Efficacy and effectiveness of water, sanitation, and hygiene interventions in emergencies in low- and middle-income countries: a systematic review

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There are increasing numbers of people affected by natural disasters, disease outbreaks, and conflict. Water, sanitation, and hygiene (WASH) interventions are used in nearly all emergency responses to help reduce disease risk. However, there is a lack of summarized evidence on the efficacy and effectiveness of these interventions. We conducted a systematic review of the published and grey literature on the efficacy and effectiveness of short-term WASH interventions in emergency response in low- and middle-income countries, including: developing theory of change models; setting inclusion criteria; conducting the search; selecting evaluations for inclusion; assessing the quality of the evidence; and analysing the included evaluations. Overall, 15,026 documents were identified and 106 studies describing 114 evaluations met inclusion criteria. Interventions from 39 countries were included. Most included evaluations (77 per cent) had high risk of bias and half were from grey literature (50 per cent). For the majority of interventions, we found that WASH interventions consistently reduced both the risk of disease and transmission in emergency contexts; however, programme design and beneficiary preferences were important considerations to ensure WASH intervention efficacy and effectiveness. Critical programme design characteristics included simple interventions that were appropriately timed, community-driven, and had linkages between relief and development. Barriers and facilitators to WASH interventions in outbreak response were taste and smell of treated water, communication methods, inaccurate perception of efficacy, and trust/fear. Foundational research is needed on commonly implemented, under-researched interventions, as well as investigating the relative cost-effectiveness of emergency WASH interventions.

Keywords: emergency WASH, systematic review, evidence, disaster

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Emergencies – including natural disasters, conflicts and disease outbreaks – are occurring at increasing rates and affecting a growing number of people. Natural disasters (i.e. earthquakes, hurricanes, flooding events, disease outbreaks, or droughts) affect more than 200 million people annually (EM-DAT, 2014). Climate change is expected to increase the scale and frequency of natural disasters, while the rapidly expanding urban and slum populations in disaster-prone regions mean a larger number of people may be impacted by natural disasters (Walker et al., 2012). Currently, more than 1.5 billion people are potentially threatened by conflict and violence (Institute for Economics and Peace, 2014; IISS, 2015). In 2015, there were more than 60 million displaced persons worldwide, the highest number ever recorded (UNHCR, 2015). Lastly, disease outbreaks have increased in number and diversity (Smith et al., 2014). Between 1980 and 2013, there were 12,102 outbreaks in 219 nations, impacting more than 44 million people. These increases are attributed to microbial adaption of pathogens, changing human susceptibility, climate change, changing human demographics (inclusive of increasing mobility), economic development, breakdowns in public health, poverty, social inequality, war, and famine.

With a growing number of people at risk, evidence-based strategies to provide interventions to affected populations are needed to prevent and control a variety of communicable diseases (Sphere Project, 2011; JMP, 2014; Watson et al., 2007; Darcy et al., 2013; Parkinson, 2009; Connolly et al., 2004; Toole, 1995, 1996). According to the *Humanitarian Charter and Minimum Standards in Humanitarian Response:*

> Water and sanitation are critical determinants for survival in the initial stages of a disaster. People affected by disasters are generally much more susceptible to illness and death from disease, which to a large extent are related to inadequate sanitation, inadequate water supplies and inability to maintain good hygiene.

Emergency WASH interventions should provide access to safe water and sanitation and promote good hygiene practices with dignity, comfort, and security (Sphere Project, 2011). WASH interventions in emergency situations are not necessarily intended to provide long-term sustainable access, but instead provide rapid relief. *Water* interventions aim to increase water quantity and/or improve water quality; *sanitation* interventions aim to isolate faeces from the environment; *hygiene* interventions aim to prevent transmission through hands, and more broadly, promote awareness among affected populations on the disease and equip these populations to act; and *environmental hygiene* interventions reduce risks by disinfecting household objects and managing rubbish.

WASH interventions are commonly implemented as part of emergency response activities by United Nations (UN) agencies, local governments, and emergency responders. WASH interventions currently used in emergency response may be known to be efficacious and effective, but were mostly adopted from development contexts which may not transfer well to emergency contexts (Darcy et al., 2013; Parkinson, 2009). There is currently little evidence on the efficacy and effectiveness

in emergency situations in low- and middle-income countries (LMIC) (Blanchet et al., 2013; Ramesh et al., 2015; Brown et al., 2012a; Taylor et al., 2015). The weak evidence base in emergencies is attributed to two factors: 1) prioritizing rapid response activities over research and 2) acknowledging the difficulty of conducting research in the rapidly changing and unstable settings of emergencies (Spiegel et al., 2007). Responders also note that there is a lack of technical knowledge related to data collection, lack of personnel to collect data, and lack of clear goals for how to use the information (Vujcic et al., 2015).

In the absence of evidence, responders often default to familiar interventions using 'intuition' and 'if it worked before, it will work again' (Darcy et al., 2013; Loo et al., 2012; Steele and Clarke, 2008). As the efficacy and effectiveness of WASH interventions depend on contextual factors unique to each emergency (Bastable and Russell, 2013; Loo et al., 2012; Parkinson, 2009), contextually appropriate information on WASH intervention effectiveness may provide more relevant and effective guidance for responders and lead to better WASH interventions in emergencies. With the many evidence gaps, there has been an increasing demand for improving the evidence base of emergency interventions, health as well as WASH, from responders, academics, and donors (Samarasekera and Horton, 2017; Hawkins and Pérache, 2017; Waldman and Toole, 2017; Kayabu and Clarke, 2013; Cairncross et al., 2013). In particular, the Emergency Environmental Health Forum and Global WASH Cluster meetings are also increasingly focused on sharing WASH evidence.

In 2015, a systematic review on the efficacy of WASH interventions for cholera response (Taylor et al., 2015) and another on the health impact of WASH interventions in emergencies (Ramesh et al., 2015) concluded that there is a lack of data to establish firm evidence for implementing WASH interventions in outbreaks and emergencies. As Taylor et al. (2015) only covered published studies of a certain quality and Ramesh et al. (2015) only included manuscripts documenting health impacts, neither review incorporated all available information sources or full scope of evaluation methods and outcomes available in emergency contexts. Ideally, a synthesis of evidence would include both published and grey literature, as well as quantitative and qualitative information on outcomes, impacts, and influencing contextual factors that contribute to programme effectiveness and efficacy in order to fully encompass the evidence base (Brown et al., 2012b).

The objective of this review was to assess the outcomes and impacts of short-term emergency WASH interventions in LMIC, including both published and grey literature, with the aim of including a broader set of contextual factors that may shape intervention effectiveness. We specifically intended to address five particular research objectives for WASH interventions during emergency response:

- What are the effects of use of service in emergency WASH situations?
- What are the health-related outcomes in emergency WASH situations?
- What are the non-health-related outcomes in emergency WASH interventions?
- What contextual factors act as barriers or facilitators to implementation and uptake and the effectiveness in emergency WASH situations?
- What is the cost-effectiveness of emergency WASH interventions situations?

Methods

To address these research questions, we conducted a systematic review of published and grey literature, including development of: 1) theory of change models; 2) search strategy; 3) inclusion criteria; 4) selection and processing strategy; 5) quality of evidence appraisal; and 6) analysis plan. Please note that efforts were made to follow the protocol and procedures with standard systematic review procedures outlined by the *Cochrane Review* (Higgins and Green, 2011), including the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist; however, due to the acceptance of low-quality manuscripts, grey literature, and the wide variety of outcome measures beyond health outcomes, strict adherence to these procedures was not appropriate and these protocols were modified to purpose, as described below. The full systematic review protocol was peer-reviewed and made publicly available before conducting the review (Yates et al., 2015a). Each step of the systematic review process is summarized below.

Theory of change model development

A theory of change model was developed for each WASH intervention to describe the theoretical route from intervention activities to outputs, outcomes, and impacts, while also identifying influencing factors and assumptions. We developed a model for each of the eight WASH activities we anticipated seeing in the review: increasing access to water; source-based water treatment; household water treatment (HWT); temporary or permanent latrines; latrine alternatives; hygiene promotion (including handwashing); distribution of soap and/or hygiene materials/kits; and environmental hygiene. Theory of change diagrams for each intervention can be found in the protocol (Yates et al., 2015a).

Search strategy. A search strategy was developed to identify published and unpublished grey literature. Individualized search terms and strings were developed for each of the eight WASH interventions from their associated theory of change, and included keywords and outcome and impact measures specific to that intervention. The search strings were used in a total of nine peer-reviewed databases and 10 searches, in English (7), French (2) and English/Spanish (1) including: Cochrane Library, Google Scholar, IDEAS, LILACs, Ovid Medline (PubMed), Scopus, Web of Science, Academic Search Premier (English and French), and ArticleFirst. Searching took place in November and December 2015, and was re-run in September 2016. Six journals identified as most likely to have relevant research and reference lists of included evaluations and reviews identified in the searches were screened by hand. Responder websites were also searched with keywords, including: non-governmental organizations (NGO), UN, and other relevant websites. Additionally, solicitation for relevant documents was carried out through email and personal contacts. Requests for information were sent to the international community via the Global WASH Cluster in September 2015 and February 2016, and to the International Network on Household Water Treatment and Safe Storage in September 2015. Overall, more than 75 organizations were contacted through email.

Lastly, personal solicitations, online posts, and international conferences were also used to collect information.

Inclusion criteria. Inclusion criteria were established according to the populations, interventions, comparisons, outcomes, and study types (PICOS) framework (Yates et al., 2015a).

Populations. All age, gender, and socioeconomic populations in World Bank-defined LMIC in 2014 were eligible for inclusion. Populations must also have been affected by an emergency. For this analysis, an 'emergency' was defined as an event affecting a specific population that requires national or international assistance because local capacity is overwhelmed (UNISDR, 2007). A decision tree was used to aid the determination of an emergency, which can be found in the protocol (Yates et al., 2015a). For natural disasters, conflict, or outbreaks, factors used to help define an emergency included: a United Nations Disaster and Coordination response, international funding appeal, population displacement, or acute events in chronic emergencies. An outbreak was defined in accordance with WHO definitions (WHO, 2016) and limited to communicable diseases for which WASH interventions can break known transmission routes, specifically: cholera, Ebola, hepatitis E, hepatitis A, typhoid fever, acute watery diarrhoea and bacillary dysentery (shigellosis).

Interventions. A WASH intervention was eligible for review if it targeted an emergency-affected population and was carried out within 12 months of the start of the emergency. Interventions must have been field-based. Laboratory research and health-focused interventions (i.e. clinic or hospital interventions) were excluded.

Comparisons. No specific comparisons were required for inclusion.

Outcomes. Evaluations were included if at least one intermediate outcome (use of service or non-health outcome) or final impact (disease reduction or cost-effectiveness) was reported. Use of service includes three specific indicators: self-reported use, confirmed use, and effective use. Self-reported use is beneficiary-reported use without additional verification. Confirmed use is when an evaluator tests or observes the use or service in some way (i.e. testing free chlorine residual (FCR) in chlorine-based water treatment programmes). Effective use is a measure of improving quality of contaminated water requiring confirmed use and microbiological testing of untreated and treated water to ensure there is water quality improvement. Cost-effectiveness included economic analyses investigating cost benefit, cost utility, cost per beneficiary, and cost per disability adjusted life-year (DALY) averted. Disease reduction data were included if beneficiary morbidity and mortality impact were self-reported or clinically measured. Non-health outcomes of preferences from the population on use of interventions (e.g. ease of use, taste or smell of water), quality of life improvement (e.g. feeling safer, time savings), and agency preferences for interventions were included.

Study types. Experimental, quasi-experimental, non-experimental, mixed-methods, and qualitative methodological study type designs were eligible for review.

Dates for inclusion were 1995–2016. Both peer-reviewed and unpublished grey literature documents were eligible. Personal blogs, diaries, newspapers articles, magazine articles, website postings, poster abstracts, and legal proceedings/court documents were not included. Review documents were not included, but individual references in review documents were screened for inclusion.

Selection and processing. Identified studies were screened first by titles, then by abstracts, and full texts. From abstract to final inclusion, studies were independently double-screened by two of the authors. Any discrepancies were discussed with a third author for final decision. Throughout the screening process, references were managed with Endnote X7 (New York, NY, USA) and Microsoft Excel 2010 (Redmond, WA, USA). Data collection was completed with a detailed coding sheet using Microsoft Excel 2010, and included author and publication details, type of intervention, context of the intervention, study design, study quality, effect estimation, outcomes and impacts, and barriers and facilitators to implementation (further described in detail in Appendix A within the supplemental information). Data collection was completed and double-screened by four research assistants.

Quality of evidence. Each included evaluation was assessed for the potential risk of bias. For quantitative studies, the bias assessment tool was based on the *Cochrane Handbook* 'Risk of bias' tool and formatted similarly to Baird et al. (2013) (Higgins and Green, 2008). The risk of bias was assessed through five categories: selection and confounding; spillover effects and contamination; incomplete outcome; selective reporting; and other risks of bias. For qualitative studies, four appraisal categories were adapted from Spencer et al. (2003): design; bias; data collection; and clarity of findings. Each category was scored as 'low risk,' 'high risk', or 'unclear'. The summary risk of bias for a study was based on the number of 'low-risk' assessments across the four or five categories depending on research design.

To establish the summary quality of evidence from multiple studies of varying qualities and study designs for each WASH intervention, a protocol was developed based on the Grading of Recommendations Assessment, Development and Evaluation (GRADE) of evidence outlined in *Cochrane Handbook* (Higgins and Green, 2011) but modified to have less emphasis on randomized controlled trials (RCTs) (as it was not expected the search would return many RCTs). The baseline was determined by the study designs in the intervention; then downgraded or upgraded considering biases, effect size, consistency, and generalizability. The summary of evidence was then described through four categories, which mimic GRADE (Oxman and GRADE Working Group, 2004): *high evidence* is defined as further research is very unlikely to change confidence in the estimate of effect or accuracy; *moderate evidence* as further research is likely to have an important impact on confidence in the estimate of effect or accuracy and may change the estimate; *low evidence* as further research is very likely to change the estimate; and *very low evidence* as any estimate of effect or accuracy is very uncertain.

Analysis plan. Considerations for missing data and meta-analysis techniques were described in the protocol; however, the low-quality research designs identified and included in the review undermined the relevance of meta-analysis and therefore most contingency measures were not utilized. Formal heterogeneity analysis with I^2 could

not be completed, as reported outcomes were too different for direct comparison. Potentially important factors, such as timing of response, scale, and quality of the intervention, were planned for evaluation in the protocol, but were not able to be adequately assessed or compared due to the lack of quality and consistent reporting in the documents included in the systematic review.

A narrative synthesis approach is used to summarize the information gathered. A summary of all included evaluations is first presented with descriptions of emergencies by country, intervention type, published or grey literature, risk of bias assessment, and evaluation methodology. Then, for each WASH intervention, a description of the intervention is presented, followed by information on the number of studies identified, risk of bias, outcomes and impacts, and summary of evidence. Results were then condensed in general tables and a map of evidence.

Please note that the original eight WASH intervention categories were broken down into 13 more detailed interventions that remained within the original scope: saltwater pumping; well disinfection; large- and small-scale source-based treatment; HWT with chlorine-based products; HWT with filters; HWT with other options; latrines; latrine alternatives; hygiene promotion including social mobilization; hygiene kit distribution; environmental hygiene; and WASH package (a term for when multiple interventions were delivered in the same response). Intervention definitions were based on common practice within the WASH sector. Please note: specific guidance for each intervention is outside the scope of this review and not described herein. Please also note: for space considerations, interventions with less than three evaluations are not described individually herein. We refer the reader to the full report for interventions with few evaluations (Yates et al., 2017).

Results

Overall, 15,026 documents were identified in the systematic review process. After applying the three selection filters, 106 studies were included, describing evaluations of 114 relevant contexts (Figure 1). The included evaluations are summarized for comparison in tabular format in Appendix A and the full report (Yates et al., 2017).

The included evaluations describe WASH interventions in 39 countries, with the highest frequency of evaluations from Zimbabwe and Haiti. Africa was the most common World Bank Region (43 per cent), while South Asia (24 per cent) and Latin America and the Caribbean (21 per cent) were also strongly represented. Water interventions represented the most included evaluations (n = 47, 41 per cent), followed by hygiene (n = 27, 24 per cent) and WASH package (n = 24, 21 per cent); sanitation interventions were least represented (n = 16, 14 per cent).

An equal number of evaluations were identified from the peer-reviewed (n = 57, 50 per cent) and grey literature (n = 57, 50 per cent). Please note several studies (e.g. documents or manuscripts) had more than one evaluation or case study, thus the difference between 106 studies and 114 evaluations. Although the overall number of evaluations was balanced between published and grey literature, differences were seen by intervention; water had more published evaluations and hygiene and WASH package had more grey literature evaluations. Half of the

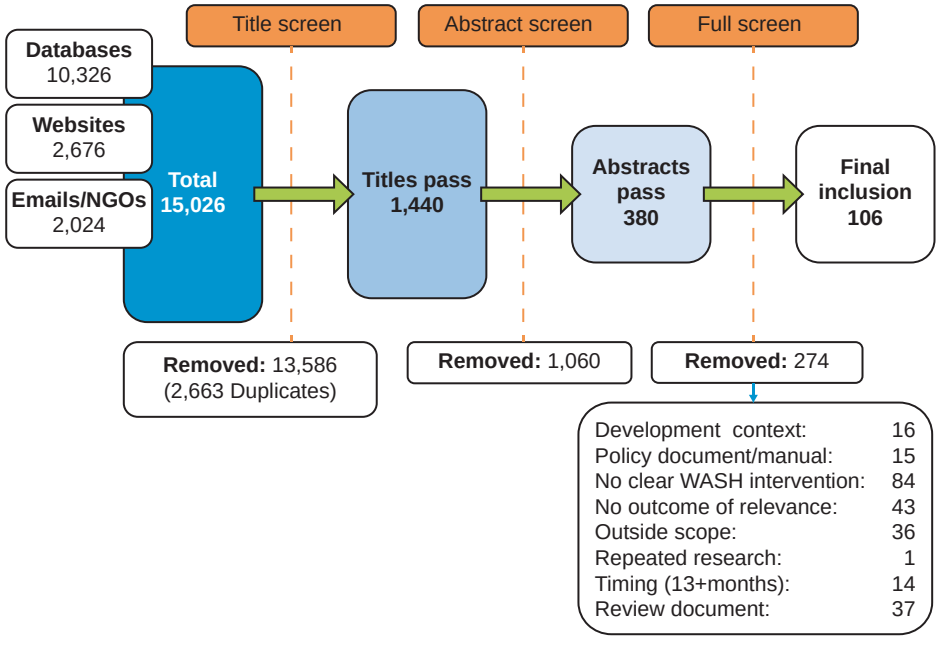

Figure 1 Screening process

evaluations (57/114) were published or documented between 2010 and 2015, and 85 per cent (97/114) were within the last 10 years. The high proportion of documents in the last decade coincides with several major emergencies, including the South-east Asian tsunami in 2004; cholera outbreaks in Zimbabwe and Haiti in 2008 and 2010; the earthquake in Haiti in 2010; flooding in Pakistan in 2010; and typhoons in the Philippines and Bangladesh in 2013 and 2008.

The majority of the studies (77 per cent, 82/106) had a high risk of bias (Figure 2). The quantitative evaluations were mostly completed on water interventions, which were also more likely to be published and had less risk of bias. For example, published water evaluations were 23 per cent low risk of bias (7/30), while only 3 per cent of the other WASH intervention evaluations had a low risk (2/76). Conversely, nearly all (96 per cent, 23/24) of the WASH package evaluations were field commentary or qualitative evaluations, all were unpublished and most were high risk of bias evaluations (83 per cent, 20/24). The study designs of included evaluations were weak, as only 9 per cent (10/106) of studies had any type of control group and less than 4 per cent (4/106) were RCTs. Diversity of outcomes was also weak, with measured health impacts in only 8 per cent (9/106) of the interventions.

We present the evaluations in the main categories of water, sanitation, hygiene, and WASH package. All identified interventions are summarized in Table 1 and Table 2, as well as Appendix A; descriptions of all included evaluations can be found in the full report, available from the International Initiative for Impact Evaluation (3ie) website (www.3ieimpact.org).

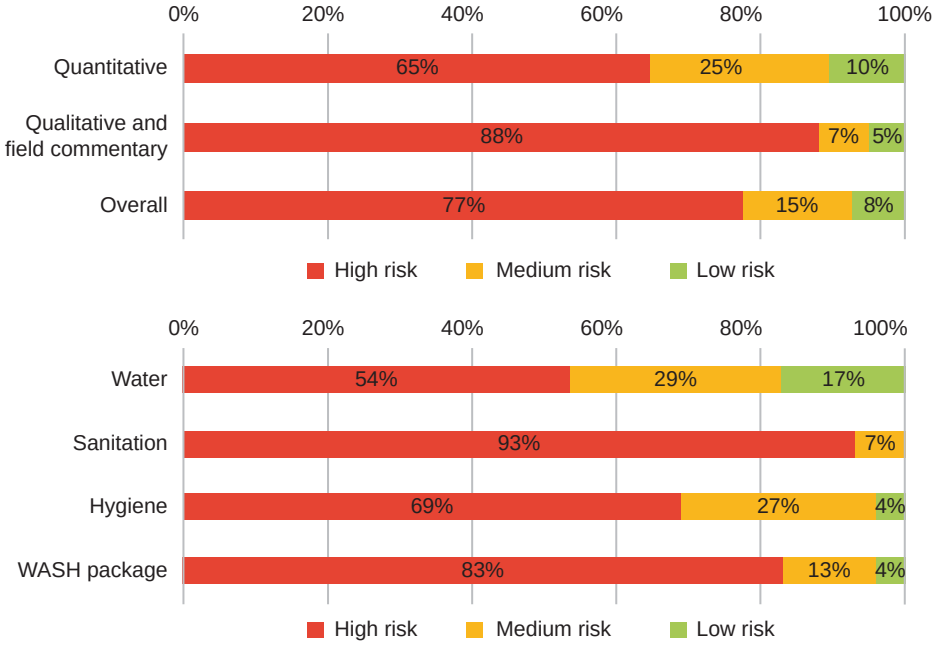

Figure 2 Risk of bias by evaluation method and sector

Water

Water interventions were separated into three general intervention types, with seven specific interventions, including: water point rehabilitation (saltwater pumping and well disinfection), source-based treatment (large- and small-scale), and HWT (chlorine-based treatments, water filters, and other, less common methods). Of these seven specific interventions, five had more than three evaluations, including: saltwater pumping, well disinfection, small-scale source treatment, chlorine-based HWT, and HWT with filters.

Saltwater pumping. Pumping and cleaning a well to physically remove silt, sand, and debris is a common activity after a flood or tsunami (Vithanage et al., 2009). Pumping wells flooded with seawater is expected to reduce the impact of saltwater intrusion (as measured by salinity or conductivity) and speed the recovery of the well to return to normal operation. Six evaluations of well pumping were identified with low (4) and high (2) risk of bias (Lytton, 2008; Villholth, 2007; Vithanage et al., 2009; Saltori and Giusti, 2006; Fesselet and Mulders, 2006; Lipscombe, 2007). All evaluations were after the 2004 South-east Asian tsunami, in similar porous and sandy soil types. A facilitating factor was that the communities perceived that saltwater pumping was necessary to safely rehabilitate the well, although communities over-estimated the impact of pumping (Villholth, 2007; Lipscombe, 2007; Saltori and Giusti, 2006). A barrier was that communities did not like the taste of the rehabilitated well water and preferred deliveries of trucked water (despite irregular supply and low quantity of trucked water), complicating the transition to recovery phase (Villholth, 2007;

Lipscombe, 2007). All evaluations concluded that pumping wells had, at best, no effect and recommended not using pumping, but instead using alternative water sources until well salinity levels naturally decreased.

Well disinfection. A common emergency response intervention is to directly disinfect a contaminated well with chlorine (Branz et al., 2017). The objectives of well disinfection are to reduce microbiological contamination and/or maintain FCR in the well. Six evaluations of low (3) and high (3) risk of bias were identified that described four slightly different approaches to well disinfection with chlorine from six different countries (note, two evaluations used multiple methods): 1) a shock dose of liquid chlorine (bleach) added directly to the well; 2) pot chlorination where powdered chlorine, sand, and gravel in a pierced container/jerrican was inserted into the well; 3) pot chlorination with locally pressed chlorine tablets in a perforated container; and 4) floating pot chlorinator (commercial plastic devices used in swimming pools) (Rowe et al., 1998; Libessart and Hammache, 2000; Garandeau et al., 2006; Guevart et al., 2008; Cavallaro et al., 2011; Luby et al., 2006). Shock chlorination is a one-time activity to simply disinfect, whereas the three pot chlorinator methods were intended to slowly disperse chlorine over time and maintain consistent FCR. Ideally, the FCR would be greater than or equal to 0.2 mg/L and less than or equal to 2.0 mg/L, which is the range ensuring water treatment but not exceeding taste or guideline thresholds (CDC, 2012).

One-time shock chlorination did not provide FCR protection for more than a few hours and did not reduce microbiological contamination (Rowe et al., 1998; Luby et al., 2006). Traditional pot chlorination inconsistently maintained measurable FCR for 1–4 days (Libessart and Hammache, 2000; Garandeau et al., 2006; Guevart et al., 2008; Cavallaro et al., 2011). Floating pot chlorinators could be effective, but could only be imported and required specialized tablets (Garandeau et al., 2006). In comparative evaluations, although with inconsistent methods, pressed HTH tablets with a pot chlorination approach maintained FCR for 3–4 days and were the preferred mode of well disinfection by responders (Libessart and Hammache, 2000; Garandeau et al., 2006). Microbiological disinfection of treatments was assessed in only one evaluation and did not have impact (Luby et al., 2006). Communication with community members was an important programmatic consideration identified, as well disinfection interventions were often perceived to maintain FCR for longer than it was maintained (Cavallaro et al., 2011; Rowe et al., 1998).

Source treatment. Source-based treatment interventions occur at the source or point of collection (Branz et al., 2017). Large-scale water treatment was considered the treatment of more than 200 L (0.2 m^3) of water with systems operated and managed by responders (as opposed to beneficiaries). Small-scale source treatment is water treatment that occurs at the point of collection one beneficiary at a time.

Large-scale source water treatment included three types of interventions through four evaluations, including: bulk water treatment (BWT) (Dorea et al., 2009), decentralized BWT (ACF, 2014b), and water trucking (Gupta and Quick, 2006; Lantagne and Clasen, 2013). Individually, large-scale source treatment interventions had

fewer than three interventions, thus specific results are not included herein. Overall, BWT and water trucking are well-known interventions, with established methods in emergencies; however, the interventions are not often evaluated, particularly at the beneficiary level.

Small-scale source water treatment included two types of interventions: chlorine dispensers (Yates et al., 2015b) and bucket chlorination (Branz et al., 2017).

Dispensers. A chlorine 'dispenser' programme includes hardware installed next to a water source that dispenses chlorine solution, a local 'promoter' who refills the dispenser and conducts community education, and a supply chain of chlorine refills. Users treat water by turning a valve that dispenses a controlled amount of chlorine solution. Dispensers were used in three different cholera contexts presented in one low-bias manuscript in Haiti, Sierra Leone, and Democratic Republic of Congo (DRC) with three different responding organizations; one additional context was carried out in a non-acute emergency in Senegal (Yates et al., 2015b) . Results varied over two acute evaluations (2–8 weeks after installation) and three sustained evaluations (4–7 months after installation) for reported use (26–75 per cent acute, 31–75 per cent sustained), confirmed use (11–34 per cent acute, 5–18 per cent sustained), and effective use (10–28 per cent acute, 0–10 per cent sustained) metrics. Spillover effects from other water treatment options were present and assist in explaining results, as the municipal water system in DRC was functional in the sustained evaluation and 32 per cent of households in Haiti reported using chlorine tablets as an alternative treatment. With regression analysis of household survey data, factors consistently associated with higher use across contexts were speaking to the promoter within the last month and collecting water from a source with a dispenser. The three implementing organizations gathered at project end and reflected on factors leading to success. These included: appropriate source selection; chlorine solution quality and supply chain; dispenser hardware installation and maintenance; integration into a larger WASH programme; promoter recruitment and remuneration; experienced programme staff; partnering with local organizations; conducting ongoing monitoring; and having a sustainability plan.

Bucket chlorination. Bucket chlorination is a common emergency response intervention where a person is stationed near a water source and adds a dose of chlorine directly into the recipients' water collection container. No evaluations of bucket chlorination were identified in the review; however, bucket chlorination was mentioned twice as an activity in the included evaluations (Grayel, 2011; Neseni and Guzha, 2009).

Household water treatment. HWT products (also called point-of-use water treatment products) are interventions used in the home to improve quality of household drinking water (Lantagne and Clasen, 2012). These may be distributed as a sole intervention or included as one of several items in a hygiene kit, which may also include hygiene promotion. HWT was the most studied intervention with 39 evaluations with a mixture of high, medium, and low risk of bias. For analysis, HWT interventions were separated by: chlorine-based products

(chlorine tablets, liquid chlorine, combined flocculant/disinfectants), filters (ceramic, hollow-fibre, sand), and other products – solar disinfection (SODIS), coagulants, safe storage, and boiling.

HWT, chlorine-based products. The most common HWT products distributed in emergencies were chlorine products, likely because they effectively inactivate most bacterial and viral pathogens, lead to residual protection, are low cost, and easy to use and transport (Lantagne and Clasen, 2012) Chlorine-based HWT products were separated into three sub-categories: chlorine tablets, liquid chlorine, and flocculants/disinfectants.

Chlorine tablets. Sodium dichloroisocyanurate chlorine tablets (e.g. Aquatabs®) were evaluated in 12 contexts; half (six) were low risk of bias, one medium risk and five were high risk of bias. The tablets (33–167 mg) were freely distributed through hygiene kits and intended to treat 5–20 L of water. The reported use ranged between 1 and 84 per cent (n = 9), while confirmed use ranged between 1 and 87 per cent (n = 11). Effective use ranged between 5 and 63 per cent (n = 4). The highest rates were reported in South Sudan and Haiti where 92 per cent of households reported recent household promotion and 75–82 per cent of households knew the correct use because of a long-running treated water campaign (ACF, 2014c; Lantagne and Clasen, 2013). The taste and smell of chlorine tablets was reported as a barrier to use in nearly half of the contexts (5/11) from three countries (ACF, 2009; Lantagne and Clasen, 2012; Imanishi et al., 2014; Ruiz-Roman, 2009; Johnston, 2008). Overdosing may have led to strong smells/taste, as some beneficiaries did not have the appropriate water storage container for the tablet size distribution (Imanishi et al., 2014; ACF, 2009; Johnston, 2008; Varampath, 2008). Knowing a HWT method before the emergency and ease of use were correlated with use in Zimbabwe (Imanishi et al., 2014) and Nepal (Lantagne and Clasen, 2012). Health impact was measured in one document after the typhoon/flooding in Bangladesh; a 55 per cent diarrhoea reduction was measured in children under five but was not statistically significant (RR 0.45, 95 per cent CI 0.19–1.03) (Johnston, 2008).

Liquid chlorine. Small bottles of 1–1.25 per cent sodium hypochlorite (e.g. WaterGuard, sized so one cap treats 20 L of water) and commercial bleach (where the dosage is generally in drops), were assessed in nine evaluations within six countries, with four high, two medium, and three low risk of bias evaluations. Reported use ranged between 6 and 88 per cent, and confirmed use ranged between 1 and 69 per cent. Effective use was not measured. While not definitive, some of the heterogeneity may be explained by the active promotion of liquid chlorine before the emergency in the two evaluations with higher usage rates in DRC (Tokplo, 2015) and Madagascar (Mong et al., 2001). Cost may explain the low use in Madagascar (Dunston et al. 2001) as free distribution of the same product had much higher rates in the same region (Mong et al., 2001). Excessive dosing was observed in Madagascar (FCR >3.5 mg/L) (Mong et al., 2001) and taste was noted as a hindrance to use in Nepal and the Philippines (Lantagne and Clasen, 2012; Plan, 2013). Liquid chlorine was linked to long-term development approaches including promotion (ACF, 2014d),

cost recovery and social marketing (Dunston et al., 2001), local production (Date et al., 2013), and vouchers (ACF, 2014d), as liquid chlorine is regularly used in development situations, and responses can scale up existing ongoing development interventions. These development programme linkages were not described in other HWT interventions.

Combination flocculants/disinfectants. Flocculant/disinfectant sachets (e.g. P&G Purifier of Water® 'PuR') are most often used to treat turbid water. Users add the contents of a sachet to 10 L of water, stir for five minutes, wait five minutes for the solids to settle, filter the water through a cloth into a second bucket, and wait 20 minutes before drinking. PuR was assessed in seven evaluations: two low and five high risk of bias. Reported use ranged between 6 and 83 per cent (n = 3) and confirmed use ranged between 4 and 95 per cent (n = 6). High use was reported with strong promotion and knowledge of how to use PuR (Doocy and Burnham, 2006; ACF, 2014c; Colindres et al., 2007). Low knowledge was reported in an NFI (non-food items) distribution with minimal promotion in Kenya, where only 2.3 per cent of households could describe the five steps necessary for PuR, translating to similarly low reported use of 6 per cent and confirmed use of 4 per cent (Lantagne and Clasen, 2012). Community preference to taste and smell of PuR ranged widely, with two populations (Haiti and Liberia) reporting liking the taste (Doocy and Burnham, 2006; Colindres et al., 2007) and two populations reporting not liking the taste or smell (Bangladesh and Vietnam) (Hoque and Khanam, 2007; Handzel and Bamrah, 2006). Similarly, PuR was diversely described as easy to use in one evaluation (Colindres et al., 2007), but also 'too time-consuming' in another (Hoque and Khanam, 2007). When PuR was distributed together with chlorine tablets, PuR was preferred by beneficiaries (Johnston, 2008; Hoque and Khanam, 2007). Health impact was reported in two evaluations, a randomized control trial for cholera in Liberia and typhoon response in Bangladesh. In Liberia, PuR use reduced diarrhoea incidence by 67 per cent (adjusted RR 0.33; 95 per cent CI 0.30–0.37) (Doocy and Burnham, 2006), with similar results of 77 per cent reduction in Bangladesh (RR 0.23; 95 per cent CI 0.07–0.72) (Johnston, 2008).

HWT, filters. HWT filter types include: ceramic, sand, and hollow-fibre filters. These filters are generally effective at removing protozoa and bacteria, and some hollow-fibre filters can also remove viruses. Filters provide immediate water treatment that can also last into the recovery phase (3–9 months after the disaster) without additional distributions from responders. Six evaluations in five countries were identified in the review with two low and four high risk of bias evaluations (Palmer, 2005; Clasen and Boisson, 2006; Lantagne and Clasen, 2013; Ensink et al., 2015; Cressey, 2015). Reported filter use ranged from 53–100 per cent (n = 3) in the acute evaluations and 0–96 per cent (n = 7) in sustained evaluations 6–16 months after distribution. Effective use ranged from 8–20 per cent (n = 2) in the acute phase, and 0–28 per cent in sustained evaluations (n = 7). Factors impacting filter interventions included: turbidity, filter capacity, and taste. Muddy, turbid source waters can quickly clog filters, reducing the flow rate and limiting the microbiological effectiveness (Clasen and Boisson, 2006). Also, the time needed to treat enough water

for a household may not match beneficiary needs or expectations (Cressey, 2015), but beneficiaries often reported improved taste with filter use (Clasen and Boisson, 2006; Ensink et al., 2015; Palmer, 2005).

HWT, other products. Other HWT interventions (non-chlorine or non-filter) were separated into four sub-categories: SODIS, coagulants, safe storage, and boiling. Fewer than three interventions per category were identified for these HWT interventions, thus specific results are not included herein. Generally, other HWT products were evaluated using higher-quality evaluation methods with several RCTs measuring health impact: self-reported cholera cases were 88 per cent less likely in children under five with a SODIS intervention in Kenya ($p = 0.014$) (Conroy et al., 2001) and safe storage interventions reduced diarrhoea by 16 per cent ($p < 0.05$) in Liberia (Doocy and Burnham, 2006) and 8 per cent ($p = 0.06$) in Malawi (Roberts et al., 2001). Overall, these less common HWT interventions were consistently reported to be simple, sustainable, and accepted by the communities.

Sanitation

The goal of sanitation programmes in emergency response is to break disease transmission by isolating faeces from the environment (Sphere Project, 2011), using either output-driven approaches (e.g. latrine construction or latrine alternatives) (Bastable and Lamb, 2012) or community-driven approaches (e.g. community-led total sanitation (CLTS)) (Majumdar and Coonrod, 2010). *Note: Community-driven approaches are described within 'Social mobilization' below.*

Latrines. Latrine construction was often carried out with water and/or hygiene interventions described in other sections of this review; 12 evaluations were focused on provision of latrines, 11 were high risk of bias and mostly field commentaries. Latrine use or impact was rarely evaluated, so analysis was limited to reporting common themes: acute disaster latrines, eco-sanitation (ecosan), rehabilitation of damaged latrines, vulnerability targeting, and reduced disease burden. Acute disaster latrines were considered as interventions less than one week from disaster. In dense urban areas or places where digging is not feasible, portable toilets were successful at providing safe, dignified sanitation immediately after the Haiti earthquake, but require thoughtful consideration for desludging and final sludge disposal (Eyrard, 2011). Raised latrines were also temporary solutions used in Haiti and Bolivia, which included a cubicle structure placed over a barrel or tank operating in a similar way to porta-johns®, but required less frequent desludging (Bastable and Lamb, 2012; Kinstedt, 2012). Simple 'shallow-trench latrines' were trialled with success in the Pakistan flood response in 2010, constructed as a temporary solution with tarpaulin and timber/bamboo poles (Singh, 2012; Bastable and Lamb, 2012). Ecosan includes many latrine designs (e.g. urine diversion or composting toilets) but all focus on decomposition of waste, rather than desludging. Ecosan latrines were informally evaluated in nine countries after earthquakes, floods, and in camp settings (Bastable and Lamb, 2012; Mwase, 2006; Kinstedt, 2012), but were considered best suited for

recovery or development phases. Rehabilitating latrines was a viable option after an earthquake in Iran and flood in China. Rehabilitating latrines was better suited than temporary latrines because materials were locally and immediately available, longer-lasting, and more culturally appropriate, with similar costs to other options (Pinera et al., 2005; Lin et al., 2008). Specific consideration for women and vulnerable populations (i.e. people with disabilities, the elderly, pregnant women, and children) were documented in South Sudan, India, and Liberia (de Lange et al., 2014; Moyenga and Rudge, 2011; Visser, 2012; Singh, 2009). Targeting was not found to be burdensome but led to more appropriate latrine designs (e.g. locking doors, handrails) with marginal additional costs. In South Sudan, female use of latrines was significantly higher ($p < 0.001$) where women were specifically engaged in the latrine design process compared with another part of the camp in the area without dedicated targeting (de Lange et al., 2014). Increasing latrine coverage was noted to impact disease rates in China and Nepal but sanitation interventions were carried out with other interventions simultaneously, with unknown spillover effects (Lin et al., 2008; Puddifoot, 1995). Overall, while each context is unique, it was consistently found that beneficiaries will use latrines provided they are safe, clean, and offer privacy.

Latrine alternatives. Latrine alternative interventions (e.g. Peepoo® bags) include a supply of bags (often biodegradable), a safe private location (in the home or a community cubicle), and a system of waste collection. Latrine alternatives were a short-term solution aimed to fill a temporary gap in sanitation services, often due to timing or location constraints. Three evaluations, all high risk of bias, were included in the review, two from the Haiti earthquake and one from the Typhoon Haiyan response in the Philippines (Patel et al., 2011; Coloni et al., 2012; Parsa, 2014). All three contexts were in internally displaced persons (IDP) settings and were intended to be used for 4–8 weeks. In Haiti, self-reported use was 91 per cent, whereas use based on distribution records was much lower at 13 per cent (range: 8–18 per cent). It was noted that distribution records and estimated camp population may underestimate the use, although a full-scale operational project 10 times larger than the trial may also explain the differences. In the Philippines, use of latrine alternatives was 74 per cent from NGO monitoring. Intended location of use could be a factor, as Peepoo® interventions at households had high use (>70 per cent), compared with community cubicles (<20 per cent). Cultural acceptance of using bags to defecate was a concern from responding agencies. In Haiti, responders identified that this was an existing practice, termed 'flying toilets', while in the Philippines, the practice did not previously exist, but key informant interviews and focus group discussions suggested that Peepoo® bags would be acceptable. Management and disposal of the bags was different in each context, and some not successful, as 100 per cent of beneficiaries from the Haiti pilot reported disposing of bags in 'indiscriminate locations' (Coloni et al., 2012). Hauling the waste away was considered easier than desludging a latrine, which often requires specialized equipment with excessive costs. There was also consideration for community involvement in all evaluations, which ranged from community volunteers to cash for work (CFW).

Hygiene

Hygiene messages educate affected populations on disease risks and transmission routes. Often in emergencies, *hygiene promotion* is condensed to key messages, such as handwashing at critical times (Vujcic et al., 2015). Promotion can be at schools, in large community groups, or at the household level. For this review, *social mobilization* is considered a subset of interventions within hygiene promotion and includes strategies for engaging and facilitating communities to address identified risks with local solutions. There was no isolated evaluation of hygiene behaviour change (e.g. changing in handwashing behaviour from promotional activities) identified in the review; however, there were evaluations of hygiene promotion and social mobilization.

Hygiene promotion. Hygiene promotion was examined through nine evaluations of medium and high risk of bias describing preferred message delivery and health impacts. Common hygiene factors that were evaluated were: person sharing the message (i.e. community health worker, NGO, friend, neighbour, family member, local leader), how it was shared (i.e. radio, TV, posters/pamphlets, theatrical skits, face to face), and location (e.g. home, school, place of worship, community). Face-to-face communication was preferred by beneficiaries in seven evaluations (Williams et al., 2015; Matemo, 2014; Contzen and Mosler, 2013; Date et al., 2013; Einarsdbttir et al., 2001; Wall and Chéry, 2011; Khan and Syed, 2008). Additionally, material demonstrations (i.e. instruction on HWT), visits by community health workers, and conversations with friends and family were consistently reported positively. Short radio 'spots' or radio communication was the other consistently preferred and trusted source for hygiene messages. However, delivering simple, clear messages was noted as a challenge in four evaluations. Different and conflicting messages undermined the response in the Haiti cholera and Liberia Ebola responses (Wall and Chéry, 2011; Meyer Capps and Njiru, 2015) and it was unclear if hearing a message on the radio translated to action or a realistic understanding of the local situation (Wall and Chéry, 2011). There were also noted difficulties with dialect differences (Einarsdbttir et al., 2001) and errors in printed information (Neseni and Guzha, 2009). Other impacts from hygiene education included a reported decline in morbidity and diarrhoea rates (WHO, n.d.; Williams et al., 2015), increase in HWT use (Date et al., 2013), and changes in behaviour by reducing physical contact (i.e. hugs, shaking hands) during a cholera outbreak (WHO, n.d.).

Handwashing was a primary component of 'key hygiene messages' used in emergency response that was mentioned in 17 evaluations included in the review, with six reporting building handwashing stations (ACF, 2015a; Plan, 2013; Visser, 2012; Varampath, 2008; Singh, 2009; Fortune and Rasal, 2010). While handwashing was widely promoted, it was rarely evaluated and often combined with other activities. Only two documents with low and high risk of bias reported specific outcomes or impacts of handwashing interventions in emergencies.

Social mobilization. Social mobilization describes strategies for engaging communities and responders facilitating communities to address identified risks with local

solutions. Social mobilization approaches define a process, often at a community level, often with outputs determined by the community (Majumdar and Coonrod, 2010). A notable example is community-led total sanitation (CLTS), where communities are engaged through a facilitator with a specific process and encouraged to build their own latrines from locally available materials, ultimately intending to end open defecation at a community level.

Social mobilization strategies were identified in nine evaluations in seven countries; most (7) were high risk of bias and five interventions were aimed specifically at sanitation but described here because of the mobilization approach. Social mobilization was effective at reducing disease risk, output of structures, and building stronger community relationships. A long-running CLTS intervention was found to have a high and significant impact on rates of Ebola as open defecation-free (ODF) communities were 17 times less likely to have cases of Ebola than non-CLTS communities (OR = 0.06, 95 per cent CI 0.01–0.32, $p < 0.001$) (Meyer Capps and Njiru, 2015). Social mobilization was also assessed descriptively to reduce disease transmission in outbreaks (ACF, 2015a; Rees-Gildea, 2013; Neseni and Guzha, 2009). Community-driven sanitation resulted in thousands of latrines and community structures in Uganda, Pakistan, and Zambia – all in less than four-month interventions with low material input from responders (Waterkeyn et al., 2005; Miziniak, 2007; Khan, 2012). Furthermore, ACF piloted a community Ebola management project based on the CLTS approach, which resulted in 80 per cent of villages planning to build community isolation rooms for Ebola patients and handwashing stations (ACF CLEME). Alternatively, after the Haiti earthquake, a pilot CLTS project had limited success carried out in five IDP camps as the disaster-affected population was conditioned for free distributions and there were scarce resources available (Pollo, 2010).

Overall and in the right context, stronger community relationships were described in four of the social mobilization evaluations (trust, group cohesion, and ownership) (Wall and Chéry, 2011; Waterkeyn et al., 2005; ACF, 2015a; Miziniak, 2007). Compared with a purely educational campaign that is 'top-down', designed to deliver or extract information (Contzen and Mosler, 2013), community mobilization (engagement) approaches were conducive to NGOs: listening to communities, dispelling fears and stigmas and learning how to adapt to the context.

Hygiene kit distribution. Hygiene kit distributions (e.g. NFIs) were mentioned in 21 evaluations, commonly distributed and heavily overlapping with HWT interventions. HWT products, soap, and safe water storage containers (e.g. jerrican or buckets with lids) were the most commonly included items. The primary goal of most hygiene kit distributions was to deliver HWT products and/or support hygiene activities addressed in other intervention categories with mixed risk of bias. Valuing items differed by gender, but also with time since the emergency (Mountfield, 2013; Hayden, 2012; ACF, 2015b). Differences in kits caused confusion (e.g. varying Aquatabs doses) (Varampath, 2008; Imanishi et al., 2014). Standard-sized kits may not address the needs of larger families or those with different preferences or needs (Gauthier, 2014; Simpson et al., 2009; Ruiz-Roman, 2009). Vouchers were used

in a specially organized market to offer flexibility and choice to beneficiaries in the DRC (Pennacchia et al., 2011), and cash-based assistance in the Philippines was also preferred. Pre-positioning hygiene kits was noted as a key aspect of the response (Simpson et al., 2009; DeGabriele and Musa, 2009; Neseni and Guzha, 2009; Ruiz-Roman, 2009; Lantagne and Clasen, 2012; Varampath, 2008), while non-functioning markets and procurement delays reduced the overall impact of interventions, especially considering the rapidly changing needs of beneficiaries in acute emergencies (ACF, 2007; Khan and Syed, 2008; Varampath, 2008; Mountfield, 2013; Wango, 2011; Neseni and Guzha, 2009).

Menstrual hygiene management (MHM) interventions and specific hygiene kits for women (aka dignity kits) often include women's underwear and sanitary pads, and are regularly distributed with an increase in gender mainstreaming (Khan and Syed, 2008; ACF, 2014a; Singh, 2009; Baker and Mbogha, 2009). Identifying culturally appropriate items was noted as an issue (Khan and Syed, 2008; ACF, 2014a) and focus groups from three separate needs assessments identified needs for access to water, a private safe space for washing, increased education, appreciation of the influence of local beliefs, and local MHM materials (Parker et al., 2014; Hayden, 2012; Wickramasinghe, 2012).

Environmental hygiene. Environmental hygiene interventions identified in the review were jerrican disinfection, spraying household surfaces with a chlorine solution and disinfection kit distribution. No evaluation on improving local environment conditions was identified in the review – e.g. vector control, site drainage, solid waste management as defined by the *Sphere Handbook* (Sphere Project, 2011) – although several organizations reported activities or results such as 'improved garbage practices' (Dinku, 2011), construction of solid waste areas and drainage improvements (Pennacchia et al., 2011; Plan, 2013), and decongestion and rehabilitation of sewer pipes (Neseni and Guzha, 2009).

Jerrican disinfection. Jerrican disinfection uses a chlorine solution to wash water collection containers and reduce disease transmission risks. Jerrican disinfection was investigated in three high risk of bias evaluations, all in camp settings, and all assessed with no beneficiary input. All three jerrican cleaning methods (three slightly different methods) were assessed to reduce disease risk, but with very weak evaluation methods. Chlorine concentration degradation was noted in all three documents (Steele et al., 2008; Walden et al., 2005; Roberts et al., 2001). One-time disinfection did not have a long-term impact on recontamination.

Household spraying. Household spraying was mentioned as an activity in five documents but not evaluated (Neseni and Guzha, 2009; Gauthier, 2014; Grayel, 2011, 2014; Dunoyer and Sudre, 2012). A known outbreak activity, household or community spraying was noted to have several potential drawbacks: 1) stigmatizing households; 2) logistical, financial, and staffing resources required; 3) false sense of protection to households; and 4) limited impact as 80–85 per cent of people infected with cholera are asymptomatic (Grayel, 2011). The *UNICEF Cholera Toolkit* also recommends that household spraying by responders should *not* be carried

out (UNICEF, 2013); however, it is recommended that families of cholera patients should thoroughly clean the house with soap and chlorine solution. Self-reported use of household disinfection kit contents was high (> 90 per cent) in a high risk of bias evaluation during the Haiti cholera outbreak (Gartley et al., 2013).

WASH package

WASH interventions were regularly implemented in combination by responders to address multiple transmission routes and attempt to provide comprehensive protection to beneficiaries. Overall, 24 WASH package evaluations from 12 countries were identified; all 24 were grey literature documents, most (22/24) were field commentary documents with limited analysis and high bias. The specific intervention activities included in the WASH package mirror the results above, with more water and hygiene interventions completed than sanitation interventions. Each WASH package intervention includes a different combination of interventions based specifically on the needs of the context; please see Appendix A for descriptions of individual interventions. However, the water interventions included in the WASH package were more likely to include well rehabilitation and water trucking (compared with HWT) and were more often described as activities, but not evaluated for outcomes or impacts.

Health impacts were reported through reduced diarrhoea and cholera rates (Pennacchia et al., 2011; Gauthier, 2014; ACF, 2007; Baker and Mbogha, 2009; van der Wijk, 2010). Improved hygiene behaviour was self-reported in Zimbabwe (DeGabriele and Musa, 2009), DRC (Pennacchia et al., 2011) , and Somalia (Dinku, 2011), although respondents in Zimbabwe acknowledged that the behaviours were not consistently practised. Additional impacts included reported reduced time needed to collect water, with undocumented methods (Dinku, 2011; Pennacchia et al., 2011; Plan, 2013; Visser, 2012; Alem, 2004), 'psychosocial support' to cholera-affected communities after a hygiene kit distribution (Neseni and Guzha, 2009), and a change in people's attitude, especially towards open defecation in Sierra Leone (Ngegba, 2002).

The importance of expert staffing was documented in Zimbabwe (Simpson et al., 2009; El-Mahmid and Roussy, 2009), whereas integrating epidemiological experts into response and surge capacity was described as important in the DRC (Grayel, 2014; Gauthier, 2014). Pre-positioned hygiene kits were useful for quick initial distributions (Lantagne and Clasen, 2012; Ruiz-Roman, 2009; Neseni and Guzha, 2009; DeGabriele and Musa, 2009; Simpson et al., 2009), and programmes without pre-positioned stock at times described difficulty in procuring items, leading to delays thereafter (Neseni and Guzha, 2009; Wango, 2011). Similarly, accessible flexible emergency funding facilitated response in South Sudan and Haiti (Gauthier, 2014; Condor and Rana, 2011), while securing adequate funding and knowing when to trigger rapid scale-up are identified as challenges (Simpson et al., 2009). In outbreak response, sanitation and water trucking were rarely carried out, while in general emergency response, both sanitation and water trucking were more prominent. These field commentaries had a high risk of bias but consistent

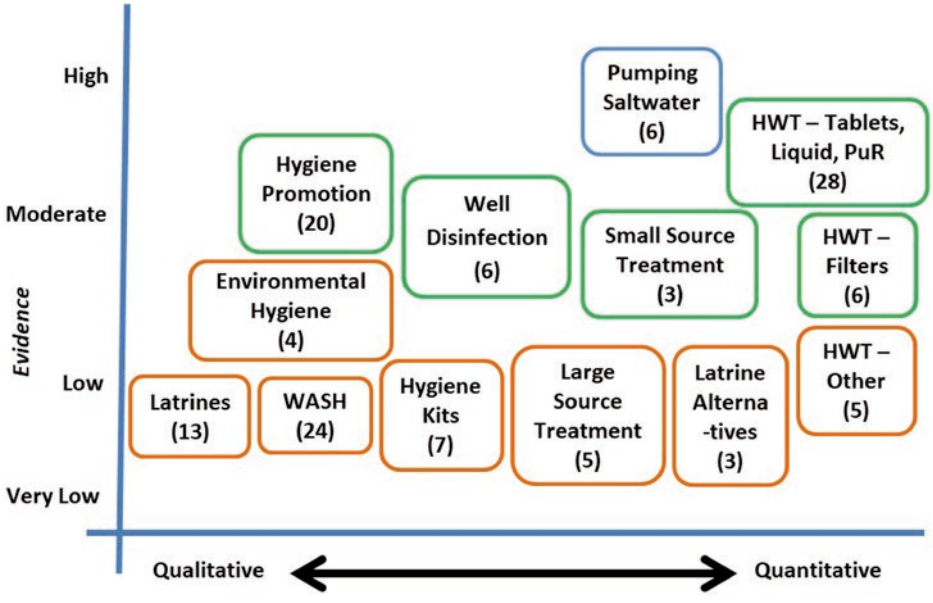

Figure 3 Summary map of evidence

descriptions of anecdotal health impacts and non-health behaviour change impacts. Expert staffing and rapid response timing were consistently identified as critical factors for programme success.

Cost-effectiveness

Cost-effectiveness and economic outcomes were not assessed because outcomes were too heterogeneous for analysis, despite the fact that cost-related outcomes were mentioned in nearly half of evaluations (43 per cent, 46/106).

Summary of evidence

Summaries of findings and assessment of evidence are presented in Table 1 and Table 2. Overall, the quality of evidence is low; this was attributed to weak study designs that lacked control groups and had high likelihood of spillover effects. As can be seen in Figure 3, water interventions, source-based treatment, and HWT had more evaluations, better evidence, and were assessed more quantitatively. Hygiene, sanitation, and WASH package interventions were assessed with lower-quality, more qualitative evaluations. The majority of quantitative evaluations designs were weak cross-sectional designs relative to true experimental designs. The weak evaluations designs were expected from the onset of the protocol development, but still greatly undermine the ability to establish a strong evidence base. While most of the evaluations were poor-quality with high bias, the strength of evidence comes from the consistency and collaboration of reported outcomes.

Table 1 Water intervention summary of evidence

Intervention	*Number of studies*	*Quality of outcomes*			*Summary of findings*	*Overall evidence*
		Health	*Use*	*Non-health*		
Saltwater pumping	6	Not assessed	Not assessed	High	Evidence suggests that well pumping after a saltwater intrusion is NOT efficacious. Waiting for seasonal rains naturally reduced salinity faster compared with pumping.	High
Well disinfection	6	Not assessed	Not assessed	Moderate	Inconsistent evaluation methods, but consistent results. Pot chlorination with pressed chlorine tablets can maintain FCR for 3–4 days in a well; pot chlorination with powdered chlorine also had some success.	Moderate
Large-scale, source-based treatment	4	Not assessed	Moderate	Moderate	BWT – Well-established treatment methods (not evaluated), requires well-trained staff and regular monitoring. Smaller, decentralized BWT offers mobility and flexibility to respond in difficult locations. Water trucking is a common activity in emergencies, but FCR was inconsistent and microbiological contamination was frequent, with limited evaluations.	Low
Small-scale, source-based treatment	3	Not assessed	Moderate	Moderate	Variation in reported, confirmed, and effective use – criteria for favourable contexts outlined through case studies. Speaking with promoter and easy access to dispenser associated with increased use.	Moderate
HWT – chlorine-based products, chlorine tablets	11	Very low	Moderate	Moderate	Low and wide range of reported and confirmed use with an outlier. Taste and smell consistently described as a barrier to use.	Moderate
HWT – chlorine-based products, liquid chlorine	9	Not assessed	Moderate	Moderate	Low and wide range of reported and confirmed use. Links with development and sustainability, including prior exposure and free distribution as factors.	Moderate
HWT – chlorine-based products, flocculant/ disinfectants	7	Low	Moderate	Moderate	Use varied greatly – knowledge of use a factor. Preferred by beneficiaries compared with other chlorine tablets when distributed together. High potential health impact with high use.	Moderate
HWT – filtration	6	Not assessed	Moderate	Moderate	Use varied greatly – acute use was higher than long-term use. Improved taste consistent among populations.	Moderate
HWT – other	5	Low	Very low	Moderate	Limited evaluations for each intervention. Not common in emergency response, ease of use and community acceptance reported. Consistent reduced disease risks.	Low

Table 2 Sanitation, hygiene, and WASH package intervention summary of evidence

Intervention	*Number of studies*	*Quality of outcomes*			*Summary of findings*	*Overall evidence*
		Health	*Use*	*Non-health*		
Latrines	15	Low	Low	Moderate	Reduced diarrhoeal rates with increased coverage and use. Ease of access, cleanliness, and privacy are important non-health considerations. Targeting vulnerable groups increased use.	Low
Latrine alternatives	12	Not assessed	Low	Low	Reported use range: 8–91%; interventions promoting use in the home had higher rates of use.	Low
Hygiene promotion	18	Low	Low	Moderate	Descriptions and documentation of disease or disease risk reductions. Personal communication and radio are preferred and trusted by the community. Community trust and ownership important factors.	Moderate
Hygiene kit distribution	13	Not assessed	Low	Moderate	Reported use of contents was high. Quantity of materials and timeliness of distribution are key factors. Low-quality evaluations, HWT primary component of hygiene kits.	Low
Environmental hygiene	4	Very low	Low	Low	With weak evaluations, jerrican disinfection consistently reported to reduce disease transmission risk and chlorine concentration monitoring is necessary. Household spraying consistently not recommended for responders.	Low
WASH package	24	Low	Not assessed	Low	Weak evaluations had consistent anecdotal descriptions of disease reductions, behaviour adjustments and support; staffing and timing also important factors.	Low

Discussion

To determine the efficacy and effectiveness of WASH interventions in emergencies, we investigated: use of interventions, reductions in the risk of disease; critical programme design and implementation characteristics; non-health related (beneficiary) factors; and cost-effectiveness to emergency WASH response.

Objective 1: Use of interventions in emergency WASH

Emergency WASH interventions were implemented in a variety of contexts and there was no 'silver bullet' intervention that is universally applicable in all circumstances (Clarke and Steele, 2009). Through this review, 13 WASH interventions were identified and 11 could be 'efficacious' – theoretically able to increase access to safe water and sanitation or improving hygiene and thus reduce the risk of disease transmission. The two interventions that are generally not recommended include well pumping to reduce salinity and household spraying. Well pumping to reduce salinity after a coastal flood was the only intervention that had evidence that it was not efficacious and therefore is not recommended. The efficaciousness and effectiveness of household spraying was unclear and requires further investigation. Five interventions had minimal beneficiary involvement but known efficacy, thus intervention design and implementation were primary barriers to impact. Bulk water treatment, well disinfection, and jerrican disinfection could be efficacious but were not evaluated at the beneficiary household level, thus the effectiveness depended on how the intervention was carried out by the responding agency in the particular context. WASH package interventions and hygiene kit distributions were not evaluated for impact, but instead reported on beneficiary coverage or access. For the remaining interventions, small-scale source water treatment, HWT, latrines, latrine alternatives, and hygiene promotion, effectiveness varied and outcomes were conditional based on the emergency context, beneficiary knowledge, or cultural and social preferences.

Disease reduction was not regularly evaluated and remains a gap in the literature; however, the evidence from this review validates the causal chain for emergency WASH interventions. While WASH interventions may not all require the same method or level of evaluation, there are gaps in knowledge along the progression from basic provision of WASH services to beneficiary involvement. Interventions with access to WASH services and measured high use also had large and significant reductions in diarrhoea (Johnston, 2008; Doocy and Burnham, 2006; Meyer Capps and Njiru, 2015; Puddifoot, 1995; Roberts et al., 2001). Breakages along the causal chain are also apparent due to context and social barriers. The barrier between effective outcomes and impact (disease reduction) was primarily attributed to behavioural preferences rather than impact use. Wide variation in use was dependent on familiarity of products, ease of use, personal preferences to taste/smell, and culture. Education and promotion were also key factors that could facilitate or hinder impact of emergency WASH.

Objective 2: WASH interventions that reduce disease risk

WASH interventions have the potential to reduce disease in emergencies. Weak designs and limited number of evaluations explain the low quality of evidence,

but interventions consistently reduced disease risk and risk of disease transmission. Interventions directly measuring a health impact were few and mostly in HWT – chlorine tablet, PuR, SODIS, and safe storage – and assessed as low or very low quality of evidence as there was only one to two evaluations for each intervention type. Additionally, latrine use and a CLTS intervention documented reduced disease risk, but were also low-quality evidence. More common than disease reduction evaluations were interventions that evaluated the risk of transmission through non-health indicators. Interventions documenting FCR in drinking water are known to reduce disease transmission and had moderate quality of evidence including: well disinfection, dispensers, and HWT (liquid chlorine, chlorine tablets, and PuR). Environmental hygiene interventions using chlorine to clean jerricans reduced short-term transmission risk with measurable FCR, yet had low quality of evidence. Overall, WASH interventions consistently reduced both the risk of disease and the risk of transmission in emergency contexts; however, programme design and beneficiary preferences are important considerations to ensure WASH interventions reach their potential.

Objective 3: Impact of non-health related outcomes

In the review, four community perceptions and preferences that consistently affect the success of emergency WASH interventions are identified through a mixture of evaluation methods and risk of bias assessments, including: taste and smell; communication methods; inaccurate perception of efficacy; and trust/fear. Taste and smell of HWT hindered use (e.g. chlorine treatments can have an off-putting smell or taste) or facilitated use (e.g. filters and flocculant disinfectants improved taste). Radio and face-to-face communication were consistently reported as 'most trusted' or 'most valued' for hygiene communication. Community understanding of some interventions overestimates the effectiveness and risk reduction (i.e. saltwater pumping, household spraying, and well disinfection). Correct knowledge of intervention use was also a factor. Social mobilization and open communication between the community and NGOs build trust and greater community cohesion.

Objective 4: Programme design and implementation characteristics associated with more effective programmes

Four programme design and implementation characteristics, identified through a mixture of research designs and across risk of bias assessments, were consistently reported as positive programme characteristics, including: simple interventions that were appropriately timed, community-driven and had linkages between relief and development. Some of the most basic interventions (e.g. safe storage with a jerrican or bucket, simple hygiene messages, or hygiene kit provision) had a clear positive impact. These interventions required little to no promotion and led to incremental improvements that reduced the risk of disease. Prepositioned stock, quick release of funds, and early triggers for rapid scale-up were important facets of a positive response, particularly with hygiene kit and HWT interventions. Engagement in the

community empowers and builds trust and community-driven interventions can increase awareness, trigger behaviour change, and identify local solutions. Linking with pre-existing programming builds upon recipient population familiarity and having a sustainability plan encourages better cultural understanding and improves emergency response programmes.

Objective 5: Cost-effectiveness of emergency WASH interventions

Cost-effectiveness of emergency WASH interventions could not be assessed, as there were only minimal and heterogeneous economic outcomes in the evaluations included in the review.

Relevance

Previous systematic review efforts included only health impact evaluations (Ramesh et al., 2015) or did not incorporate grey literature (Taylor et al. 2015) ; thus, few lessons learned were generated in these reviews. Our inclusion criteria permitted a greater quantity of less technical evaluations than is traditional to systematic reviews, which increased the relevant work to allow identification of consistencies among interventions and synthesis of current information, albeit with some indirect comparisons. Continuing to build and reassess the WASH evidence base is needed to improve decision-making and improve how interventions are carried out.

Gaps

It is clear from the results of the review that some of the most commonly implemented WASH interventions in emergencies are severely under-researched. We need additional research for: repairing damaged waterpoints, water trucking, bucket chlorination, household spraying, handwashing, latrine construction, environmental clean-up, and formal economic analysis. Additionally, there was disparity between what was researched and published in the literature and what was implemented by responders and written up as grey literature: water treatment interventions were most commonly researched and published by academics and WASH package interventions were commonly implemented and reported by responders. While we need more research on specific WASH interventions that are under-researched, it is anticipated that the implementation and non-health factors identified in this review would remain critical, especially for more complex WASH interventions.

To improve the evidence on WASH interventions in emergencies, clear reporting with consistent evaluation methods and common and robust approaches is needed. In lieu of non-experimental evaluations that are difficult to conduct in emergencies, well-designed, non-experimental and qualitative evaluations can be used to increase the evidence base. Evaluations should be conducted at the beneficiary level, to better understand, rather than presume, the outcomes and impacts. Publishing results, while not necessary, does offer transparency and an additional sharing platform for the humanitarian community. The majority of manuscripts included in this review date from the last 10 years. With the increasing ease of sharing information and

demand for more evidence, documenting advances in emergency evidence should occur at regular intervals (e.g. every four to five years).

In conducting the review, it was more difficult than expected to: assess whether the WASH intervention was in the same geographic location as the emergency; compare interventions conducted at different times in the response phases (acute, recovery, development); clearly suggest impact without suitable control groups to compare; and search and extract information from grey literature. There was also a notable lack of evaluations from the more recent emergencies of the West African Ebola outbreak and the Syrian regional response. Despite these limitations, the strength of this review is in its broad inclusion criteria and assessment of intermediary outcomes and final impacts, which led to a comprehensive review of available evidence that is policy-relevant and actionable.

There were several limitations to this research. There is no comprehensive or consolidated website or location with responder evaluations; thus, there was difficulty in securing non-published evaluations, likely influencing the results. Most organizations that submitted documents to the review provided only a select handful of reports, and it is likely that the provided reports were limited to those with favourable outcomes or innovative approaches. The two organizations that provided the most documents, Action Contre la Faim and Oxfam, were also the most included, which likely influenced results. Self-reported data (such as diarrhoeal disease incidence or use of HWT products) was subject to both recall and courtesy bias, which would likely overestimate positive outcomes. FCR, diarrhoea incidence and prevalence, and *Escherichia coli* microbiological results are proxies for the outcomes and impacts of disease. Outcomes were reported inconsistently. For example, confirmed use of a HWT intervention was the clearest outcome measured (using FCR); however, reporting thresholds varied by: 'detectable,' > 0.0 mg/L, > 0.1 mg/L, ≥ 0.2 mg/L and ≥ 0.5mg/L. Furthermore, database searching was completed primarily in English; keywords searched may not have captured all relevant evaluations with variations of intervention names or names in local languages. The diverse outcome reporting and low-quality evaluations also limited intended analysis. For example, the timing and scale of a response were considered vital factors from the onset of the protocol; however, there was a lack of clarity in reporting, which ultimately eliminated the possibility of analysis for timeliness or scale of response. An assessment of project quality would have been desirable, but without timely evaluations, consistent metrics, and independent assessments, there remains a gap between sharing specific WASH intervention success compared with general project management and logistic challenges. And lastly, only WASH interventions implemented in short-term emergency settings were included, likely excluding interventions derived from other sectors, chronic emergencies, or long-term development approaches.

Conclusion

A systematic review process was used to identify more than 15,000 documents; ultimately, 114 evaluations of WASH interventions in emergencies were included in the review. We found that most WASH interventions were efficacious and that they

consistently reduced both the risk of disease and the risk of transmission in emergency contexts; however, programme design and beneficiary preferences were important considerations to ensure that WASH interventions in the specific emergency response context reached their potential efficacy. Some of the most commonly implemented WASH interventions in emergencies were found to be severely under-researched, and further research investigating outcomes and impacts of specific interventions is recommended. Improving the evidence base through quality evaluation methods, consistent reporting metrics, and a greater understanding of beneficiary impact is also needed. It is recommended that responders implement efficacious, simple interventions that are appropriately timed, community-driven, and have linkages between relief and development in collaboration with the recipient communities to address barriers and facilitators to use.

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References

ACF (2007) *UNOCHA Emergency Funding Water and Sanitation Program in Kebri Dehar District, Somali Region*, Action Contre La Faim – France.

ACF (2009) *Household NFI Monitoring Report (PDM) May 2009*, Action Contre La Faim – Zimbabwe.

ACF (2014a) *Feasibility Study and Piloting of a Decentralized Safe Water Access Solution Dedicated to Emergency and Natural Catastrophes through a Pre-Trained Community Based Emergency Response Team (ERT) 'Aquasure'*, Action Contre la Faim.

ACF (2014b) *DRM and WASH Post Distribution Monitoring Report KPK, Pakistan-November 2014*, Action Against Hunger – International.

ACF (2014c) *Hygiene Kits Post Distribution Monitoring Report*, Action Contre La Faim – South Sudan.

ACF (2014d) *Projet Pilote de l'Approche de Marché Pour la Promotion du Chlore Liquide*, Action Contre La Faim.

ACF (2015a) *Community Led Ebola Management and Eradication (CLEME) Trigger Behavioral Change to Strengthen Community's Resilience to Ebola Outbreaks*, Action Contre La Faim.

ACF (2015b) *Non Food Items and Emergency Shelter Post Distribution Monitoring Report, Yobe State, Nigeria*, Action Contre la Faim.

Alem, G. (2004) *Evaluation of Emergency Water Supply and Sanitation*, Oxford, UK: Oxfam GB.

Baird, S., Ferreira, F.H., Ozler, B. and Woolcock, M. (2013) 'Relative effectiveness of conditional and unconditional cash transfers for schooling outcomes in developing countries', *Campbell Systematic Reviews* 9 <http://dx.doi.org/10.4073/csr.2013.8>.

Baker, J. and Mbogha, E. (2009). *Final Evaluation Oxfam's North Kivu Emergency Response*, Oxfam.

Bastable, A. and Lamb, J. (2012) 'Innovative designs and approaches in sanitation when responding to challenging and complex humanitarian contexts in urban areas', *Waterlines* 31: 67–82 <http://dx.doi.org/10.3362/1756-3488.2012.007>.

Bastable, A. and Russell, L. (2013) *Gap Analysis in Emergency Water, Sanitation and Hygiene Promotion*, London: Humanitarian Innovation Fund.

Blanchet, K., Sistenich, V., Ramesh, A., Frison, S., Warren, E., Hossain, M., Knight, A., Lewis, C., Smith, J., Woodward, A., Dahab, M., Pantuliano, S. and Roberts, B. (2013) *An Evidence Review of Research on Health Interventions in Humanitarian Crises*, London: London School of Hygiene and Tropical Medicine.

Branz, A., Levine, M., Lehmann, L., Bastable, A., Ali, S.I., Kadir, K., Yates, T., Bloom, D. and Lantagne, D. (2017) 'Chlorination of drinking water in emergencies: a review of knowledge to develop recommendations for implementation and research needed', *Waterlines* 36: 4–39 <http://dx.doi.org/10.3362/1756-3488.2017.002>.

Brown, J., Cavill, S., Cumming, O. and Jeandron, A. (2012a) 'Water, sanitation, and hygiene in emergencies: summary review and recommendations for further research', *Waterlines* 31: 11–29 <http://dx.doi.org/10.3362/1756-3488.2012.004>.

Brown, J., Jeandron, A., Cavill, S. and Cumming, O. (2012b) *Evidence Review and Research Priorities: Water, Sanitation, and Hygiene for Emergency Response*, London: DFID <https://assets.publishing.service.gov.uk/media/57a08aad40f0b649740006f0/Evidence_review__WASH_for_emergency_response_March_2012.pdf> [22 November 2017].

Cairncross, S., Cumming, O., Jeandron, A., Rheingans, R., Ensink, J., Brown, J., Cavill, S., Baker, S., Schmidt, W.-P., Amery, J., Bibby, S., Harvey, M., Howard, G., Mulligan, J., O'Connor, H., Ryan-Collins, L., Swann, P., Wijesekera, S. and Woolnough, D. (2013) *Water, Sanitation and Hygiene Evidence Paper*, London: Department for International Development.

Cavallaro, E.C., Harris, J.R., Da Goia, M.S., Dos Santos Barrado, J.C., Da Nóbrega, A.A., De Alvarenga Junior, I.C., Silva, A.P., Sobel, J. and Mintz, E. (2011) 'Evaluation of pot-chlorination of wells during a cholera outbreak, Bissau, Guinea-Bissau, 2008', *Journal of Water and Health* 9: 394–402 <http://dx.doi.org/10.2166/wh.2011.122>.

CDC (2012) *Chlorine Residual Testing* [pdf], Atlanta, GA: Centers for Disease Control and Prevention <www.cdc.gov/safewater/publications_pages/chlorineresidual.pdf> [accessed 22 November 2017].

Clarke, B.A. and Steele, A. (2009) 'Water treatment systems for relief agencies: the on-going search for the "Silver Bullet"', *Desalination* 248(1–3): 64–71 <http://dx.doi.org/10.1016/j.desal.2008.05.039>.

Clasen, T. and Boisson, S. (2006) 'Household-based ceramic water filters for the treatment of drinking water in disaster response: an assessment of a pilot programme in the Dominican Republic', *Water Practice & Technology* 1 <http://dx.doi.org/10.2166/wpt.2006.031>.

Colindres, R.E., Jain, S., Bowen, A., Domond, P. and Mintz, E. (2007) After the flood: an evaluation of in-home drinking water treatment with combined flocculent-disinfectant following Tropical Storm Jeanne - Gonaives, Haiti, 2004', *Journal of Water and Health* 5: 367–74 <http://dx.doi.org/ 10.2166/wh.2007.032>.

Coloni, F., Van den Bergh, R., Sittaro, F., Giandonato, S., Loots, G. and Maes, P. (2012) 'Biodegradable bags as emergency sanitation in urban settings: the field experience', *Waterlines* 31: 122–32 <http://dx.doi.org/ 10.3362/1756-3488.2012.010>.

Condor, J. and Rana, R. (2011) *Evaluation of the International Organization for Migration's Ongoing Activities on Support to the Flash Appeal for the Haiti Earthquake and Cholera Outbreak*, IOM International Organization for Migration.

Connolly, M.A., Gayer, M., Ryan, M.J., Salama, P., Spiegel, P. and Heymann, D.L. (2004) 'Communicable diseases in complex emergencies: impact and challenges', *Lancet* 364: 1974–83 <https://doi.org/10.1016/S0140-6736(04)17481-3>.

Conroy, R.M., Meegan, M.E., Joyce, T., McGuigan, K. and Barnes, J. (2001) 'Solar disinfection of drinking water protects against cholera in children under 6 years of age', *Archives of Disease in Childhood* 85: 293–5 <http://dx.doi.org/10.1136/adc.85.4.293>.

Contzen, N. and Mosler, H.-J. (2013) 'Impact of different promotional channels on handwashing behaviour in an emergency context: Haiti post-earthquake public health promotions and cholera response', *Journal of Public Health* 21: 559–73 <https://doi.org/10.1007/s10389-013-0577-4>.

Cressey, S. (2015) *Post-Distribution Assessment Report for Point of Use Water Filter Distribution in Palei*, Ecublens, Switzerland: Medair.

Darcy, J., Stobaugh, H., Walker, P. and Maxwell, D. (2013) *The Use of Evidence in Humanitarian Decision Making ACAPS Operational Learning Paper*, Medford, MA: Feinstein International Centre.

Date, K., Person, B., Nygren, B., Were, V., Kola, S., Ayers, T. and Quick, R. (2013) 'Evaluation of a rapid cholera response activity-Nyanza Province, Kenya, 2008', *Journal of Infectious Diseases* 208: S62–8 <https://doi.org/10.1093/infdis/jit198>.

De Lange, R., Lenglet, A., Francois Fesselet, J., Gartley, M., Altyev, A., Fisher, J. and Shanks, L. (2014) 'Keeping it simple: a gender-specific sanitation tool for emergencies', *Waterlines* 33: 45–54 <http://dx.doi.org/ 10.3362/1756-3488.2014.006>.

DeGabriele, J. and Musa, A. (2009) *An Emergency Response to Humanitarian WASH-related Emergencies in Zimbabwe*, Action Contre la Faim & Welthungerhilfe Zimbabwe.

Dinku, S. (2011) *Emergency Water, Sanitation, and Hygiene Interventions for AWD and Drought Affected Pastorial Communities in Borana Zone, Ethiopia*, Action Contre La Faim – International (ACF – IN).

Doocy, S. and Burnham, G. (2006) 'Point-of-use water treatment and diarrhoea reduction in the emergency context: an effectiveness trial in Liberia', *Tropical Medicine & International Health* 11: 1542–52 <http://dx.doi.org/ 10.1111/j.1365-3156.2006.01704.x>.

Dorea, C.C., Luff, R., Bastable, A. and Clarke, B.A. (2009) 'Up-flow clarifier for emergency water treatment', *Water and Environment Journal* 23: 293–9 <http://dx.doi.org/10.1111/j.1747-6593.2008.00142.x>.

Dunoyer, J. and Sudre, B. (2012) *Le choléra au Tchad en 2011 et les stratégies d'intervention associées*, Action Contre la Faim – France.

Dunston, C., McAfee, D., Kaiser, R., Rakotoarison, D., Rambeloson, L., Hoang, A.T. and Quick, R.E. (2001) 'Collaboration, cholera, and cyclones: a project to improve point-of-use water quality in Madagascar', *American Journal of Public Health* 91: 1574–6 <http://dx.doi.org/10.2105/AJPH.91.10.1574>.

Einarsdbttir, J., Passa, A. and Gunnlaugsson, G. (2001) 'Health education and cholera in rural Guinea-Bissau', *International Journal of Infectious Diseases* 5: 133–8 <https://dx.doi.org/10.1016/S1201-9712(01)90087-6>.

El-Mahmid, I. and Roussy, S. (2009) *Zimbabwe Emergency Response*, Action Contre la Faim.

EM-DAT (2014) *EM-DAT The International Disaster Database* [online] <http://www.emdat.be/> [accessed 10 November 2017].

Ensink, J.H.J., Bastable, A. and Cairncross, S. (2015) 'Assessment of a membrane drinking water filter in an emergency setting', *Journal of Water and Health* 13: 362–70 <http://dx.doi.org/10.2166/wh.2014.025>.

Eyrard, J. (2011) 'Sanitation in emergencies: lessons learned from Port-au-Prince: the portable toilets', paper presented at the *35th Water, Engineering and Development Centre (WEDC) Conference, Loughborough University of Technology*.

Fesselet, J.-F. and Mulders, R. (2006) 'Saline wells in Aceh', *Waterlines* 24: 5–8 <http://dx.doi.org/10.3362/0262-8104.2006.003>.

Fortune, V. and Rasal, P. (2010) *British Red Cross – Mass Sanitation Module 2010 Haiti Earthquake Response Post Deployment Learning Evaluation*, British Red Cross.

Garandeau, R., Trevett, A. and Bastable, A. (2006) 'Chlorination of hand-dug wells in Monrovia', *Waterlines* 24: 19–21 <http://dx.doi.org/10.3362/0262-8104.2006.008>.

Gartley, M., Valeh, P., de Lange, R., Dicarlo, S., Viscusi, A., Lenglet, A. and Fesselet, J.F. (2013) 'Uptake of household disinfection kits as an additional measure in response to a cholera outbreak in urban areas of Haiti', *Journal of Water and Health* 11: 623–8 <http://dx.doi.org/10.2166/wh.2013.050>.

Gauthier, J. (2014) *A Real-time Evaluation of ACF's Response to Cholera Emergency in Juba, South Sudan*, Action Contre la Faim – International.

Grayel, Y. (2011) *Evaluation Externe Réponse d'Urgence à l'Epidémie de Choléra en Haïti*, Action Contre la Faim – International.

Grayel, Y. (2014) *Programme d'Intervention pour Limiter et Prévenir la Propagation de l'Epidémie du Choléra*, Action Contre la Faim – International.

Guevart, E., Van Hecke, C., Noeske, J., Solle, J., Bita Fouda, A. and Manga, B. (2008) 'Handmade devices for continuous delivery of hypochlorite for well disinfection during the cholera outbreak in Douala, Cameroon (2004)', *Médecine tropicale: revue du Corps de santé colonial* 68: 507–13.

Gupta, S.K. and Quick, R. (2006) 'Inadequate drinking water quality from tanker trucks following a tsunami disaster, Aceh, Indonesia, June 2005', *Disaster Prevention and Management: An International Journal* 15 <https://doi.org/10.1108/dpm.2006.07315aaa.001>.

Handzel, T. and Bamrah, S. (2006) *Trip Report Evaluation of Pilot Intervention to Improve Household Drinking Water Dong Thap Province, Vietnam*, Atlanta, GA: UNICEF, Institute of Hygiene and Public Health, U.S. Centers for Disease Control and Prevention.

Hawkins, V. and Pérache, A. (2017) 'Humanitarian medicine is more than a technical exercise', *Lancet (London, England)* 2226–8 <http://dx.doi.org/10.1016/S0140-6736(17)31352-1>.

Hayden, T. (2012) *Menstrual Hygiene Management in Emergencies: Taking Stock of Support from UNICEF and Partners*, UNICEF and RedR Australia.

Higgins, J.P. and Green, S. (2008) *Cochrane Handbook for Systematic Reviews of Interventions*, Wiley Online Library.

Higgins, J.P. and Green, S. (2011) *Cochrane Handbook for Systematic Reviews of Interventions*, Version 5.1.0, updated March 2011, London: The Cochrane Collaboration.

Hoque, B.A. and Khanam, S. (2007) *Efficiency and Effectiveness of Point-of Use Technologies in Emergency Drinking Water: An Evaluation of PUR and Aquatab in Rural Bangladesh*, Dhaka, Bangladesh: Environment and Population Research Center.

IISS (2015) *Armed Conflict Survey 2015*, London.

Imanishi, M., Kweza, P.F., Slayton, R.B., Urayai, T., Ziro, O., Mushayi, W., Francis-Chizororo, M., Kuonza, L.R., Ayers, T., Freeman, M.M., Govore, E., Duri, C., Chonzi, P., Mtapuri-Zinyowera, S., Manangazira, P., Kilmarx, P.H., Mintz, E., Lantagne, D. and Zimbabwe Typhoid Fever, O. (2014) 'Household water treatment uptake during a public health response to a large typhoid fever outbreak in Harare, Zimbabwe', *American Journal of Tropical Medicine and Hygiene* 90: 945–54 <https://doi.org/10.4269/ajtmh.13-0497>.

Institute for Economics and Peace (2014) *Global Terrorism Index 2014* [pdf] <http://economicsandpeace.org/wp-content/uploads/2015/06/Global-Terrorism-Index-Report-2014.pdf> [accessed 10 November 2017].

Johnston, R. (2008) *Point-Of-Use Water Treatment in Emergency Response: Experiences in Cyclone Sidr*, New York: UNICEF.

Joint Monitoring Programme (JMP) (2014) *Progress on Drinking Water and Sanitation 2014 Update*, Geneva, Switzerland.

Kayabu, B. and Clarke, M. (2013) 'The use of systematic reviews and other research evidence in disasters and related areas: preliminary report of a needs assessment survey', *PLoS Currents* 5 <http://dx.doi.org/10.1371/currents.dis.ed42382881b3bf79478ad503be4693ea>.

Khan, F. and Syed, R. (2008) *Assessment of Hygiene Communication Plan in the Aftermath of the 2005 Earthquake in Pakistan*, IRC.

Khan, R. (2012) *CLTS in 2010 Post-flood Emergency Response Effort, Pakistan*, World Vision Pakistan.

Kinstedt, K. (2012) *The Application of Ecological Sanitation for Excreta Disposal in Disaster Relief*, Hamberg, Germany: Institute of Wastewater Management and Water Protection.

Lantagne, D.S. and Clasen, T.F. (2012) 'Use of household water treatment and safe storage methods in acute emergency response: case study results from Nepal, Indonesia, Kenya, and Haiti', *Environmental Science & Technology* 46: 11352–60 <http://dx.doi.org/10.1021/es301842u>.

Lantagne, D. and Clasen, T. (2013) 'Effective use of household water treatment and safe storage in response to the 2010 Haiti earthquake', *American Journal of Tropical Medicine and Hygiene* 89: 426–33 <https://doi.org/10.4269/ajtmh.13-0179>.

Libessart, Y. and Hammache, Y. (2000) 'Integrated chlorination campaign in Mogadishu', paper presented at *26th WEDC Conference, Water, Sanitation and Hygiene: Challenges of the Millennium, Dhaka, Bangladesh* [pdf] <https://www.unicef.org/cholera/Annexes/Supporting_Resources/Annex_9/Libessart_WEDC_paper-pot_chlorinators.pdf> [accessed 21 November 2017].

Lin, L.-F., Zhang, Y.-R. and Yan, Z.-Q. (2008) 'Rapid evaluation on the risk of vector and emergency vector control after the earthquake', *South China Journal of Preventive Medicine* 4: 3–3.

Lipscombe, S. (2007) 'Groundwater salinity and hand dug wells in Ampara, Sri Lanka', *Waterlines* 26: 12–13 <http://dx.doi.org/10.3362/0262-8104.2007.034>.

Loo, S.-L., Fane, A.G., Krantz, W.B. and Lim, T.-T. (2012) 'Emergency water supply: a review of potential technologies and selection criteria', *Water Research* 46: 3125–51 <https://doi.org/10.1016/j.watres.2012.03.030>.

Luby, S., Islam, M.S. and Johnston, R. (2006) 'Chlorine spot treatment of flooded tube wells, an efficacy trial', *Journal of Applied Microbiology* 100: 1154–58 <http://dx.doi.org/10.1111/j.1365-2672.2006.02940.x>.

Lytton, L. (2008) 'Deep impact: why post-tsunami wells need a measured approach', *Proceedings of the Institution of Civil Engineers: Civil Engineering* 161(1): 42–8.

Majumdar, B.A. and Coonrod, J. (2010) 'Social mobilization: an innovative approach to meeting water-sanitation related MDG targets in the larger context of eradicating poverty', paper presented at the *Sustainable Development Conference (SDC), Islamabad, Pakistan*.

Matemo, C. (2014) *Use of H2S Tests to Monitor Water Quality in Insecure Environment*, Action Contre la Faim – Kenya.

Meyer Capps, J. and Njiru, H. (2015) *Open Defecation Status, Community-Led Total Sanitation and Ebola Virus Disease (EVD) in Voinjama and Kolahun Health Districts, Lofa County, Liberia (2014)*, Silver Spring, MD: Global Communities.

Miziniak, J. (2007) *Sustainable Relief Programming for dispersed communities Case Study: Zambia Floods 2007*, Oxfam.

Mong, Y., Kaiser, R., Ibrahim, D., Rasoatiana, Razafimbololona, L. and Quick, R.E. (2001) 'Impact of the safe water system on water quality in cyclone-affected communities in Madagascar', *American Journal of Public Health* 91: 1577–9 <http://dx.doi.org/10.2105/AJPH.91.10.1577>.

Mountfield, B. (2013) *SMS Survey Hygiene Parcels, La Piste Port-Au-Prince (Haiti)*, IFRC.

Moyenga, D. and Rudge, L. (2011) *Sanitation Solutions for a Refugee Camp: Field Trial of Sanitation for the Vulnerable*, 2ie and ACF.

Mwase, H. (2006) *The Potential of Ecosan to Provide Sustainable Sanitation in Emergency Situations and to achieve 'quick wins' in MDGs*, Doctoral dissertation, Unesco-IHE Institute for Water Education, Delft, Netherlands.

Neseni, N. and Guzha, E. (2009) *Evaluation of the WASH Response to the 2008–2009 Zimbabwe Cholera Epidemic and Preparedness Planning for Future Outbreaks*, Harare: Zimbabwe WASH Cluster.

Ngegba, S. (2002) *Water and Sanitation Programme*, Tearfund UK.

Oxman, A.D. and GRADE Working Group (2004) 'Grading quality of evidence and strength of recommendations', *BMJ* 328: 1490–4.

Palmer, J. (2005) 'Community acceptability of household water filters in Sri Lanka after the tsunami', unpublished.

Parker, A.H., Smith, J.A., Verdemato, T., Cooke, J., Webster, J. and Carter, R.C. (2014) 'Menstrual management: a neglected aspect of hygiene interventions', *Disaster Prevention and Management* 23: 437–54 <https://doi.org/10.1108/DPM-04-2013-0070>.

Parkinson, J. (2009) *A Review of the Evidence Base for WASH interventions in Emergency Responses*, Atkins.

Parsa, N., Berndtsson, M. and Nee, M. (2014) 'Human waste management in first phase response, protecting groundwater and human health: case study from Haiyan 2013', paper presented at the *37th WEDC International Conference, Hanoi, Vietnam* [pdf] <https://wedc-knowledge.lboro.ac.uk/resources/conference/37/Parsa-1997.pdf> [accessed 23 November 2017].

Patel, D., Brooks, N. and Bastable, A. (2011) 'Excreta disposal in emergencies: Bag and Peepoo trials with internally displaced people in Port-au-Prince', *Waterlines* 30: 61–77 <http://dx.doi.org/10.3362/1756-3488.2011.006>.

Pennacchia, V., Poidatz, J. and Hearne, N. (2011) *Bridging the Gap: Providing Water and Sanitation and Non-Food Item Assistance to Returnees, IDPs and Host Communities in North Kivu*, Catholic Relief Services (CRS).

Pinera, J.F., Reed, R.A. and Njiru, C. (2005) 'Restoring sanitation services after an earthquake: field experience in Bam, Iran', *Disasters* 29: 222–36 <http://dx.doi.org/10.1111/j.0361-3666.2005.00288.x>.

Plan (2013) *Emergency Assistance to Typhoon Usagi-Affected Populations in Central Luzon*, Plan.

Pollo, F. (2010) *CLTS Pilot in Haiti*, Oxfam America, Oxfam Spain, Oxfam Quebec and ACF (Action contre la Faim/Action against Hunger) France.

Puddifoot, J. (1995) 'Pit latrines in Nepal: the refugee dimension', *Waterlines* 14: 30–2 <https://doi.org/10.3362/0262-8104.1995.042>.

Ramesh, A., Blanchet, K., Ensink, J.H.J. and Roberts, B. (2015) 'Evidence on the effectiveness of water, sanitation, and hygiene (WASH) interventions on health outcomes in humanitarian crises: a systematic review', *PLoS ONE* 10: 1–20 <https://dx.doi.org/10.1371/journal.pone.0124688>.

Rees-Gildea, P. (2013) *Sierra Leone Cholera ERU Operation Review*, International Federation of Red Cross and Red Cresent Societies (IFRC).

Roberts, L., Chartier, Y., Chartier, O., Malenga, G., Toole, M. and Rodka, H. (2001) 'Keeping clean water clean in a Malawi refugee camp: a randomized intervention trial', *Bulletin of the World Health Organization* 79: 280–7.

Rowe, A.K., Angulo, F.J., Roberts, L. and Tauxe, R. (1998) 'Chlorinating well water with liquid bleach was not an effective water disinfection strategy in Guinea-Bissau', *International Journal of Environmental Health Research* 8: 339–40 <https://dx.doi.org/10.1080/09603129873444>.

Ruiz-Roman, E. (2009) *Evaluation of the Blanket Distribution of Nonfood Items as Part of the Cholera Response in Zimbabwe*, Unicef Zimbabwe.

Saltori, R. and Giusti, A. (2006) 'Challenges of tsunami and conflict affected rural water supply in Sri Lanka', paper presented at the *32nd WEDC International Conference, Colombo, Sri Lanka* [pdf] <https://wedc-knowledge.lboro.ac.uk/resources/conference/32/Saltori.pdf> [accessed 23 November 2017].

Samarasekera, U. and Horton, R. (2017) 'Improving evidence for health in humanitarian crises', *The Lancet* 390: 2223–4 <http://dx.doi.org/10.1016/S0140-6736(17)31353-3>.

Simpson, R., Bazezew Legesse, N. and Mubayiwa, R. (2009) *Real Time Evaluation of the Cholera Response in Zimbabwe*, Oxfam International.

Singh, P. (2012) 'Note from the field: the Pakistan floods: success of the household trench latrine', *Waterlines* 31: 133–5 <http://dx.doi.org/10.3362/1756-3488.2012.011>.

Singh, C.B. (2009) Evaluation report 'Sustaining the lives and dignity of IDPs in Purnea district – Bihar', unpublished.

Smith, K.F., Goldberg, M., Rosenthal, S., Carlson, L., Chen, J., Chen, C. and Ramachandran, S. (2014) 'Global rise in human infectious disease outbreaks', *Journal of The Royal Society Interface* 11: 20140950 <http://dx.doi.org/10.1098/rsif.2014.0950>.

Spencer, L., Ritchie, J., Lewis, J. and Dillon, L. (2003) *Quality in Qualitative Evaluation: A Framework for Assessing Research Evidence*, London: Government Chief Social Researcher's Office.

Sphere Project (2011) *Sphere Handbook: Humanitarian Charter and Minimum Standards in Disaster Response*, Geneva, Switzerland: Sphere Project.

Spiegel, P.B., Le, P., Ververs, M.-T. and Salama, P. (2007) 'Occurrence and overlap of natural disasters, complex emergencies and epidemics during the past decade (1995–2004)', *Conflict and Health* 1: 1 <http://dx.doi.org/10.1186/1752-1505-1-2>.

Steele, A. and Clarke, B. (2008) 'Problems of treatment process selection for relief agency water supplies in an emergency', *Journal of Water and Health* 6: 483–9 <http://dx.doi.org/10.2166/wh.2008.059>.

Steele, A., Clarke, B. and Watkins, O. (2008) 'Impact of jerry can disinfection in a camp environment: experiences in an IDP camp in Northern Uganda', *Journal of Water and Health* 6: 559–64 <http://dx.doi.org/10.2166/wh.2008.072>.

Taylor, D.L., Kahawita, T.M., Cairncross, S. and Ensink, J.H.J. (2015) 'The impact of water, sanitation and hygiene interventions to control cholera: a systematic review', *PLoS ONE* 10: 1–19 <https://dx.doi.org/10.1371/journal.pone.0135676>.

Tokplo, H. (2015) *Project de Reprise Communautaire de la Lutte Contre le Choléra et les Maladies Hydriques dans les Zones de Santé de Minova (Sud Kivu) et de Kirotshe (Nord Kivu), R.D. Congo*, Action Contre la Faim – R.D. Congo.

Toole, M.J. (1995) 'Mass population displacement: a global public health challenge', *Infectious Disease Clinics of North America* 9: 353–66.

Toole, M.J. (1996) 'Vulnerability in emergency situations', *Lancet* 348: 840.

UNHCR (2015) *World at War: UNHCR Global Trends 2014 Forced Displacement*, Geneva, Switzerland: UNHCR.

UNICEF (2013) *Cholera Toolkit 2013*, New York: UNICEF.

UNISDR (2007) 'Terminology on DRR' [online], UNISDR <https://www.unisdr.org/we/inform/terminology> [accessed 29 July 2016].

Van der Wijk, J. (2010) *Evaluation of the DEC-funded CAFOD Health and WASH Project in the DRC*, Caritas.

Varampath, A. (2008) *South Asia floods; WASH interventions/capacity review: focusing on key WASH interventions and capacity of agencies to deliver these*, RedR.

Villholth, K.G. (2007) 'Tsunami impacts on groundwater and water supply in eastern Sri Lanka', *Waterlines* 26: 8–11 <http://dx.doi.org/10.3362/0262-8104.2007.033>.

Visser, M. (2012) *WaSH Provision in Bahn Refugee Camp in Nimba, Liberia*, ACF.

Vithanage, M., Villholth, K.G., Mahatantila, K., Engesgaard, P. and Jensen, K.H. (2009) 'Effect of well cleaning and pumping on groundwater quality of a tsunami-affected coastal aquifer in eastern Sri Lanka', *Water Resources Research* 45 <http://dx.doi.org/10.1029/2008WR007509>.

Vujcic, J., Ram, P.K. and Blum, L.S. (2015) 'Handwashing promotion in humanitarian emergencies: strategies and challenges according to experts', *Journal of Water Sanitation and Hygiene for Development* 5(4): 574–85 <http://dx.doi.org/10.2166/washdev.2015.009>.

Walden, V.M., Lamond, E.A. and Field, S.A. (2005) 'Container contamination as a possible source of a diarrhoea outbreak in Abou Shouk camp, Darfur province, Sudan', *Disasters* 29: 213–21 <http://dx.doi.org/10.1111/j.0361-3666.2005.00287.x>.

Waldman, R.J. and Toole, M.J. (2017) 'Where is the science in humanitarian health?' *The Lancet* 390: 2224–6 <https://doi.org/10.1016/S0140-6736(17)31275-8>.

Walker, P., Glasser, J. and Kambli, S. (2012) *Climate Change as a Driver of Humanitarian Crises and Response*, Feinstein International Center.

Wall, I. and Chéry, Y.G. (2012) *Ann Kite Yo Pale or Let Them Speak: Best Practice and Lessons Learned in Communication with Disaster Affected Communities, Haiti 2010* [pdf], BBC World Service Trust, UKaid, InternewsEurope <www.cdacnetwork.org/tools-and-resources/i/20140610200806-rzzty%20> [accessed 21 November 2017].

Wango, K. (2011) 'SRCS/IFRC Response to the 2010/11 Somalia Drought SRCS and IFRC', unpublished report.

Waterkeyn, J., Okot, P. and Kwame, V. (2005) 'Rapid sanitation uptake in the internally displaced people camps of northern Uganda through community health clubs', paper presented at the *31st WEDC International Conference: The Benefits from Water and Environmental Sanitation, Kampala, Uganda* [pdf] <https://wedc-knowledge.lboro.ac.uk/resources/conference/31/WaterkeynJ.pdf> [accessed 22 November 2017].

Watson, J.T., Gayer, M. and Connolly, M.A. (2007) 'Epidemics after natural disasters', *Emerging Infectious Diseases* 13: 1–5 <https://dx.doi.org/10.3201/eid1301.060779>.

WHO (2016) 'Disease outbreaks' [online], WHO <www.who.int/topics/disease_outbreaks/en/> [accessed 14 July 2016].

WHO (no date) Guidance on communication with respect to safe drinking water and household hygiene: Literature review, interviews and case studies, Geneva: WHO.

Wickramasinghe, D. (2012) 'Managing menstrual hygiene in emergency situations: how far from reality?' *Bangladesh Development Journal* 9: 31–56.

Williams, H.A., Gaines, J., Patrick, M., Berendes, D., Fitter, D. and Handzel, T. (2015) 'Perceptions of health communication, water treatment and sanitation in artibonite department, Haiti, March-April 2012', *PLoS ONE* 10: 1–17 <https://dx.doi.org/10.1371/journal.pone.0142778>.

Yates, T., Vujcic, J., Leandre Joseph, M. and Lantagne, D. (2015a) *Short-term Hygiene Interventions in Emergency Response Situations: A Systematic Review and Impact Analysis Protocol*, International Initiative for Impact Evaluation.

Yates, T.M., Armitage, E., Lehmann, L.V., Branz, A.J. and Lantagne, D.S. (2015b) 'Effectiveness of chlorine dispensers in emergencies: case study results from Haiti, Sierra Leone, Democratic Republic of Congo, and Senegal', *Environmental Science & Technology* 49: 5115–22 <http://dx.doi.org/10.1021/acs.est.5b00309>.

Yates, T.M., Allen, J., Landre Joseph, M. and Lantagne, D. (2017) 'Short-term WASH interventions in emergency response: a systematic review', in Masset, E. and Leach, B. (eds.) *Systematic Review 33*, London: International Initative for Impact Evaluation (3ie).