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Effectiveness of stand-alone and multi-component water, sanitation and hygiene interventions to reduce mortality in childhood: a network meta-analysis

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Supplementary Appendix

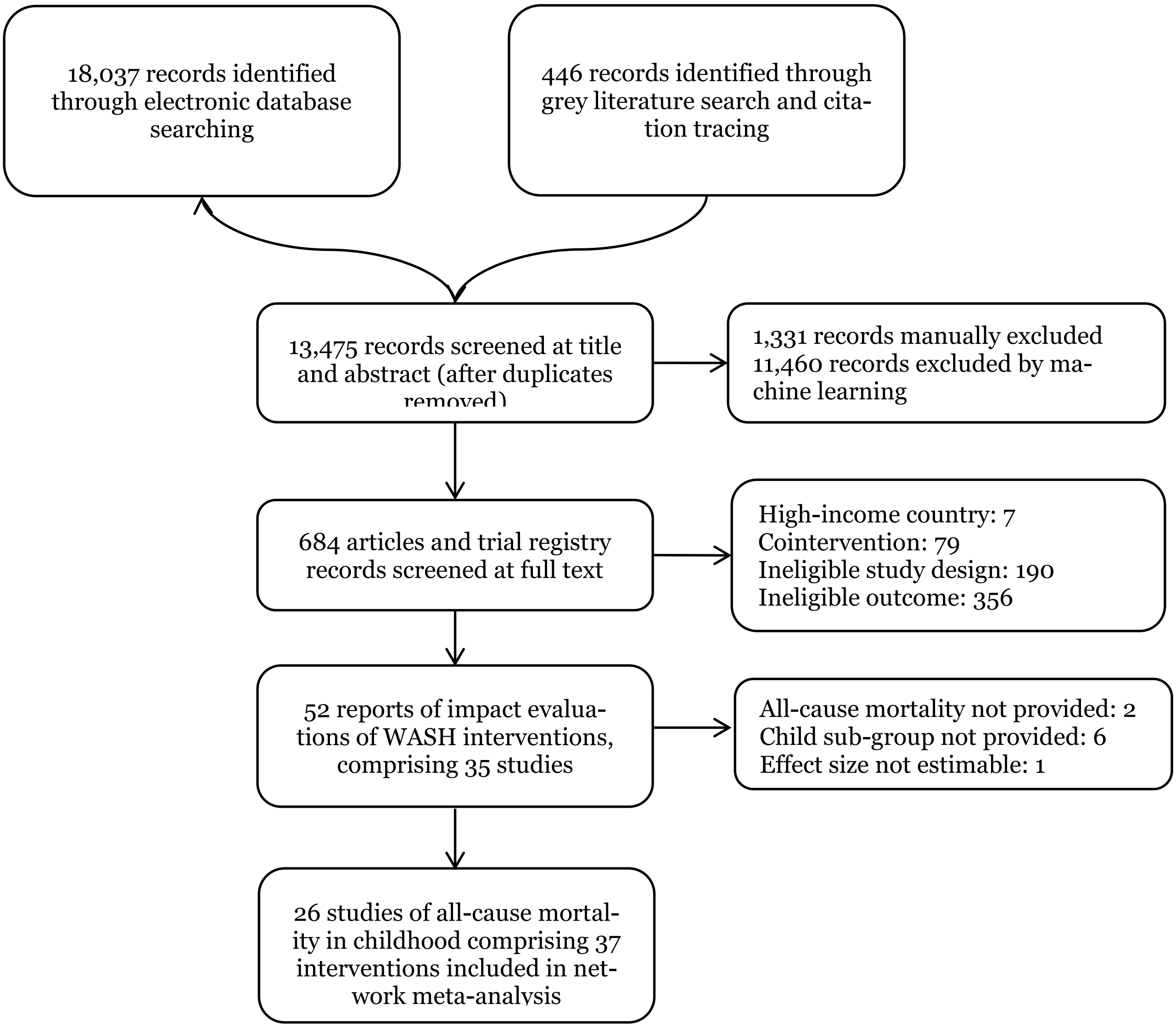

Figure SA1 Study selection flow diagram Note: flow diagram of the systematic review by Sharma Waddington et al. (2023), from which we excluded six studies that did not present information mortality among children aged 5 and under (Emerson et al, 2004; Gyorkos et al. 2013; Jain et al, 2010; Luby et al, 2006; Lule et al, 2005; Ryder et al, 1985) and two that presented information on diarrhoea mortality (Semenza et al, 1998; Messou et al, 1997).

Details of the included studies

Stand-alone water supply improvements were made in two intervention studies across 3,780 observations in total; one study provided improved community water supplies through decentralised delivery (Abou-Ali et al, 2010), and a second provided more reliable piped water supplies to households (Ercumen et al, 2015b). Three interventions across 8,186 total observations provided improved latrines alone, including pit latrines (Null et al, 2018), and pour-flush latrines (Luby et al, 2018; Gebre et al, 2011), sometimes in combination with children's potties and sanitation scoops (Luby et al, 2018; Null et al, 2018). In two studies comprising 7,864 observations, sanitation was promoted through community-wide total sanitation, which also contained components of hygiene promotion (Clasen et al, 2015; Pickering et al, 2015), and in one other study (3,301 observations) latrines were provided to all households in the community alongside water supplies and hand- washing (Reese et al, 2019). Three interventions in Latin America, comprising 5,867 observations, connected households to the water supply and sewerage network (Galiani et al, 2005; Instituto Apoyo, 2000; Rasella, 2003). Stand-alone drinking water treatment and/or protection was provided in ten studies across 10,365 total observations, including chlorination (Crump et al, 2005; Ercumen et al, 2015a; Luby et al, 2018; Mengistie et al, 2013; Null et al, 2018), flocculation (Crump et al, 2005), solar disinfection (Conroy et al, 1999; du Preez et al, 2011), filtration (Boisson et al, 2010; Morris et al, 2018; Peletz et al, 2012), and water storage containers (Ercumen et al, 2015a; Peletz et al, 2012). Drinking water treatment via flocculation was provided alongside hygiene promotion in one study (272 observations) (Bowen et al, 2012), while three others (4,376 observations) combined drinking water chlorination, latrines and hand-washing stations with health education (Null et al, 2018; Humphrey et al, 2019; Luby et al, 2018). Further details are included in the tables below.

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology[(a)]*	*Intervention[(b)]*	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
	Water supply technology										
1.	Abou-Ali et al. (2011)	Egypt	National	Community water supply connection (WAS)	Decentralised provision (community-driven development) (WAS)	0-59s	Improved (98% use improved water supplies)*	Improved (91% use improved sanitation)*	QED (matched cross-section)	372 (T=186)	20
2.	Ercumen et al. (2015b)	India	Urban	Piped water supplies of improved reliability (WAS)	Direct hardware provision (WAS)	0-23s	Improved (89% use own tap water supply)	Improved (79% use own latrine)	QED (matched cohort)	3,408 (T= 1,713)	2.4
	Drinking water treatment and storage technology										
3.	Boisson et al. (2010)	DRC	Rural	Household water treatment (LifeStraw filter) (WAT)	Direct hardware provision (WTF)	0-59s	Unimproved (12% use spring water, else surface water)	Unimproved (37% use own latrine)	RCT	1,144 (T=546)	13

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology[(a)]*	*Intervention[(b)]*	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
4.	Conroy et al. (1999)	Kenya	Rural, pastoralist	Solar disinfection (SODIS) (WAT)	Direct hardware provision (WTO)	0-71s	Unimproved (38% use improved water supplies in rural Kenya, likely lower in study)*	Unimproved (28% use improved sanitation in rural Kenya, likely lower in study)*	Quasi-RCT	349 (T=175)	13
5.	Crump et al. (2005)	Kenya	Rural	Household water treatment (flocculant) (WAT)	Direct hardware provision (WTC)	0-59s	Unimproved (2% collect spring water, else surface water)	Unimproved (29% use improved sanitation in rural Kenya)*	Cluster-RCT	487 (T=239)	170
6.	Crump et al. (2005)	Kenya	Rural	Household water treatment (chlorine) (WAT)	Direct hardware provision (WTC)	0-59s	Unimproved (2% collect spring water, else surface water)	Unimproved (29% use improved sanitation in rural Kenya)*	Cluster-RCT	476 (T=228)	170

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology[(a)]*	*Intervention[(b)]*	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
7.	Du Preez et al. (2011)	Kenya	Rural and urban	Solar disinfection (SODIS) (WAT)	Direct hardware provision (WTO)	6-59s	Improved (65% use improved water supplies)	Unimproved (7% use flush toilet, else pit latrines often public or shared)	RCT	1,089 (T=555)	11
8.	Ercumen et al. (2015a)	Bangladesh	Rural	Household water treatment (chlorine) and safe storage container (WAT)	Direct hardware provision (WTC+WTS)	6-30s	Improved (95% use improved water supplies)*	Unimproved (32% use improved sanitation)	RCT	1,208 (T=603)	3.0
9.	Ercumen et al. (2015a)	Bangladesh	Rural	Safe storage container (WAT)	Direct hardware provision (WTS)	6-30s	Improved (95% use improved water supplies)*	Unimproved (32% use improved sanitation)	RCT	1,211 (T=606)	3.0
10.	Luby et al. (2018)	Bangladesh	Rural	Household water treatment (chlorine) (WAT)	Direct hardware provision (WTC)	0-23s	Improved (74% use	Improved (54% use own latrine)	Cluster-RCT	2,087 (T=701)	25

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology[(a)]*	*Intervention[(b)]*	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
							tubewell water)				
11.	Mengistie et al. (2013)	Ethiopia	Rural	Household water treatment (chlorine) (WAT)	Direct hardware provision (WTC)	0-59s	Unimproved (26% use improved water supplies in rural Ethiopia)*	Unimproved (37% with latrine present)	Cluster-RCT	849 (T=427)	7.7
12.	Morris et al. (2018)	Kenya	Rural	Household water treatment (filter) (WAT)	Direct hardware provision (WTF)	4-16s	Unimproved (<50% use improved water supplies)	Unimproved (32% used basic sanitation in rural Kenya)*	RCT	240 (T=120)	51
13.	Null et al. (2018)	Kenya	Rural	Household water treatment (chlorine) (WAT)	Direct hardware provision (WTC)	0-23s	Unimproved (75% use “improved water source”, on	Unimproved (17% have access to improved latrine)	Cluster-RCT	3,826 (T=920)	22

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology*[(a)]	*Intervention*[(b)]	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
							average 24 mins round-trip from home, excl. wait time)				
14.	Peletz et al. (2012)	Zambia	Rural, HIV-affected	Household water treatment (LifeStraw filter) and storage container (WAT)	Direct hardware provision (WTF)	0-23s	Unimproved (<50% use improved water supplies)	Unimproved (27% use improved sanitation facility)	RCT	120 (T=61)	149
	Sanitation technology										
15.	Gebre et al. (2011)	Ethiopia	Rural	Iron-reinforced latrine slab provision, pit latrine promotion (SAN)	Direct hardware provision and latrine promotion (SAC)	12-59s	Unimproved 26% use improved water supplies in rural Ethiopia)*	Unimproved (<20% with usable latrines)	Cluster-RCT	5,507 (T= 2,578)	2.9

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology[(a)]*	*Intervention[(b)]*	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
16.	Luby et al. (2018)	Bangladesh	Rural	Double-pit pour flush latrine, sani-scoop and potty provision (SAN)	Direct hardware provision (SAC)	0-23s	Improved (74% use tubewell water)	Improved (54% use own latrine)	Cluster-RCT	2,086 (T=700)	25
17.	Null et al. (2018)	Kenya	Rural	Pit latrine, plastic latrine slab, sani-scoop and potty provision (SAN)	Direct hardware provision (SAC)	0-23s	Unimproved (75% use “improved water source”, on average 24 mins round-trip from home, excl. wait time)	Unimproved (17% have access to improved latrine)	Cluster-RCT	3,812 (T=906)	22
	Hygiene technology										
18.	Bowen et al. (2012)	Pakistan	Urban	Soap and hygiene education (HYG)	Direct hardware provision with health messaging	0-95s	Unimproved (85% use “improved	Improved (98% have toilet	Cluster-RCT	335 (T=157)	1.0

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology[(a)]*	*Intervention[(b)]*	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
					(HYO)		water supplies", but only available for 2 hours per week in some cases)	without flush tank at home)			
19.	Cole et al. (2012)	South Africa (informal housing)	Urban	Soap, detergent and hygiene education (HYG)	Direct hardware provision with health messaging (HYO)	0-59s	Unimproved (93% use communal water supplies)	Unimproved (7% use improved latrine facility)	QED (non-randomized cluster trial)	470 (T=244)	17
20.	Cole et al. (2012)	South Africa (formal housing)	Urban	Soap, detergent and hygiene education (HYG)	Direct hardware provision with health messaging (HYO)	0-59s	Improved (87% use piped water supplies to the house)	Improved (71% use improved latrine facility)	QED (non-randomized cluster trial)	406 (T=169)	9.0

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology[(a)]*	*Intervention[(b)]*	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
21.	Luby et al. (2004)	Pakistan	Urban	Antibacterial soap and hygiene education (HYG)	Direct hardware provision with health messaging (HYO)	0-35s	Improved (30% use municipal supply or bore-hole and 60% use tanker truck water supplies)	Improved (98% have toilet without flush at home)	Cluster-RCT	2,358 (T= 1,574)	2.0
22.	Luby et al. (2004)	Pakistan	Urban	Plain soap and hygiene education (HYG)	Direct hardware provision with health messaging (HYO)	0-35s	Improved (30% use municipal supply or bore-hole and 60% use tanker truck water supplies)	Improved (98% have toilet without flush at home)	Cluster-RCT	2,468 (T= 1,684)	2.0

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology[(a)]*	*Intervention[(b)]*	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
23.	Luby et al. (2018)	Bangladesh	Rural	Handwashing station and soap with hygiene education (HYG)	Direct hardware provision with health messaging (HYH)	0-23s	Improved (74% use tubewell water)	Improved (54% use own latrine)	Cluster-RCT	2,080 (T=694)	25
24.	Nicholson et al. (2014)	India	Urban	Soap provision and hygiene promotion (HYG)	Direct hardware provision with social marketing (HYO)	60-71s	Improved (98% use improved water source)	Unimproved (7% use own toilet)	Cluster-RCT	2,155 (T= 1,098)	1.3
25.	Null et al. (2018)	Kenya	Rural	Handwashing station and soap with hygiene education (HYG)	Direct hardware provision with health messaging (HYH)	0-23s	Unimproved (75% use "improved water source", on average 24 mins round-trip from home, excl. wait time)	Unimproved (17% have access to improved latrine)	Cluster-RCT	3,836 (T=930)	22

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology*[(a)]	*Intervention*[(b)]	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
26.	Ram et al. (2017)	Bangladesh	Rural	Handwashing station and health promotion (HYG)	Direct hardware provision with social marketing (HYH)	0-1s	Improved (97% use tub-well water source)	Unimproved (39% use improved sanitation)*	RCT	253 (T=127)	18
27.	Rhee et al. (2008)	Nepal	Rural	Soap and hygiene education (HYG)	Direct hardware provision with hygiene counselling (HYO)	0-1s	Improved (80% use improved water supplies in rural Nepal)*	Unimproved (10% have latrine at home)	QED (cohort design)	23,662	22
	Multiple WASH technologies										
28.	Bowen et al. (2012)	Pakistan	Urban	Household water treatment (flocculant), soap and hygiene education (WAT+HYG)	Direct hardware provision with health messaging (WTC+HYO)	0-95s	Unimproved (85% use “improved water supplies”, but only available for	Improved (98% have toilet without flush tank at home)	Cluster-RCT	361 (T=183)	1.0

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology[(a)]*	*Intervention[(b)]*	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
							2 hours per week in some cases)				
29.	Clasen et al. (2014)	India	Rural	Pour-flush single-pit latrine (with Y-joint for future second pit connection) and hygiene promotion (HYG+SAN)	Latrine subsidy, community-wide sanitation and hygiene promotion (HYS+SAC)	0-59s	Improved (all eligible villages had improved water supply)	Unimproved (10% have functional latrine at home)	Cluster-RCT	3,880 (T= 1,919)	4.0
30.	Galiani et al. (2005)	Argentina	Urban	Piped water supply and sewerage connection (WAS+SAN)	Privatisation (WAS+SAI)	0-59s	Improved (98% use improved water supplies)*	Improved (72% have sewerage connection)	QED (natural experiment double-difference)	3,870	6.3
31.	Humphrey et al. (2019)	Zimbabwe	Rural	Water treatment (chlorine), latrine and handwashing stations with hygiene education	Direct hardware provision with hygiene counselling (WTC+HYH+SAC)	0-18s	Improved (62% use improved water supplies)	Unimproved (29% use improved latrine)	Cluster-RCT	1,956 (T=996)	36

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology[(a)]*	*Intervention[(b)]*	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
				(WAT+HYG+SAN)							
32.	Instituto Apoyo (2000)	Honduras	Rural	Household (piped) and community water supplies, latrines and sewerage connection (WAS+SAN)	Decentralisation (community-driven development) (WAS+SAI)	0-59s	Improved (77% use improved water supplies in rural Honduras)*	Improved (54% used improved sanitation in rural Honduras)*	NRSI (matched pipeline)	1,105 (T=636)	60
33.	Luby et al. (2018)	Bangladesh	Rural	Household water treatment (chlorine), latrines (pour-flush, sani-scoop and potty provision), handwashing station and hygiene education (WAT+HYG+SAN)	Direct hardware provision with health messaging (WTC+HYH+SAC)	0-23s	Improved (74% use tubewell water)	Improved (54% use own latrine)	Cluster-RCT	2,092 (T=706)	25

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology[(a)]*	*Intervention[(b)]*	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
34.	Null et al. (2018)	Kenya	Rural	Household water treatment (chlorine), sanitation (pit latrine, sani-scoop and potty provision), handwashing station and hygiene education (WAT+HYG+SAN)	Direct hardware provision with health messaging (WTC+HYH+SAC)	0-23s	Unimproved (75% use “improved water source”, on average 24 mins round-trip from home, excl. wait time)	Unimproved (17% have access to improved latrine)	Cluster-RCT	3,834 (T=928)	22
35.	Pickering et al. (2015)	Mali	Rural	Pit latrines and hygiene promotion (HYG+SAN)	Community-wide total sanitation with hygiene promotion (SAC+HYS)	0-59s	Unimproved (41% use improved water source)	Unimproved (35% use own latrine)	Cluster-RCT	3,984 (T= 2,097)	63
36.	Rasella (2003)	Brazil	Urban	Piped water supply and sewerage connections (WAS+SAN)	Direct hardware provision (WAS+SAI)	0-59s	Improved (98% use improved water source	Improved (73% use improved sanitation in	NRSI (non-RCT)	892	25

#	*Study by main WASH technology*	*Country*	*Location, group*	*WASH technology*[(a)]	*Intervention*[(b)]	*Age group*	*Baseline water*	*Baseline sanitation*	*Design*	*Sample size*	*CMR (per 1,000)*
							in urban Brazil)*	urban Brazil)*			
37.	Reese et al. (2019)	India	Rural	Piped water supply, pour-flush pit-latrines, handwashing station and hygiene education (WAS+SAN)	Direct hardware provision with hygiene promotion (WAS+SAI)	0-59s	Improved (72% have improved water source)	Unimproved (17% have improved latrine)	NRSI (cohort design)	3,301 (T= 1,530)	1.0

Notes: (a) In brackets are reported the WASH technologies categories used in the NMA: WAS (water supply), WAT (water treatment and protection), HYG (hygiene), and SAN (sanitation); (b) in brackets are reported the disaggregated WASH technologies used in the NMA: WAS (water supply), WTC (water chlorination), WTF (water filtration), WTO (solar disinfection), WTS (water storage), HYH (hygiene hardware), HYS (hygiene software), HYO (soap provision), SAC (community-level sanitation), SAI (individual-level sanitation); CMR crude mortality rate in counterfactual group; T= gives sample size in intervention group; * data imputed using household dataset (for relevant year, country and location) from washdata.org.

Additional subgroup analyses

We conducted two additional subgroup analyses. In the first subgroup analysis we disaggregated the WASH intervention categories further. We decomposed water treatment interventions into chlorination (WTC), filtration (WTF), solar disinfection (WTO) and safe water storage (WTS). Further, we disaggregated hygiene interventions into hardware (HYH), which provides handwashing stations, software (HYS), which promotes hygiene through informational campaigns and hygiene education, and provision or promotion of the use of soap (HYO). Finally, we disaggregated sanitation interventions into those that operate at the collective level (SAC), such as community-wide total sanitation, from those that operate at the individual level (SAI), such as the provision of sanitation services to private homes. The network graph is displayed in Figure SA1.

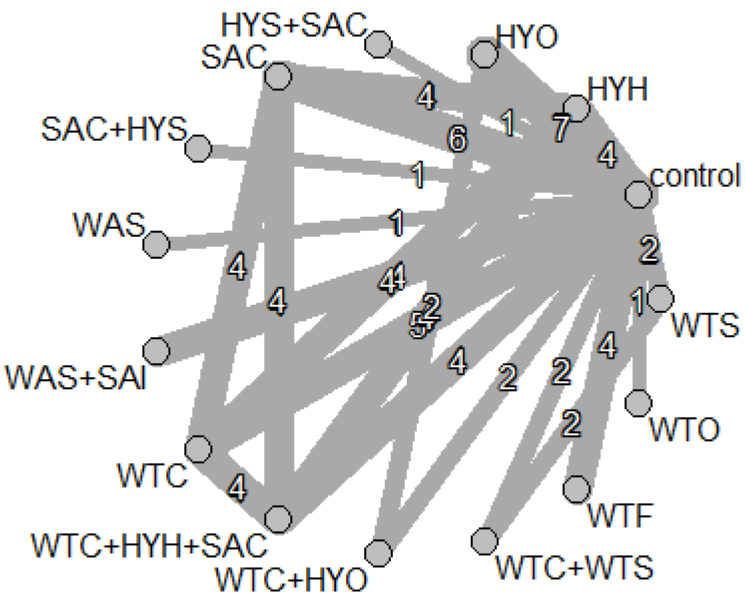

Fig. SA2 Network graph of the disaggregated WASH interventions The graph includes the intervention categories used in the forest plot of Fig SA2 in this supplementary Appendix. WASH technologies are: water supply (WAS), water chlorination (WTC), water filtration (WTF), solar disinfection (WTO), water storage (WTS), hygiene hardware (HYH), hygiene software (HYS), soap provision (HYO), community-level sanitation (SAC), individual-level sanitation (SAI).

The results of the meta-analysis are shown in the forest plot of Fig, SA2. The results suggest that the provision of soap is the most effective intervention (*OR* = 0.62, 95%*CI*[0.42, 0.89]), followed by improved water supplies (*OR* = 0.62, 95%*CI*[0.44, 0.88]). Among water treatment interventions only chlorination appears to reduce mortality significantly. The effects of all other interventions and combinations are either of small magnitude or do not reach statistical significance. The disaggregation of interventions allows a more granular analysis, but some categories have just one or two observations, with obvious consequences in terms of statistical power. These results are interesting for exploratory purposes but should be interpreted cautiously due to small sample sizes.

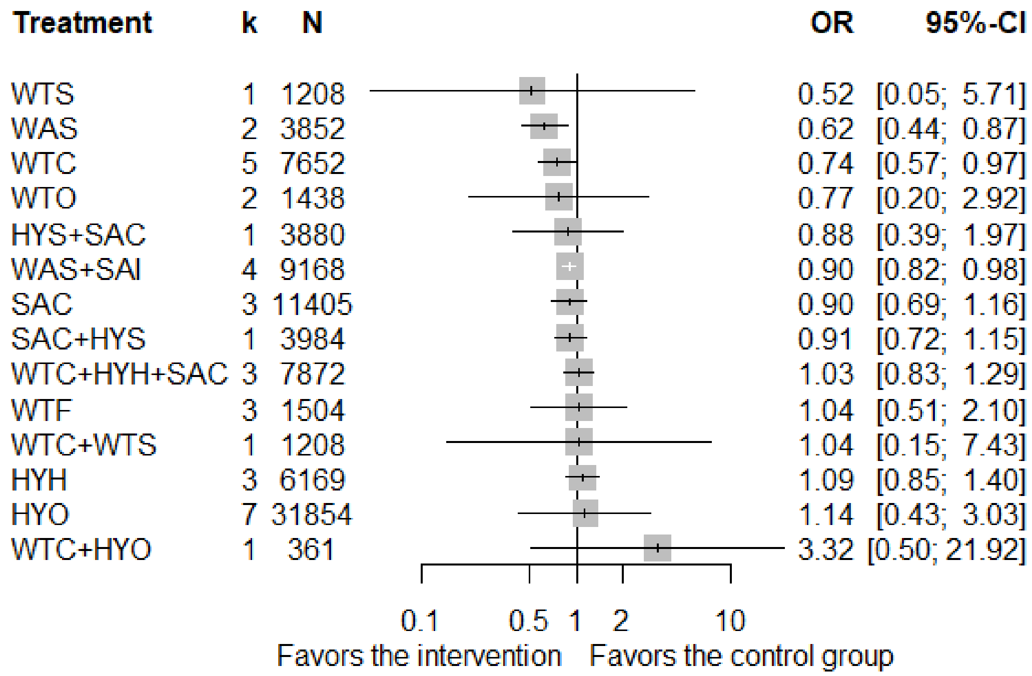

Fig. SA3 Forest plot of all-cause mortality in childhood by detailed WASH technology. k is the number of direct comparisons; N is the number of participants; OR is the odds ratio with a 95% confidence interval; the bars in the chart represent the estimated effect sizes (ORs) with a 95% confidence interval; τ^2=0.003[0.000, 0.006] (confidence interval calculated using 500 study-level bootstrap replications).

Our second subgroup analysis splits the sample by study design (Fig. SA3). Of the 30 studies included, 21 used randomised assignment (RCTs) and nine used a quasi-experimental design. The effects estimated in the quasi-experiments tend to be larger than those estimated by RCTs. All water supply studies included in our meta-analysis were quasi-experiments, hence the larger effects observed for these interventions may reflect study design.[1]

[1] We note that the odds ratios were calculated from crude mortality rates excluding losses to follow-up

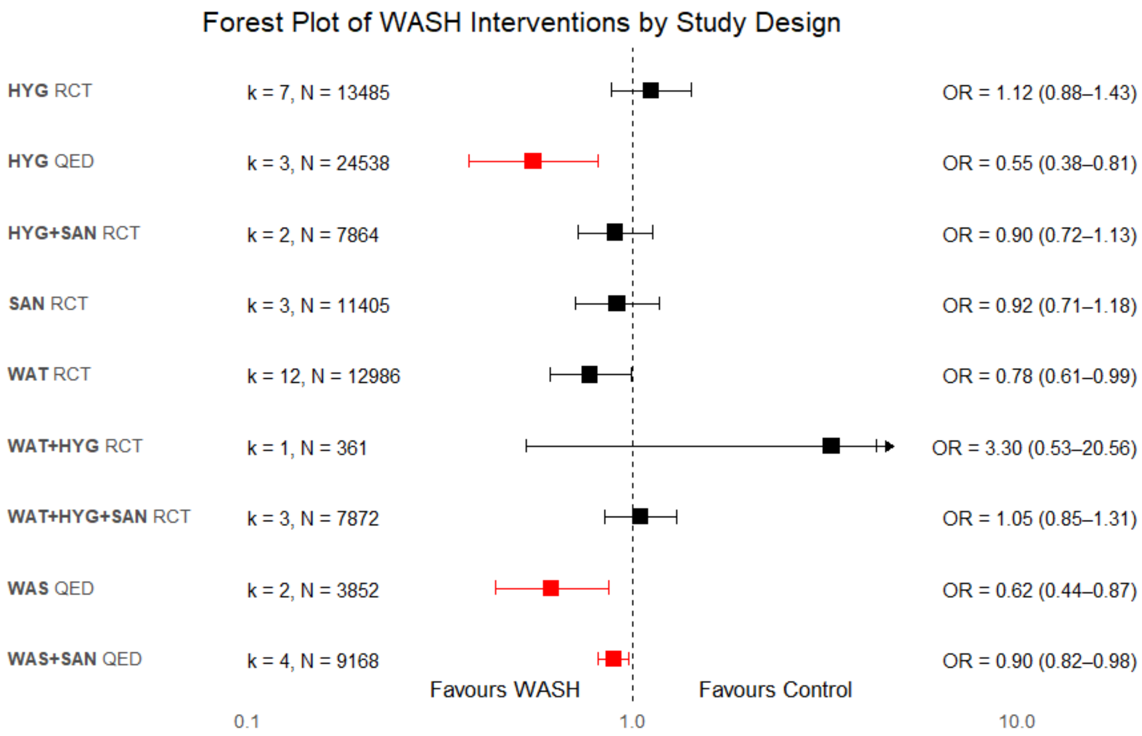

Fig. SA4 Forest plot of all-cause mortality in childhood by study design. Notes: k is the number of direct comparisons; N is the number of study participants; OR is the estimated odds ratio with a 95% confidence interval; the bars in the chart represent the estimated effect sizes (ORs) with a 95% confidence interval; τ^2=0.000[0.000, 0.032] (confidence interval calculated using 500 study-level bootstrap replications) among RCT studies, τ^2=0.000[0.000, 0.016] among QED studies.

from migration, which would tend to equivalise treatment effect estimands across RCTs and quasi-experimental designs.