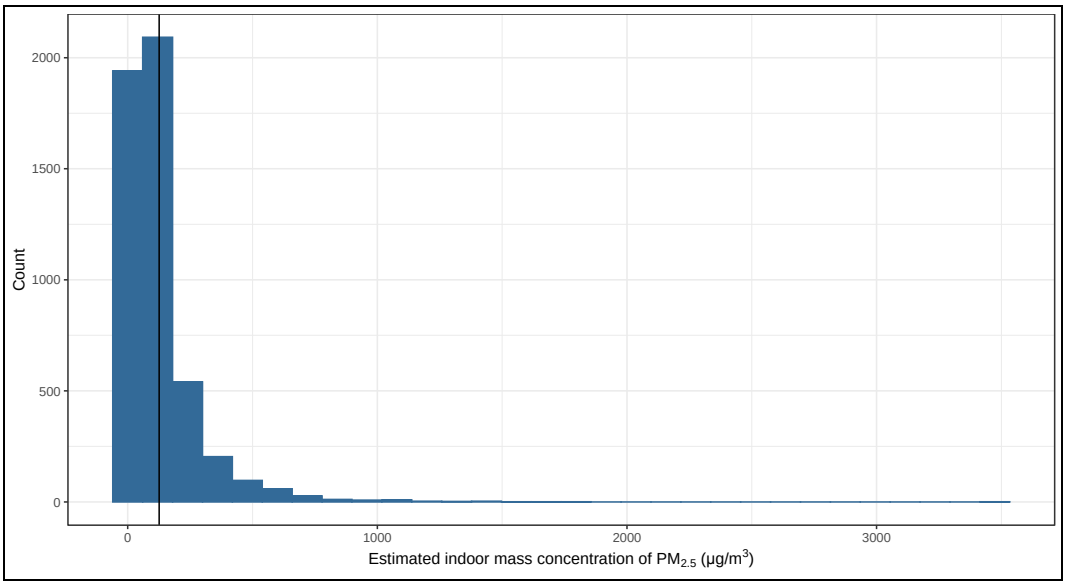

Figure S9: Histogram of 5,000 estimated concentrations output from the box model for one household. The solid black line is the mean estimate from the 5,000 draws (~125 µg/m^3).

References

WHO/UNICEF, 2014. Progress on drinking water and sanitation: 2014 update. World Health Organization, Geneva, Switzerland.

WK, 2019. Online Weather Database: 2345 天气王 [2345 Weather King] (accessed 2019-10-13) [http://tianqi.2345.com]. URL http://tianqi.2345.com (accessed 10.13.19).

Source Data for Figures Presented in the Main Text and Supplemental Material

Table S9: Source data for Figure 1. Proportion of households boiling drinking water and using bottled water by study village

Village Code	Boil: Electric Kettle	Boil: Pot	Bottled Water	Untreated Water	Total Households per Village
1	10	6	12	2	30
2	9	6	14	1	30
3	5	23	1	1	30
4	9	7	13	1	30
5	10	7	10	3	30
6	6	4	8	10	28
7	13	5	12	0	30
8	5	7	15	2	29
9	17	3	1	9	30
10	15	0	0	14	29
11	6	2	18	4	30
12	5	3	18	4	30
13	6	4	12	8	30
14	0	10	15	5	30
15	9	5	5	11	30
16	5	28	0	0	33
17	12	17	1	0	30
18	1	29	0	0	30
19	6	28	0	0	34
20	1	32	0	0	33
21	10	22	0	0	32
22	1	33	0	0	34
23	8	1	20	1	30
24	4	8	18	0	30
25	10	6	12	2	30
26	21	4	5	0	30
27	6	3	21	0	30
28	8	3	18	0	29
29	15	4	8	3	30
30	9	7	13	0	29
Totals	**242**	**317**	**270**	**81**	**910**

Table S10: Source data for Figure 2. Household water treatment use by head of household's age: Guangxi & Henan Summer data

	HoH Age = 20-41	HoH Age = 42-49	HoH Age = 50-57	HoH Age = 58-64	HoH Age = 65-68
Boil: Electric Kettle	56	47	58	39	42
Boil: Pot	35	45	63	82	92
Bottled Water	75	59	65	45	25
Total Households	166	151	186	166	159

Table S11: Summary data for Figure 3. Geometric mean of Log10 concentrations for Total Bacteria (TB), Total Coliforms (TC), and Thermotolerant Coliforms (TTC) by household water treatment (HWT) method

		Total Bacteria	Total Coliforms	Thermotolerant Coliforms
Boil: Electric Kettle	Mean	1.18	0.46	0.18
	SE	0.09	0.06	0.03
	N	240	242	240
Boil: Pot	Mean	0.85	0.63	0.16
	SE	0.07	0.05	0.03
	N	316	317	316
Bottled Water	Mean	2.40	0.74	0.48
	SE	0.05	0.05	0.04
	N	268	269	267
Untreated Water	Mean	2.31	1.11	0.93
	SE	0.12	0.12	0.10
	N	81	81	81

Table S12: Summary data for Figure 5. Geometric mean of Thermotolerant Coliforms (TTC) concentrations by household water treatment (HWT) method, province, and season

		Guangxi – Summer	Guangxi – Winter	Henan - Summer
Boil: Electric Kettle	Mean	0.35	0.08	0.01
	SE	0.06	0.04	0.00
	N	123	69	117
Boil: Pot	Mean	0.56	0.02	0.00
	SE	0.08	0.02	0.00
	N	91	13	225
Bottled Water	Mean	0.48	0.08	0.49
	SE	0.06	0.08	0.04
	N	151	11	116
Untreated Water	Mean	0.99	0.15	0.22
	SE	0.11	0.08	0.11
	N	75	18	6

Table S13: Summary data for Figure 7a. Associations between measured/observed and self-report/survey data for average boiling durations

Observed (SUMs iButtons)	Reported (survey)
35.00	25
0.00	5
11.00	5
0.00	5
15.53	15
14.40	15
7.18	45
12.50	5
8.62	4.5
7.28	4.5
26.95	15
10.33	5
24.91	20
7.71	5
15.00	8
5.00	6
5.14	7
6.60	5
11.60	7
6.67	5
6.32	5
7.33	5
24.80	5
7.20	10
11.00	10

10.00	10
21.71	12
6.56	5
7.67	5
8.86	5
7.08	6
8.27	5
11.00	4
10.00	5

Table S14: Summary data for Figure 7b. Associations between measured/observed and self-report/survey data for average daily frequencies of boiling

Observed (SUMs iButtons)	**Reported (survey)**
2.33	3
1.00	0.33
0.33	2
0.00	2
5.00	1
1.67	0.5
0.67	1
3.67	1
0.67	1.5
1.00	2
2.67	3.5
8.33	7.5
7.33	0.5
3.00	0.3
1.00	1
3.67	1
2.33	1
5.67	2.5
0.33	1
1.33	1
2.33	0.5
3.67	3.5
1.67	1
1.00	1
3.67	1
9.33	3
1.00	2
1.67	2
3.33	2
1.67	2
1.67	1
5.33	1
6.00	3
1.00	1
2.33	1
4.33	2
3.67	3

1.00	3
0.33	3

Table S15: Summary data for Figure S3. Geometric mean of Log10 concentrations and counts for Thermotolerant Coliforms (TTC) by JMP-defined source water classifications.

Drinking Water Source Classified as "Improved" by JMP		Log10 TTC (MPN/100mL)	Proportion of Samples with TTC Detected
No	Mean	0.367	0.272
	SE	0.035	0.022
	N	408	408
Yes	Mean	0.294	0.287
	SE	0.025	0.020
	N	498	498

Table S16: Source data for Figure S4. Household water treatment use by household size in thirds

	1-3 Persons	4-5 Persons	>5 Persons	Total
Boil: Electric Kettle	85	92	65	242
Boil: Pot	166	92	57	315
Bottled Water	79	119	71	269
Untreated Water	39	24	18	81
Total	369	327	211	907

Table S17: Summary data for Figure S5. Geometric mean of Log10 concentrations for Total Bacteria (TB), Total Coliforms (TC), and Thermotolerant Coliforms (TTC) by HWT method – with Guangxi winter data included

		Total Bacteria	Total Coliforms	Thermotolerant Coliforms
Boil: Electric Kettle	Mean	1.23	0.38	0.16
	SE	0.08	0.05	0.03
	N	309	311	309
Boil: Pot	Mean	0.89	0.60	0.16
	SE	0.07	0.05	0.03
	N	329	330	329
Bottled Water	Mean	2.40	0.72	0.47
	SE	0.05	0.05	0.04
	N	279	280	278
Untreated Water	Mean	2.22	0.97	0.79
	SE	0.12	0.11	0.09
	N	99	99	99

Table S18: Source data for Figure S6. Household water treatment rates during the summer and winter in four Guangxi villages

	Guangxi Summer	Guangxi Winter	Total
Boil: Electric Kettle	43	72	115
Boil: Pot	30	14	44
Bottled Water	10	11	21
Untreated Water	34	20	54
Total	117	117	234

Table S19: Source data for Figure S8. Gender and age of person/s who boiling drinking water by fuel type

	Clean Fuels	Coals	Wood	Crop Residue	Total
Females age>15y	9	7	121	5	142
Males age>15y	3	1	28	1	33
F & M age>15y	2	1	8	1	12
Varies	15	3	91	6	115
Total	29	12	248	13	302