Diarrhoeal disease outbreaks associated with sanitation provision failures in refugee camps worldwide: a literature review

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ABSTRACT

**Objectives:** The objective of this review is to identify sanitation failures that have contributed to the occurrence of diarrhoeal disease outbreaks among displaced populations living in camps.

**Methods:** Three electronic databases (Medline, Embase, Global Health) and reference lists were searched for peer-reviewed literature using a systematic approach. Articles published since 1960 describing both diarrhoeal disease outbreaks and sanitation characteristics in camps hosting displaced populations were included. Evidence linking outbreaks to sanitation-related factors was synthesised and critically appraised.

**Results:** The search yielded 608 articles, of which 12 met inclusion criteria. They described cholera and shigellosis outbreaks occurring in 21 different camps between 1974 and 2009. Recurring contributing factors across outbreaks included a sudden population influx, inadequate provision or maintenance of latrines, sudden rains and insufficient safe water quantities. Most studies were descriptive only or did not consider sanitation-related exposures in risk factor analyses. However, two case-control studies found that cases were significantly more likely than controls to share latrines with several households. Two other case-control studies identified an increased risk of infection from exposure to drinking contaminated river or shallow well water.

**Conclusions:** Evidence from previous outbreak investigations illustrates how sanitation failures, particularly following population influxes, can contribute to the occurrence of diarrhoeal disease outbreaks in refugee camps. Further development and application of sanitation assessment tools and metrics would enable more robust evaluation of risks associated with specific sanitation-related exposures and the effectiveness of interventions. Recent guidelines address the identified risk factors but stakeholders should be aware of the impact of population dynamics.
Keywords: Sanitation, water contamination, displaced populations, refugee camp, diarrhoeal disease outbreak, epidemic.
INTRODUCTION

The United Nations High Commission on Refugees (UNHCR) estimates that the number of people displaced by war, famine, civil strife or natural disaster reached 68.5 million at the end of 2017, 85% of whom are hosted in developing countries (UNHCR, 2018). About 40% of them live in camps, the majority of which are in Low and Middle Income Countries (LMICs), where resources and infrastructure are in short supply (UNHCR, 2018). Assistance from international agencies and non-governmental organisations (NGOs) helps provide basic services but funding is seldom sufficient to ensure that all needs are met (United Nations High Level Panel on Humanitarian Financing, 2016).

One of the most challenging, yet crucial, aspects of camp management is sanitation, which includes five stages: containment, collection, transport, treatment and final disposal or reuse (Bill & Melinda Gates Foundation, 2010; USAID, 2016). A failure at any stage of the chain can contaminate soil and water, thus establishing a reservoir for a pathogen to spread not only within a camp, but also beyond its boundaries. In 1997, the Red Cross and Red Crescent Societies, in partnership with other NGOs, initiated the Sphere project in order “to develop a set of universal minimum standards in core areas of humanitarian response” (The Sphere Project, 2011), including Water, Sanitation and Hygiene (WASH) services. The Sphere Handbook, first published in 2000, specifies the number of people per latrine that should not be exceeded (20) and the minimum per person safe water quantity (15 litres/day) that should be available, among other criteria for outbreak prevention (Campbell and Howard, 2012).

Yet, in October 2010, a cholera outbreak hit Haiti seven months after an earthquake displaced 1.5 million people (Schuller and Levey, 2014). It was later discovered that the pathogen had been imported from an endemic country and introduced by a pipe discharging human waste from a United Nations Stabilisation Mission in Haiti (MINUSTAH) camp into the Artibonite River (Piarroux et al., 2011), causing 480,000 cases and 7,000 deaths within a year (Piarroux and Faucher, 2012). The Haiti outbreak is an example of a sanitation failure leading to the spread of a pathogen into a susceptible population as a consequence of inadequate management of human excreta disposal by an organisation that had the means, awareness and responsibility to uphold standards and guidelines.
Data from the UNHCR Health Information System have been analysed in studies examining water and sanitation provision and the associated diarrhoeal disease burden (Cronin et al., 2008, 2009; Hershey et al., 2011). Cronin et al. (2009) collected data from 130 camps and found that more than a quarter of them failed to meet sanitation standards in 2005. In another study by Cronin and colleagues (2008), covering 39 camps, 132,000 cases of diarrhoea were estimated to be “attributable to incomplete water and sanitation provision” out of an aggregated camp population of 1 million. From 2006 to 2010, diarrhoeal diseases were estimated to be associated with 7% of deaths and 10% of overall morbidity in children under five years of age living in 90 camps distributed across 16 countries (Hershey et al., 2011).

Several recent reviews examining the impact of WASH interventions on reducing the incidence of diarrhoeal diseases in low resource settings have highlighted a lack of published evidence regarding the effectiveness of sanitation-specific interventions (Brown et al., 2012; Ramesh et al., 2015; Blanchet et al., 2017). Their focus on interventions implies that outbreak investigations that searched for the cause of the outbreaks might not have been included. Examining the sanitation-related risk factors that contributed to past outbreaks could help the framing and evaluation of interventions and might guide future research. The aim of this review is to synthesize the findings of peer-reviewed articles that have documented both outbreak investigations and sanitation characteristics in camps hosting displaced populations over the last 60 years.

**METHODS**

**Search strategy and inclusion criteria**

A search for literature published in English and in French from 1960 to April 2018 was undertaken, using a systematic approach, in the Medline, Embase and Global Health databases on 25 April 2018. Each database was searched using the subject headings and keywords associated with the key concepts ‘sanitation’, ‘diarrhoea’ and ‘refugee camp’. The Boolean operators OR and AND were used to link each subject heading with the associated
keywords and to combine the three key concepts/keywords, respectively. Appendix A describes the full search strategy and search strings.

Articles were initially screened by title and abstract. Eligibility was determined in a stepwise approach based on whether articles met all of the following criteria: 1) a diarrhoeal disease outbreak was investigated; 2) the outbreak occurred in a camp hosting a displaced population; and 3) sanitation characteristics were described. Where abstracts did not provide sufficient information, full texts were retrieved and the same stepwise approach was used to determine final inclusion. In addition, reference lists of relevant articles were screened to identify further eligible papers based on the same criteria.

Data extraction and analysis

Data extraction, analysis and synthesis were conducted following the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) statement (Moher et al., 2009). For each included article, data was extracted on: study design; outbreak characteristics; person, place and time parameters; sanitation provision characteristics; measures of effect; and potential sources of bias. Information on contributing factors such as water source, quantity and quality, weather events, cultural factors and any other relevant information were also extracted. A summary table was developed to synthesize outbreak, camp and WASH characteristics, as well as any contextual factors that may have contributed to the outbreak’s occurrence.

A critical appraisal of the evidence was conducted for each study using a common checklist adapted from the Critical Appraisal Skills Programme guidelines (CASP, 2017), from the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (von Elm et al., 2007) and from Reingold’s guidelines for outbreak investigations (Reingold, 1998) (see Appendix B: critical appraisal checklist).

In addition to the overall critical appraisal based on the checklist, the strength of the evidence linking sanitation failure and outbreak occurrence in each study was classified as possible, probable or strong based on the inclusion of a sanitation parameter in statistical analyses and/or the description of the mechanism for pathogen transmission in the epidemiological investigation (see Table 1). Sanitation variables were considered both within
a camp and at the individual or household level to determine: a) whether identified cases were significantly more likely to have been exposed to sanitation-related risk factors; b) whether attack rates differed between populations with contrasting sanitation characteristics; and, c) whether the outbreak began within one incubation period from the time of the suspected sanitation failure.

### Table 1: criteria for classifying the strength of the evidence linking sanitation failures and outbreak occurrence

<table>
<thead>
<tr>
<th>Possible</th>
<th>Circumstantial evidence linking sanitation failure to outbreak occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probable</td>
<td>Statistically significant association between exposure to a sanitation variable and being a case found in univariate analysis. Or descriptive epidemiological investigation suggests likely mechanism for sanitation failure leading to drinking water contamination</td>
</tr>
<tr>
<td>Strong</td>
<td>Statistically significant association between exposure to sanitation variable (e.g. person/latrine ratio, access to clean latrine, shared latrine as dichotomous variable) and being a case found in multivariate analysis after adjusting for other explanatory factors. Or descriptive epidemiological investigation provides detailed description of person, place and time parameters linking sanitation provision failure to the outbreak.</td>
</tr>
</tbody>
</table>

### RESULTS

#### Study characteristics

A total of 608 articles were identified through the systematic database search and screened by title/abstract: 561 were not eligible and 47 were examined further, of which 10 met inclusion criteria. The reference list search yielded an additional two studies, resulting in the inclusion of twelve articles in the review (see Figure 1). The articles reported on 21 outbreaks that occurred between 1974 and 2009 (see Table 2 and Appendix C).

Two outbreaks took place near Dhaka, Bangladesh; one in 1974 among the landless rural population resettled after independence (Khan and Shahidullah, 1982), the other in 1978 in a camp hosting Burmese refugees fleeing civil war (Khan and Munshi, 1983). All the other outbreaks were in East Africa, along the Great Rift Valley. Of these, one took place in the Sudanese camp of Shagarab in 1985 among Ethiopian refugees fleeing famine (Mulholland,
105 four occurred during the Mozambican civil war in three camps along the Malawi-
106 Mozambican border in 1988 (Moren et al., 1991), 1990 (Swerdlow et al., 1997) and 1992
107 (Mulemba and Nabeth, 1994) and in a fourth camp in Zimbabwe in 1992 (Bradley et al., 1996).
Figure 1: Study selection flowchart

921 records from database search
   Medline: 314
   Embase: 416
   Global Health: 191

313 duplicates removed

608 records screened by title/abstract

561 records excluded
   • No diarrhoeal disease outbreak investigated: 492
   • Not a camp setting: 38
   • Sanitation not addressed: 31

47 full texts retrieved and assessed for eligibility

37 records excluded
   • No full text: 4
   • No diarrheal disease outbreak investigated: 18
   • Not a camp setting: 4
   • Not enough information on sanitation: 11

10 articles included

2 articles retrieved through the citation search

12 articles included in the review
One of the most severe cholera epidemics broke out in Goma, Zaire (now the Democratic Republic of the Congo, DRC), in July 1994, during the Rwandan civil war, infecting close to 700,000 refugees. It was followed by an outbreak of bacillary dysentery caused by *Shigella dysenteriae* type 1 (Sd1); these two outbreaks were described in two articles (Goma Epidemiology Group, 1995; Bechen et al., 1996). One study described 11 Shigellosis outbreaks that occurred from 1993 to 1995 in camps in Tanzania, DRC (including the Goma outbreak) and Rwanda, using data collected by Médecins Sans Frontières (MSF) (Kernéis et al., 2009). Finally, two cholera epidemics occurred in Kakuma camp (Kenya) in 2005 (Shultz et al., 2009) and in 2009 (Mahamud et al., 2012). The camp had been established in 1991 to host refugees from neighbouring countries. The search did not yield any articles published after 2012 that met inclusion criteria.

Overall, the strength of evidence linking specific sanitation related factors with the occurrence of an outbreak, and with individual risk of infection in an outbreak, was assessed as strong in one study, probable in seven and possible in four (see Table 2). Four studies used a matched pair case-control design (Moren et al., 1991; Swerdlow et al., 1997; Shultz et al., 2009; Mahamud et al., 2012) but, of these, only two included a sanitation variable as an exposure (Shultz et al., 2009; Mahamud et al., 2012). The other two examined water source and contact with a specific location as exposures, considering sanitation-related risk factors as contributing to water contamination in the discussion only (Moren et al., 1991; Swerdlow et al., 1997). Of the eight other studies, one presented the results of a spatio-temporal statistical model comparing the same outbreak occurring in a camp and farm community (Bradley et al., 1996) and the remaining seven were descriptive (Khan and Shahidullah, 1982; Khan and Munshi, 1983; Mulholland, 1985; Mulemba and Nabeth, 1994; Goma Epidemiology Group, 1995; Bechen et al., 1996; Kernéis et al., 2009).
Table 2: Study characteristics and critical appraisal summary

<table>
<thead>
<tr>
<th>Author(s) (publication year)</th>
<th>Country</th>
<th>Year of outbreak</th>
<th>Study design</th>
<th>Epidemiological curve</th>
<th>Sanitation as exposure</th>
<th>Strength of evidence linking sanitation failure to outbreak&lt;br&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khan &amp; Shahidullah (1982)</td>
<td>Bangladesh</td>
<td>1974</td>
<td>Descriptive</td>
<td>No</td>
<td>No</td>
<td>Possible</td>
</tr>
<tr>
<td>Khan &amp; Munshi (1983)</td>
<td>Bangladesh</td>
<td>1978</td>
<td>Descriptive</td>
<td>No</td>
<td>No</td>
<td>Possible</td>
</tr>
<tr>
<td>Mulholland (1985)</td>
<td>Sudan</td>
<td>1985</td>
<td>Descriptive</td>
<td>No</td>
<td>No</td>
<td>Probable</td>
</tr>
<tr>
<td>Moren et al. (1991)</td>
<td>Malawi</td>
<td>1988</td>
<td>Matched case control</td>
<td>Yes</td>
<td>Yes</td>
<td>Probable</td>
</tr>
<tr>
<td>Swerdlow et al. (1997)</td>
<td>Malawi</td>
<td>1990</td>
<td>Matched case control</td>
<td>Yes</td>
<td>Yes</td>
<td>Probable</td>
</tr>
<tr>
<td>Mulemba &amp; Nabeth (1994)</td>
<td>Malawi</td>
<td>1992</td>
<td>Descriptive</td>
<td>No</td>
<td>No</td>
<td>Possible</td>
</tr>
<tr>
<td>Goma Epidemiology Group (1995)</td>
<td>DRC</td>
<td>1994</td>
<td>Descriptive</td>
<td>Yes</td>
<td>No</td>
<td>Probable</td>
</tr>
<tr>
<td>Bradley et al. (1996)</td>
<td>Zimbabwe</td>
<td>1992</td>
<td>Statistical modelling</td>
<td>Yes</td>
<td>No</td>
<td>Possible</td>
</tr>
<tr>
<td>Bechen et al. (1996)</td>
<td>DRC</td>
<td>1994</td>
<td>Descriptive</td>
<td>Yes</td>
<td>No</td>
<td>Probable</td>
</tr>
<tr>
<td>Kernéis et al. (2009)</td>
<td>Tanzania, DRC &amp; Rwanda</td>
<td>1993-94</td>
<td>Descriptive</td>
<td>Yes</td>
<td>No</td>
<td>Probable</td>
</tr>
<tr>
<td>Schultz et al. (2009)</td>
<td>Kenya</td>
<td>2005</td>
<td>Matched case control</td>
<td>Yes</td>
<td>Yes</td>
<td>Strong</td>
</tr>
<tr>
<td>Mahamud et al. (2012)</td>
<td>Kenya</td>
<td>2009</td>
<td>Matched case control</td>
<td>Yes</td>
<td>Yes</td>
<td>Probable</td>
</tr>
</tbody>
</table>

* see table 1 for classification criteria

Only one study showed strong evidence of an association between a measured sanitation parameter and the likelihood of being a case in multivariable statistical analysis. Three other studies included sanitation as an exposure parameter but the evidence was not conclusive enough to confirm the association. Among the eight remaining studies, those that showed the distribution of cases over time (epidemiological curve) and described a possible mechanism of transmission were given a higher score in the critical appraisal.
### Table 3: Outbreak characteristics

<table>
<thead>
<tr>
<th>Author(s) (publication year)</th>
<th>Camp (country) Year of outbreak</th>
<th>Pathogen (serotype) Case definition&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Total camp pop. (n)</th>
<th>Total cases (n)</th>
<th>AR (%)</th>
<th>Duration (weeks)</th>
<th>Recent Pop influx*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khan and Shahidullah (1982)</td>
<td>Dhaka (Bangladesh) 1974</td>
<td><em>V. cholera</em> Syndromic, requiring IV rehydration</td>
<td>73,162</td>
<td>177</td>
<td>0.24&lt;sup&gt;2&lt;/sup&gt;</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>Khan and Munshi (1983)</td>
<td>Leda (Bangladesh) 1978</td>
<td><em>V. cholera</em> &amp; <em>S. dysenteriae</em> Positive faecal culture</td>
<td>17,695</td>
<td>Vc: 128&lt;sup&gt;3&lt;/sup&gt; Sd: 1,741&lt;sup&gt;4&lt;/sup&gt;</td>
<td>Vc: 0.72&lt;sup&gt;5&lt;/sup&gt; Sd: 9.84&lt;sup&gt;6&lt;/sup&gt;</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Mulholland (1985)</td>
<td>Shagarab (Sudan) 1985</td>
<td><em>V. cholera</em> (Inaba) Syndromic + direct stool observation Active case finding</td>
<td>30,000</td>
<td>1,166</td>
<td>3.89</td>
<td>6</td>
<td>Yes</td>
</tr>
<tr>
<td>Moren et al. (1991)</td>
<td>Mankhokwe (Malawi) 1988</td>
<td><em>V. cholera</em> (Inaba) Diarrhoea, vomiting or collapse due to dehydration Active case finding</td>
<td>29,745</td>
<td>784</td>
<td>2.60</td>
<td>9</td>
<td>Yes</td>
</tr>
<tr>
<td>Swerdlow et al. (1997)</td>
<td>Nyamithuthu (Malawi) 1990</td>
<td><em>V. cholera</em> (Inaba) Syndromic. Requiring IV rehydration</td>
<td>80,519</td>
<td>1,931</td>
<td>2.40</td>
<td>16</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Abbreviations: Vc: Vibrio cholera, Sd: Shigella dysenteriae

<sup>1</sup> All case definitions imply admission to health care facility.

<sup>2</sup> Weighted average of sections A (AR=0.16), B (AR=0.40) and C (AR=0.43)

<sup>3</sup> Calculated based on 5.5% rectal swabs positive for cholera of a total of 2321 collected (2321/100)x5.5=128. Cultures limited to 10 per day. The authors do not mention whether one culture corresponds to one case.

<sup>4</sup> Calculated based on 75% rectal swabs positive for Shigella of a total of 2321 collected : (2321/100)x75=1741

<sup>5</sup> Calculated based on 128 inferred cholera cases and mean camp population: (128/17,695)x100 = 3.80

<sup>6</sup> Calculated based on 1741 inferred Shigella cases and mean camp population: (1741/17,695)x100=9.84

<sup>144</sup> "recent" influx is considered as being 6 months or less prior to the first cases being reported but ranged from days (Goma Epidemiology Group, 1995; Bechen et al., 1996; Kernéis et al., 2009) to 6 months (Khan and Munshi, 1983)

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<sup>146</sup> Kernéis et al., 2009 to 6 months (Khan and Munshi, 1983)

<sup>147</sup> 1 All case definitions imply admission to health care facility.

<sup>148</sup> 2 Weighted average of sections A (AR=0.16), B (AR=0.40) and C (AR=0.43)

<sup>149</sup> 3 Calculated based on 5.5% rectal swabs positive for cholera of a total of 2321 collected (2321/100)x5.5=128. Cultures limited to 10 per day. The authors do not mention whether one culture corresponds to one case.

<sup>150</sup> 4 Calculated based on 75% rectal swabs positive for Shigella of a total of 2321 collected : (2321/100)x75=1741

<sup>151</sup> 5 Calculated based on 128 inferred cholera cases and mean camp population: (128/17,695)x100 = 3.80

<sup>152</sup> 6 Calculated based on 1741 inferred Shigella cases and mean camp population: (1741/17,695)x100=9.84

<sup>153</sup> 7 Calculated based on 1741 inferred Shigella cases and mean camp population: (1741/17,695)x100=9.84
Table 3 (cont.): Outbreak characteristics

<table>
<thead>
<tr>
<th>Author(s) (publication year)</th>
<th>Camp (country)</th>
<th>Pathogen</th>
<th>Total camp pop (n)</th>
<th>Total cases (n)</th>
<th>AR (%)</th>
<th>Duration (weeks)</th>
<th>Recent pop influx*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mulemba and Nabeth (1994)</td>
<td>Lisungwi (Malawi) 1992</td>
<td>Cholera Syndromic Active case finding</td>
<td>51,930</td>
<td>3730</td>
<td>7.18</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Bradley et al. (1996)</td>
<td>Tongogara (Zimbabwe) Farm (F) vs Camp (C) 1992</td>
<td>V. cholera (Ogawa &amp; Inaba) Syndromic</td>
<td>C: 48,000 F: 8,000</td>
<td>C: 1,155 F: 436</td>
<td>C: 2.41 F: 5.50</td>
<td>C: 18 F: 21</td>
<td>Yes</td>
</tr>
<tr>
<td>Kernéis et al. (2009)</td>
<td>Goma (DRC) 1994</td>
<td>V. cholera (Ogawa) Diarrhoea, dehydration S. dysenteriae type 1 bloody stool</td>
<td>800,000</td>
<td>Vc: 70,0007 Vc: 7.308 Sd1: - Sd1: 15,543</td>
<td>4</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Shultz et al. (2009)</td>
<td>Kakuma (Kenya) 2005</td>
<td>V. cholera (Inaba) Syndromic Active case finding</td>
<td>90,000</td>
<td>348</td>
<td>0.49</td>
<td>6</td>
<td>Yes</td>
</tr>
<tr>
<td>Mahamud et al. (2012)</td>
<td>Kakuma (Kenya) 2009</td>
<td>V. cholera (Inaba) Syndromic Active case finding</td>
<td>62,015</td>
<td>163</td>
<td>0.27</td>
<td>12</td>
<td>Yes</td>
</tr>
</tbody>
</table>

7 Estimate from Bechen (1996). Goma Epidemiology group (1995) provides a range of between 58,000 and 80,000.  
8 Based on high population estimate of 800,000 and low estimate of total cases of 58,000. 

The variation in case definitions prevented any comparisons between outbreaks. Outbreak duration and attack rates seemed to be unrelated to camp size. Higher attack rates were reported in the Shigella outbreaks, reflecting easier detection of cases (visible blood in the stool). All but one camp saw a sudden influx of population within six months preceding the identification of first case.
Outbreak characteristics

Eighteen outbreaks occurred within six months of a population fleeing war, famine or
drought, two soon after the transfer of a group from one camp to another and one three years
after the population had been established in the camp. *Vibrio cholerae* O1 biotype El Tor,
serotypes Inaba, Ogawa, or both were isolated from faecal specimens in 11 outbreaks. Three
studies mentioned only “cholera” without further specification. *Shigella dysenteriae* type 1
(Sd1) was isolated in Goma (DRC) in 1994 shortly after the onset of the cholera outbreak, in
Leda camp (Bangladesh), where cholera was also identified, and in all 11 dysentery outbreaks
documented by MSF (see Table 3).

In the two articles describing the Goma outbreak, the authors calculated the number
of cases retrospectively, based on the number of bodies collected in the streets of the town
before surveillance could be put in place, and triangulated this estimate with clinic data and
household surveys (Goma Epidemiology Group, 1995; Bechen et al., 1996). Apart from these
two studies and that of Khan and Munshi (1983), who used positive faecal samples as a case
definition, the number of cases was determined from health care facility records using
syndromic case definitions. Five articles noted that active case finding was undertaken after
the first cases were detected. None attempted to differentiate between primary and
secondary cases (see table 3).

Total camp populations ranged from 8,588 to 215,589 and all but two studies provided
an Attack Rate (AR), using total camp population as the denominator (see table 3). ARs were
much lower in the cholera outbreaks, ranging from 0.24% in Dhaka (patients requiring IV
rehydration) to 7.30% in Goma (all individuals presenting to the cholera treatment centre),
compared with the dysentery outbreaks (range: 5.5% in Kashusha to 39.1% in Kibumba, both
in DRC, same case definition). Case definition specificity could have introduced a degree of
selection bias as those who sought treatment a) had not yet died b) had severe enough
symptoms to seek care and c) were aware of the presence of a treatment centre.

Where indicated, mean outbreak duration was 14 weeks, ranging from 4 to 29 weeks
with the peak occurring between 6 and 43 days after the start of data collection (see Table 3
and Appendix C). Five studies showed a rapid increase in the number of cases within months
or days of a population influx. Only two studies identified a potential index case, one of which
was among new arrivals, but neither could confirm where, or from whom, the person had acquired the pathogen (see Appendix C).

Case Fatality Rates (CFR) for cholera were given in eight studies, and ranged from 0.37% in Lumashi to 6.5% in Goma. A large proportion of deaths were thought to be iatrogenic in two cholera outbreaks. Antibiotic resistance and inappropriate prescription practices were thought to have contributed to the high CFRs in 9 of the 11 Shigella outbreaks described by Kernéis et al. (2009).

Sanitation characteristics and defecation practices

Five studies reported a persons per latrine ratio, which ranged from 13 to 1,029. The ratio was greater than 100 in six camps. Sphere standards, first published in 2000, recommend a maximum person per latrine ratio of 40 during the acute phase of a complex emergency (i.e. within the first three months of population displacement) and of 20 thereafter (The Sphere Project, 2011). The two studies that reported on outbreaks that occurred after these guidelines were published, both at Kakuma camp, either did not provide a ratio or reported the official figure of 13 persons per latrine and emphasized the great variability in latrine distribution within the camp (see Table 4).

Five articles described sanitation facility characteristics, which included sewer-connected toilets, ventilated and improved pit latrines, unprotected surface latrines and trench latrines. Rocky and/or volcanic soil limited or prevented the digging of latrines in the Goma and in Leda camps. Latrine emptying or excreta collection practices were mentioned only by Mahamud et al. (2012), who observed that a large number of latrines were full and non-functional without further description in the 2009 Kakuma outbreak. Two articles mentioned lack of latrine cleaning, which was under the responsibility of the users, as a barrier to utilisation. Open defecation in fields, bushes, the banks of ponds, rivers or lakes and/or compound grounds was reported in eight studies (see Table 4 and Appendix C).
## Table 4: Sanitation characteristics

<table>
<thead>
<tr>
<th>Author(s) (publication year)</th>
<th>Camp (Country)</th>
<th>Persons per latrine (n)</th>
<th>Latrine type</th>
<th>Alternative defecation practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khan and Shahidullah (1982)</td>
<td>Dhaka (Bangladesh) sections A, B, C</td>
<td>A: 130 B: 325 C: 405</td>
<td>A: enclosed, connected to sewer B&amp;C: surface, unprotected ¹</td>
<td>A: - B&amp;C: Open field, ponds</td>
</tr>
<tr>
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<td>Trench</td>
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<td>Shagarab (Sudan)</td>
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<td>Open field Compound ground</td>
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<tr>
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<td>Mankhokwe (Malawi)</td>
<td>-</td>
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<td>Swerdlow et al. (1997)</td>
<td>Nyamithuthu (Malawi)</td>
<td>-</td>
<td>-</td>
<td>Open field Riverbed</td>
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<tr>
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<td>Lisungwi (Malawi)</td>
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<td>Communal</td>
<td>-</td>
</tr>
<tr>
<td>Bradley et al. (1996)</td>
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<td>C: 28</td>
<td>Ventilated Improved pit ²</td>
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<tr>
<td>Kernéis et al. (2009)</td>
<td>Nsangwa Kuduha Rukundo (Tanzania) Benaco Lumashi (Rwanda)</td>
<td>60-120 200</td>
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<td>-</td>
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<tr>
<td>Goma Epi Group (1995)</td>
<td>Mungunga Kibumba Kalehe Kashusha Inera (DRC)</td>
<td>1029 500 184</td>
<td>Lake Kivu</td>
<td>Open field Open field</td>
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<td>Bechen et al. (1996)</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
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</tr>
<tr>
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<td>13³</td>
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<tr>
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<td>Kakuma (Kenya)</td>
<td>-</td>
<td>Household Communal Some non-functional</td>
<td>Bushes, Riverbed Compound ground</td>
</tr>
</tbody>
</table>

¹ No containment of human waste from environment, no covering or pit  
² No further description given in text  
³ Wide variations in distribution throughout the camp, household latrines included in total
Sanitation-related risk factors for outbreak occurrence

Delayed provision of sanitation facilities after a population influx

Insufficient latrine provision after a recent population influx in the camp was mentioned in six articles (see Table 5). The heterogeneity in case definitions prevented comparisons between cholera outbreaks but Kernéis et al. (2009) showed that, in the Shigella outbreaks, higher ARs were found in camps that had a higher persons per latrine ratio and where the humanitarian response was delayed or lacked capacity. In Goma, despite early warning (from international players present in the area) of potential large population displacements, the agencies on the ground received support only after the outbreak had been reported by international media (Goma Epidemiology Group, 1995; Bechen et al., 1996; Kernéis et al., 2009). In Leda camp, agencies arrived on the scene several months after the refugees were settled (Khan and Munshi, 1983). In Lisungwi, communal latrines were built when refugees first arrived but were insufficient (Mulemba and Nabeth, 1994).

Shultz et al. (2009) evaluated the association between “sharing a latrine with three or more households” and becoming a case, which yielded an Odds Ratio (OR) of 2.17 (95%CI: 1.01-4.68) after adjusting for recent arrival and water storage in a sealed container. Though recent arrivals had more than four times the odds of symptomatic disease (OR: 4.66, 95%CI: 1.35-16.05), the authors could not establish with any certainty whether they introduced the pathogen into a non-immune population or provided a pool of susceptibles for an endemic strain. However, the sections of the camp that saw the highest ARs also had the lowest latrine coverage and hosted the majority of new arrivals (Shultz et al., 2009). In Nyamithuthu, Swerdlow et al. (1997) found that 86% of the cases had arrived three months prior to becoming infected.

In the 2009 Kakuma outbreak, sharing a communal latrine was associated with higher odds of becoming a case in bivariate analysis, with an OR of 3.33 (95% CI: 1.34-8.30) but was not found to be statistically significant in multivariate analysis (data not shown in article), which included only dirty water storage containers and hand washing with soap as covariates in the final multivariate model (Mahamud et al., 2012). Although the authors noted that 12,000 people had been transferred from another camp one month earlier, recent arrival was
not found to be a significant risk factor (OR: 1.83; 95% CI: 0.68-4.96) (Mahamud et al., 2012).

However, almost half of eligible cases could not be located for an interview and controls were excluded if any member of the compound had experienced diarrhoea as of two days after outbreak detection, thus introducing potential selection bias.

The high proportion of asymptomatic individuals in cholera-infected populations (Sack et al., 2004) implies a high risk of differential misclassification bias in the case-control studies.

In the other articles, the risk of ecological fallacy (Carneiro and Howard, 2011) prevented the isolation of sanitation failure effects from water and hygiene-related factors when estimating exposure.

Open defecation and the use of unsafe water sources

Open defecation practices were described as contributing factors in nine outbreaks, as the areas that had been used for defecation were also used for drinking, washing and bathing in the context of limited water availability (see table 5). The daily per person quantity of safe water provided at the time of outbreak detection was given in seven studies and ranged from 0.2 to 20 Litres per person per day with only one camp meeting the minimum daily requirement set by Sphere of 15 Litres of water per person (The Sphere Project, 2011).

In Nyamithuthu, cases were 16 times more likely to have “visited the river” and to drink river water (OR: 16.1; 95% CI: 2.0-351.2) (Swerdlow et al., 1997). In contrast, Shultz et al. (2009), suspecting that the river might have been a common source of infection in the 2005 Kakuma outbreak, found that cases were not significantly more likely to drink river water compared with controls despite the riverbank having been used for defecation. However, they acknowledged that a high risk of recall and misclassification bias, an on-going education campaign and a small sample size, might have under-estimated the association.

Cultural factors were described in four studies. In Dhaka (Khan and Shahidullah, 1982) and Kakuma in 2005 (Shultz et al., 2009), populations migrating from rural areas were reported to have placed little value in the use of latrines, resorting to open defecation instead, and to have shown little concern for the upkeep and maintenance of shared facilities. Visible human faeces were observed on compound grounds in Shagarab (Mulholland, 1985) and in
Kakuma in 2009 (Mahamud et al., 2012), where the authors noted that some camp dwellers considered children’s faeces harmless.

**Accidental water contamination**

The most precise description of the mechanism by which drinking water was contaminated by infected faeces was given by Mulholland (1985), who described tanker trucks driving through a muddy field used for defecation before their tanks were filled in a lake to supply the camp with drinking water. In the Mankhokwe outbreak, heavy rains destroyed half the latrines 15 days before the first cases of cholera were detected and cases were 4.5 times more likely than controls to use the water from shallow wells (95%CI: 1.0-20.9, p=0.04); the distance between the surface of the water table and the bottom of nearby pit latrines was less than 1 metre (Moren et al., 1991). In both outbreaks that occurred in Bangladesh, heavy rain filled ditches and holes that had previously been used for defecation, and camp residents were reported to have used the rain water for washing and bathing (Khan and Shahidullah, 1982; Khan and Munshi, 1983).
### Table 5: Sanitation and water accessibility

<table>
<thead>
<tr>
<th>Author(s) (publication year)</th>
<th>Camp (country)</th>
<th>Persons per latrine (n)</th>
<th>Safe water quantity (L/person/day)</th>
<th>Defecation at water source</th>
<th>Delayed response</th>
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</tr>
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<td></td>
<td></td>
<td>4-12</td>
<td></td>
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<td>-</td>
<td>-</td>
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<td>Benaco</td>
<td>-</td>
<td>3.7</td>
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<td>15</td>
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</tr>
<tr>
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<td>Katale</td>
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<td></td>
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DISCUSSION

The search for peer-reviewed literature yielded 12 articles, published between 1982 and 2012, describing diarrhoeal disease outbreaks and sanitation characteristics in 21 camps hosting displaced populations. The evidence of an association between specific sanitation failures and infection risk was difficult to isolate in the context of safe drinking water shortages. Nonetheless, based on the evidence found in these articles, three main sanitation-related risk factors were identified as having contributed to pathogen transmission, both in isolation and concurrently: 1) lack of sanitation provision due to a delay in humanitarian response after a population influx; 2) open defecation in the proximity of lakes, rivers or ponds used for washing, bathing and drinking; and 3) direct contact between faecal sludge and water sources after heavy rains.

The focus on sanitation failures was motivated by recent reviews that found a lack of evidence on the effectiveness of sanitation-specific interventions in controlling communicable diseases during complex emergencies (Brown et al., 2012; Ramesh et al., 2015; Blanchet et al., 2017). Despite the low threshold for the level of detail on sanitation provision required for inclusion, only 12 articles met inclusion criteria, reflecting the dearth of published peer-reviewed outbreak investigations that evaluated exposure to sanitation-related parameters in camps. A limitation was to have excluded grey literature, where relevant evidence might have shown improvements – or lack thereof – in sanitation provision since the publication of Sphere guidelines.

The findings of the present review do not suggest that no outbreaks have occurred in camps since 2009. Rather, they show that very few published articles reporting on outbreak investigations examined sanitation-related factors, which is likely due to the difficulty in measuring individual-level exposure. A search on ProMED, an online report system for infectious disease outbreaks which is widely used internationally (Promedmail, no date), showed that, between 2009 and 2014 alone, 18 diarrhoeal disease outbreaks occurred in refugee camps. The lack of precision in these reports precluded their inclusion in this study however.

This confirms the need for further research, particularly when considering that the outbreaks that were investigated occurred in camps where a) health care services were in
place, b) surveillance was under way and considered reliable and c) sanitation provision data was available. Given the high likelihood of publication bias, these outbreaks could have been quite different from others that were not detected, not documented in peer-reviewed journals, or in which surveillance was not systematic (Bruckner and Checchi, 2011). Future research should explore the use of more robust indicators reflecting latrine utilisation and condition as well as accessibility. Questionnaires should include items on whether the use of latrines is systematic, occasional and/or concurrent with open defecation practices. The conditions of the latrines used and whether users had any direct contact with faeces should also be documented.

Examining the environmental determinants of cholera outbreaks in inland Africa from 1970 to 2012, Rebaudet et al. (2013), noted the importance of drinking water contamination either through open defecation near water sources in the context of droughts or secondary to the flooding of latrines into shallow wells, which is consistent with the findings of this review. They also suggested that human behaviour and social factors, along with population mobility and migration, were more likely to explain geographical patterns than seasonality or the presence of an established environmental reservoir (Rebaudet et al., 2013).

All but one outbreak examined here took place within six months of the arrival of a population fleeing war, famine and/or drought, therefore in the context of a complex humanitarian emergency (Toole and Waldman, 1997). A delay in adapting sanitation capacity to a population influx would have increased the potential for direct contact with infected faeces and for subsequent water contamination, to which both new arrivals and existing camp dwellers would have been exposed (Lam et al., 2015). Cronin et al. (2009) have shown that, in camps where the persons per latrine ratio is greater than 30, the percentage of the population with access to improved sanitation is approximately 10%; this increases to 25% when the ratio is between 21 and 30. They also demonstrated that access to sanitation plays a more important role in controlling diarrhoea than access to water (Cronin et al., 2009).

The use of river, pond or lake water for domestic purposes, and for drinking in the context of insufficient safe water resources, would have exposed a susceptible population either to an existing environmental reservoir or, more likely, to a common source, established with the introduction of the pathogen by an infected individual. A similar mechanism of transmission was suspected in Juba, Sudan, in 2007, among refugees returning from camps
(Centers for Disease Control and Prevention, 2009) and in Kenya, in 1994, among Somali
refugees and Kenyan nationals living in slums (Iijima et al., 1995).

Most of the outbreaks reported on in this review occurred in established camps after
a sudden influx of population. Given the location of current conflicts, civil strife and extreme
weather conditions, it is likely that such population movements will continue in future as
people migrate to existing camps, overwhelming sanitation and water services that have been
planned for temporary occupation and for a limited number of people. The creation of the
Sphere project in 1997 (The Sphere Project, 2011) shows that the will to improve sanitation
services in camps has been in place for at least twenty years. Yet in 2015, a WHO working
panel on cholera control highlighted that progress in implementing these guidelines was slow,
particularly in terms of anticipation and response during high-risk periods (Seukap Pena et al.,
2016).

Adequate sanitation provision can contribute to the prevention not only of diarrhoeal
disease outbreaks but also of vector borne diseases and hookworm, dracunculiasis and
schistosomiasis infections as well (Esrey et al., 1991; Cairncross and Valdmanis, 2006).
Compared with other WASH interventions, such as soap distribution, container chlorination
and community education, sanitation provision in camps generally requires a greater degree
of planning in order to be effective.

Camp dwellers should be involved in designing and building facilities in order to ensure
they are appropriate in terms of customs and habits. Innovation in designing temporary
shared facilities should be encouraged, funded and evaluated in terms of impact and
effectiveness. More importantly, allocating resources and ensuring continuity of service, both
for the initial construction of facilities and for their maintenance should not be neglected. To
quote Francesco Checchi and colleagues (2007), “timely and appropriate relief, grounded in
clearly outlined, scientifically sound reasoning, focusing discussion on substantive matters
and reducing the scope for political manipulation” is paramount. Stakeholders should be
aware of basic infectious disease epidemiology concepts and should mobilize the appropriate
resources to ensure sanitation facilities are adapted to the camp context, as well as
topography, weather patterns and cultural norms.
CONCLUSION

A search for peer-reviewed articles describing both a diarrhoeal disease outbreak and sanitation characteristics in refugee camp settings yielded 12 articles published over the past 60 years. A number of sanitation-related factors were identified as having contributed to outbreak occurrence, in particular delayed latrine provision following a population influx and inadequate maintenance of existing facilities, which contributed to open defecation and subsequent water contamination. However, few studies measured sanitation characteristics in detail and only two considered them as exposures in risk factor analyses. Further research using more robust measurement tools and greater collaboration between the WASH and health sectors are necessary in order to design interventions that are adaptable, readily available and culturally appropriate. Using in-country resources and involving the local population in the design of sanitation infrastructure that will meet their needs will likely encourage the use and maintenance of facilities, and therefore reduce the risk of disease transmission. Though major actors of the humanitarian relief field have emphasised the role of coordination, collaboration and accountability in upholding sanitation and camp management standards, the role of population dynamics in pathogen transmission should be highlighted in order to justify resource allocation, and to emphasise the necessity for funds to be readily available.


Promedmail (no date). Available at: https://www.promedmail.org/ (last accessed: 30 November, 2018).


## APPENDICES:

### A. Detailed search strategy

<table>
<thead>
<tr>
<th>Steps</th>
<th>Search terms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sanitation (concept A)</strong></td>
<td><strong>Subject headings</strong>&lt;br&gt;Medline, Embase: Sanitation; risk factors&lt;br&gt;Global health: Sanitation; latrines</td>
</tr>
<tr>
<td>1</td>
<td><strong>Keywords</strong>&lt;br&gt;Sanitation OR latrine* OR toilet* OR WASH OR excr?eta disposal OR hygiene OR defecat* OR f?eces OR water OR risk factor</td>
</tr>
<tr>
<td>2</td>
<td>1 OR 2 → all results for concept A</td>
</tr>
<tr>
<td><strong>Diarrhoeal disease outbreak (concept B)</strong></td>
<td><strong>Subject headings</strong>&lt;br&gt;Medline, Embase: Diarrhea AND epidemic&lt;br&gt;Global health: Infectious diseases</td>
</tr>
<tr>
<td>4</td>
<td><strong>Keywords</strong>&lt;br&gt;(Diarrh* OR Cholera* OR Dysenter* OR Shigell* OR E* Coli OR Rotavirus OR Norovirus OR Astroivirus OR Salmonell* OR Amoeb*)</td>
</tr>
<tr>
<td>5</td>
<td>4 OR 5 → all results for concept B</td>
</tr>
<tr>
<td>6</td>
<td>3 AND 6 → all results for concepts A and B</td>
</tr>
<tr>
<td><strong>Refugee camps (concept C)</strong></td>
<td><strong>Subject headings</strong>&lt;br&gt;Medline, Embase: Refugee OR refugee camp&lt;br&gt;Global Health: refugees</td>
</tr>
<tr>
<td>8</td>
<td><strong>Keywords</strong>&lt;br&gt;Refugee* OR internally displaced person* OR IDP OR Displace*</td>
</tr>
<tr>
<td>9</td>
<td>8 OR 9 → all results for concept C</td>
</tr>
<tr>
<td>10</td>
<td>6 AND 10 → all results for concepts B and C</td>
</tr>
<tr>
<td>11</td>
<td>3 AND 10 → all results for concepts A and C</td>
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<td>12</td>
<td>3 AND 6 AND 10 → all results for concepts A and B and C</td>
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</table>
### B. Critical appraisal checklist

(All items scored equally. Overall score attributed based on percentage of criteria met)

<table>
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<tr>
<th>Author (pub year) title:</th>
<th>Study design:</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Score:</td>
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</table>

#### A. Introduction

1. Aim and Objectives clearly stated?
2. Study design presented?
3. Outbreak location and dates described?
4. Period of data collection stated?
5. Sanitation measured as exposure?

#### B. Case definition and control selection

6. Appropriate case definition (specificity vs sensitivity)?
7. Cases representative of study population?
8. Established, reliable system for detecting cases?
9. Pathogen identified?
10. Controls randomly selected from susceptible population?
11. Matched controls?
12. Recall, ascertainment or classification bias acknowledged?
13. Appropriate sample size?

#### C. Outbreak investigation

14. Epidemiological curve presented and interpreted?
15. Susceptible population described?
16. Population characteristics and dynamics described?
17. Attack rate provided and reliable?
18. Case fatality rate provided and reliable?

#### D. Exposures

19. Sanitation characteristics described, including person:latrine ratio?
20. Other defecation practices described?
21. Water quantity, source and quality described?
22. Seasonal information provided?
23. Soil/ground conditions described?
24. Other confounders or effect modifiers identified?

#### E. Statistical methods

25. All statistical methods described and appropriate?
26. Crude associations presented?
27. Confounding controlled for?
28. Interaction examined?
29. Missing data and loss to follow-up addressed?

#### F. Results and discussion

30. Unadjusted estimates and, if applicable, adjusted estimates given?
31. 95% Confidence intervals and tests of significance presented?
32. Limitations of the study discussed, including incomplete data?
33. Sources of potential bias discussed?
34. Mechanism of pathogen transmission explored?
35. Alternative interpretations for end of outbreak considered?

#### G. Implications
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<th>Question</th>
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<tr>
<td>36. Are the results coherent with other available evidence?</td>
<td></td>
</tr>
<tr>
<td>37. Can the results be used to inform stakeholders?</td>
<td></td>
</tr>
<tr>
<td>38. Can these results be used to make recommendations?</td>
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</table>
### Appendix C: Article Summary Table

<table>
<thead>
<tr>
<th>Author(s) (publication year)</th>
<th>Country, camp name (population)</th>
<th>Outbreak dates &amp; pathogen</th>
<th>Study population, case definition &amp; data source</th>
<th>Outcome measures</th>
<th>Risk factors</th>
</tr>
</thead>
</table>
| Bechen et al. (1996)         | Zaire Goma (800,000)           | July to 14/08/1994        | Case: Bodies of deceased collected, watery diarrhoea and/or dehydration. Data source: dispensaries, cholera wards | AR: 10% (estimated by authors)  
Mortality rate:  
Katalé: 41,3/10,000  
Kibumba: 28,1/10,000.  
85-90% attributable to diarrhoea. | Volcanic soil— cannot dig latrines  
Lake Kivu only water source.  
Drinking water: 0.2L/person/day mid July, increased to 2L/person/day in late July and 5L/person/day in August but decrease in number of cases before increase in water distribution.  
*Civil war in Rwanda. Late humanitarian response despite predictability of outbreak.* |
Compares camp to commercial farming community  
no info on data source | Cases: 1,155 (camp) vs 436 (farm)  
AR: 2.4% (calculated based on data provided)  
Doubling time in camp: 1.2 days in first 11 days.  
Doubling time in farm: 4.3 days in first 30 days. | Camp: Ventilated and improved latrines, 28 people/latrine boreholes, lagoons, river and irrigation canal.  
Safe water sources: 1borehole/10,000 people in camp vs 1 borehole/320 people in farm  
Women of childbearing age and children at greatest risk.  
*Civil unrest and drought in Mozambique. Camp run by Zimbabwe government and UNHCR, established in 1983.* |
| Goma Epidemiology Group (1994) | Zaire Katale (n=80,000), Mugunga (n=150,000) | Early July – 14 August 1994 | Case: Non-specific. UNHCR definition  
Sources: agencies that collected bodies, health facilities, agencies caring for unaccompanied children, UNHCR, cluster survey | AR: 7.3% (estimate for all refugees in Goma, not specific to camps)  
Mugunga: 88% deaths from diarrhoeal disease, 57% diarrhoeal deaths due to cholera | Rocky, volcanic soil with poor drainage – cannot dig latrines, wells or graves.  
Open defecation predominant  
Lake is main water source  
All ages equally affected.  
*Civil war in Rwanda. Late humanitarian response. Lack of security. Former Rwandan political and military leaders in camp control population.* |
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<tr>
<td>Kernéis et al. (2009)</td>
<td>Descriptive</td>
<td>Rwanda, Tanzania, DRC (11 camps)</td>
<td>Nov 1993-Feb 1995</td>
<td>Any person with diarrhoea (passage of 3 or more watery or loose stools in past 24 hours) and visible blood in the stool (WHO def.)</td>
<td>Mean ARs by camp size: small: 18.3% (+/-9.9), medium: 13.5% (+/-4.8), large: 28.1% (+/-9.4)</td>
<td>Tanzania: drinking water &amp; latrines available within first few days, sphere standards met. Goma (DRC): person/latrine ratios Katale: 184; Kibumba; 500 Mugunga: 1029, Water sources: streams, lake. Bukavu (DRC): good organisation of camp site. Rwanda: variable. 8 of 11 outbreaks occurred in the dry season, all within 3 months of arrival of refugees. ARs higher among &lt;5 age group. Civil wars in Burundi and Rwanda. Outbreaks occur within 3 months of refugee arrival. Difference in ARs attributed to camp management.</td>
</tr>
<tr>
<td>Khan and Munshi (1983)</td>
<td>Descriptive</td>
<td>Bangladesh Leda (n=17,695)</td>
<td>1978</td>
<td>Cases: patients admitted to diarrhoea clinic. 2,321 stool samples collected and analysed (not from all cases) Sources: clinics, public health office in camp</td>
<td>Number of cases and AR not given &amp; cannot be calculated with available data 60% all illness due to diarrheal disease. 29.9% rectal swabs positive</td>
<td>356 Trench latrines (ratio 50:1), dug by refugees. Rocky ground, hand pump tube wells cannot be sunk. Water supplied by tanker truck. Heavy rains, Ditches &amp; ponds used for washing &amp; bathing. 10,000 new arrivals. Burmese refugees arrived in first quarter of 1978. Camps officially opened in April/May.</td>
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<tr>
<td>Khan and Shahidullah (1982)</td>
<td>Descriptive</td>
<td>Bangladesh Dhaka camp A (n=49,675), camp B (n=11,375) &amp; camp C (n=12,112)</td>
<td>1974 and 1975 Vibrio cholerae</td>
<td>Case: Patient admitted to ICDDR, B¹ Source: 1974 camp census (total population), ICDDR, B¹ records.</td>
<td>ARs A: 1.61/1,000² B: 3.95/1,000 C: 4.29/1,000</td>
<td>Camp A: latrines connected to sewer, water piped. (ratio 130:1) Camps B &amp; C: built in 1971, no planning for sanitation or drinking water: Latrines consist of fenced surface without pit or covering. Some built on bank of pond. Ratio camp B 325:1, camp C: 405:1. Open defecation common, use of river water &amp; surface water after rain. Homogenous cultural and socioeconomic background <strong>Landless rural population refugees after independence of Bangladesh (1971)</strong></td>
</tr>
<tr>
<td>Mahamud (2012)</td>
<td>Matched case-control (93 pairs)</td>
<td>Kenya Kakuma (n=62,015)</td>
<td>18 Sep – 15 Dec 2009 Vibrio cholerae (Inaba)</td>
<td>Cases: WHO definition in any camp resident &gt;2 y.o. admitted to treatment centre with onset of illness after 01 Oct 2009 Controls matched on location and age Sources: camp records, treatment centre, population survey</td>
<td>Total cases: 163 AR: 2.7/1,000 overall AR: 9.5/1,000 in Kakuma2 area CFR: 1.8%</td>
<td>Bivariate analysis: Sharing communal latrine OR=3.33 (95%CI: 1.34-8.30, p=0.001) Human faeces visible on ground of compound OR=6.50 (95%CI 1.47-28.8, p=0.04) Open defecation common, children’s faeces considered harmless Water sources: shallow wells in riverbed, stagnant water at tap stand <strong>Long-standing camp. 12,000 new arrivals from Dadaab camp 1 month prior.</strong></td>
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¹ ICDDR, B: International Centre for Diarrhoeal Disease Research, Bangladesh
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<td>Moren et al. (1991)</td>
<td>Matched-pair case-control (51 pairs)</td>
<td>Malawi, Mankhokwe (n=29,745)</td>
<td>15 March – 17 May 1988, Vibrio cholerae (Inaba)</td>
<td>Case: “Person with an acute onset of profuse watery stools or profuse vomiting or collapse due to dehydration”, who was treated in the camp’s cholera treatment centre Controls: randomly selected &amp; matched for age, sex, and location Source: cholera treatment centre, household survey</td>
<td>Total cases: 784, AR: 2.6% (range: 0.9 – 5.1), AR higher in Market section throughout and among 5-14 age group in market section: 6.7%, CFR: 3.3%</td>
<td>Univariate analysis: Lack of communal latrines at market Water table 5m below surface, latrines 3-4m deep. 5 of 24 wells positive for faecal coliforms. Shallow wells vs boreholes used: OR=4.5 (95%CI 1.0-20.9, p=0.04) Contact with market OR=3.5 (95%CI=0.7-16.9, p=0.09) No association with food exposure. End of rainy season. Heavy rains 15 days prior: half latrines destroyed. Recent gathering of 30,000 refugees. 400,000 Mozambican refugees flee to Malawi. Established camp.</td>
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| Mulholland (1988)            | Descriptive | Sudan, Shagarab East (SE) | 15 May – 30 Jun 1985 | "rice water stools" (observed by nursing staff), cold extremities, profound dehydration | Total cases: 348 | Trench latrines, poorly utilized, scattered at camp periphery.  
Open defecation on compound ground (children & ill adults, at night) & in muddy fields.  
Water trucked in from nearby dam. Bladder tanks filled after driving through field used for defecation.  
Clay soil, poor drainage. Road built through camp without drainage provisions. Rainstorm 3 days prior.  
4-year-old boy with vomiting & diarrhoea during transport to SE2).  
Famine in Ethiopia. 20,000 Refugees in two transit camps transferred during month prior to start of outbreak. |
|                              |        | Section 1 (n=10,000) | Vibrio cholerae (Inaba) | Source: clinic records, door-to-door case finding by health workers | Cases S1: 287  
Cases S2: 879  
AR S1: 2.9%  
AR S2: 4.5% | |
|                              |        | Section 2 (n=20,000) |  |  |
| Schultz et al. (2009)        | Matched case-control (90 cases/170 controls) | Kenya Kakuma (n=90,000) | April 2005 | Vibrio cholerae (Inaba) | Cases: “Any person of any age with profuse, effortless watery diarrhoea (3 or more stools per 24 hours) admitted to the IRC cholera ward between 01/4 and 30/06/2005”. Includes <5 age group.  
Controls: matched by age and location within camp  
Sources: hospital records, survey | Total cases: 348  
AR overall: 4.9/1,000  
AR Kakuma 2: 15.9/1,000  
AR area 57 of Kakuma 1: 15.0/1,000  
AR area 58 of Kakuma : 12.1/1,000 | Multivariable analysis:  
- Sharing a latrine with 3 more households OR=2.17 (95%CI: 1.01-4.68)  
- Recent arrival adjusted OR=4.66 (95%CI: 1.35-16.05).  
New arrivals placed in Kakuma 2  
Lack of latrines where cases clustered (average ratio for camp: 13:1 – wide variations).  
Upkeep by camp dwellers.  
Boreholes provide 8-17L/person/day (estimate accounts for leakage and uses other than domestic)  
Cases not more likely than controls to use water from riverbed.  
Long standing camp (established in 1991) IRC provides health and sanitation services. Coordination by ministry of health and UNHCR. |
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<td>Swerdlow et al. (1997) A: Matched case-control (50 pairs) B: Unmatched case-control (47 patients/137 households)</td>
<td>Malawi Nyamithuthu (n=57,000 on 15/10, 74,000 on 15/11)</td>
<td>23 Aug – 15 Dec 1990 Vibrio cholerae (Inaba)</td>
<td>Cases (A and B): “diarrhoeal illness in a person admitted to an IV treatment tent at Nyamithuthu camp between 23 August and 15 December, 1990”. Controls A: matched by age, sex and date of arrival. Controls B: cluster-survey, door-to-door household selection. Source: treatment tent records, camp registration records.</td>
<td>Overall cases: 6,114 Admitted to IV treatment tent: 1,931 AR (requiring IV treatment) =2.4% CFR (among IV treated)=3.5%</td>
<td>Univariate analysis: Obtaining drinking water from river: OR=3.0 (95%CI: 1.4-6.4) Multivariable analysis: Visited river and drank river water: Adjusted OR=16.1 (2.0-31.2) Open defecation in fields and at river predominant. Drilled wells but critical water shortages leading to river water use. Extreme heat. 86% cases arrived 3 months prior. 52% &lt;16 days prior. New arrivals located at greater distance from well with no access to latrines. Cholera isolated in pooled water sample from 4 households. Mozambican refugees fleeing armed conflict. Camp opened in 1988, planned for 50,000. Sudden, unexpected influx of 20,000 refugees from 15/10 to 15/11/1990. Fourth outbreak of cholera in 2 years.</td>
</tr>
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