UK Health Security Agency

# Safe drinking water alternatives

## A rapid evidence summary

# Contents

# Main messages

1. This rapid evidence summary (search up to 11 July 2023) searched for, identified, and summarised primary studies exploring safe alternative sources of drinking water if sanitised water (tap or bottled) is not available, and the hierarchy in which these options should be used.

2. Some evidence, including one randomised controlled trial, showed that water treatment (for example, water boiling or water chlorination) reduced incidence of adverse health outcomes (such as gastroenteritis) compared with untreated water (1, 2).

3. Several studies identified frequent bacteriological contamination of alternative water sources following a disaster, including in wells, springs, and rivers (3 to 14). Providing households with chlorine appears to be effective in reducing bacteriological contamination of water (15, 16).

4. Data included in this report is mostly observational, and so cause and effect cannot be established. In addition, most studies were conducted in settings outside of the UK and involved restriction of water supply due to natural or human made catastrophes such as floods in developing countries. This may mean generalisability of the evidence to the UK setting is limited. However, water chlorination may be an effective method that can also be applied in UK settings for reducing gastrointestinal and some infectious conditions.

# Purpose

This rapid evidence summary searched for, identified, and summarised primary studies exploring the following review questions:

1. What are the safe alternative sources of drinking water if sanitised water (tap or bottled) is not available?
2. What is the hierarchy in which these options should be used in the context of a national power outage or disaster?

# Methods

A rapid evidence summary was completed in July 2023, which identified primary evidence to answer the research questions specified above. We searched Ovid MEDLINE and OVID Embase to identify primary studies to answer the review questions, published prior to 11 July 2023. Title and abstract screening was completed by 2 reviewers, with 10% screened in duplicate (and any disagreements resolved by discussion). Full text screening was undertaken by 4 reviewers, with 10% completed in duplicate and disagreements resolved by discussion.

Data extraction was undertaken by 5 reviewers, and not duplicated. Due to time constraints critical appraisal of included studies was not undertaken.

A protocol was produced before the literature search was conducted, including the review question, the eligibility criteria, and all other methods. Full details of the methodology are provided in the protocol in (Annexe A).

# Evidence

There were 1,145 articles identified for title and abstract screening and 50 progressed to full text screening of these, 23 were included (1 to 23). Detailed results on each outcome can be found in the data extraction tables in Annexe B. There were 8 studies reporting health outcomes, 16 studies reporting water quality outcomes, and 2 reporting both type of outcomes.

## Health outcomes

One study investigated whether household exposures to water service problems could be related to acute gastrointestinal illness or acute respiratory illness across 4 southwestern Alabama (United States) communities consuming surface water sources disinfected with chlorine (2). Results showed acute gastrointestinal illness, but not acute respiratory illness, prevalence was 2 times higher in households using un-boiled tap water to drink, cook, brush teeth, or preparing infant formula relative to households not consuming un-boiled tap water for the same behaviours (2). Results showed disruption to water systems may have an adverse impact on public health consuming household water. However, this study was cross-sectional, and so cannot establish cause and effect and has several important methodological limitations such as lack of random allocation. Different levels of baseline risk of experiencing poorer outcomes are likely to have impacted the magnitude and direction of the relationship between water emergency and acute gastrointestinal illness or other health outcomes.

Two studies investigated the impact of cholera outbreak following cyclone flooding on gastrointestinal problems including a study based in Bangladesh reporting on diarrhoea (19) and one in West Bengal, India, reporting on acute diarrhoea with severe dehydration admitted to any healthcare facilities (17). There was mixed evidence showing individuals drinking from tube wells during the flood were not at greater risk of diarrhoea than those drinking tap water but tube well users were at greater risk of diarrhoea than tap water users after the flood. A similar pattern of findings was observed for diarrhoea not associated with cholera (19). This study was cross-sectional and therefore caution in interpreting study outcomes is warranted. The second study found non-chlorinated piped water may pose a risk of developing watery diarrhoea with severe dehydration while water treated with chlorine may protect against developing this condition (17). There was however no evidence linking mixed water or water from tube wells and risk of developing the same condition (17). Mixed water was not specifically defined and therefore it is problematic to interpret this find as absence of a relationship between exposure and outcome in this study.

Two further studies conducted in Bangladesh (21, 22) also reported on outcomes related to different water use following floods. In a cross-sectional sample of households, lack of distribution rate of water purification tablets and type of water storage vessels, but not water sources, were associated with greater odds of diarrhoea months after a flood (21). A cohort study conducted a household survey to investigate difference between flood and non-flood areas on death, diarrhoea, or acute respiratory infection as a function of water source (tube well, surface or filtered) and found no difference in rates on any of the outcome after adjusting for pre-flood differences (22). In the cross-sectional study, there was a larger proportion of males (94%) and therefore whether the study findings are also applicable to females in the general public is questionable (11). This study had recruited a modest sample of participants (N=517) within which multiple groups were created for comparison which reduced the number of participants per groups and likely reduced statistical power which can compromise the validity of study outcomes. Also, both the cross-sectional (11) and cohort study (14) findings are difficult to generalise to UK settings because these studies were performed in settings where clinical and demographic characteristics of study participants are likely different than those in the UK.

One randomised controlled trial conducted in Sudan investigated whether chlorination could disinfect well-tank-faucet systems and reduce rates of gastroenteritis (1). Results show 15 days of chlorination compared to placebo reduced gastroenteritis among those who had been refugees for at least one month (1). One case-cohort study conducted in Darfur investigated different water sources as potential risk factors for acquiring hepatitis E virus during an outbreak. This study reported that drinking chlorinated surface water was associated with greater risk of hepatitis E virus than drinking unchlorinated water and that drinking chlorinated water surface water was a risk factor for hepatitis E virus with jaundice (7). One cross-sectional study conducted in Syria during war settings found water source (pipes or truck) did not affect odds of developing diarrhoea in households where approximately half of the surveyed sample lived in damaged or shared accommodation (19). In this study the odds of having diarrhoea did not differ between receiving water from pipes or truck in children aged 5 years or younger (23). The cohort and cross-sectional study however did not adjust for important confounding factors such as baseline disease risk profiles which may have had an impact on the magnitude and direction of the outcome estimate. Moreover, generalising findings from these studies into UK settings is problematic because disease prevalence and participants' baseline risk profiles following population displacement or war is likely to have a different impact on relevant outcomes compared to a national power outage in the UK.

# Water quality outcomes

Three observational studies investigated water quality outcomes in alternative water sources in refugee camps following a disaster: one in Sudan (7), one in Ethiopia (3), and one in Bangladesh (11). Looking specifically at *Escherichia coli* (*E. coli*) Sidker and others (11) evaluated 3 water sources (unimproved water sources (for example, open well water), groundwater pumped by hand, groundwater pumped by electric pump). They reported that none fully met international standards, with water from unimproved sources having the highest levels of *E. coli.* Ashuro and others compared hand-pumped wells, dug wells with rope, and protected and unprotected spring water (3). They identified that over 50% of water sources sampled had faecal coliforms present, with faecal coliforms most frequently present in samples from dug wells with rope (90%), and least frequent in dug wells with hand pumps (44.9%). When investigating a hepatitis E outbreak at a refugee camp, Guthmann and others (7) found that 41.7% of samples from the same river (either unchlorinated pumped groundwater versus chlorinated surface water) had coliforms present, and river water samples had higher concentrations of coliforms compared to water lines. Water, sanitation and hygiene facilities within refugee camp settings are likely to differ significantly compared with a UK setting, and crowding is much more common, limiting generalisability of the findings.

Five studies (6 reports) assessed water quality outcomes in the context of a flooding or tsunami-based disaster (4, 5, 10, 12, 13, 18). Countries included Sri Lanka (4, 18), Haiti (5), India (10), Bangladesh (12) and Thailand (13). Among the studies, faecal coliforms such as *E. coli* were found to be contaminating a wide variety of water sources. For example, in a cross-sectional study of water sources post-tsunami in Sri Lanka, there was significantly more *E. coli* in well water versus tap water ($p=0.007$), with ceramic filters proving ineffective for well water (4, 18). A cross-sectional study in Haiti found all 10 sampled water sources were contaminated with faecal coliforms, including natural springs, community taps, 2 wells and a river (5). A further cross-sectional study in Kanyakumari District, Tamil Nadu, India, found faecal coliforms were contaminating a variety of alternative water sources such as bore wells (14 out of 23, 60.9%), public wells (13 out of 17, 76.5%) and public fountains (1 out of 9, 11.1%) (10). Significance testing for comparison between sources was not available and some water sources had only a single sample analysed. Similar bacteriological contamination of various water sources was demonstrated after a flood in Bangladesh and a tsunami in Thailand (12, 13) (Annexe B). Generalisability of these findings to a UK non-flood setting is very limited as flood waters increase the risk of contamination of alternative water sources (24).

Six studies assessed water quality outcomes in the context of an earthquake, or mixed disaster settings which included an earthquake (6, 8, 9, 14, 15, 20). Countries included Indonesia (6), India (20), Haiti (8, 9, 14) and a single study across Nepal, Haiti, Kenya and Indonesia (15). One cross-sectional study was conducted in Indonesia, in June 2005 following a tsunami in 2003 and an earthquake in 2005 (6). A variety of alternative water sources were found to be contaminated with *E. coli*, including samples from boreholes (14 out of 100, 14%), rainwater (25 out of 98, 26%), tanker trucks (41 out of 285,14%), wells (124 out of 324, 38%), springs (45 out of 156, 29%) and surface water (23 out of 37, 62%). Factors associated with reduced *E. coli* contamination of household drinking water included using an improved water source (not defined), water chlorine level ≥0.1 mg/L, having a safe water system (undefined) for stored water and using a latrine (Annexe B). Similar findings were obtained in a post-earthquake cross-sectional study in Kupwara, Kashmir, India where water sources including tap, tube well and stream water were all deemed unsatisfactory due to tests indicating the presence of faecal bacteria (Annexe B) (20).

Several studies reported on water quality outcomes post-earthquake in Haiti (8, 9, 14). A cohort study assessed water quality in the acute emergency and post emergency phase, finding *E. coli* contamination of water sources had reduced from 71% of protected and 81% of unprotected water sources in the acute emergency phase, to 45% of protected water and 74% of unprotected sources in the recovery phase (8). Households in some areas had received household water treatment and safe storage products, and *E. coli* contamination of water was significantly lower for those who had received chlorine tablets plus a safe storage water container, versus other strategies (p=0.005, Annexe B) (8). The same authors conducted a cross-sectional study of household water and safe storage treatment methods across a variety of disaster settings (flood, earthquake, cholera outbreak), which was observational rather than experimental (15). Chlorine liquid or tablets were used in Nepal and Indonesia, chlorine tablets or flocculant/disinfectant in Kenya, and chlorine tablets/liquid, or ceramic or bio-sand filters in Haiti. Usage appeared low in some settings (11.7% uptake based on free residual chlorine in Kenya). In Haiti, Significant *E. coli* contamination was avoided for 53.1% of users of chlorine tablets in rural settings (44.7% urban, 10% settlements), for 10.8% of those using ceramic filters, and 19.5% of those using bio-sand filters. Additional studies in Haiti provided further evidence of high *E. coli* contamination rates of alternative water sources post-earthquake (9, 14). These were 50.9% for improved water sources (tap, fountain, kiosk; borehole with handpump; protected spring; private kiosk with vended water; piped water onto plot), and 83% for unimproved water sources (unprotected springs, river or canal, unclassified surface water, dug well, undefined water source) (9). Following both an earthquake and a subsequent hurricane in Haiti, Widmer and others screened non-surface water points such as wells and pumps (14). They found that among unimproved water sources, contamination was less likely in spring water (53.4%) versus hand-dug wells (79.4%). Overall, generalisability to a UK setting is constrained due to significant differences in socioeconomic and environmental contexts among these studies.

One observational study evaluated the presence of free residual chlorine in piped water compared to water delivered by trucks (16). Compared with piped water, trucked water had less free residual chlorine (and so was more unsafe). Additionally, the authors found that households who received chlorine or chlorine alongside water disinfection training had an increased likelihood of increased free residual chlorine in their drinking water (and so safer water).

## Other evidence

An initial scoping search suggested there were no reviews available that directly answered the review question, and therefore the review protocol for the summary focused on primary studies. However, 3 potentially relevant reviews were identified during article screening (25 to 27). These have been described below:

1. Backer and others (26) reviewed guidelines for water disinfection for wilderness, international travel, and austere situations. A systematic search was supplemented by a panel of experts in wilderness medicine. They outline available methods for controlling microbiological contamination of water in situations where drinking water sources are unpotable. The evidence assessed both laboratory and clinical studies. The authors conclude that optimal water treatment technique will be situation dependent.
2. Gambhir and others (27) reviewed household water treatment following emergencies and disasters in a narrative review. Various methods to purify household water are described, however are not ranked hierarchically. However, this review included limited referencing from primary or review-level data to support conclusions.
3. Loo and others (25) reviewed potential technologies and selection criteria for emergency water treatment techniques in a narrative review. Each included water technology was evaluated across 10 criteria. The authors concluded that selection of water treatment is situation dependent.

# Health inequalities

All of the available evidence is in the context of a disaster setting, including floods, tsunamis, earthquakes or war. Some of studies were specifically in people in refugee camps as a result of the disaster. Therefore the evidence represents people at risk of health inequalities, however, it was not possible to explore inequalities through variations across populations and subgroups. For example, although the evidence includes people in different ethnic groups, and in rural settings, it does not enable comparisons to be made between groups covered in different studies.

# Limitations

This rapid evidence summary used streamlined systematic methods to accelerate the review process. Most article screening was completed without duplication, and therefore it is possible relevant studies may have been missed. Due to time constraints critical appraisal was not undertaken which limits our ability to interpret the findings in the context of risk of bias.

Most of the evidence presented is observational with several cross-sectional studies and so cause and effect cannot be established, limiting the external validity of these studies. In addition, most studies were conducted in settings outside of the UK and involved restriction of water supply due to natural or human made catastrophes such as floods in developing countries with large variation in the type of disasters and settings (such as in refugee camps or during war times). Water quality and baseline risk of developing medical conditions such as diarrhoea is likely different in refugee camps than it is in community-dwelling people in the UK. Outcomes should be considered in context, and so generalisability of the evidence in this report to the UK setting is limited.

The research question to be answered by this report was broad to pick up any potentially relevant evidence. The breadth of the research question in this report means that, while the included evidence met eligibility criteria, it does not all directly answer the research question because many included studies only provided indirect evidence addressing the research question limiting the extent to which conclusions can be drawn and generalised. From the available evidence it was not possible to rank alternative water sources hierarchically.

# Evidence gaps

There was no available evidence from UK settings in the context of sanitised tap water not being available. There was also a gap in the evidence for the hierarchy of the options which had been studied.

# Conclusion

This review included 23 primary studies presenting health and/or water quality outcomes; 8 of which presented health outcomes such as diarrhoea, gastroenteritis, and 16 presented water quality outcomes such as bacteriological contamination with *E. coli*. There was limited evidence suggesting that disruption of delivery of safe drinking water through usual sources may lead to poorer water quality and greater rates of gastrointestinal illness (but not acute respiratory illness), although this may be reduced with water treatment (such as boiling or chlorination). However, findings were limited by a lack of evidence directly addressing the research questions of interest. The variation in study settings and outcomes limits the extent to which the included evidence can be translated into real life settings in the UK.

# Acknowledgments

We would like to thank colleagues within the All Hazards Public Health Response division who either reviewed or input into aspects of the review. Search terms for power outage and power cuts were adapted from literature searches developed by Caroline De Brun, Knowledge and Evidence Specialist for UKHSA South West.

# Disclaimer

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- are only valid as of the date stated on the review

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# Annexe A. Protocol

## Eligibility criteria

| | **Included** | **Excluded** |
|---|---|---|
| Population | All (adults and children) | |
| Settings | Community settings | Hospitals<br>Laboratory settings |
| Context | National power outage or post-disaster<br><br>(Evidence from other settings that provide useful information may be included.) | |
| Intervention or exposure | Sanitised water alternatives, for example (but not limited to):<br>• boiled water<br>• water purified with purification tablets<br>• water from toilet cisterns<br>• water from foods<br>• rainwater<br>• water from rivers and streams<br>(Note: information regarding how to make the water options safe will also be included.) | Water for purposes other than drinking (for example, sanitation) |
| Outcomes | • negative health impacts from water-borne infections<br>• gastrointestinal problems (for example, diarrhoea)<br>• mortality<br>• water quality outcomes | |
| Language | English language | Non-English language studies |
| Date of publication | Any | |

| | Included | Excluded |
|---|---|---|
| Study design | • observational studies (cohorts, case control, and cross-sectional studies, as well as case reports and series)<br>• randomised controlled trials | • editorial<br>• letters<br>• opinion pieces<br>• guidelines<br>• reviews |
| Publication type | Published studies | |

# Search strategy

1. (water and drink*).tw,kf.
2. Drinking Water/
3. Drinking/
4. Water/
5. 3 and 4
6. 1 or 2 or 5
7. (alternative* or source* or purification or boil*).tw,kf.
8. (tank* or heat* or ice or ice-cube*).tw,kf.
9. (food* or fruit* or vegetable* or liquid* or fluid*).tw,kf.
10. (pool* or spa or spas).tw,kf.
11. (river* or stream* or lake* or rain* or pond* or spring* or reservoir* or groundwater or wastewater or well or wells).tw,kf.
12. (desalinat* or purif* or iodine or distil*).tw,kf.
13. (filtrat* or filter* or chlorinat* or disinfect*).tw,kf.
14. (pipe* or stormwater*).tw,kf.
15. Water Purification/
16. Water Supply/
17. Ice/
18. food/ or fruit/ or vegetables/
19. groundwater/ or lakes/ or ponds/ or rivers/ or Waste Water/
20. Iodine/
21. Distillation/
22. Filtration/
23. Disinfection/
24. Rain/
25. or/7-24
26. exp Disasters/
27. (disaster* or emergency or emergencies).tw,kf.
28. Electric Power Supplies/
29. Electricity/
30. 28 or 29

31. (failure* or supply or supplies or cut or cuts or outage* or insecurity or instability or unstable or limited).tw,kf.
32. 30 and 31
33. Disaster Planning/
34. (power outage* or blackout* or "no power").tw,kf.
35. 26 or 27 or 32 or 33 or 34
36. 6 and 25 and 35

# Annexe B. Data extraction table

| Study | Study design | Setting and demographics | Disaster type | Sampling | Water sources | Health outcomes | Water quality outcomes |
|---|---|---|---|---|---|---|---|
| Ashuro and others 2021 (3) | Cross-sectional | Internally displaced people sites, Gedeo Zone, Southern Ethiopia, November to December 2018 | Refugee camp | 213 water samples taken collected from a cross all water sources used in the camps (138 well with hand pump, 43 protected springs, 10 dug well with rope, 22 unprotected springs) | Wells with hand-pump<br><br>Dug wells with rope<br><br>Protected and unprotected springs (protected not defined) | N/A | Overall, 107 out of 213 (50.2%) of water samples tested positive for faecal coliforms. Stratified by water source, samples were contaminated with faecal coliforms in:<br>• 44.9% dug well with hand pump samples<br>• 53.5% protected spring samples<br>• 60.9% unprotected spring samples<br>• 90% dug well with rope samples<br>World Health Organization (WHO) standard reported by authors was 0 faecal coliform count per 100ml for drinking water |
| Bhunia and others 2011 (17) | Case-control | Cholera outbreak in Sundurban area of West Bengal India, 2009, following Cyclone Aila<br><br>Median age cases 22 years (range 5 to 80 years), controls 22 years (range 5 to 71 years) | Cyclone<br>Flood | Case-control study conducted from 5 to 9 June 2009<br><br>Case definition: patient aged ≥5 years with acute watery diarrhoea (3+ loose stools per day) with severe dehydration admitted to any healthcare facility among residents of Gosaba block. Matched 1:3 case:control. Controls from same | Non-chlorinated piped water<br><br>Mixed water (undefined)<br><br>Tube well water<br><br>Chlorine-treated water<br><br>Boiled water<br><br>Water from a narrow mouthed container | Association between being a case vs control measured with adjusted OR + 95% CI<br><br>Non-chlorinated piped water OR 16 (4.9 to 51) – potential risk factor<br><br>Mixed water (undefined) OR 0.96 (0.44 to 2.1) – no clear association<br><br>Tube well water OR 0.51 (0.26 to 1.0) – no clear association | N/A |

| Study | Study design | Setting and demographics | Disaster type | Sampling | Water sources | Health outcomes | Water quality outcomes |
|---|---|---|---|---|---|---|---|
| | | | | neighbourhood, without diarrhoea, matched for race and socioeconomic status<br><br>57 cases, 171 controls | | Chlorine treated water 0.06 (0.02 to 0.18) – potentially protective | |
| Casanova and others 2012a and 2012b (2 reports of same study) (4, 18) | Cross-sectional | Post 2004 tsunami, Sri-Lanka | Tsunami | 452 households completed survey and water sampling (random sampling using random number generator) | Study assessed rates of ongoing use of ceramic water filters distributed post-tsunami<br><br>Water sources of participants were surveyed and included: tap inside and/or outside the house, lined or unlined shallow hand-dug well, deep drilled well, lake or pond, river/stream/canal, rainwater, purchased water, and other | N/A | 71% of participants reported using the filter on the day of the survey or the day before<br><br>There was significantly more *E. coli* in source water from wells versus taps (p <0.0001). The ceramic filter appeared to reduce *E. coli* counts (versus no filter use) in those using tap water (p=0.006), but not among those using well water (p=0.007) |
| Colindres and others 2007 (5) | Cross-sectional | Haiti; rural communities | Flash floods following tropical storm Jeanne, 18 September 2004 | 100 households interviewed; 22 of these had PuR-treated water which were sampled for chlorine and coliform bacteria.<br>Ten water sources tested for faecal coliform bacteria (6 springs, 2 wells, one river, 1 tap) | Community water sources: natural springs, community taps, 2 wells, a river. All households had water storage vessels (81% used 5-hallon buckets, 91% of the buckets had lids); 18% used 5-gallon clay containers usually capped with a saucer)<br><br>Water treatment methods included boiling, chlorination, flocculation with a local cactus, or sand and gravel filtration; 92% of households had used a (new) combined flocculent-disinfectant product PuR | N/A | Residual free chlorine levels of stored drinking water (target range 0.2mg to less than 2mg per litres of water): 10 samples less than 0.1mg/l, 2 samples less than 0.2mg/l, 9 samples within range, and one sample more than 2mg/l<br><br>All 10 water sources were contaminated with coliform bacteria (faecal coliform counts per 100ml reported for each source tested) |

| Study | Study design | Setting and demographics | Disaster type | Sampling | Water sources | Health outcomes | Water quality outcomes |
|---|---|---|---|---|---|---|---|
| Gargano and others 2015 (2) | Cross-sectional | Household exposures to water service problems (Alabama US); household survey in 4 communities | Freeze-related community-wide water emergency | Household survey in 4 communities (A–D) in the 2 affected counties | Household | Affected household, use unboiled tap water for potable purposes 2·5 95% CI 1·0–6·0<br><br>Did not report obtaining tap water 2·6 95% CI 1·1–6·2 | N/A |
| Gupta and others 2007 (6) | Cross-sectional | Aceh Besar, Simeulue and Nias districts, Indonesia in June 2005 following a tsunami in December 2003 and an earthquake in March 2005<br><br>Aceh besar: temporary living centres consisting of wooden barracks<br><br>Nias and Simeulue: islands only accessible by aircraft or boat | Tsunami<br>Earthquake | Two-stage sampling. First stage: 21/83 accessible communities selected at random with probability proportional to number of households, and stratified by 4 population strata. Second stage: systematic random sample of households<br><br>Households interviewed: 653 out of 8,292 (7.8%) Aceh Besar, 206 out of 5,658 (3.6%) Nias, 268 out of 2,052 (13.1%) Simeulue<br><br>Drinking water tested for residual free chlorine and present or absence of *E. coli* | Borehole, rainwater, tanker trucks, well, spring, surface water, other (bottled/municipal) | N/A | Proportion of samples contaminated with *E. coli*:<br>• borehole 14 out of 100 (14%)<br>• rainwater 25 out of 98 (26%)<br>• tanker trucks 41 out of 285 (14%)<br>• well 124 out of 324 (38%)<br>• spring 45 out of 156 (29%)<br>• surface water 23 out of 37 (62%)<br>• other (bottled or municipal) 8 out of 26 (8%)<br><br>Factors associated with reduced *E. coli* contamination of household drinking water from adjusted multivariate analysis:<br>• improved water source Aceh Besar OR 0.48 (95% CI 0.26 to 0.87) and Simeulue OR 0.48 (95% CI 0.26 to 0.87)<br>• chlorine ≥0.1mg/L Aceh Besar OR 0.42 (95% CI 0.23 to 0.77) and Nias OR 0.28 (95% CI 0.16 to 0.51)<br>• safe water system used in stored water Simeulue |

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| | | | | | | | OR 0.41 (95% CI 0.29 to 0.59)<br>• using a latrine Simeulue OR 0.35 (95% CI 0.24 to 0.52) |
| Guthmann and others 2006 (7) | case-cohort study of hepatitis E virus (HEV) infection, and retrospective cohort study of asymptomatic HEV infection | June-September 2023; >72,000 additional individuals in Mornay (village and camp)<br><br>From June 2004: outbreak of hepatitis E in the camp | Refugee camp or population displacement (Darfur conflict) | Case-cohort study: n=82 outbreak cases selected + n=162 randomly selected from Mornay population<br><br>Retrospective study of asymptomatic cases: n=104 from the random sample of Mornay population | 2 main sources:<br>• unchlorinated groundwater pumped from a river (50m and 16m deep)<br>• surface water from the same river but pumped at 4m and alter chlorinated (Medecins sans Frontieres)<br><br>Other minor sources include water taken directly from the river and water from protected wells<br><br>*the 'river' is a 'wadi' which partially dries in the dry season | Case cohort results:<br>• consumption of chlorinated surface water as a risk for HEV infection with jaundice (OR, 2.49; 95% CI, 1.22 ti 5.08)<br>• drinking chlorinated surface water potentially accounted for 59.8% of HEV infection with jaundice (attributable risk percentage)<br><br>Retrospective cohort results:<br>• people drinking chlorinated surface water likelihood of acquiring asymptomatic HEV infection: RR 1.26 (95 %CI 0.61-2.59) | Coliforms found in 5 out of 12 (41.7%) water samples<br><br>In the 2 *wadi* ("river) samples, high concentrations of coliforms (56/100 mL and uncountable coliforms/100 mL) compared to the 3 other positive samples (2 water lines and one house container; all with concentrations <10 coliforms/100 mL)<br><br>Free residual chlorine concentration at the tap from the chlorinated system: 0.3-0.6 mg/L |
| Hashizume and others 2008 (19) | Cross-sectional | Dhaka, Bangladesh post flood event in 1998 which led to a cholera outbreak | Flood | Surveillance data from International Centre for Diarrhoeal Disease Research Bangladesh (every 50th patient presenting with diarrhoea is surveyed and samples taken for microbiological analysis) | Tube well<br><br>Tap water | Observed versus expected cholera and non-cholera diarrhoea cases compared (excess risk), stratified by a number of variables including tube well vs tap water source, for both flood and post flood period.<br><br>Ratio of observed to expected cases for cholera during flood: 4.7 (95% CI 3.6 to 6.2) for tube well users and 6.7 (5.4 to 8.2) for tap water uses (p=0.05). | N/A |

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| | | | | | | For cholera post flood:<br>2.7 (2.3 to 3.1) for tube well users and 1.6 (1.3 to 1.9) for tap water uses ($p<0.001$).<br><br>For non-cholera diarrhoea during flood:<br>1.9 (1.6 to 2.2) for tube well users and 1.7 (1.5 to 1.9) for tap users ($p>0.2$)<br><br>For non-cholera diarrhoea post-flood:<br>1.4 (1.2 to 1.5) for tube well users and 1.1 (1.0 to 1.2) for tap users ($p=0.002$) | |
| Karmakar and others 2008 (20) | Cross-sectional | Kupwara, Kashmir, India, post earthquake on 8 October 2005<br><br>Study conducted 8 to 21 November 2005 | Earthquake | 16 water samples collected from a variety of water sources as per a referenced procedure.<br><br>Underwent hydrogen sulfide test ($H_2S$: portable water quality test which is designed to detect bacteria of faecal origin which are able to reduce organic sulfur to sulfide as $H_2S$ gas). Three samples collected in duplicate and also tested using standard presumptive coliform count | Tap water (from unspecified source, spring or stream), tube well, stream water<br><br>Control – bottled water | N/A | Apart from 2 samples, all of the water sources were unsatisfactory due to positive $H_2S$ tests indicating present of faecal bacteria. The satisfactory results were obtained from one tube well sample and one tap water sample<br><br>Stream or tap water with a stream or spring source was associated with unpotability ($p=0.001$) |
| Kunii and others 2002 (21) | Cross-sectional | 1998, Bangladesh | Flood | Structured face to face interviews with one person of each household (n=517 | • 93.2% tube-well<br>• 6.0% river<br>• 0.8% tap water | A range of factors identified as risk factors for diarrhoea. Those related to drinking water were and for which a significant | N/A |

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| | | | | households, September to October 1998, 2 months after the flood started) | In all houses, drinking water kept in big jar (65.1%) or small bottle (34.9%), and 36% kept without a lid<br><br>Only 1.0% of respondents practised boiling and 6.7% chlorinating water before drinking<br><br>11.3% of respondents had been provided by water purification tablets during the flood | association was found (logistic regression):<br>• lack of distribution rate of water purification tablets (OR: 0.40, 95%CI 0.17 to 0.94; p= 0.035)<br>• type of water storage vessels (OR: 3.68 , 95%CI 2.16 to 6.27, p<0.001)<br>Water source not significant: OR: 0.48 0.17 to 1.41 0.182 | |
| Lantagne and others 2013 (8)<br><br>(same emergency as reported in Lantagne 2012 (15); more detailed results for the Haiti population in this 2013 report, at 2 time points) | Cohort<br>(initial cross sectional study during the acute phase, with a second 8 months later in the recovery phase to households who had received household water treatment and safe storage [HWTS] products during the acute emergency) | Haiti | Earthquake | Household surveys (n=442) in survey 1 (from 4 HWTS programmes), 218 in survey 2 (from 3 HWTS programmes)<br><br>Household stored water samples (chlorinated, or tanker truck water), compared to unimproved sources<br>Protected sources included community source, closed well, capped spring, or rainwater catchment. Unprotected sources: open well, river, or unprotected spring | Household drinking water, treated with chlorine-based products or untreated tanker truck water<br><br>5 HWTS methods with no geographical overlap: chlorine tablets and safe storage containers and training; chlorine tablets without training; ceramic filters with training; biosand filters with training; chorine powder (the chlorine tablets and safe storage distribution, and the biosand programmes were in use pre-earthquake) | N/A | In acute emergency phase:<br><br>*E. coli* contamination in 70 of 99 (71%) protected sources, 30 of 37 (81%) unprotected sources, and 14 of 25 (56%) tanker truck water samples (p<0.001 for tanker water versus unprotected sources). Within treated water sources (the 5 HWTS options), *E. coli* contamination significantly lower with chlorine tablets plus safe storage container than with the 4 other HWTS programmes combined p=0.005<br><br>Total coliforms (% samples with less than 1 CFU/100ml after treatment: 63% with chlorine tablets plus safe storage, 13% chlorine tablets, 20% ceramic filter, 8% biosand filter. With less |

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| | | | | | | | than 10 CFU/100ml: 49%, 10%, 12%, 20% respectively<br><br>In recovery phase:<br>*E. coli* contamination in untreated household water from 39 of 87 (45%) protected sources, 31 of 42 (74%) unprotected sources, no data on tanker water (p<0.001 for protected versus unprotected sources). Within treated water sources (the 5 HWTS options), *E. coli* contamination significantly lower with chlorine tablets plus safe storage container than with the 4 other HWTS programmes combined p=0.005<br><br>Total coliforms (% samples with less than 1 CFU/100ml after treatment: 46% for chlorine tablets plus safe storage, no data chlorine tablets, 0% ceramic filter, 28% biosand filter.<br>With less than 10 CFU/100ml, 41%, no data, 11% and 18% respectively |
| Lantagne and others 2012 (15)<br><br>(the Lantagne 2013 study reports on the same Haiti emergency included in | Cross-sectional (reporting 4 to 8 weeks of the emergency) | Four acute emergency situations (Nepal, Haiti, Kenya, and Indonesia) | Flood or cholera (n=1)<br>Earthquake (n=2)<br>Cholera outbreak (n=1) | Household surveys (n=1,521)<br><br>Household water samples (treated and untreated) (n=1,565) | Multiple household water and safe storage treatment (HWTS) methods: chlorine liquid or tablets in Nepal and Indonesia; chlorine tablets or flocculant/disinfectant in Kenya, and chlorine tables or liquid, ceramic or biosand filters in Haiti | N/A | No data on CFU reported for Nepal or Indonesia<br><br>Kenya: 11.7% used chlorinated product based on residual free chlorine: 5.3% using chlorine tablets had less than 1 CFU/100ml and 4.4% less than 10CFU/100ml |

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| Lantagne 2012, with a further time point for evaluation) | | | | | | | (2.3% and 2.3% for those using flocculant/disinfectant)<br><br>For Haiti, % with less than 1 CFU/100ml were 67.5% in users of chlorine tablets (rural), 56.8% (urban), 13% settlements; 19.8% using ceramic filters, 8.4% using biosand filters<br><br>For Haiti, % with less than 10 CFU/100ml were 53.1% in users of chlorine tablets (rural), 44.7% (urban), 10% settlements; 10.8% using ceramic filters, 19.5% using biosand filters |
| Milojevic and others 2012 (22) | Cohort | Matlab region of Bangladesh.<br><br>(n=66,777 residents in flood areas, n=144,362 in non-flood areas) | Flood | Household survey, interview (monthly)<br>Hospital patient data | Surface water, tube wells | No significant differences in risk ratios for death, diarrhoea or acute respiratory infection by water source (tube well, surface or filtered) between flood and non-flood areas when pre-flood differences controlled for | N/A |
| Patrick and others 2013 (9) | Cross-sectional | Rural Artibonite, Haiti<br><br>88.4% of respondents female, mean age 41 years (range 16 – 90 years) | Earthquake with subsequent cholera epidemic | Sampling frame: all households in rural Artibonite<br><br>40 clusters of 12 households giving 480 households, 37 out of 40 clusters were reached, 433 out of 480 household interviews completed | Improved sources: public tap/fountain/kiosk, borehole with handpump, protected spring, private kiosk with vended water, piped water onto plot<br><br>Unimproved sources: unprotected springs, river/canal, unclassified surface water, dug well, undefined water source | N/A | Improved water sources: 50.9% positive for *E. coli* and 23.6% had *E. coli* concentrations > 10 MPN/100ml which equates to at least an intermediate risk level according to WHO classification<br><br>Unimproved water sources: 83% positive for *E. coli* and 69.8% had *E. coli* |

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| | | | | | | | concentrations >10 MPN/100ml<br><br>Amongst the water sources, protected springs (2 out of 2), piped water into the plot (1 out of 1), river/canal (6 out of 6) and dug wells (14 out of 14) appeared to have the highest rates of *E. coli* positivity – all 100%. Lower rates were seen for private kiosks with vended water (0 out of 6, 0%) and boreholes with hand pump (3 out of 18, 16.7%) |
| Rajendran and others 2006 (10) | Cross-sectional | Tsunami-hit coastal areas of Kanyakumari District, Tamil Nadu, India | Tsunami 26 Dec 2004 | 151 water samples from various drinking water sources in affected areas, prior to clean-up and decontamination procedures<br><br>Underwent analysis of coliform counts and additional pathogen detection (Salmonella and Vibrio species) | Overhead tank<br>Sintex plastic tank<br>Packed drinking water<br>Bore well<br>Public well<br>Public fountain<br>Sump<br>Reservoir<br>Filter house<br>Bottle<br>Aqua guard | N/A | Coliform positivity / total samples (%):<br><br>• overhead tank 17 out of 43 (39.5)<br>• sintex plastic tank 9 out of 29 (31.0)<br>• packed drinking water 0 out of 25 (0)<br>• bore well 14 out of 23 (60.9)<br>• public well 13 out of 17 (76.5)<br>• public fountain 1 out of 9 (11.1)<br>• sump 1 out of 1 (100)<br>• reservoir 1 out of 1 (100)<br>• filter house 0 out of 1 (0)<br>• bottle 0 out of 1 (0)<br>• aqua guard 0 out of 1 (0)<br>• overall 56 out of 151 (37.1)<br>Salmonella Paratyphi B and NAG Vibrio were isolated |

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| | | | | | | | from 2 different well water samples |
| Salih and others 2019 (1) | Randomised double-blind controlled trial | Long-term refugee camp, Sudan.<br><br>Population: individuals who have been resident >1 month, drink from one water tank (n=341) | Refugee camp | Survey, completed at baseline and 15 days post-intervention | Wells (n=4).<br>Chlorinated with tablets (OASIS1000, Hydrachem) (1gm per $1m^3$) (n=2) versus placebo (n=2) | Cases of Highly Credible Gastroenteritis were significantly lower compared to baseline (-82.8%) in the treatment group, and significantly lower post-intervention in treatment group versus placebo (p=0.008).<br>Compared to control group, cases of diarrhoea were significantly lower post-intervention in the treatment group (p=0.012) | None. |
| Sikder and others 2018a (16) | Cross-sectional: observational assessment of ongoing emergency response | Southern Syria<br><br>Average number of people per household = 6 (range 5 to 7)<br><br>68% households had a child aged <5 years old | War | Four groups of WASH (water, sanitation and hygiene) risk reduction modalities in 2 regions and a no intervention area (but not trial design – observational)<br><br>Sample size calculations for the household survey allowed for clustering – 1,000 households required, 1,006 households surveyed | Piped water<br>Trucked water | N/A | Piped water (versus trucked water) associated with increased likelihood of free residual chlorine ≥0.1mg/L (for example, safer water): adjusted OR 3.5 (95% CI 1.8 to 6.7)<br><br>Households receiving chlorine associated with increased likelihood of free residual chlorine ≥0.1mg/L (for example, safer water): adjusted OR 6.1 (95% CI 3.4 to 11.0)<br><br>Households which received water disinfection training associated with increased likelihood of free residual chlorine ≥0.1mg/L (for example, safer water): unadjusted OR 4.7 (95% CI 2.2 to 9.9), not included in adjusted analysis |

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| Sikder and others 2018b (23) | Cross-sectional | 17 sub-districts of Dar'a and Quineitra, Syria<br><br>Avg household size 7.6 persons with 46.5% living in damaged or shared accommodation | War | Household survey in June to July 2016 and February 2017<br>1,281 survey responses | Water trucks, network (piped), other | Water trucks were the most frequent source of water (approximately 77%). In 2 weeks prior to survey completion, 20.4% to 32.8% reported a child under 5 in their household had diarrhoea. No statistically significant association with main source of water (2016; OR 1.02 95% CI [0.88, 1.18]; (2017; OR 0.71, 95% CI [0.61, 0.82])) | In 2017, no statistically significant effect of water source (trucks, piped) on presence of free chlorine residual in household water samples (OR 1.59, 95% CI [1.23, 2.05]) |
| Sikder and others 2020 (11) | Mixed-methods evaluation (observational) | Five camps in Cox's Bazar, Bangladesh<br><br>Evaluation of 3 different water chlorination programmes | Refugee camp | Survey of 29 water collection points, household survey n=487, plus focus group discussions and key informant interviews | Bucket chlorination (water from unimproved sources)<br><br>In-line chlorination (groundwater via handpumps)<br><br>Piped water chlorination (groundwater via electric submersible pump) | N/A | *E. coli* CFU/100 mL<br>Geometric mean (geometric sd):<br>• bucket chlorination 451.0 (6.5)<br>• in-line chlorination 1.5 (2.4)<br>• piped water chlorination 1.0 (1.0)<br><br>For example, higher *E. coli* loads in the bucket chlorination system |
| Sirajul and others 2007 (12) | Longitudinal combined with experimental | Amalapur, Dhaka City, Bangladesh<br><br>Densely populated area with unplanned housing and baseline inadequate water and sanitation systems<br><br>August 2004 to January 2005 | Flood, 2004 | 300 water samples from 20 different drinking water sources across 7 geographical strata (2 to 3 sampling sites per stratum), sampling undertaken from 3 August 2004 to 2 January 2005 and indicators monitored over time | Taps<br>Hand pumps<br>Overhead tanks<br>Trucked water<br><br>Collected samples treated with 4 different disinfectants: alum potash, Zeoline®-200 (commercially available sodium-hypochlorite solution; Zeolite India Pvt. Ltd., Kolkata, India), Halotab (Halazone USP, 15 mg; | N/A | Each sample analysed for coliforms, vibrio cholerae and chemical parameters. Samples then treated with one of 4 different disinfectants. Out of 300 water samples, only the heavily contaminated samples were selected for testing the efficacy of various disinfectants.<br><br>Level of unacceptable drinking water sources |

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| | | | | | Sonear Laboratories Ltd., Dhaka, Bangladesh) and bleaching powder (calcium hypochlorite) | | ranged from 23·8% to 95·2%, 28·6% to 95·2% and 33·3% to 90·0% for total coliforms, faecal coliforms and faecal streptococci respectively. Bacteriological contamination of water by source not reported<br><br>Treatment efficiency of the 4 disinfectants:<br>Zeoline®-200 most effective (83·8%) against total coliforms followed by Halotab (81·5%), alum (73·0%) and bleaching powder (64·7%). Halotab (77·1%), Zeoline®-200 (72·6%) and bleaching powder (72·4%) more effective against faecal streptococci than alum potash (29·7%) |
| Tharnpoophasiam and others 2006 (13) | Case-control | Eight weeks post-tsunami. Coastal Phang-Nga province, Thailand | Tsunami | Affected area: 4 coastal villages<br><br>Control:<br>4km inland (where tsunami water did not reach | Surface water (n=16 samples from canals and man-made ponds), shallow wellwater (n=34 samples), drinking water (n=8, bottled or supplied by truck) | N/A | Microbiological: In wells in the affected area, E cloacae was found in 2 wells, A hydrophilia (diarrhoea-causing) in one well, and staphylococcus coagulase positive (causing food poisoning and dermatitis) in one well compared with E cloacae in one well in the control area. No enteric bacteria found in drinking water<br><br>Physical-chemical: Well water had significantly higher salinity, Ph, conductivity and total dissolved solids in the |

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| | | | | | | | affected area vs control (p<0.001) |
| Widmer and others 2014 (14) | Longitudinal | Post-earthquake Haiti, 2012 and 2013 | Earthquake<br>Hurricane | Screened non-surface water points from 345 sites | Non-surface water points (for example, wells, pumps) | N/A | Faecal coliform bacteria: identified in 37.3% of water sources. In unimproved water sources, contamination significantly less likely in spring water (53.4%) vs hand-dug wells (79.4%). Wells with India Mark II pumps were significantly less likely to be contaminated (p<0.001)<br><br>Toxigenic V cholerae O1: not isolated in any water point sampled |

# About the UK Health Security Agency

UKHSA is responsible for protecting every member of every community from the impact of infectious diseases, chemical, biological, radiological and nuclear incidents and other health threats. We provide intellectual, scientific and operational leadership at national and local level, as well as on the global stage, to make the nation health secure.

UKHSA is an executive agency, sponsored by the Department of Health and Social Care.



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Published: December 2025
Publishing reference: GOV-16950 (CPHR010b)

Suggested citation: Brini S, Carter N, Harris T, De Brun C, Carville S. Safe drinking water alternatives: a rapid evidence summary. UKHSA; 2025