DOI:
10.1016/S2215-0366(18)30173-1

Document Version
Peer reviewed version

How to inform the public about protective actions in a nuclear or radiological incident: A systematic review

Louis Gauntlett[1, 2], Richard Amlôt[2], G James Rubin[1]

[1] King's College London, Department of Psychological Medicine, Cutcombe Road, London, SE5 9RJ, United Kingdom.

[2] Emergency Response Department Science & Technology, Public Health England, Porton Down, Salisbury, Wiltshire, SP4 0JG, United Kingdom.

Corresponding Author: Dr G James Rubin, e-mail: gideon.rubin@kcl.ac.uk, telephone: 02078485684

Keywords: Nuclear; Radiological; Radiation; Emergency; Communication; Pre-incident

Abstract

Background/objective How the public behave following a nuclear emergency will help to determine overall levels of morbidity and mortality. Pre-event education might help to shape behaviour, but how best to engage people with emergency communications for low likelihood, high impact events is unknown. We conducted a systematic review to identify factors which predict behaviour in preparation for a nuclear incident; factors which predict behaviour in the immediate aftermath of a nuclear incident; and preferences among members of the public for information designed to educate them about actions to take in the event of a nuclear incident.

Method We searched multiple databases for relevant papers. Papers were included if: they included a sample of the general public, related to an actual or hypothetical radiation incident, explored factors associated with pre- or post-incident behaviour or preferences for information receipt; used self-report or objective outcome data; and were published in English.

Results We included sixteen studies which reported factors associated with preparatory behaviour, 23 for factors associated with post-incident behaviour and 26 studies which examined information preferences. In general preparedness, behaviour was predicted by factors including perceived coping efficacy and having children amongst others, but a lack of preparedness was attributed to fatalistic attitudes. Importantly, for pre-incident communications to be accepted and recommendations adhered to, the source must be trusted and perceived to be credible, though it is notable that family needs, such as collecting children from school, are a stronger predictor of behaviour in a nuclear emergency than communicated directives from authorities.

Conclusions If pre-incident education about nuclear incidents is to be used, a number of factors, including the source and method of communication, as well as the content and format of messaging, may increase public engagement with messages and promote the uptake of protective behaviours in a radiation event.

Introduction

Recent advances in the capability and willingness of terrorists and state actors to use unconventional weapons[1] have raised the spectre of catastrophic attacks against civilian populations. The potential for chemical, biological, radiological and nuclear (CBRN) weapons to generate large numbers of casualties, economic harm and widespread fear unfortunately acts as an incentive[1,2] and reports exist of terrorist groups trying to acquire radiological capability[3] and operating weapon development facilities.[4]

Radiological and nuclear incidents are perhaps the most alarming to the public and emergency planners alike. Catastrophic terrorist attacks, including use of a nuclear device, were identified as amongst the highest priority risks in the 2015 UK National Risk Register[5] and as having the highest impact severity in the 2017 edition, with civil emergencies such as nuclear power plant (NPP) leaks also figuring highly.[6]

If such events happen, public reactions will play a substantial role in determining eventual mortality rates.[7] In one model of a nuclear detonation in Los Angeles, the potential number exposed to harmful radiation fell from 285,000 to 45,000 when people sheltered in even moderately protective buildings.[8] Immediate evacuation following release of radioactive material can result in increased exposure as well as hindering the ability of emergency responders to attend the scene.[9] Other behaviours, such as moving quickly away from windows following the flash of a detonation[10] assembling an emergency supply kit ahead of time[11,12] and (for those near an NPP) collecting potassium iodide (KI) tablets to take in the event of a release[7] are also likely to reduce mortality rates. However, planners have often assumed that panic and lack of knowledge will prevent the public from following instructions on how to protect themselves.[13]

Generic advice has been written about how to communicate health emergency risks with the public. Recent guidelines emphasise, among other things, the need to consider social and cultural influences on risk perception,[14] the importance of understanding personal risk exposure[15] and media relations training for emergency responders.[16] Yet, whether the public are likely to engage in specific protective behaviours during situations likely to create fear is unknown. Whilst practical guidelines do exist[17] little attention has been paid in the literature on how best to communicate with the public about protecting oneself in a radiation event. While the likelihood of a major nuclear emergency remains low, the need to engage in protective behaviours rapidly means that if the public are to be educated about protective behaviour, this must happen before any incident occurs. But will the public attend to messages[18], and what should they say in order to combat fatalism[12] whilst avoiding being considered unnecessarily alarmist?[13] To address these questions, in this systematic review we identify:

1) factors which predict behaviour in preparation for a nuclear incident;

2) factors which predict behaviour in the immediate aftermath of a nuclear incident;

3) preferences among members of the public for information designed to educate them about actions to take in the event of a nuclear incident.

Method

Study Identification We searched Ovid (Embase; Medline), PsycINFO (NICE HDAS), Web of Science and the Emergency Planning College online library (http://epc.cirqahosting.com/HeritageScripts/Hapi.dll/search1) from inception to January 2017. Keywords and MeSH terms were grouped into three categories: nuclear terms and events (e.g. "radiation", "Chernobyl"), radiological terms and events (e.g. "dirty bomb", "Litvinenko") and behavioural terms (e.g. "shelter", "evac*"). The full strategy is shown in the appendix. Searches were conducted up to 31st May 2017. Titles and abstracts were downloaded using Endnote software if potentially relevant. We undertook detailed review of the full text of papers plausibly meeting our inclusion criteria.

Inclusion criteria We used five inclusion criteria. First, only studies which sampled the general public were included. We excluded studies if the population sampled had received occupational training in emergency response procedures.

Second, we included studies relating to actual or hypothetical incidents involving a radiation hazard in which the potential for physical harm was present.

Third, we included studies if they explored factors associated with behavioural response before a radiation incident occurred and/or in the immediate aftermath. Studies were also included if they assessed preferences relating to pre-event or post-event information provision.

Fourth, we included studies if they used self-report (such as questionnaire or interview) or objective methods (such as footfall data) to assess actual or intended behaviour. For information preferences, we included outcomes measured through self-report, objective indices or any related measure.

Fifth, due to resource constraints, we only included papers published in English.

Data extraction Where possible, we extracted data from each study regarding design, type of incident, location, sample, what predictors or correlates of behaviour were studied and outcome assessment.

Risk of bias We appraised the quality of included studies using Downs and Black's[19] checklist.[20,21] This has been validated for assessment of both randomised and observational studies. Items assess:

reporting, external validity, internal validity and confounding. Items not relevant to studies included in this review were not assessed (e.g. blinding). Studies were scored out of twenty-two with a high score equating to high quality. A table of quality assessment scores is given in supplementary materials.

Procedure LG conducted the literature search, application of inclusion criteria, data extraction and quality appraisal with RA and GJR providing consistency checks of a subset of results.

We grouped studies according to the predictors of behaviour that were assessed. Further subdivisions were based on whether incidents were nuclear or radiological, actual or hypothetical, and whether the study used a quantitative or qualitative approach. Differences in outcomes between studies relating to accidental nuclear facility radiation emergencies and deliberate detonation of nuclear or radiological devices are explicitly mentioned where these were apparent.

For quantitative studies we extracted effect sizes where possible, and used a narrative approach to their synthesis. We used meta-ethnography to synthesise qualitative studies.[22] This involves induction and interpretation of original data across a seven-step process allowing for building of a 'comparative understanding'.[23] This process allowed for identification of the clearest categorises within which outcomes are reported.

Prospero registration This review was registered with Prospero on 20/01/2017 and was added to the Prospero database on 23/01/2017. Registration number: CRD42017055664.

Role of the funding source The research was funded by the National Institute for Health Research Health Protection Research Unit (NIHR HPRU) in Emergency Preparedness and Response at King's College London in partnership with Public Health England (PHE), in collaboration with the University of East Anglia and Newcastle University. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR, the Department of Health or Public Health England.

The funders played no role in the writing of manuscript or decision to submit it for publication.

The authors have not been paid to write this article by a pharmaceutical company or other agency.

The corresponding author had full access to all the data in the review and had final responsibility for the decision to submit for publication.

Results

Search results We identified 9480 records by database searching. Following de-duplication, another 155 were identified from forward-citation and reference list searching of included papers, the behavioural science database at Public Health England and the Emergency Planning College library.

Outcomes from four studies were reported across multiple papers.[24–26,27–28,29–31,32–33] Therefore, while the total number of papers included was 41, the total number of studies included was 31.

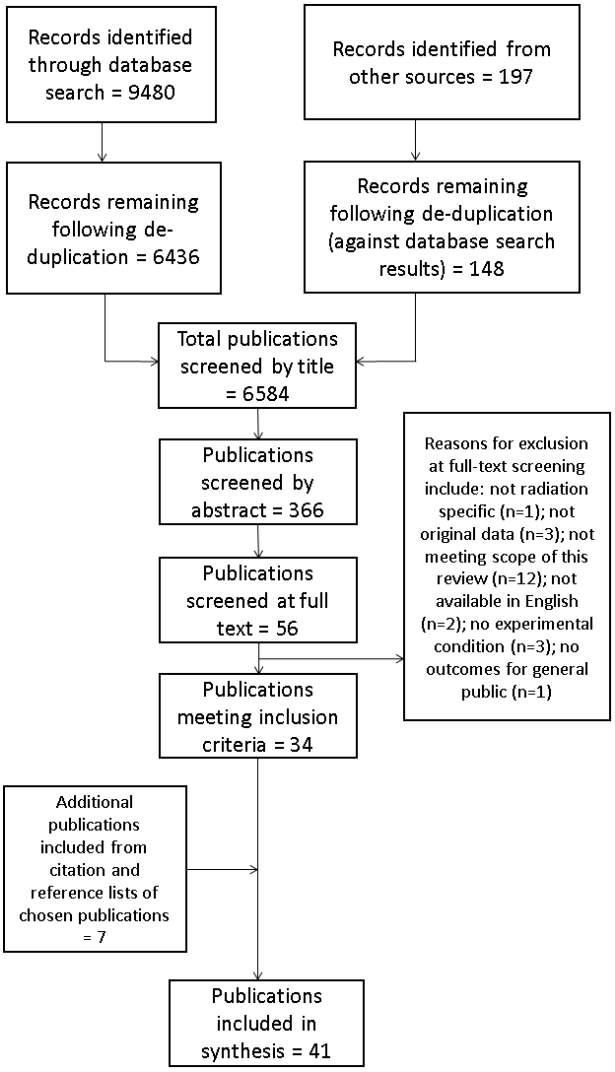

Figure 1 – PRISMA flow diagram of study selection

Study characteristics Thirty-three papers reported outcomes of quantitative methods, three used qualitative methods, three used a mixed methods approach and two employed an experimental design. Twenty-four studies were undertaken with US or Canadian populations and 11 with European populations. The remaining studies six were conducted in Japan and Australia.

Nineteen articles (based on 13 studies) presented data on behavioural responses to real emergencies (including the Fukushima and Three Mile Island leaks) or events such as mass distribution of iodine prophylaxis, while 23 concerned hypothetical situations. See tables 1-3.

Quality Assessment Other than two papers, those using qualitative methods tended to score poorly for methodological robustness, with quantitative studies receiving a mixed range of scores. Studies generally scored poorly for adequate adjustment for confounding variables, quality of reporting, description of the distribution of principal confounders, and estimates of random variability. A number of studies using quantitative methods failed to report probability values. Studies scored particularly highly for the clarity of study aims and findings, and for selecting participants from the same population.

Predictors of behaviour in preparation for a radiation emergency

16 studies reported factors associated with preparatory behaviour (see Table 4 for details).

Information seeking

One high quality survey[34] identified several cognitive factors associated with information seeking about nuclear emergencies, specifically the perceived probability and likely personal impact of an incident, one's perceived ability to cope, and worry. Perceptions of government or front-line preparedness were not associated with information seeking. In a study of people in the vicinity of Three Mile Island, information seekers were found to be more highly educated but were not necessarily those reporting the most worry.[29]

Preparedness

Individual aspects of preparedness behaviour (such as compiling a first aid kit or supplies) have been variously associated with being older, a resident of rural areas, having higher education,[35] and with the perceived probability of an incident, coping efficacy, perceived front-line preparedness, and worry.[34] Few preparedness actions were found in residents near a nuclear facility who believed the site to be safe, but that in an emergency there would be no time to evacuate.[36]

Mixed evidence was found for predictors of evacuation and sheltering preparedness, with preparedness being associated with having children under 18, whilst barriers to preparedness included denial/unwillingness and feeling unable to plan for the unknown/fatalism.[37,38]

Collection and potential use of KI was explored solely in studies of nuclear facility leak preparedness measures. One study found only 5% of almost 80,000 people living within ten miles of three Michigan NPPs collected free iodine via a voucher system. Non-collectors had planned for a nuclear plant emergency to a lesser extent than collectors. Stated reasons for collection included preparedness (58%), safety (18%), the fact that it was free (14%), and because it was recommended (13%). Reasons for non-collection included lack of awareness (36%), not receiving a voucher (12%), being 'uninterested' (7%) and feeling it unnecessary (4%).[39] In an experiment, no difference was found between a standard nuclear safety leaflet and one supplemented with extra information about state-level preparedness in terms of how frequently they were kept or read by households which received them.[40]

Adherence to evacuation recommendations

Two studies of evacuation behaviour found pre-incident warnings of an impending nuclear attack would prompt 66% to leave, rising to 73% if warnings intensified such as via presidential message,[41] in contrast to 18%-19% for a radiological dispersal device (RDD) attack, rising to 24% if warned by a 'top local official'.[38] Significantly fewer would evacuate if they learnt an actual attack was in progress.[41]

Predictors of behaviour immediately following a radiation emergency

23 studies tested factors associated with post-incident behaviour (see Table 5 for details).

Information seeking

Among British nationals living near Fukushima uncertainty about exposure to radiation or its hidden effects was found to cause distress and anxiety which were in-turn associated with heightened information-seeking behaviour.[42]

Adherence to evacuation recommendations

The leak at Three Mile Island resulted in self-evacuation of 54% of the entire local population following an advisory that pregnant women and children should leave.[43] Self-evacuees were more likely than those who remained to have attained high school education and be parents.[31]

The likelihood of evacuating decreased with age, increased with household size and a significant association existed between behaviour and behaviour of neighbours. Stated reasons for evacuating were having received the advisory to do so (68%), fear of harm (46%), confusion (41%) and anticipation of a broader evacuation order with associated problems such as traffic gridlock (8%).[43] Three lower quality studies noted situational danger (cited by 30% and 91%) or concerns around forced evacuation (14% to 76%).[32,33,44] Reasons for non-evacuation were low perception of danger,

fear of looting, waiting for an order for the general public to evacuate and believing oneself to be at a safe distance.[32,33,43,44] Receiving conflicting reports was cited as both a reason to, and not to evacuate.[44] Conflicting evidence exists as to whether close proximity to an NPP promotes or deters evacuation.[45-47] Two reasonably robust papers and a third less so found actual (from Fukushma[26]) and anticipated[46] evacuees were more likely to be families with children under 19 and internet users.[25]

Similar findings have been reported in studies assessing intended evacuation in hypothetical scenarios involving deliberate attacks. Here, factors promoting anticipated evacuation have included: official announcements, news coverage, having children under 18[41] and perceived likelihood of harm.[48] A majority of parents (55%) reported they would attempt to collect children from school during an incident even if knowledgeable about school evacuation plans and their children's location.[41]

Adherence to sheltering recommendations

Participants in three qualitative studies regarding radiation attacks (two of high quality and concerning RDD detonation) found sheltering recommendations counterintuitive, reducing their likelihood of adherence.[49-51] Trust in information source, perception and knowledge of the issue, checking information with trusted others (such as family and friends), family needs[51] and receiving a leaflet which included decontamination information[50] tended to increase adherence. A fourth study noted reduced adherence to sheltering in ethnic minority groups following a deliberate attack due to a desire to gather the family together before attempting to evacuate.[52]

Studies using quantitative methods found 8% within 50 miles of an NPP[53], 23% within 20km[54] and 33% in the US capital region[45] were unlikely to comply with sheltering instructions in a nuclear emergency; 11%[55] to 15·5%[37] in an RDD incident. Six studies,[36-38,53-55] three of high quality, found prioritising collection or checking on children or other family members was a primary reason for non-adherence in both nuclear accident and deliberate attack scenarios. Anticipated adherence would increase if people were able to communicate with, or know that loved ones were safe[55] or if they believed that food and water would be delivered[37,38] in scenarios involving a deliberate attack. Further reasons for non-adherence with sheltering advice in both scenario types were low confidence or trust in community or government preparedness planning, feeling safer elsewhere, and to get supplies.[45,53,55] Two studies of RDD detonation response[37,55] found adherence with sheltering recommendations was predicted by community attachment, being over 65 and trusting the information source. Adherence with sheltering-at-work was 39%[37] and was higher in those aware of their building's sheltering arrangements or those confident in their community's ability to manage an RDD attack.[38]

Preferences for information in the event of a radiation incident

26 studies examined information preferences (see Table 6 for details).

Information seeking

Choice of information source Two studies explored preferred pre-incident information sources, finding leaflets to be preferred by 62% of residents within 3km of an NPP[36] and that residents of the US capitol region preferred local television and radio (25% and 21% respectively), general internet searching (28%) and family/friends (24%/21%) for RDD information.[38]

Two high quality focus group studies found preferred information sources during a nuclear attack would be the media (television/radio), internet, national level experts, word of mouth, emergency broadcast systems and local authorities,[52] while young males would also seek out their peers.[51]

Seven further studies explored sources during a radiation emergency using quantitative methods; high quality reports found friends or family, first responders,[12] local or national media[56] and internet news/government websites[37] were preferred. These findings are supported by four less robust surveys.[24,53,57,58] In an RDD emergency television network news and news or government websites were preferred; while social media, healthcare providers and the CDC were preferred by fewer than 2%.[38]

Pre-incident nuclear information was found to be confusing and unclear in two studies (focus groups[52]; experimental design[40]). For example, participants did not fully understand the terms, 'shelter-in-place' and 'plume'. Low-literacy participants given literacy aided materials reported increased ability to carry out instructions.[59] An intervention leaflet was preferred to an existing nuclear safety leaflet due to greater ease of understanding, being more informative, offering a pin-up summary, and using preferred pictures and layout.[40] Studies using focus groups and RDD scenarios found leaflet length, density and complexity, lack of illustrations, accessibility for disabilities[60] and recommendations without explanation[50] to be criticisms, whilst a live voice delivering messages was preferred to a recording during an incident.[49]

Preferences for information content Pre-incident, 77% of the US public expressed interest in knowing government and community RDD response plans[55] whilst 77% of participants presented with a scenario in which radiological materials were found in possession of terrorists would seek health-related information.[60]

Following the incident at Three Mile Island,[43] some (number not reported) sought information on impact, whilst British nationals in Japan made requests for more information, consistency, clarity and regular updates during the Fukushima disaster.[42] In a hypothetical nuclear emergency, guidance on countermeasures and food safety would be sought by 86% of Italian respondents.[58]

One focus group study using a hypothetical RDD emergency found desired information to include protective actions, water/food contamination, actions of authorities and requests for behavioural recommendations according to how close someone was to the site of the incident.[50]

Perceived credibility of information source

Multiple studies explored trust and credibility. Their results varied: UK non-governmental sources,[60] scientists (also rated most competent alongside authorities[61]) and the US President[38] all tended to be rated as most trustworthy, followed by local public health departments[53] and national news/media.[37,57] Least trusted were US national media and local authorities,[38,51] nuclear industry,[61] local religious leaders and government.[37,57]

In general, increased trust was associated with consistency between messengers and messaging from authorities, such as expert medical advice[50], whilst perceived reliability was associated with the use of basic terminology,[30] and increased confidence with recommended protective actions having been proven effective.[52] A series of studies demonstrated that acceptance of information during an incident was predicted by one's level of agent-specific knowledge, trust in the message source, [27,62] whether the disaster is assumed to have low potential to cause personal harm and being from a directly affected population.[28]

Regarding information preferences of different subgroups, Bass[63] found low literacy (mostly ethnic minority) survey respondents fell into three categories based on their perceptions of information sources and anticipated adherence: those most likely to trust that information is accurate and to adhere to sheltering instructions despite believing that authorities are unlikely to provide them with the same level of support as they do others; those least likely to adhere or prepare out of distrust in authorities and their information and; those likely to adhere to sheltering instructions given by local, but not national sources.

Discussion

How the public would behave immediately following a catastrophic nuclear or radiological incident is uncertain. For example in a hypothetical RDD or nuclear scenario most people in the US capital region report that they would shelter-at-home or in their workplace.[38,45] whereas actual nuclear incidents have seen self-evacuation to be common, particularly among those receiving information felt to be confusing or unclear.[40,52] Given the likely link between behaviour and the overall health effects of a nuclear incident, encouraging protective behaviours should be a priority. Recommendations are listed in box 1.

Encouragingly, rates of information seeking suggest a desire amongst the public to learn protective actions.[34,50,52,55,58,60] This includes a wish to understand pragmatic issues, many of which could only be addressed after the specifics of an incident are understood. Some aspects could be addressed prior to any incident, however. In particular, studies of public communication around NPP emergencies display a desire to better understand risk (such as of the event happening) whilst regarding a deliberate attack there is a clear desire to understand threat (such as the likelihood of harm coming to those not directly affected). Immediately following the Fukushima emergency, for example, more than one-third of questions posed over the internet sought radiation-related knowledge.[64]

Yet are the public receptive to messages about radiation or protective behaviour in advance of an incident occurring? Theories surrounding the uptake of protective behaviour in other contexts suggest that certain pre-requisites may be required before messages are attended to or acted on, including a degree of perceived threat and a perception that the recommended behaviour may be effective.[65] In the absence of such conditions, information campaigns may be ignored or quickly forgotten.[18] In contrast, public information campaigns can increase knowledge,[59,66] which may increase receptivity to future messages when a threat becomes more apparent.[27] Certainly, in the literature we have reviewed, perception of risk appears to be an important predictor of behaviour, influencing: acceptance of messages,[28] taking preparatory measures (fewer in those with high radiation risk perception),[36] self-evacuation[48] and information seeking.[60] Communicating with the public while perceptions of risk are low may result in messages being ignored. Nonetheless, if pre-incident communication is to be used, our results do offer guidance regarding what information should be given and how it should be conveyed.

Source and Method

A trend for greater preference for traditional media sources exists for pre-incident information relating to NPP emergency preparedness than for attack scenarios, whereas more would seek information using the internet if an attack were to occur. However, the shift towards public preparedness against catastrophic terror in the risk communication literature, precipitated by the WTCD attacks in 2001 coincided with the rise of the internet and social media. Changes over time in communication technology inevitably raise questions about applicability of older findings to the current context. Nonetheless the general point raised by many studies would seem to remain true: people will seek information from sources they trust.

Receiving messages from trusted sources was highlighted in multiple studies, though opinions inevitably differed as to who is trusted. A comparison of sources[61] found government authorities were viewed as most credible (and were a preferred pre-incident source[24,37,38,53,57,58]), although scientists were considered more trustworthy and equally competent as nuclear industry. The nuclear industry,

despite being perhaps best placed to provide information regarding radiation safety, appear least trusted to do so. If an incident were to occur, the public also want to hear from sources with knowledge particular to them and their area, such as local media, local authorities or friends and family, suggesting a primary concern in knowing how personally affected they might be as opposed to the national situation.

Given this heterogeneity, perhaps the best that can be recommended is the old adage of multiple sources 'speaking with one voice'; having messages endorsed by multiple experts and agencies increases the chances of them being accepted[17]. In today's media climate this approach may be difficult to achieve. In many instances, the media actively seek out opposing views,[67] oftentimes subjective in nature,[68] which increases distrust of scientists and public health messages.[69] The finding that scientists appearing on national media lost credibility[60] highlights this point. It is perhaps unrealistic to expect one-voice communication to occur in an incident of this nature. The 2018 false alert of a nuclear attack in Hawaii is an example in which the authoritative voice was one of many and was arguably lost amongst social media feeds. This perhaps supports the apparent need for corroboration of information from peers.[51] Ideally, different endorsements are needed for different groups. For example, one high quality study[51] conducted with low-income residents of urban areas found most trust in local media and a need to have an established community spokesperson endorse authority recommendations further.

Content and format

Two experiments were included in this review both of which found clarity and ease of understanding were commonly requested both pre- and during incident messaging. This is a pressing concern amongst low literacy individuals who may require decision aided materials which would improve knowledge of actions and intention to adhere to sheltering instructions as was the outcome of one experiment.[59] However, this was also expressed within the wider public. Consistency in messages within and across sources is also desirable and associated with adherence to recommendations.[32,33,51] Inevitably, substantially more information is desired immediately following an incident than pre-incident, relating to issues such as food and water contamination,[58] actions of authorities and recommendations specific to where the individual is at that time,[50] as well as regarding the likelihood of further attacks.[60]

The other experiment, a study of the effectiveness of a pre-incident communications leaflet[40] found advisories best recalled were arguably those with the most personal impact on the recipient, such as not collecting children from school and not using mobile phones. Instructions less well recalled (e.g. to take KI if told to) are perhaps considered out-of-the-ordinary in terms of activities undertaken regularly or are ones not previously considered. Other criticisms of leaflets such as excessive length,

density and complexity, lack of illustrations, accessibility issues for disabilities and recommendations backed up by facts without explanations represent potential barriers to the reception of information; however, whilst recall of certain advisories increased with a developed leaflet, no significant difference in intended adherence or understanding was found.

Several instances of apparent fatalism hindering the likely uptake of messages were found. For example, many individuals living close to an NPP felt that preparing for an emergency was not worthwhile since they would not have time to evacuate[36] and were disinterested in collecting free KI.[39] To encourage preparedness, pre-incident communications should provide information regarding the efficacy of the suggested behaviour. This may require a degree of education about the nature of radiation, the mechanism underlying the benefits of KI, conditions under which evacuation or sheltering would be appropriate and how people might be informed as to which action is recommended depending on the nature of the incident.

Greater detail in communications regarding the processes that exposed survivors might experience, such as an explanation of decontamination procedures,[50] may increase adherence. Adherence to recommendations will likely increase if the public can be reassured, for example, that food and water can be delivered to them whilst sheltering[47] or that they can be evacuated to somewhere where support will be offered. This extends to psychological support.[36]

In addition to neighbours and friends influencing behavioural responses, with individuals looking to the actions of others to inform their own decisions, family needs are fundamental in shaping actions, with several studies[33,38,41,43,48,50,54,55] identifying a desire to collect children from school and make contact with loved ones, even at the expense of increasing exposure to radioactive material. This latter phenomenon has been observed in previous non-radiological incidents[18] and must be addressed in pre-incident communications, perhaps by providing parents with information as to what the responsibility of schools are in protecting children.

Gaps in understanding

A number of gaps emerged from the literature that appear central to our understanding of effective public communication in the pre-incident phase. One gap relates to use of social media in radiation emergency communications. Social media is likely used by a large number who would choose the internet as a source and method of information gathering following an incident. It is unclear at this stage to what extent social media could be used to disseminate and promote pre-incident public education for radiological and nuclear emergencies. Secondly, more data is needed on how different information sources can foster trust in the public. Trust is central to whether information is accepted and recommended actions adhered to. Previous studies have largely quantified levels of trust in sources and few have explored the facilitation of trust, or distrust.

The longer-term impact of any information campaign is a third key knowledge gap. Hopefully, any pre-event messages that are disseminated will never need to be used. However, maintaining knowledge over time is important. To date, studies have generally only focused on the immediate impact of messages. Whether messages about high impact events which later do not come to pass have a wider, detrimental, effect on the credibility of future messages on related issues is also unknown.[70] This presents a challenge for communicators, and the frequency with which messages need to be repeated and reinforced is an area worthy of further investigation.

Limitations

Relatively few studies included in this review provided evidence about actual observed behaviour. Those that were available often suffered from methodological deficits, possibly related to their reactive nature and the need to begin research promptly during the immediate period following an emergency. It was therefore necessary to include anticipated behavioural responses from hypothetical scenarios in drawing our conclusions. Arguably, studies using hypothetical scenarios are flawed: how can members of the public be expected to know how they would react or what information they would want in such extreme circumstances? A possible counter to this is that many studies used well researched and realistic injects in their studies; yet the difference between viewing a news report of a real attack taking place versus watching it from the comfort of a focus group is inescapable. In exploring anticipated adherence and information needs in a radiation emergency, hypothetical studies make up the majority of research in this area. Though the methodological quality of hypothetical scenario studies in this review was stronger than that of studies from actual events in most instances, this limitation must be considered in our interpretation of results.

One observation of study quality was the absence of effect sizes reported for some studies using quantitative methods. This made comparison between study outcomes difficult, allowing us to judge only whether findings were generally in the same direction. Future research in this area should address this in order to ensure direct comparison can be made between populations.

The literature would also benefit from variation in the populations studied: few studies explored information preferences across populations with potentially differing information needs. In addition, few studies used mixed methods; meaning information gathered regarding potential predictors of behaviour (such as using focus groups) were not explored further in terms of strength of predictors.

Finally, available resources meant that we could only include studies published in English in our review. There are likely to be studies conducted in other countries that have experienced nuclear incidents or a nuclear threat (e.g. Japan and South Korea) where efforts to prepare the public have been ongoing for some time. A future review should seek to identify studies published in languages

other than English, focusing particularly on countries that have been observed to implement pre-incident public information campaigns.

Conclusion

Ultimately, the decision to use pre-incident communication regarding protective behaviours for use in such a high impact, low likelihood event is likely to be a political one. Our review highlights a number of factors that could increase engagement with key messages, and promote the uptake of protective behaviours and emergency interventions that will save lives in the unlikely event of a catastrophic radiation emergency. Without consideration of best practice in pre-incident public communication for radiation emergencies a catastrophic incident could become worse than we currently fear; it is essential that we plan for this.

Authors' contributions

LG conducted the literature search, application of inclusion criteria, data extraction, quality appraisal and wrote the first draft. GJR and RA checked the application of the inclusion criteria and data extraction and contributed to subsequent drafts.

Declaration of interests

The authors listed above certify that they have no affiliations with or involvement in any organisation with any financial or non-financial interest in the subject matter or materials in this manuscript.

References

1 North Atlantic Treaty Organisation (NATO). Fighting weapons of terror. 2015. http://www.nato.int/cps/en/natohq/news_122272.htm). Accessed: 6th February 2017.

2 Mazzone A. The Use of CBRN Weapons by Non-State Terrorists. *Global Security Studies* 2013; **4**(4): 23–30.

3 Shuster S. Inside the Uranium Underworld: Dark Secrets, Dirty Bombs. http://time.com/magazine/ published: 6th April 2017.

4 Meulenbelt S E, Nieuwenhuizen M S. Non-State actors' pursuit of CBRN weapons: From motivation to potential humanitarian consequences. *International Review of the Red Cross* 2015; **97**(899): 831–58.

5 Cabinet Office. National Risk Register (NRR) of Civil Emergencies and Emergency Planning. https://www.gov.uk/government/publications/national-risk-register-for-civil-emergencies-2015-edition.

6 Cabinet Office, National Security and Intelligence. National Risk Register (NRR) of Civil Emergencies and Emergency Planning. https://www.gov.uk/government/publications/national-risk-register-of-civil-emergencies-2017-edition.

7 Khripunov I. Involving the public in nuclear terrorism preparedness: Reflections on the Washington Nuclear Summit. *Bulletin of the Atomic Scientists* 2015; **66**(4): 33–41.

8 Buddemeier B. Reducing the consequences of a nuclear detonation: Recent research. *The Bridge (Nuclear Dangers)* 2010; **40**(2): 28-38.

9 Sugimoto T, Shinozaki T, Naruse T, Miyamoto Y. Who was concerned about radiation, food safety, and natural disasters after the great East Japan earthquake and Fukushima catastrophe? A nationwide cross-sectional survey in 2012. *PLoS ONE* [Electronic Resource] 2014; **9**(9): e106377. doi: https://doi.org/10.1371/journal.pone.0106377

10 Buddemeier B, Dillon M. Key response planning factors for the aftermath of nuclear terrorism. Report for Lawrence Livermore National Laboratory: August, 2009.

11 Ablah E, Konda K, Kelly L. Factors predicting individual emergency preparedness: a multi-state analysis of 2006 BRFSS data. *Biosecur Bioterror* 2009; **7**(3): 317–30.

12 Taylor M, Young W, Griffin B, et al. The public and a radiological or nuclear emergency event: threat perception, preparedness, and anticipated response. *Aust J Emerg Manage* 2011; **26**(1); 8–39.

13 Preston J, The strange death of UK civil defence education in the 1980s. *History of Education* 2014; **44**(2): 225–42.

14 Communicating risk in public health emergencies: a WHO guideline for emergency risk communication (ERC) policy and practice. 2017; World Health Organisation: Geneva.

15 Rubin G J, Amlôt R, Page L. The London polonium incident: lessons in risk communications. *Health Physics* 2011; **101**(5); 545-50.

16 Glik D C. Risk communication for public health emergencies. *Annual Review of Public Health*, 2007; 28; 33-54.

17 Communication with the Public in a Nuclear or Radiological Emergency. 2012; International Atomic Energy Agency: Vienna.

18 Rubin G J, Brewin C, Greenberg N, Simpson J, Wessely S. Psychological and behavioural reactions to the bombings in London on 7 July 2005: cross sectional survey of a representative sample of Londoners. *BMJ* 2005; **331**(7517); 606.

19 Downs S H, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J. Epidemiol. Community Health* 1998; **52:** 377–84.

20 Deeks J J, Dinnes J, D'Amico R, et al. Evaluating non-randomised intervention studies. *Health Technology Assessment* 2003; **7**(27).

21 Pettigrew M, Roberts H. *Systematic Reviews in the Social Sciences: A Practical Guide*. Blackwell: Massachusetts 2006.

22 Noblitt G, Hare R. *Meta-ethnography: Synthesizing qualitative methods*. Sage: Newbury Park, CA 1988.

23 Barnett-Page E, Thomas J. Methods for the synthesis of qualitative research: a critical review. *BMC Medical Research Methodology* 2009; **9**(59).

24 Kanda H, Takahashi K, Mizushima S, Koyama K. Comparing acquisition of radiation health knowledge and preventive behavior of working adults during and after the Fukushima disaster. *Disaster Med Public Health Prep.* 2013; **7**(4): 431–32.

25 Kanda H, Takahashi K, Sugaya N, Mizushima S, Koyama K. Internet usage and knowledge of radiation health effects and preventive behaviours among workers in Fukushima after the Fukushima Daiichi nuclear power plant accident. *Emerg Med J.* 2013; **31**(e1): e60-65.

26 Kanda H, Sugaya N, Takahashi K, Mizushima S, Koyama K. General workers living with younger children in Fukushima performed more preventive behavior against radiation during and after the nuclear disaster. *Asian Pac J Cancer Prev.* 2013; **14**(11): 6893–97.

27 Perko T, Železnik N, Turcanu C, Thijssen P. Is knowledge important? Empirical research on nuclear risk communication in two countries. *Health Physics* 2012; **102**(6): 614–25.

28 Perko T, Thijssen P, Turcanu C, Van Gorp B. Insights into the reception and acceptance of risk messages: Nuclear emergency communication. *J Risk Res.* 2014; **17**(9): 1207–32.

29 Prince-Embury S. Information seekers in the aftermath of technological disaster at Three Mile Island. *J Appl Soc Psychol.* 1991; **21**(7): 569–84.

30 Prince-Embury S. Information attributes as related to psychological symptoms and perceived control among information seekers in the aftermath of technological disaster. *J Appl Soc Psychol.* 1992; **22**(14): 1148–59.

31 Prince-Embury S. Psychological symptoms as related to cognitive appraisals and demographic differences among information seekers in the aftermath of technological disaster at Three Mile Island. *J Appl Soc Psychol.* 1992; **22**(1): 38-54.

32 Perry R W. Citizen Evacuation in Response to Nuclear and Nonnuclear Threats. 1981. (Report No. BHARC-81/013).

33 Perry R W. Population evacuation in volcanic eruptions, floods, and nuclear power plant accidents: Some elementary comparisons. *J Community Psychol.* 1983; **11**(1): 36-47.

34 Lee J E C, Lemyre L. A social-cognitive perspective of terrorism risk perception and individual response in Canada. *Risk Analysis* 2009; **29**(9): 1265–80.

35 Lemyre L, Lee J E C, Turner M C, Krewski D. Terrorism preparedness in Canada: A public survey on perceived institutional and individual response to terrorism. *Int J Emerg Manag.* 2007; **4**(2): 296–315.

36 Malešič M, Prezelj I, Juvan J, Polič M, Uhan S. Evacuation in the event of a nuclear disaster: Planned activity or improvisation? *Int J Disaster Risk Reduct.* 2015; **12**: 102–11.

37 Williams M T, Saathoff G B, Guterbock T M, MacIntosh A, Bebel R. *Community Shielding in the National Capital Region: A Survey of Citizen Response to Potential Critical Incidents*. 2005. Retrieved 13th April 2017 from the Critical Incident Analysis Group, University of Virginia, Center for Survey Research: https://med.virginia.edu/ciag/wpcontent/uploads/sites/313/2015/12/community_shielding_report_body.pdf

38 Guterbock T M, Lambert J H, Bebel R A, Ellis J M, Kermer D A. *Population Behaviors in Dirty Bomb Attack Scenarios: A Survey of the National Capital Region*. 2010. Retrieved 12th April 2017 from U.S: Virginia: http://www.vaemergency.gov/wp-content/uploads/drupal/VDEM%20Report.v2.pdf

39 Zwolinski L R, Stanbury M, Manente S. Nuclear power plant emergency preparedness: results from an evaluation of Michigan's potassium iodide distribution program. *Disaster Med Public Health Prep* 2012; **6**(3): 263–9.

40 Hellier E, Edworthy J, Newbold L, Titchener K, Tucker M, Gabe-Thomas E. Evaluating the application of research-based guidance to the design of an emergency preparedness leaflet. *Applied Ergonomics* 2014; **45**(5): 1320–9.

41 Nasar J L, Greenberg M L. The preparedness and reactions of citizens to warnings and crisis relocation for nuclear attack. *J Appl Soc Psychol* 1984; **14**(6): 487–500.

42 Rubin G J, Amlôt R, Wessely S, Greenberg N. Anxiety, distress and anger among British nationals in Japan following the Fukushima nuclear accident. *Br J Psychiatry* 2012; **201**(5): 400–7.

43 Cutter S, Barnes K. Evacuation behavior and Three Mile Island. *Disasters* 1982; **6**(2): 116–24.

44 Houts P S, Miller R W, Takuhata G K, Ham K S. Health-Related Behavioral Impact of the Three Mile Island Nuclear Incident. Report Submitted to the TMI Advisory Panel On Health Research Studies of The Pennsylvania Department of Health, Part 1. 1980. Retrieved 2nd May 2017 from the Pennsylvania State University, College of Medicine website: https://archive.org/details/healthrelatedbehOOhout

45 Miller I S. Dispositional and situational variables related to evacuation at Three Mile Island. *Dissertation Abstracts International* 1981; **42**(5-B): 2071.

46 Zeigler D J, Johnson J H. Evacuation Behavior in Response to Nuclear Power Plant Accidents. *The Professional Geographer* 2010; **36**(2): 207–15.

47 Pheby D, Robinson P. Public health: Nuclear accidents: How people react. *Health Visitor* 1990; **63**(4): 119–21.

48 Gerber B J, Ducatman A, Fischer M, Althouse R, Scotti J R. The Potential for an Uncontrolled Mass Evacuation of the DC Metro Area Following a Terrorist Attack: A Report of Survey Findings. 2006. Retrieved 12th April 2017 from U.S: Virginia: https://www.researchgate.net/publication/315800462_The_Potential_for_an_Uncontrolled_Mass_Evacuation_of_the_DC_Metro_Area_Following_a_Terrorist_Attack_A_Report_of_Survey_Findings_The_Potential_for_an_Uncontrolled_Mass_Evacuation_of_the_DC_Metro_Area_F

49 Oak Ridge Institute for Science and Education. *Formative Research IND Message Testing with the General Public. 2011.* Oak Ridge Associated Universities (ORAU). U.S: Tennessee.

50 Rogers M B, Amlôt R, Rubin G J. The impact of communication materials on public responses to a radiological dispersal device (RDD) attack. *Biosecur Bioterror*2013; **11**(1): 49-58.

51 Bass S B, Greener J R, Ruggieri D, et al. Attitudes and perceptions of urban African Americans of a "dirty bomb" radiological terror event: results of a qualitative study and implications for effective risk communication. *Disaster Med Public Health Prep* 2015; **9**(1): 9-18.

52 Becker S M. Emergency communication and information issues in terrorist events involving radioactive materials. *Biosecur Bioterror*2004; **2**(3): 195-207.

53 Nyaku M K, Wolkin A F, McFadden J, et al. Assessing radiation emergency preparedness planning by using community assessment for public health emergency response (CASPER) methodology. *Prehosp Disaster Med* 2014; **29**(3): 262–9.

54 Van Bladel L, Pauwels A, Smeesters P. The Challenge of Interacting with the Public on Nuclear Emergency Preparedness and Iodine Prophylaxis. Presentation to *Investing in Trust: Nuclear Regulators and the Public*, Paris, France. 2000.

55 Lasker R D. *Redefining Readiness: Terrorism Planning Through the Eyes of the Public*. 2004. New York, NY: The New York Academy of Medicine, Survey Research Center, Institute for Social Research, University of Michigan.

56 Vyncke B, Perko T, Van Gorp B. Information Sources as Explanatory Variables for the Belgian Health-Related Risk Perception of the Fukushima Nuclear Accident. *Risk Analysis* 2016; **20**(20): 1–14.

57 Radiological Threat Awareness Coalition. *Nationwide Survey of Likely 2008 General Election Voters* (RTAC Nationwide Survey #1421). 2008.

58 Carini F P M. Attitudes of rural population in emergency exposure situations. *J Environ Radioact* 2011; **102**(4): 363–9.

59 Bass S B, Gordon T F, Gordon R, Parvanta C. Using eye tracking and gaze pattern analysis to test a "dirty bomb" decision aid in a pilot RCT in urban adults with limited literacy. *BMC Med Inform Decis Mak* 2016; **16**(67). doi: https://doi.org/10.1186/s12911-016-0304-5

60 Pearce J M, Rubin G J, Selke P, Amlôt R, Mowbray F, Rogers M B. Communicating with the public following radiological terrorism: results from a series of focus groups and national surveys in Britain and Germany. *Prehosp Disaster Med* 2013; **28**(2): 110–9.

61 Latré E, Perko T, Thijssen P. Does It Matter Who Communicates? The Effect of Source Labels in Nuclear Pre-Crisis Communication in Televised News. *J Contingencies Crisis Manage* 2018; **26**(1): 99-112.

62 Murakami M, Nakatani J, Oki T. Evaluation of Risk Perception and Risk-Comparison Information Regarding Dietary Radionuclides after the 2011 Fukushima Nuclear Power Plant Accident. *PLoS ONE* [Electronic Resource] 2016; **11**(11): e0165594. doi: http://dx.doi.org/10.1371/journal.pone.0165594

63 Bass S B, Gordon T F, Maurer L, et al. How Do Low-Literacy Populations Perceive "Dirty Bombs"? *Implications for Preparedness Messages. Health Security* 2016; **14**(5): 331–344.

64 Ohno K, Endo K. Lessons learned from Fukushima Daiichi nuclear power plant accident: efficient education items of radiation safety for general public. *Radiat Prot Dosimetry* 2015; **165**(1-4): 510–2.

65 Rogers R W, Prentice-Dunn S, Gochman D S. *Handbook of health behavior research 1: personal and social determinants.* 1997. Plenum Press: New York, NY.

66 Železnik N, Perko T. *Are Communication Campaigns Enough to Enhance the Radiation Related Knowledge?* Presentation to the 21st International Conference: Nuclear Energy for New Europe, Ljubljana, Slovenia. 2012.

67 Smith J. Dangerous news: media decision making about climate change risk. *Risk Analysis* 2005; **25**(6): 1471-82.

68 Prezelj I, Perko T, Cantone M C, Gallego E, Tomkiv K, Oughton D H. The limits of public communication coordination in a nuclear emergency: lessons from media reporting on the Fukushima case. *Journal of Radiological Protection* 2016; **36**(2): 45-63.

69 Mythen G A. Critical Introduction to the Risk Society, in *Ulrich Beck*. 2004; Pluto Press.

70 Rubin G J, Finn Y, Potts H W, Michie S. Who is sceptical about emerging public health threats? Results from 39 national surveys in the United Kingdom. *Public Health* 2015; **129**(12): 1553–62.

Box 1. Recommendations based on the findings of this review

- Pre-incident communication regarding preparedness actions should be targeted at the recipient population (i.e. residents close to an NPP should receive advice regarding KI collection and use)
- Advisories as to potential actions (evacuation; shelter-in-place) should include details as to how individuals can find out which action is most suitable to them (such as based on their location to the emergency), and who they can expect to give this information
- Information regarding recommended actions should clearly explain reasons why these might be advised, including the circumstance under which there might be a danger in non-adherence
- Preferred methods of distribution are likely to differ: pre-incident information will benefit from being accessible in the public's own time such as leaflet, letter or website information, whereas information distributed during an incident are likely to involve a preference for internet communications
- Information should seek to minimise uncertainty in the public by outlining frequently requested information including exposure effects (means of contamination; symptoms), protective actions to take and the length of time people may potentially be required to shelter
- Pre-incident information should include links to further information including low-literacy aided and preferred language materials
- Information should specifically address the impact on families/children such as protective actions for parents/caregivers to take, actions to take if children are at school in an incident and health effects for children
- Evidence supporting advisories should be provided (potentially making reference to past radiation events and to scientific evidence) but should be presented in clear, non-jargon language making clear that the actions outlined have been proven to offer protection and increase safety
- Potential food and water contamination should be addressed including what could safely be consumed
- Actions that would be taken by authorities, particularly regarding public protection, in the event of a radiation emergency should be addressed where possible
- Combined sources may be used in presenting information: for example, messages presented by recognised government officials should cite health protection agencies and/or nuclear industry sources
- Where multiple sources make information available, a consistent message must be relayed
- Basic terminology should be used in all communications
- Information presented in the event of a radiation emergency should echo information presented pre-incident with reassurance given that if pre-incident communications were not received or have been forgotten that there are ways of accessing them still if opportunity allows)

Appendix 1

Table 1. Methodologies for studies involving nuclear agents (Survey designs)

Ref	Study Design	Participant demographics (if listed)	Inclusion criteria	Variables measured	Event / location
63.	Survey (face-to-face)	N=50; 58% female; ages 18-88	Low literacy adults recruited from local community	Predictors of adherence with sheltering instructions	Hypothetical RDD scenario / US
52.	Secondary survey data: Marist College Institute for Public Opinion: government threat protection; Pew Internet and American Life Project	Not reported	None specified	Information seeking (preferred source, during incident); Perceived source credibility; Predictors of adherence with sheltering instructions	Hypothetical small IND / US
58.	Survey (unspecified) (71% response rate)	N=353; 45% females; ages <25 to >70	Local area agricultural group members	Information seeking (preferred source, during incident); Perceived source credibility	No scenario used / Italy
43.	Survey (postal) (40% response rate)	N=359	Residents in 5 mile radius of TMI	Information seeking	Three Mile Island / US
45.	Survey (telephone)	N=800 (83% white ethnicity; 66% employed; 66% married)	Residents within states surrounding Washington DC	Perceived source credibility; Predictors of adherence with sheltering instructions; Predictors of adherence with evacuation instructions	Hypothetical nuclear detonation / US
38.	Survey (telephone)	N=2657	Residents of national capital region (Virginia, Maryland, Pennsylvania, West Virginia, Delaware, Columbia District)	Information seeking (preferred source, -pre-incident); Information seeking (preferred source, during incident); Perceived source credibility; Predictors of adherence with sheltering instructions; Predictors of preparedness behaviour	Hypothetical RDD scenario / US
44.	Survey (telephone) (Survey 1: 75% response rate; Survey 2: 82%; Survey 3: response rate unreported)	Survey 1: N=692; Survey 2: N=1506; Survey 3: N=954 (sample close to national norm for heads of household age, gender, Hispanic ethnicity. Below norm for African American ethnicity, single status. Above norm for marital status, family size)	Survey 1: residents within 0-5 mile radius of TMI; Survey 2: residents within 0-55 mile radius of TMI; survey 3: unknown	Perceived source credibility; Evacuation behaviour (actual); Sheltering behaviour (actual)	Three Mile Island / US
26.	Survey (paper) (79·60% response rate)	N=1110; 29% female; ages: <30 to >60	Radiation seminar attendees; not subject to mandatory evacuation	Evacuation behaviour (actual)	Fukushima / Japan
24; 25.	Survey (80·3% response rate)	N=1119; 26% female; ages: <40 to >60	Health seminar (Fukushima Occupational Health Promotion Centre) attendees	Information seeking (preferred source, pre- and during incident); Predictors of adherence with evacuation instructions	Fukushima / Japan
55.	Survey (telephone)	N=2545 (Small differences between samples and corresponding estimates from 3-year averages (2001–2003)		Information seeking (pre- incident); Perceived source credibility; Predictors of adherence with sheltering instructions; Predictors of preparedness behaviour	Hypothetical RDD scenario / US
61.	Survey (face-to-face)	N=1031; 51% female; ages: 18 to 55		Perceived source credibility	Simulated TV news segment(s) / Belgium
34.	Survey (telephone) (9·70% response rate)	N=1502; 51% female		Predictors of preparedness behaviour; Predictors of information seeking; Predictors of avoidance behaviour	CBRN terrorism / Canada
35.	Survey (telephone) (9·70% response rate)	N=1502; 51% female		Information seeking (preferred source, pre-incident)	No scenario used / Canada
36.	Survey (unspecified) (50% response rate)	N=502	Residents within 3km of Krško NPP	Information seeking (preferred sources, pre-incident); Predictors of preparedness behaviour	Hypothetical evacuation / Slovenia

45.	Survey (telephone)	N=248	Residents within 10 mile radius of TMI	Evacuation behaviour (actual); Predictors of adherence with evacuation instructions	Three Mile Island / US
62.	Survey (online)	N=9249; 46% female; ages: 20-69	Residents of Fukushima, Tokyo or Osaka	Information seeking (preferred sources, during incident); Perceived source credibility	Fukushima / Japan
41.	Survey (telephone) (80% response rate)	N=200	Random selection from local area phone directory; residents over 18 years	Evacuation adherence (anticipated); Sheltering adherence (anticipated)	Hypothetical nuclear attack / US
53.	Survey (face-to-face) (91% response rate)	N=192	Residents within 50 miles of an NPP	Information seeking (preferred source, during incident); Perceived source credibility	No scenario used / US
60.	Surveys (telephone)	N=2005 (Britain: N=1000; Germany: N=1005); 56% female; mean age: 50·1 (SD=15·6)		Information seeking (preferred source, during incident); Perceived source credibility; Predictors of information seeking; Predictors of avoidance behaviour	Hypothetical RED scenario / Britain; Germany
27; 28.	Survey (Belgium: face-to-face; Slovenia: telephone)	N=1031 (Belgium; representative of population for province, region, level of urbanization, gender, age, and professional status); N=983 (Slovenia; representative of adult population for gender, age, education, level of urbanization, region)	Residents within vicinity of facility	Predictors of preparedness behaviour; Predictors of information seeking; Pre-incident knowledge; Predictors of risk information acceptance	Radio-isotope facility leak (Fleurus); KI distribution campaign (Belgium); Long-term radioactive waste disposal (Slovenia)
32; 33.	Secondary survey data: Nuclear Regulatory Commission (telephone survey); Rutgers University; Michigan State University (postal surveys)	Not reported		Evacuation behaviour (actual); Sheltering behaviour (actual)	Three Mile Island / US
47.	Survey (postal) (44% response rate)	38% female (under-representation of older respondents)		Predictors of adherence with evacuation instructions	Hypothetical nuclear plant accident / UK
29; 30; 31.	Survey (paper)	N=117; 49% female; mean age: 41	Attendees of TMI Public Health and information workshop series on cancer, radiation and epidemiology	Perceived source credibility; Information seeking (during incident)	Three Mile Island / US
57.	Survey (unspecified)	N=502; 52% female; ages: 18 to 65		Information seeking (preferred source, during incident); Perceived source credibility	Hypothetical RDD scenario / US
42.	Survey (online)	N=284; 28% female; ages: 18-46	British nationals living in or near Fukushima	Information seeking (preferred source, during incident)	Fukushima / Japan
12.	Survey (postal/online)	N=324; 48·5% female; ages: <25 to 65	Members of Australia Nuclear Science & Technology mailing list	Information seeking (preferred source, during incident)	No scenario used / Australia
54.	Survey (postal) (28% response rate)	N=1407 (representative of population, mostly male, > 80%, homeowners)	Residents within 20km of major nuclear installations	Predictors of KI use	Nuclear awareness campaign / Belgium
56.	Survey (face-to-face)	N=938 (population representative sample)		Information seeking (preferred source, during incident)	Fukushima / Belgium
37.	Survey (telephone)	N=1071 (Females over represented: 60%)	Residents of the National Capital Region	Information seeking (preferred source, during incident); Perceived source credibility; Predictors of adherence with sheltering instructions; Predictors of adherence with evacuation instructions; Predictors of preparedness behaviour; Predictors of information seeking	Hypothetical RDD scenario / US
46.	Survey (telephone)	N=2595	Residents of Nassau and Suffolk Counties (vicinity of Shoreham NPP)	Evacuation adherence (anticipated); Predictors of adherence with evacuation instructions	Hypothetical evacuation / US

39.	Survey (telephone) (60% response rate)	N=153; KI users: 60% female, KI non-users: 59% female; Mean age, KI users: 63·3(SD=13.7), KI non-users: 60·1(SD=15·2)	78 free KI voucher users; 75 non-users; residents within 10 mile of nuclear plant.	Information seeking (during incident); Predictors of KI use	KI distribution campaign / US

Table 2. Methodologies for studies (qualitative designs e.g. Focus Groups, interviews)

Ref	Study Design	Participant demographics (if listed)	Inclusion criteria	Relevant topics of discussion	Event / location
51.	Focus groups	N=37; 32% female; ages: 18–65	African-American; urban residential attendees of community centres	Predictors of instruction adherence	Hypothetical RDD scenario / US
52.	16 Focus groups (12 w/ general public) (4 w/ first responders not included in review)	N=163 (focus groups total); 52% female; mean age: 42.6	12 public groups: 3 African American groups (2 urban, 1 rural); 3 white (2 urban, 1 rural); 3 Hispanic (2 urban, 1 rural); 1 Asian (urban); 1 English second language, 1 Indigenous American	Information seeking (preferred source, during incident); Perceived source credibility; Predictors of adherence with sheltering instructions	Hypothetical small IND scenario / US
36.	Semi-structured interviews	Not reported	Leaders of institutions (e.g. head teachers); residents within 3km of Krško NPP	Information seeking (preferred sources, pre-incident); Predictors of preparedness behaviour	Hypothetical evacuation / Slovenia
49.	Focus groups	N=108; 48% female; ages: 25-54		Information seeking (preferred source, during incident)	IND message testing / US
60.	Phase 1: focus groups (7 British, 5 German); Phase 3: focus groups (using intervention leaflet)	Phase 1: N=52 (Britain), N=35 (German); Phase 2: N=570 (Britain), N=563 (Germany)	Britain: purposive sampling: parents/ travellers through mainline London train station; Germany: random selection from Stuttgart City Records	Information seeking (preferred source, during incident); Perceived source credibility; Predictors of information seeking; Predictors of avoidance behaviour	Hypothetical RED scenario / Britain; Germany
50.	Focus Groups	Phase 1: N=22; phase 2: N=64 (mix of gender, age, ethnicity, education and parents)		Information seeking (preferred source, pre-incident); Information seeking (preferred source, during incident); Perceived source credibility; Predictors of adherence with sheltering instructions; predictors of adherence with recommended actions (general)	Hypothetical RDD scenario / UK

Table 3. Methodologies for studies (Experimental designs)

Ref	Study Design	Participant demographics (if listed)	Inclusion criteria	Aims measured	Event / location
59.	Pilot test of decision aid tool	N= 50 (Intervention group: N=29; Control: N=21); 48% female; ages: 23-67	Low literacy adults recruited from community sites	Predictors of adherence with sheltering instructions	Hypothetical RDD scenario / US
40.	Field evaluation of leaflet (survey; focus group); (Survey: 16·5% response rate); Intervention: 8% response rate)	Survey: N=631; 55% female; mean age 53·2; Focus groups: N=30; 25 females; mean age 43·5; Intervention phase: N=112	Residents within radius of nuclear sites; higher and lower income households	Predictors of preparedness behaviour; Information preferences	Nuclear safety information leaflet distributed by NPP operator to homes within 2km radius; Trial leaflet / UK

Table 4. Predictors of behaviour in preparation for a radiation emergency (significant effects in bold)		Risk of bias score
Information Seeking	***34.*** (QN) **Predictors: perceived probability (β=0·16, t=4·88, p<0·001), perceived personal impact (β=0·08, t=1·93, p=0·05), coping efficacy (β=0·10, t=3·43, p<0·001), worry (adjusted R2=0·05, F(3, 1096)=21·80, p<0·001, with β=0·19, t=6·22, p<0·001); negatively associated with perceived seriousness (β=-0·08, t=−2·05, p<0·05);** perceived government or front-line preparedness not significant	16
	29. (QN) Information seekers near TMI were more highly educated and male but not necessarily those reporting most worry (effect not reported)	17
Preparedness	***57.*** (QL; QN) 63% not feeling prepared for RDD attack; 36% stocked food, 35% water	12
	48. (QN)~62% 'very'/ 'somewhat' prepared to stay away from home >one week	16
	34. (QN) Predictors: **perceived probability (β=0·25, t=7·98, p<0·001), perceived coping efficacy (β=0·06, t=2·15, p<0·05), perceived front-line preparedness (β=0·15, t=4·06, p<0·001**); worry (adjusted R2=0·05, F(3,1096)=21·95, p. <0·001, with β=0·25, t=8·10, p<0·001). Perceived seriousness, governmental preparedness, self-efficacy, personal impact not significant	16
	35. (QN) **Older respondents more likely to have emergency supply kit (F(1, 827)=12·16, p<001); urban area residents established emergency plans (F(1, 1438)=4·34, p<·05), put together emergency supply kit (F(1, 1438)=6·50, p<·05), obtained information about potential shelters (F(1, 1438)=4·73, p<·05) to lesser extent than rural residents; less educated respondents received first aid or CPR training to a lesser extent (F(1, 1430)=9·17, p<·01)**	15
	36. (QN) Few preparedness behaviours due to belief nuclear sites are safe/ in emergency there would not be time to evacuate (effect not reported)	15
	53. (QN) ~85% had 3-day supply of non-perishable food, 76% a way to cook without utilities; 65%a 3-day supply of drinking water; 67% prepared a first-aid kit, (among households with medication users) 63% had a 7-day supply	12
	39. (QN) 5% collected free KI; **voucher non-users reported not having planned for a NPP emergency to a greater extent (60%) than users (26%) x2=18·47, p<·0001);** reasons for (pre-incident) uptake of KI: be prepared (58%), safety (18%), free (14%), recommended (13%); reasons for non-use: not knowing about program (36%), 'don't know' (19%), didn't receive voucher (12%), 'not interested' (7%), felt KI unnecessary (4%)	17
	38. (QN) 40% had some preparedness plans including respondents who experienced an event that caused them to stay at home or to evacuate, more highly educated, those with children <18, older respondents (effects not reported); differences regarding race, geographic location, income not significant; barriers to preparedness: denial/ unwillingness (22%), other priorities (17%), lack of time (15%), no reason (12%), cant plan for unknown/ fatalism (10%), 'don't know what to do' (9%), lack of money/ resources (3%)	19
	37. (QN) 27% stored food for >10 days, 31% 6-10 days, 15% <6 days, 27% none; 21% water stored for >10 days, 17% 6-10 days, 21% <6 days, 41% none; ~0·4% reported no sheltering capacity; respondents with children, pet owners, those with strong community attachment, full-time workers, those aged 50-64 more likely to have a designated meeting place; education and income not predictors	16
Adherence to recommendations	***61.*** **(QL)** Acceptance of (pre-incident) recommendations not affected by perceived credibility of actor giving information	19
	62. (QN) **Trusters of central government believed information accurate (B=1·97, 95%CI=1·73–2·24)/ accepted risks (B=2·04, 95%CI=1·80–2·32)**	17
	41. (QN) 66% would leave if warned via media of impending nuclear attack, if warning intensified (such as televised Presidential message) 73% would probably/ definitely leave; **fewer (48%) would leave if learned of actual attack occurring (compared with media warning (x2=5·98, df=1 p<·01) or presidential TV warning (x2=9·96,df=1, p<·01)**	14
	27. (QN) **Perception of radiation risks (β=-0·3, SE=0·04), prior knowledge (β= 0·2, SE=0·02) most influential acceptance predictors of message acceptance (Slovenia: e.g. 'LILW will not cause health consequences'); prior knowledge (β=-0·357, SE=0·042), attitude towards science and technology (β=-0·350, SE=0·116), perception of radiation risks (β=0·264, SE=0·1), living close to NPP (β=0·739, SE=0·242) predicted acceptance of messages (Belgium); differences in message acceptance between respondents living farther from NPP and local population (Slovenia: β= 0·1; Belgium: B=0·7);** confidence in authorities not significant	13
	28. (QN) **Interaction of specific knowledge and trusting authorities predicted message acceptance in affected population (β =0·029, SE=0·009, p<0·01);** specific knowledge not significant **(joint effect of specific knowledge and disaster potential did predict acceptance in general population (β=·13, SE=0·42, p<0·01); attitude toward science and technology marginally significant effect on acceptance in affected population (those with a more positive attitude less inclined to accept messages (β=-1·077, SE=0·402, p<0·05)); respondents believing NPP accident potentially disastrous accepted messages less than those assuming low disaster potential in general (β=−1·66, SE=0·540, p<0·01) and directly affected (β=46, SE=0·108, p<0·001) populations;** education and age not significant	17
	38. (QN) 18%-19% would evacuate if given prior notice of incident; 19% would leave location if instructed by Governor/ Mayor (highest level of shelter-in-place adherence), 21% if local fire chief, 24% if 'a top local official' or 'the local emergency manager'	19
	40. (Experiment) 86% adhered to instructions to keep both leaflets (94% read both)	17

Table 5. Predictors of behaviour immediately following a radiation emergency (significant effects in bold)		Risk of bias score
Information Seeking	***42.*** (QN) Uncertainty (e.g. doubt around exposure) caused emotional symptoms: distress, anxiety, anger, found to predict information seeking behaviour	19
Adherence to recommendations	***52.*** (QL) Minority groups would 'start rounding up…family' in reaction to a nuclear emergency	17
	49. (QL) Respondents found sheltering directives counterintuitive (such as feeling that staying inside was not safe), would likely not follow instructions to shelter-in-place	12
	51. (QL) Adherence associated with trust in source, perception of scenario, knowledge of issue, collaboration of information, family-centric needs (women/older people would check safety of children before evacuating)	20
	50. (QL) Receiving leaflet intervention (including information about decontamination) a strong influencer on adherence	17
	43. (QN) 39% within 5 miles of TMI evacuated (54% did so following advisory that only pregnant women and children evacuate); **significant association between behaviour and behaviour of neighbours (x2=56·83, df=2, p=·000, Goodman and Kruskal Tau=0·159)**; reasons for evacuating: advisory itself (68%; 21% living outside 5 mile radius, 28% had children), fear of harm (46%), confusion (lack of leadership, conflicting information (41%)), peer pressure (9%), anticipating evacuation order/ associated problems (traffic (8%)); reasons for non-evacuation: **social influence (such as neighbours' behaviour** (effect not reported), little perception of danger, fear of looting, waiting for order, proximity to hazard, age, household size	16
	48. (QN) 92% 'very'/'somewhat' likely to adhere with evacuation instructions (91% in dirty bomb emergency); sources cited as most important in evacuation decision: official announcement (43%), news coverage (43%), family/ friends (8·5%); ~67% likely to shelter if news coverage is unavailable; 19·5% with no confidence in government preparedness planning very unlikely to follow shelter-in-place advice (~5% with confidence unlikely to adhere to sheltering directive) (x2=55·63 (n=773), p<·001); **78% who perceive high likelihood that attack could harm them/ their family likely to evacuate x2=70·57 (9, n=748), p <·001, effect size γ=·32); 90% in dirty bomb scenario (x2=70·57 (9, n=748), p<·001, effect size γ=·32)**	16
	44. (QN) ~60% of households had at least one person self-evacuate during TMI; reasons for evacuation: confused by information (reducing trust in government), situation perceived dangerous (w/ influence of friends/ neighbours: 82%), avoid forced evacuation (68%); reasons for not evacuating: 'whatever happens is in God's hands' (70%), waiting for order (62%), believing no danger (30%)	12
	25. (QN) **Internet users more likely than non-users to evacuate with families to lower radiation areas (Mantel–Haenszel test conducted, p<·01); positive relationship between internet usage and preventative behaviours (internet users: M=2·6, SD=2·1; non-users: M=1·9, SD=1·7; ANCOVA conducted p<·01**)	16
	26. (QN) Families with children aged 0-6 (OR=4·8), 7-12 (OR=3·6), 13-19 (OR=2) reported evacuating during Fukushima disaster	16
	36. (QN) 2/3 expect support measures relating to physical health and safety, anticipated adherence increased in the 32% who expect psychological assistance if sheltering-in-place; non-adherence associated with prioritising collection or checking on children or other family members	15
	46. (QN) **Situational variables related to evacuation: specific instructions to evacuate, disruption of telephone service, proximity to TMI** (effects not reported)	10
	41. (QN) If knowledgeable of school evacuation plans/ children's location: 55% of parents would 'definitely' (37%)/ 'probably' (17%) collect children (no significant difference from those who would not collect their children (14% 'probably'/ 26% 'definitely')	14
	53. (QN) 96% willing to evacuate; 92% willing to shelter-in-place; reasons for non-evacuation: lack of transportation/ inconvenience/ expense; reasons for non-sheltering: wishing to reunite with family, preferring to leave quickly, lack of trust in public health officials	12
	32. (QN) Reasons for evacuating during TMI emergency: situational danger (91%), confusing information (83%), concerns with forced evacuation (76%), need to protect children (61%); reasons for not evacuating: not being ordered to (62%), conflicting reports (42%), believing no danger existed (38%), believing home to be safe distance away (31%)	3
	33. (QN) Reasons for evacuating during TMI: situational danger (30%), conflicting reports (19%), government advisory (14%), concerns w/ forced evacuation (14%); reasons for not evacuating: not ordered to (62%), conflicting reports (42%), believing no danger existed (38%), living safe distance away (31%), fear of looting (24%), having no children (23%), neighbours not having evacuated (16%)	7
	47. (QN) 13% would ignore evacuation instructions; three-quarters would evacuate in spite of sheltering instructions (particularly if > 3km from NPP)	11
	31. (QN) TMI evacuees more likely to have attained high school education, more likely female (69%), more likely parents (92%)	15
	54. (QN) Anticipated pre-incident responses to receipt of warning leaflet: self-evacuate if possible (23%), pick up children (30%), accept sheltering recommendations (96%)	13
	37. (QN) 84% would follow instructions to stay at home (15·5% would leave); community attachment predicted increased willingness to shelter at home; 94% of over 65's, 70% of 18-25s would adhere to sheltering instructions; 28% would shelter for 48 hours if knowing family safe (41% at work), 61% would leave work despite knowing building sheltering arrangements; reasons for leaving: feel safer elsewhere (37%), find children (28%), find adult family member (25%), get food/ water (11%); **bringing food, water, supplies directly to confined residents would increase cooperation (85% would shelter 48 hours at home, 75% at work)**	16
	46. (QN) ~50% would evacuate given advisory 'everyone living within 10km should evacuate'; 25% would evacuate given advisory 'those living within 5km should stay indoors';	11

	34% would evacuate given advisory 'pregnant women and pre-school children within 5km should evacuate, everyone else within 10km should stay indoors'; families closer to NPP most likely to evacuate	
	47. (QN) 71·5% if no instructions issued would stay at home; if at work 71% (maximum scenario: multiple RDDs at 1 mile distance, wind blowing toward participant) to 41% (minimum scenario: single RDD at great distance) would remain in place; reasons for non-adherence (w/ 48 hour shelter instruction): to find adult family (29%), to find children (23%), feel safer elsewhere (11%), to get food/ water (8%); 69·5% (minimum scenario), 83% (maximum) would shelter 48 hours if told loved ones safe; 90% would shelter for >48 hours if food/ water could be delivered (100% in maximum scenario); confidence in community ability to manage attack does not affect behaviour if at home **(significantly correlated with staying at work in minimum scenario)**	11
	55. (QN) 68% would shelter initially, 59% as long as instructed, 20% requiring more information to decide; trust in official pre-incident instructions correlated with anticipated adherence ; of non-adherence group: 33% would leave to find children, 28% for other family members, 22% would feel safer elsewhere, 7% believe they could avoid danger outside, 6% to get meds/food/supplies; increased adherence if able to communicate with loved ones (+14%), if knowing loved ones safe (+12%); anticipated adherence 76% among those confident in workplace preparedness plans	16

Table 6. Preferences for information in the event of a radiation incident (significant effects in bold)

		Risk of bias score
Information Seeking	***52.*** (QL; QN) Sources likely used (during incident): media (TV), radio, internet, national level experts, word of mouth, emergency broadcast system, authorities understanding local situation	17
	42. (QL) Individuals made requests (during incident) for more information, consistency, clarity, regular updates	19
	51. (QL) Young men would want to find out more information (during incident) by seeking out peers	20
	57. (QL) Preferred sources (during incident): media, medical experts	12
	36. (QN) 52% sought (pre-incident) information from media, 62% from leaflet	15
	58. (QN) Majority (effect not reported) would call local agencies/ family/ friends/ local hospital (during incident); 86% would like guidance on emergency countermeasures/ food safety advice	14
	43. (QN) Some (effect not reported) sought information regarding potential impact before evacuating following advisory (during incident)	16
	24. (QN) Main information sources (during incident): neighbours, co-workers (effect not reported)	15
	53. (QN) (during incident) 14% would use internet for information, 56% television, 18% radio	12
	12. (QN) Nuclear emergencies likely to result in demand for phone services; Preferred information sources (during incident) friends/ family (92%), first responders (76%)	18
	56. (QN) 93% used media for information during Fukushima emergency	17
	38. (QN) Preferred sources (pre-incident): general internet searching (28%), government websites (21%), news websites (21%), local TV news (25%), family (24%), friends (21%), local radio (21%); Preferred sources (during incident): television network news (80%), (internet: news/ government websites (49%), social media (<2%), healthcare provider or CDC (<2%))	19
	55. (QN) 77% 'moderately'/ 'extremely' interested in learning more about government/ community organisation plans for (pre-incident) RDD response	16
	60. (QN) 77% would seek health-related information (pre-incident) about prevention, protection, symptoms and treatment, likelihood of further attacks (RDD emergency)	16
	50. (QL) Desired information: factual, protective actions, water/food contamination, actions of authorities (during incident); Zone maps requested (w/ advice/behavioural recommendations)	17
	37. (QN) Preferred sources (during incident): local TV news (68%), local radio (63%), national TV news (49%), internet news (26%), internet unspecified (22%), internet government site (16%), local newspapers (16%), family/ friends (16%), local police (10%), local fire dept. (6%), doctors/ healthcare providers (3%)	16
	40. (Experiment) Reasons for preference of (pre-incident) intervention leaflet over existing NSIL: simpler/easier to understand, more informative, offered pin-up summary, preferred pictures, preferred layout; NSIL preferred for familiarity, preferred layout, preferred pictures	17
Perceived credibility of information source	***52.*** (QL; QN) Concerns expressed that government will not distribute all information/lack of availability in different languages (pre-incident); recommended actions more credible if proven effective	17
	51. (QL) Limited trust in national media (local media preferred), local authorities (president directives preferred) (during incident)	20
	60. (QL) Information presented in media (during incident) viewed with suspicion; positive reaction non-governmental sources; 'Independent scientist' lost credibility as 'chosen by media'	16
	50. (QL) Lack of consistency across messengers (during incident) increased confusion/ anxiety; leaflet recipients rated messages from authorities more credible	17
	57. (QL) 33% rated media as a credible (pre-incident) source of information, 30% first responders, 16% academics/ scientists, 14% government	12
	63. (QN) (pre-incident) Respondents fell into 3 categories: trust information, not response (32%: most likely to adhere), distrust information and response (18%: least likely to adhere/	19

	prepare), trust local, not global (50%: likely to adhere with sheltering instructions, most likely to have an emergency plan)	
	61. (QN) **Scientists rated more trustworthy than authorities (t(458)=3·03, p<·05); authorities rated more trustworthy than industry (t(458)=6·554, p<·05);** Authorities/ scientists rated equally competent (t(449) =-·14; p=·150), **industry less competent (t(449)=3·6, p<·01)** (pre-incident)	19
	53. (QN) 36·5% had most trust in the local public health department, 23%in local news, 11% physicians, 11% family members (pre-incident)	12
	27. (QN) (Slovenia) Trust in scientific information given by: Government (factor loading principal axis=0·779); agency for radioactive waste (axis=0·591); mayor (axis=0·530); ministry for environment and spatial planning (axis=0·735) (alpha=0·75, N=1200) (pre-incident)	13
	30. (QN) **Perceived understandability (X=·981, SD=·138),** reliability (X=·818, SD=·387) and relevance (X=·725, SD=·448) (pre-incident) consistent with course presenters giving information in basic terms	17
	38. (QN) Trust in source (pre-incident): president (~42%), homeland security (~22%), GP (~22%), surgeon general (~20%), religious leader (~20%), Governor (~19%), national/local news (~15%)	19
	37. (QN) National news most trusted source, followed by GP (pre-incident); least trusted: Mayor/ local religious leaders; medical professionals appearing on television perceived less reliable	16
	58. (QN) ~60% reported confidence in official information (during incident) (most likely women/ aged 26-40 years); 30% reported little confidence (most likely aged 41-60 years)	14
	31. (QN) **Loss of faith in experts predicted by perceived TMI threat (multi R=·70, R^2=·48, p=·000), perceived lack of control (multi R=·57, R^2=·33, p=·000)** (during incident)	15
	40. (Experiment) No significant difference between leaflets for trustworthiness (pre-incident)	17
Reception of information	***52.*** (QL) Many found information (pre-incident) confusing, unclear (such as not fully understanding the terms shelter-in-place or plume)	17
	49. (QL) A live voice (opposed to a recording) preferred in delivering messages (during incident)	12
	60. (QL) Intervention leaflet length, density and complexity of text, lack of illustrations, accessibility issues for groups with disabilities criticised) (during incident)	16
	50. (QL) (during incident) Official recommendations suggested to go beyond providing facts by offering explanations for public health recommendations (also applied to official advice encouraging return to normal after sheltering and advice encouraging the public to attend a treatment centre	17
	59. (QL; QN) **Confidence in knowing what RDD was (intervention group: M=8·76, SD=2·64; control: M=5·44, SD=3·75; t=2·78, df=28, p<·05, 95%CI=·87-5·77), how to respond (intervention: M=8·95, SD=1·5; control: M=6·67, SD=3·61; t=2·49, df=28, p<·05, 95%CI=·4-4·17), ability to carry out instructions (intervention: M=8·8, SD=·62; control: M=7·44, SD=1·94; t=2·87, df=27, p<·05, 95%CI=·386-2·3) in low literacy respondents given literacy aided material (pre-incident)**	18
	40. (Experiment) 55·5% read all leaflet information (49% reported having understood it all) (pre-incident); 57% preferred trial leaflet to existing leaflet (31%); **trial leaflet found easier to read than NSIL (F(1, 295)=19·347, p<·001, r=27);** trial leaflet found easier to understand (59%) than existing leaflets (24%)	17

Appendix 2

The following databases were searched for relevant publications: Medline (via OVID, Epub ahead of print (January 16 2017); In-Process and Other Non-Indexed Citations, Ovid MEDLINE (R) Daily and Ovid MEDLINE (R) (1946 to present) search conducted 17th January 2017); Embase (via OVID, 1974 to 2017 January 16) search conducted 17th January 2017; PsycINFO (via OVID, 1806 to January Week 2 2017) search conducted 18th January 2017; Web of Science (core collection) search conducted 20th January 2017.

Database: Ovid MEDLINE(R) <Epub ahead of print (January 16 2017), In-Process and Other Non-Indexed Citations, Ovid MEDLINE (R) Daily and Ovid MEDLINE (R) (1946 to present)>

Search Strategy:

1	Fukushima / (2122)
2	exp Radioactive Hazard Release/px (Psychology) (107)
3	Fukushima .kw (110)
4	Chernobyl / (5450)
5	Chernobyl .kw (61)
6	Chenobyl / (2)
7	Chenobyl .kw (0)
8	"Three Mile Island" / (191)
9	"Three Mile Island" .kw (1)
10	Hiroshima / (2025)
11	exp Nuclear Warfare/px (Psychology) (18)
12	Hiroshima .kw (3)
13	Nagasaki / (1698)
14	Nagasaki .kw (4)
15	Sellafield / (322)
16	Sellafield .kw (5)
17	Windscale / (67)
18	Windscale .kw (0)
19	Kyshtym / (51)
20	Kyshtym .kw (0)

21 Fukui / (669)

22 Fukui .kw (1)

23 Tokaimura / (11)

24 Tokaimura .kw (0)

25 - 30 (Nuclear adj release (33) or accident* (1140) or disaster* (307) or attack* (105) or terror* (114) or emergenc* (167)) .ab,ti,kw.

31 exp Nuclear Weapons /hi (History) (77)

32 "Radioactive Fallout"/ (4061)

33 "Radioactive Fallout" .kw (644)

34 25 or 26 or 27 or 28 or 29 or 30 (1774)

35 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 31 or 32 or 33 or 34 (15253)

36 "Dirty Bomb" / (93)

37 "Dirty Bomb" .kw (3)

38 "Radiological Dispersion Device" / (18)

39 exp Disaster Planning/hi, mt, td (History, Methods, Trends) (2155)

40 "Radiological Dispersion Device" .kw (0)

41 "Radiological Weapon" / (6)

42 "Radiological Weapon" .kw (0)

43 - 48 (radi* adj5 (accident* (2934) or release (5405) or disaster* (204) or attack* (1583) or terror* (330) or emergenc* (3328))) .ab,ti,kw.

49 Goiania / (459)

50 Goiania .kw (0)

51 Litvinenko / (24)

52 Litvinenko .kw (0)

53 "Polonium 210" / (302)

54 "polonium 210" .kw (11)

55 43 or 44 or 45 or 46 or 47 or 48 (13207)

56 36 or 37 or 38 or 39 or 40 or 41 or 42 or 49 or 50 or 51 or 52 or 53 or 54 or 55 (16048)

57 Shelter* / (10062)

58 Shelter* .kw (220)

59 "Duck and Cover"/ (7)

60 "Duck and Cover" .kw (0)

61 evac* / (20396)

62 evac* .kw (115)

63 relo* / (14588)

64 relo* .kw (120)

65 Iodine/re (Radiation Effects) (18)

66 Behav* / (1532356)

67 Behav* .kw (27776)

68 Psych* / (1369475)

69 Psych* .kw (70765)

70 - 72 (respon* adj3 crisis (625) or emergenc* (5315) or public (4638)) .ab,ti,kw.

73 adhere*/ (196883)

74 adhere*.kw (3624)

75 engage*/ (127855)

76 engage*.kw (488)

77 comply/ (9519)

78 comply.kw (1)

79 compliance/ (152734)

80 compliance.kw (1333)

81 communicat*/ (373405)

82 communicat*.kw (8136)

83 Warning*/ (22296)

84 Warning*.kw (132)

85 instruct*/ (94562)

86 instruct*.kw (320)

87 70 or 71 or 72 (10578)

57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 73 or 74 or 75 or 76 or 77 or 78 or 79 or 80 or 81 or 82 or 83 or 84 or 85 or 86 or 87 (3307960)

89 35 or 56 (29685)

90 88 and 89 (3776)

Supplementary Materials

Downs and Black (1998), risk of bias checklist (adapted). Scoring: yes=1, no=0, unable to tell=0

	Reporting								External Validity		Internal validity - bias			Internal validity - confounding (selection bias)				Power	
Ref.	Aim / objective described?	Main outcomes to be measured clearly described?	Characteristics of patients described?	Interventions described?	Distributions of principal confounders described?	Main findings described?	Estimates of random variability?	Probability values reported except where value is less than	Subjects asked to participate representative of population?	Subjects prepared to participate representative population?	16. If 'data dredging' was this made clear?	Statistical tests appropriate?	Main outcomes valid and reliable?	Were different intervention groups used or was recruitment from same population?	Were cases and controls recruited over the same period of time?	Was the randomised intervention assignment concealed?	Adequate adjustment for confounding in analyses?	Sufficient power to detect a clinically important effect?	Score
51	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	5	20
38	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0	1	5	19
42	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0	1	5	19
61	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	0	5	19
59	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	5	19
63	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	0	0	5	18
12	1	1	1	1	1	1	1	0	0	1	1	0	1	1	1	1	0	5	18
62	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	0	0	5	17
56	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	0	0	5	17
50	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	0	0	5	17
39	1	1	1	1	0	1	0	1	1	0	1	1	1	1	1	0	0	5	17

30	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	0	0	5	17
29	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	0	0	5	17
28	1	1	1	1	0	1	1	0	0	1	1	1	1	1	1	0	0	5	17
40	0	1	1	1	0	1	0	1	1	1	1	1	1	1	1	0	0	5	17
52	1	1	1	1	0	1	0	1	1	0	1	1	1	1	1	0	0	5	17
34	1	1	1	1	0	1	0	0	1	1	1	1	1	0	1	0	0	5	16
55	1	1	0	1	0	1	0	0	1	1	1	1	1	1	1	0	0	5	16
60	1	1	1	1	0	1	1	0	1	1	1	1	1	0	0	0	0	5	16
25	1	1	0	1	0	1	0	1	0	1	1	1	1	1	1	0	0	5	16
48	1	1	1	1	0	1	0	1	0	1	0	1	1	1	1	0	0	5	16
43	1	1	1	1	0	1	0	1	1	1	0	1	1	1	0	0	0	5	16
37	1	1	1	1	0	1	1	0	1	1	0	0	1	1	1	0	0	5	16
31	1	1	1	1	0	1	0	0	0	0	1	1	1	1	1	0	0	5	15
26	1	1	1	1	0	1	0	0	0	0	1	1	1	1	1	0	0	5	15
35	1	0	1	1	0	1	1	0	1	0	0	1	1	1	1	0	0	5	15
36	1	1	0	1	0	1	0	1	1	0	1	1	1	1	0	0	0	5	15
24	1	1	1	1	0	0	0	1	0	1	0	1	1	1	1	0	0	5	15
41	1	1	0	1	0	1	0	0	0	0	1	1	1	1	1	0	0	5	14
58	1	0	1	1	0	1	0	0	1	0	0	1	1	1	1	0	0	5	14
54	1	0	1	0	0	1	0	0	1	0	1	0	1	1	1	0	0	5	13
27	1	1	0	1	0	1	0	0	0	0	1	1	1	0	1	0	0	5	13

49	1	0	1	0	0	1	0	1	0	0	1	1	1	0	0	0	0	5	12
44	0	1	1	1	0	1	0	0	0	1	1	0	1	0	0	0	0	5	12
53	1	0	0	0	0	1	1	0	0	0	0	1	1	1	1	0	0	5	12
57	0	0	1	0	0	1	1	0	1	0	0	0	1	1	1	0	0	5	12
46	1	0	0	0	0	1	0	0	0	0	1	0	1	1	1	0	0	5	11
47	0	0	0	1	0	1	0	0	1	0	0	0	1	1	1	0	0	5	11
45	1	0	0	1	0	0	0	0	0	0	0	0	1	1	1	0	0	5	10
33	1	0	0	0	0	1	0	0	0	0	1	1	1	1	1	0	0	n/a	7
32	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	3