



Chemical, Biological, Radiological, Nuclear and explosive (CBRNe) events: Systematic literature review of evacuation, triage and decontamination for vulnerable people

Journal:	<i>International Journal of Emergency Services</i>
Manuscript ID	IJES-05-2018-0030.R1
Manuscript Type:	Literature Review
Keywords:	Systems, Evacuation, Decontamination, CBRNe

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Chemical, Biological, Radiological, Nuclear and explosive (CBRNe) events: Systematic literature review of evacuation, triage and decontamination for vulnerable people

Abstract

Purpose: To systematically review published literature for the research question '*what issues are considered (and changes made) for vulnerable groups as part of the Chemical, Biological, Radiological, Nuclear or explosive (CBRNe) response for casualty collection, decontamination, triage and casualty clearing processes?*'

Design: Seven-stage framework from the PRISMA statement for research question, eligibility (definition), search, identification of relevant papers from title and abstract, selection and retrieval of papers, appraisal and synthesis.

Data sources: Medline, Embase, Cochrane Library, Web of Science, Scopus (Elsevier), Chemical Abstracts, Assia (Proquest), Sociological abstracts Proquest), Cinahl, HMIC, Health business elite, PsycInfo (ebSCO), PILOTS (Proquest) and supplemented by other search strategies (e.g. exploding reference lists).

Review methods: The included references were critically appraised using the Mixed Methods Appraisal Tool (MMAT)

Results: 1855 papers were returned from the literature search, of which 221 were screened by abstract and 48 by full paper. Eleven papers were included for appraisal, of which 3 achieved a quality score of 50% or over. The papers were categorised into 3 phases on CBRNe response; evacuation, triage and decontamination.

Conclusions: Although very little new medium/high quality research is available, the findings are summarised as considerations for building design (route choice and information), communication (including vision, hearing and language differences) and the composition of the response team. It is suggested that evidence-based practice from other care domains could be considered (patient movement and handling) for fire service and ambulance guidelines.

Key points

- This review has used a framework for evidence-based service (system) design
- Previous systematic review (Carter and Amlôt, 2016) only looked at decontamination rather than wider system. It offered a different framework for describing vulnerability as types of casualty (independent-some/full support) and levels of functional needs (physical communication, social/cultural and pre-existing condition) rather than specific causes (e.g. pregnancy, literacy). No quality appraisal was reported so it is difficult to judge whether the included research is of a high or low quality.
- There is very little good quality research on CBRNe systems design for vulnerable people with only 3 papers with greater than 50% quality score for evacuation (1 paper) and decontamination (2 papers). **No research about triage was included due to low quality appraisal scores**
- Evacuation can be described for accessibility characteristics for exit, route and obstacles (Manley, et al, 2016). This takes a systems approach to consider how building planning and layout can have implications for safety critical but low frequency events.
- Decontamination recommendations include at least one additional re-robe section per mass decontamination unit (Egan and Amlôt, 2012) and adaptations to the decontamination plan including accessible equipment for non-ambulatory individuals and additional (specialist) staff in the decontamination team (sign language, interpreters and physical therapists; Taylor et al (2008)).
- **These evidence-based results should be used by practitioners to review current operational policies for vulnerable people and plan future improvements.**

Keywords: Systems, Evacuation, Decontamination, CBRNe

Introduction

When a mass casualty incident (MCI) occurs related to Chemical, Biological, Radiological, Nuclear or explosive (CBRNe) agents the response environment will probably be hazardous and ambiguous (Cornish, 2007). The numbers of injuries and fatalities, and the stability of the working situation may be unknown for a period of time.

In 2013 a CEN Technical Specification: (CBRN – Vulnerability Assessment and Protection of People at Risk) was provisionally accepted; it was intended as a common frame of reference and context to meet the complex and variable needs of a wide range of different end users. One of the challenges was the lack of a universally accepted definition of vulnerability and this is reflected in guidance which may include all (or a subset) of members of the population at risk. Lemyre et al (2009) raised concerns about the use of the term ‘vulnerable population’, suggesting that it might insinuate *‘a generic intrinsic fatalistic fragility in people. It offers a bleak outcome, suggests a passive process, and it dis-empowers individuals. It fails to distinguish between the critical pathways of risk’*. This discussion has continued and there are categories of disability relating to physical impairment including mobility, vision, hearing and stamina (ADA, 2014), children (Zhao et al, 2016; Wilkinson, 2009; Brandenburg and Regens, 2006; Stokes et al, 2004; White et al, 2002; Henretig et al, 2002), women including pregnancy (Wilkinson, 2009; White et al, 2002), elderly (Wilkinson, 2009; Stokes et al, 2004), existing impairment/illness including immunosuppression (Wilkinson, 2009; White et al, 2002), morbidly obese (Geiling, 2010) and work-related exposure for Responders/Receivers (Wilkinson, 2009).

A previous systematic literature review (Carter and Amlôt, 2016) considered psychosocial aspects of mass decontamination including likely public behaviour; responder management style; communication strategy; privacy/modesty concerns; and vulnerable groups. The conclusion was that psychosocial aspects of incident management (all populations, including vulnerable groups) had received limited attention in decontamination guidance with gaps and inconsistencies between guidance and research evidence. Despite the lack of critical review (no information about the quality of the research), the summary from the included 49 papers offers a different conceptual approach for this topic by categorising mass casualty decontamination by firstly type of casualty and secondly by 4 levels of functional needs (figure 1).

Figure 1. Vulnerable groups by type of casualty and functional needs (Carter and Amlôt, 2016)

Their recommendations included updating guidance to reflect research suggesting that parents may not be best placed to help children and that extra personnel may be helpful. They also recommended that more research was needed about communicating information and understanding the needs of vulnerable people e.g. by asking the individual what will help.

A different approach was taken with the EDEN project (2014) where an assessment protocol was developed to evaluate CBRNe Tools with respect to vulnerable people. The definition of vulnerability was very wide and had 16 defined groups (Figure 2) including reduced mobility, lack of autonomy, ignorance, poor health/illness, high public profile, social marginalisation and obligation towards others.

Figure 2. Specific causes of vulnerability (adapted from EDEN, 2014)

The impact assessment gives 7 levels to consider for services and products. The levels relate to use (inclusive design for impairments); causing offence (language, images, dignity); stigmatisation e.g. by promising during evaluation; lack of consideration (e.g. distributing food that causes an allergic reaction); lack of discrimination (sensitivity) to different levels of ability (e.g. speed of mobility); provision of particular assistance; and increasing the risk e.g. delayed evaluation (lack of inclusive design).

Method

A seven-stage framework was used in line with the PRISMA statement (www.prisma-statement.org) for research question, eligibility (definition), search, identification of relevant papers from title and abstract, selection and retrieval of papers, appraisal and synthesis.

1. Research question

The question addressed in this review is '*what issues are considered (and changes made) for vulnerable groups as part of the CBRNe response for casualty collection, decontamination, triage and casualty clearing processes?*'

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5 **2. Eligibility (inclusion/exclusion)**
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8 References were screened at the first stage by setting the database search parameters to all
9 languages where the paper had an English abstract, (1980-), worldwide (region), adult (age
10 range) and any study type.
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14 **3. Search**
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17 The complexity of the topic proved challenging for the literature search. A string search was
18 run on 13 databases (Medline, Embase, Cochrane Library, Web of Science, Scopus (Elsevier),
19 Chemical Abstracts, Assia (Proquest), Sociological abstracts Proquest), Cinahl, HMIC, Health
20 business elite, PsycInfo (ebSCO), PILOTS (Proquest) and supplemented by other search
21 strategies (e.g. exploding reference lists). The set of keywords were agreed and used in the
22 databases; example searches are shown in figure 3 (Web of Science) and Annex1 (Medline).
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30 *Figure 3. Web of Science search string*
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34 **4. Identification of relevant papers from title/abstract**
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36 References were included if they investigated, reported or reviewed:
37

- 38 • Casualty collection, decontamination, triage, casualty clearing process
 - 39 • Diagnosis, evaluation, decontamination
 - 40 • Hospital as primary site of incident (hot zone)
 - 41 • Triage with respect to clinical presentation differences for vulnerable groups
 - 42 • Physiological differences for children and adults in response to exposure (e.g. skin)
 - 43 • Vulnerable groups:
 - 44 ○ Cognitive impairment
 - 45 ○ Mobility impairment, (including bariatric), wheelchair users, older people
 - 46 ○ Sensory impairment, including vision, hearing
 - 47 ○ Clinical complications (cardiac, respiratory, diabetes, cancer etc.),
 - 48 ○ Pregnancy
 - 49 ○ Lone children
 - 50 ○ Alcohol and recreational drug use
 - 51 ○ Cultural differences, including communication where not in country of first
 - 52 language.
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60 References were excluded if:

- Not available in English language
- Not primary source (where primary source has been included)
- School/community/hospital emergency plans and preparation (not primary site)
- No information about response for vulnerable users
- Post-traumatic stress disorder
- Clinical treatment (anti-viral etc.)
- General reviews and opinions.

5. Selection and retrieval of papers

The search produced 1855 references (Table 1). These were screened by title and abstract and checked for duplication (between databases) resulting in 11 included papers (Table 2).

Table 1. Database searching results

The screening and eligibility stages both reduced the number of references and also added papers by exploring relevant reference lists from individual papers (Figure 4).

Figure 4. PRISMA diagram

6. Appraisal: MMAT checklist

The included references (n=11) were critically appraised using the Mixed Methods Appraisal Tool (MMAT; Pluye et al, 2009; 2014). The MMAT has been validated across qualitative, quantitative and mixed methods empirical studies. It allocates a score from 0-100 (in quartiles) where the overall quality for a mixed methods score cannot exceed the quality of the weakest component. The appraisal score was recorded as strong (100% MMAT), moderate (75% MMAT), limited (50% MMAT), poor (25% MMAT) and no (MMAT 0%) evidence.

Due to the paucity of literature, papers based on professional opinions were included if they:

- Had references,
- Critically (narrative) appraised the literature,
- Provided a new interpretation of the literature.

7. Synthesis

The papers were categorised into 3 phases on CBRNe response: evacuation (Manley et al, 2016); Triage (Lynch and Thomas, 2004; Lyle et al, 2009; Lemyre et al, 2010) and decontamination (Taylor et al, 2008; Mueller, 2005; Heon and Foltin, 2009; Egan and Amlôt, 2012; Abraham, 2014; Waller 2010; Li et al, 2015).

Results

Only 3 papers achieved a quality appraisal score of 50% and over; Manley et al (2016). Taylor et al (2004) and Egan and Amlôt (2012).

Evacuation

Manley, et al (2016; 75%) modelled an evacuation drill from an airport with several scenarios to consider different physical and psychological characteristics for individuals with disabilities. Their findings related to building design with the airport pier configuration raising concerns about timely evacuations; and stairway and exit configurations. They compared the impact of different vulnerabilities on evaluation and reported that people with lower stamina (possibly elderly or frail), wheelchair users, and the visually impaired were at most risk. They summarised the accessibility issues in 3 categories for exit characteristics, route characteristics and obstacle characteristics.

This is important research as it takes a systems approach to consider how building planning and layout can have implications for safety critical but low frequency events.

Triage

None of the papers achieved a score of 50% so no evidence is presented in this section.

Decontamination

A detailed examination of decontamination of ambulant casualties by Egan and Amlôt, (2012; 50%) used empirical data to inform a computer model of the Fire and Rescue Service component of the mass decontamination process after a simulated a large-scale chemical release. Movement data were collected with passive Radio Frequency Identification tags

and detection mats at pre-defined locations. This allowed the identification of flow bottlenecks and the computer model allowed redesigned decontamination configurations to be tested for both ambulance and vulnerable individuals. Recommendations were made to provide at least one additional re-robe section per mass decontamination unit.

A particular focus on communication by Taylor et al (2008; 100%) looked at 3 at-risk populations (n=45) as a review of a Hazardous Materials Casualty Response Plan: deaf with primary communication by sign language; physical disability with English as first language, including wheelchair users; able-bodied with limited English proficiency (first language is Spanish). The field exercise looked at decontamination after a simulated release of Anthrax within a contained area. Data were collected with interviews after the drill and analysed qualitatively with content analysis to give 3 themes: data: communication, disability awareness, and differing expectations. Three main adaptations were made to the decontamination plan: the use of accessible equipment for non-ambulatory individuals (as appropriate), the inclusion of sign language and Spanish interpreters as decontamination staff, and the addition of physical therapists to the decontamination team.

Discussion

The very limited availability of quality research creates challenges for evidence-based service design/practice. At the moment it would be very difficult to deliver robust guidelines beyond the level of professional opinion (consensus) and suggestions to transfer knowledge from other care domains. The research included in this review can be summarized for stages of the incident flow system as evacuation, communication and decontamination. The evidence-based results should be used by practitioners to review current operational policies for vulnerable people and plan future improvements. However, we acknowledge the practical difficulties of generalising recommendations across different response configurations, e.g. cross-professional (including civilian-military) and cross-border (Hancox et al, 2018).

We recommend that these results should be added to the recommendations from Carter and Amlôt (2016) when updating guidance, for example CEN (2013):

- **Evacuation:** Manley et al (2016) found that evacuation for vulnerable groups could be considerably improved with consideration for exit characteristics, route characteristics and obstacle characteristics.
- **Communication throughout the CBRNe response:** Taylor et al (2008) make valuable recommendations about communication (for hearing impairment and language) and managing mobility differences.
- **Decontamination flows:** Egan and Amlôt (2012) provided modelling of decontamination flow with the recommendation that bottlenecks (possibly related to speed of vulnerable groups in decontamination) could be decreased by providing at least one additional re-robe section per mass decontamination unit.

As limited research is available, one option might be to transfer knowledge about the functional needs in the 4 categories from emergency care domains to inform system design of evaluation, triage and decontamination. For example, reduced mobility associated with either/both pre-existing mobility levels and changed mobility related to the MCI.

Professional moving and handling guidelines are available (Smith, 2011) but as part of providing assistance, fire service and ambulance workers may perform tasks that expose them to musculoskeletal risks including adopting awkward postures (Doormaal et al, 1995; Ferreira and Hignett, 2005); moving patients from a bed/trolley to a stretcher (Lavender et al, 2000); and transporting patients down stairs (Studnek et al, 2010; Arial et al, 2014).

Communication issues and social/cultural needs should be informed by current best professional practice recommendations from a range of sources. Information media should use principles of inclusive design (BSI, 2005) for *'services that are accessible to, and usable by, people with the widest range of abilities within the widest range of situations without the need for special adaptation or design'*. This approach could accommodate, for example age-related visual impairments of near focus, visual field, colour perception and response to illumination (less light able to enter the eye and increased sensitivity to glare; Farage et al. 2012).

The limitations of the search process included the use of emerging exclusion criteria. This may have excluded research that would provide more information in some topic areas but it was felt necessary to set a high publication standard for inclusion to generate trustworthy results and recommendations. The MMAT (Pluye et al 2009, 2014) has been validated for different study types and provided a useful categorization approach for critical appraisal,

albeit resulting in only 3 included studies. Future reviews could include papers published in a wider range of languages to include research from non-English sources.

Conclusion

This review has taken a systems approach to consider the research for the CBRNe response process as evaluation, triage and decontamination. Although very little new medium/high quality research is available, the findings are summarised as considerations for building design (route choice and information), communication (including vision, hearing and language differences) and the composition of the response team. It has been suggested that evidence-based practice from other care domains could be considered (patient movement and handling) for fire service and ambulance guidelines.

Table 2. Included papers before Quality Appraisal (75-100% strong evidence, 50% moderate evidence, 25% limited evidence, 0% no evidence)

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Annex 1.

Medline Search strategy

1 exp Bioterrorism/ or exp Chemical Hazard Release/ or exp Biological Warfare/ or exp Chemical
2 Warfare/ or exp Radioactive Hazard Release/ or cbrn.mp. or exp Chemical Warfare Agents/ (40304)
3
4 2 cbrne.tw. (33)
5
6 3 bioterrorism.tw. (3296)
7
8 4 exp Nuclear Warfare/ (4811)
9
10 5 hazardous materials.mp. or exp Hazardous Substances/ (13888)
11
12 6 Hazmat.mp. (147)
13
14 7 biothreat*.tw. (458)
15
16 8 bio-threat*.tw. (30)
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18 9 (bio-hazard* or biohazard*).tw. (717)
19
20 10 (bio-attack* or bioattack*).tw. (10)
21
22 11 "weapons of mass destruction".mp. or exp "Weapons of Mass Destruction"/ (27869)
23
24 12 WMD.tw. (3114)
25
26 13 exp Biological Warfare Agents/ (319)
27
28 14 ((chemical or nuclear or radiological or biological or explosive) adj2 (incident* or accident* or
29 emergenc* or weapon*)).tw. (5683)
30
31 15 (bacterial adj2 (terror* or warfare* or hazard* or disaster* or event* or release* or threat* or
32 accident* or incident*)).tw. (1268)
33
34 16 ((chemical or nuclear or radiological or biological or explosive) adj2 (terror* or warfare or
35 hazard* or disaster* or event* or release* or threat*)).tw. (13265)
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37 17 or/1-16 (77827)
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39 18 casualty*.tw. (9239)
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41 19 victim*.tw. (45951)
42
43 20 patient*.tw. (5772376)
44
45 21 evacuee*.mp. (416)
46
47 22 evacuat*.tw. (18565)
48
49 23 trauma.mp. or "Wounds and Injuries"/ (278778)
50
51 24 subjects.mp. (977038)
52
53 25 sufferer*.mp. (6890)
54
55 26 wound*.tw. (169330)
56
57 27 injur*.tw. (691979)
58
59 28 mass casualties.mp. or exp Mass Casualty Incidents/ (1863)
60
1 mass emergenc*.tw. (72)
2 ((contaminat* or exposur*) adj5 (radiation or radiological or biologic* or chemical*)).tw.
3 (48317)
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5 31 or/18-30 (6997839)
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7 32 planning.mp. or exp Disaster Planning/ (297225)
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9 33 decontamination.mp. or exp Decontamination/ (10514)
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11 34 exp Patient Isolation/ or exp Hospitals, Isolation/ or isolation.mp. (241125)
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13 35 triage.mp. or exp Triage/ (18007)
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15 36 exp Protective Clothing/ or protective suits.mp. (11393)
16
17 37 protective gear.tw. (336)
18
19 38 protective cloth*.tw. (1481)
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21 39 protection.mp. or exp Radiation Protection/ (295108)
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23 40 exp Emergency Medical Services/ or exp Emergency Responders/ or emergenc* respon*.mp.
24 (125641)
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26 41 screening.mp. (509630)
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28 42 logistic*.mp. (301702)

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3 43 exp "Organization and Administration"/ (1295950)
4 44 resource allocation.mp. or Resource Allocation/ (14163)
5 45 action plan*.tw. (5615)
6 46 preparedness.mp. (10125)
7 47 hospital response.mp. (154)
8 48 disaster manag*.tw. (862)
9 49 or/32-48 (2798997)
10 50 vulnerable.mp. or exp Vulnerable Populations/ (69800)
11 51 elderly.mp. or exp Aged/ (2859063)
12 52 old* people.tw. (25538)
13 53 helpless.tw. (1101)
14 54 disabled.mp. or exp Disabled Persons/ (85894)
15 55 deaf.mp. or Deaf-Blind Disorders/ or exp Persons With Hearing Impairments/ (12389)
16 56 blind people.mp. or exp Visually Impaired Persons/ (2584)
17 57 visual* impair*.tw. (10237)
18 58 ((isolated or homeless or illerate or abandon* or neglect*) adj5 (people or person*)).tw. (4028)
19 59 child/ or child, preschool/ or infant/ (2028652)
20 60 child*.tw. (1244835)
21 61 (baby or babies).tw. (63354)
22 62 (minor or minors).tw. (207937)
23 63 pregnant.mp. or exp Pregnancy/ or exp Pregnant Women/ (882214)
24 64 mobility.mp. or exp Mobility Limitation/ (148791)
25 65 exp Chronic Disease/ (255754)
26 66 chronic disease*.tw. (51246)
27 67 long term condition*.mp. (1354)
28 68 carers.mp. or exp Caregivers/ (36065)
29 69 exp Intellectual Disability/ or exp Learning Disorders/ or exp Cognition Disorders/ or exp
30 Developmental Disabilities/ or learning difficulties.mp. (211582)
31 70 politician*.tw. (3064)
32 71 exp Famous Persons/ or public figure*.mp. (20981)
33 72 (obese or bariatric).tw. (118527)
34 73 Obesity/ (165855)
35 74 or/50-73 (6556595)
36 75 17 and 31 and 49 and 74 (908)
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Type of Casualty	
1.	Independent: not seriously injured
2.	Some Support: existing vulnerability which makes it difficult to go through mass decontamination
3.	Full Support: non-ambulant as a result of injuries or existing complaint. Need to be decontaminated by emergency responders
Functional needs	
1.	Physical impairment: unable to undergo decontamination
2.	Communication problems including vision, hearing, comprehension
3.	Different social/cultural neds including cultural and religious norms
4.	Pre-existing health or medical condition and may need medication

Figure 1. Vulnerable groups by type of casualty and functional needs (Carter and Amlôt, 2016)

1. Minors. People under 18 years and young children are vulnerable by virtue of their physical and emotional fragility; and by their lack of awareness of the consequences of their actions.
2. Older people might be less agile and slower to react to audible or visual warnings (may include dementia)
3. Women are marginalised in some societies and can be disproportionately affected including gender-based violence and discrimination.
4. Pregnancy may lead to reduced mobility and a concern for the ingestion of toxins, such as smoke or poisonous gases.
5. Migrants may have a language difference in addition to a possible low status in a society whereby aid or assistance may be delayed/denied.
6. Displaced people might be forced to leave their homes, becoming disadvantaged, overlooked or neglected.
7. People with low incomes might have limited access to computer-based media such as the internet or mobile phones for disseminating information.
8. Illiteracy (unable to read written signage or instructions) will be a disadvantage in an emergency.
9. Isolated people, including homeless people, may lack human support networks possibly leading to lack of traceability following a CBRNe incident.
10. Institutionalised and bedridden people (e.g. hospital patients and prisoners) may have a limited ability to evacuate an area.
11. People with physical impairments (hearing, sight, speech or the use of limbs, wheelchair users) may have a reduced the ability to respond to instructions and follow emergency procedures.
12. People with learning difficulties and those who are mentally ill may not fully understand the situation or take the appropriate decisions regarding their own safety.
13. People with medical conditions (immunocompromised, respiratory impairments/illnesses and allergies) may have their condition exacerbated by airborne pollutants. Illness
14. Carers who are responsible for the welfare of others may be made vulnerable through their concern for their charges (babies, children, older people or animals) and their reluctance to be physically separated from them. They might prioritise the safety of their charges over their own.
15. Emergency service personnel will be exposed to greater risk than the majority of victims.
16. Politicians and other public figures who are generally held responsible for an unpopular policy (foreign or domestic) might become a target for a terrorist attack, and hence vulnerable.

Figure 2. Specific causes of vulnerability (adapted from EDEN, 2014)

TS=(cbn* OR bioterror* OR chemical OR nuclear OR atomic OR radiologic* OR explosive OR radioactive OR biothreat* OR biohazard* OR "weapons of mass destruction") AND TS=(terror* OR hazard OR warfare OR releas* OR disaster OR accident) AND TS=("mass casualt*" OR casualt* or victim* OR evacuee* OR evacuat* OR trauma OR injur* OR "mass emergenc*") AND TS=("disaster plan*" OR "action plan*" OR isolation OR decontamin* OR triage OR "emergency medical" OR "emergency services" OR logistics OR "resource allocation" OR preparedness) AND TS=(vulnerable OR elderly OR child* OR babies OR helpless OR disabled OR pregnant OR expectant OR mobility OR "long term conditions" OR "chronic disease*" OR "learning disorder*" OR obese OR bariatric OR "public figure*" OR "famous people" OR politician*)

Figure 3. Web of Science search string

Database/(Provider)	Date Range	Results
Medline (Ovid SP)	1946-	908
Embase (Ovid SP)	1974-	415
Cochrane Library (Wiley)	All years	37
Web of Science	1970-	80
Scopus (Elsevier)	all	268
Chemical Abstracts	1907-	41
Assia (Proquest)	1987-	2
Sociological abstracts Proquest)	1952-	3
Cinahl	1981-date	49
HMIC	1979-	24
Health business elite	1922-	2
PsycInfo (ebSCO)	1984	22
PILOTS (Proquest)	1871	4
		1855

Table 1. Database searching results

Table 2. Included papers before Quality Appraisal (75-100% strong evidence, 50% moderate evidence, 25% limited evidence, 0% no evidence)

Author	Study type	Aim	Study population	Study design	Key findings
Evacuation					
Manley, M., et al (2016) [USA] (MMAT = 75%)	Model simulation	To determine the extent to which collective behaviour and overall evacuation time of passenger groups is affected by change in the built environment (e.g. large, complex structures)	Model simulation includes physical & psychological capabilities of people with disabilities	Simulation of bomb scenarios	Importance of stationary and exit configuration Inherent weaknesses of pier airport design for timely evacuation Identification of the most vulnerable group of people Particular risks from crowded or complex building interiors for people with disabilities
Triage					
Lyle et al (2009) [USA] (MMAT = 0%)	Professional opinion	To review the planning and triage considerations for prehospital providers caring for children in a mass casualty event	Sentinel events including children	Professional opinion	Summary of lessons learned - Lack of objective assessment of triage tools (e.g. Pediatric Assessment Triage) for disaster triage - No Mass Casualty Triage (MCT) tool specifically for children under 1 year old - Recommends use of JumpSTART for triage - All MCT tools have limitations as none have been validated by outcome data - There is considerable variability in the type of tool used in MCT systems - SALT (See, Assess, Life saving intervention, Treatment/Transport) attempts to incorporate elements from across MXT tools (no information about validation) - Need national standardisation disaster triage protocol
Lemyre, W. et al (2010) [Canada] (MMAT = 25%)	Professional opinion	To use a systems approach to discuss the ripple effects of radiological events on	Children	Professional opinion	Discussion about reframing the notion of vulnerability and to favour a comprehensive risk analysis approach that links risk characterisations to consequence management at both the

		children			physical and psychosocial levels
Lynch & Thomas (2004) [USA] (MMAT = 0%)	Professional opinion	To review general principles of chemical exposure and treatment of specific chemical agents and to identify specific paediatric considerations	Children	Professional opinion	Paediatric triage principles are similar to adult Trauma triage scales have been developed using child-specific criteria but need validation
Decontamination					
Li et al (2015) [Canada] (MMAT = 25%)	Professional opinion	Recommendations on managing children in R/N emergency multi-partner project team	Children	Professional opinion	4 groups of interventions for additional considerations to existing R?N protocols at local, provincial & national level 1. immediate on-site protective actions 2. monitoring & decontamination 3. Medical management 4. Long term follow up
Mueller [USA] (MMAT = 25%)	Professional opinion	Description of decontamination process	Children	Professional opinion	Recommends understanding the physiology and situational needs of children to optimise the survival and outcomes
Egan & Amlôt (2012) [UK] (MMAT = 50%)	Observation	To track the movement of casualties at 2 mass decontamination field exercises using passive RFID to inform a computer model of FRS component of mass decontamination process	Adult Exercise 1: 50 volunteer casualties Exercise 2: 130 able-bodied volunteer casualties	Simulation exercises	Flow control system was ignored or misunderstood during both exercises where casualties walked through the shower to the re-robing section without stopping Recommends changing entry/exit protocol Recommends additional re-robe section for people with disabilities

Waller, (2010) [Canada] (MMAT = 25%)	Observation	Observations including a radiological scenario	NATO exercise involving children	Observational. No information about data collection (photographs) or analysis	CHECK
Heon & Foltin (2009) [USA] (MMAT = 25%)	Professional opinion	Overview of decontamination process	Children	Professional opinion	Children should be categorised into ambulatory and non-ambulatory by age group to allow time to disrobe
Abraham [USA] (MMAT = 25%)	Professional opinion	Review/discussion of 9/11 paediatric response	Children	Professional opinion	Care tips (professional opinion) for paediatric response
Taylor et al (2008) [USA] (MMAT = 100%)		To simulate (drill) exercise to test and revise the Hazmat plan	Adult: 45 People with: physical disabilities (13); deaf (14); limited English proficiency (10) (Spanish speakers), controls (8)	Participate in mock drill, followed by interviews and focus groups. Content analysis resulting in 3 main themes: (1) communication (understanding, barriers, language); (2) disability awareness; (3) differing expectations of decontamination process	Give more information (1) before spraying with cold water; (2) about whether the decontamination process has worked Review design of PPE as design makes verbal and sign language very difficult Provide interpreters in each zone Use bilingual signs and create shower lanes Create groups to allowing copying of actions for deaf and primary language Ask everyone if they have a disability as not all disabilities are visible Ask if people need help with transferring/showering and what is the best method in doing so Try to decrease slippery flooring (wet floors) or allow shoes to be worn where people are transferring Understand that loss of mobility equipment (wheelchair, stick etc.) can make a person feel unsafe (lost independence) Remember physical disability is not the same as cognitive disability

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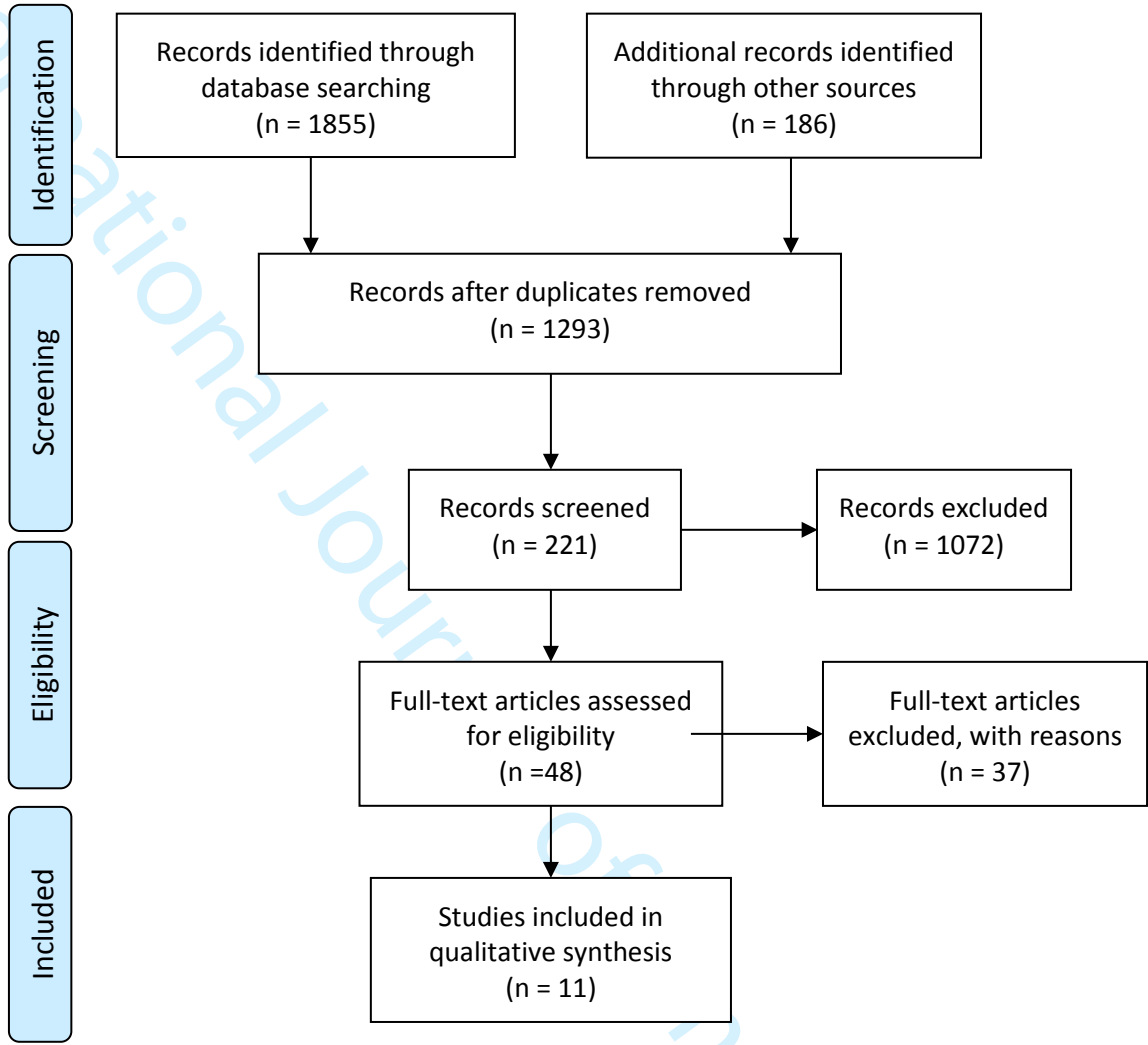


Figure 4. PRISMA diagram

Annex 1.

Medline Search strategy

1 exp Bioterrorism/ or exp Chemical Hazard Release/ or exp Biological Warfare/ or exp Chemical
2 Warfare/ or exp Radioactive Hazard Release/ or cbrn.mp. or exp Chemical Warfare Agents/ (40304)
3 cbrne.tw. (33)
4 bioterrorism.tw. (3296)
5 exp Nuclear Warfare/ (4811)
6 hazardous materials.mp. or exp Hazardous Substances/ (13888)
7 Hazmat.mp. (147)
8 biothreat*.tw. (458)
9 bio-threat*.tw. (30)
10 (bio-hazard* or biohazard*).tw. (717)
11 (bio-attack* or bioattack*).tw. (10)
12 "weapons of mass destruction".mp. or exp "Weapons of Mass Destruction"/ (27869)
13 WMD.tw. (3114)
14 exp Biological Warfare Agents/ (319)
15 ((chemical or nuclear or radiological or biological or explosive) adj2 (incident* or accident* or
16 emergenc* or weapon*).tw. (5683)
17 (bacterial adj2 (terror* or warfare* or hazard* or disaster* or event* or release* or threat* or
18 accident* or incident*).tw. (1268)
19 ((chemical or nuclear or radiological or biological or explosive) adj2 (terror* or warfare or
20 hazard* or disaster* or event* or release* or threat*).tw. (13265)
21 or/1-16 (77827)
22 casualty*.tw. (9239)
23 victim*.tw. (45951)
24 patient*.tw. (5772376)
25 evacuee*.mp. (416)
26 evacuat*.tw. (18565)
27 trauma.mp. or "Wounds and Injuries"/ (278778)
28 subjects.mp. (977038)
29 sufferer*.mp. (6890)
30 wound*.tw. (169330)
31 injur*.tw. (691979)
32 mass casualties.mp. or exp Mass Casualty Incidents/ (1863)
33 mass emergenc*.tw. (72)
34 ((contaminat* or exposur*) adj5 (radiation or radiological or biologic* or chemical*).tw.
35 (48317)
36 or/18-30 (6997839)
37 planning.mp. or exp Disaster Planning/ (297225)
38 decontamination.mp. or exp Decontamination/ (10514)
39 exp Patient Isolation/ or exp Hospitals, Isolation/ or isolation.mp. (241125)
40 triage.mp. or exp Triage/ (18007)
41 exp Protective Clothing/ or protective suits.mp. (11393)
42 protective gear.tw. (336)
43 protective cloth*.tw. (1481)
44 protection.mp. or exp Radiation Protection/ (295108)
45 exp Emergency Medical Services/ or exp Emergency Responders/ or emergenc* respon*.mp.
46 (125641)
47 screening.mp. (509630)
48 logistic*.mp. (301702)

43 exp "Organization and Administration"/ (1295950)
44 resource allocation.mp. or Resource Allocation/ (14163)
45 action plan*.tw. (5615)
46 preparedness.mp. (10125)
47 hospital response.mp. (154)
48 disaster manag*.tw. (862)
49 or/32-48 (2798997)
50 vulnerable.mp. or exp Vulnerable Populations/ (69800)
51 elderly.mp. or exp Aged/ (2859063)
52 old* people.tw. (25538)
53 helpless.tw. (1101)
54 disabled.mp. or exp Disabled Persons/ (85894)
55 deaf.mp. or Deaf-Blind Disorders/ or exp Persons With Hearing Impairments/ (12389)
56 blind people.mp. or exp Visually Impaired Persons/ (2584)
57 visual* impair*.tw. (10237)
58 ((isolated or homeless or illerate or abandon* or neglect*) adj5 (people or person*)).tw. (4028)
59 child/ or child, preschool/ or infant/ (2028652)
60 child*.tw. (1244835)
61 (baby or babies).tw. (63354)
62 (minor or minors).tw. (207937)
63 pregnant.mp. or exp Pregnancy/ or exp Pregnant Women/ (882214)
64 mobility.mp. or exp Mobility Limitation/ (148791)
65 exp Chronic Disease/ (255754)
66 chronic disease*.tw. (51246)
67 long term condition*.mp. (1354)
68 carers.mp. or exp Caregivers/ (36065)
69 exp Intellectual Disability/ or exp Learning Disorders/ or exp Cognition Disorders/ or exp
Developmental Disabilities/ or learning difficulties.mp. (211582)
70 politician*.tw. (3064)
71 exp Famous Persons/ or public figure*.mp. (20981)
72 (obese or bariatric).tw. (118527)
73 Obesity/ (165855)
74 or/50-73 (6556595)
75 17 and 31 and 49 and 74 (908)