UK Health Security Agency

Non-radiological health impacts of evacuation, temporary relocation and sheltering-in-place: review of literature

Non-radiological health impacts of evacuation, temporary relocation and sheltering-in-place: review of literature

SJ Watson, KA Jones

Abstract

In the event of a radiation emergency such as an accident at a nuclear power plant, urgent protective actions, such as evacuation and sheltering-in-place, may be implemented quickly for periods of hours or days, to protect against exposures received over relatively short timescales. While such actions will protect against harmful effects of radiation exposure, there is a risk that the actions themselves may lead to harmful health effects, both physical and psychological. For example, evacuation can be very effective at protecting small communities from radiation exposures, but for large numbers of people, or without adequate prior planning, evacuation can lead to serious physical and psychological health risks.

Non-radiological risks of evacuation and relocation have been conceptually and qualitatively known since the Chornobyl accident but there has been a lack of quantitative assessment of these risks with a greater focus on radiological health impacts than non-radiological ones. It is now recognised that non-radiological consequences may have more impact on society than the radiological consequences. Following the Fukushima accident, the number of deaths in the general population associated with protective actions was greater than that prevented by the protective actions. In cases where evacuations were unplanned and carried out in haste, the risks of the protective action were greater still, possibly orders of magnitude higher than the estimated radiation risk. Similarly, it is estimated that at least one third of the relocations that took place in 1986 following the accident at Chornobyl caused a greater estimated loss of life expectancy than that expected from the radiation exposure that would have occurred had relocations not taken place.

This review looks at the non-radiological impacts on health reported in the literature from evacuation, temporary relocation, and sheltering-in-place. A wide range of physical health effects, including injuries, obesity, diabetes, cardiovascular disease and kidney disease, are considered as well as psychological impacts such as stress, depression and anxiety. Psychological effects, which have been reported after three of the most notable nuclear accidents (Three Mile Island, Chornobyl and Fukushima), may be among the most significant non-radiological impacts resulting from an accident and can exceed the direct health effects associated with radiation exposure that would have been received if the population had remained in situ. However, until recently, assessments have tended not to take account of the psychosocial costs of protective actions.

As well as the general population, this review gives separate consideration of the non-radiological risks to vulnerable groups such as children, hospital inpatients and residents at nursing homes, and those affected by additional medical or care requirements, socioeconomic

This report from the UKHSA Radiation, Chemical and Environmental Directorate reflects understanding and evaluation of the current scientific evidence as presented and referenced in this document.

constraints, or pregnancy, as their needs may be different. Evidence from the accident at the Fukushima Daiichi Nuclear Power Plant in 2011 highlighted that there may have been severe problems for the most vulnerable groups such as hospital inpatients or residents at nursing homes for the elderly.

The growing awareness of the importance of non-radiological health impacts, and the importance of considering different populations, should lead to their inclusion in the planning and implementation of protective actions by decisions makers in the event of a radiation emergency.

This work was undertaken under the Radiation Assessments Department's Quality Management System, which has been approved by Lloyd's Register to the Quality Management Standard ISO 9001:2015, Approval No: ISO 9001 – 00002655.

Report version 1 25/09/23

Acknowledgements

Many people have contributed to this report with comments and advice on various aspects. Particular thanks go to the following contributors:

Anne Nisbet, Tom Charnock, Jon Sherwood and Keith Mortimer from the UKHSA Radiation Assessments Department

Charles Symons from the UKHSA Behavioural Science and Insights Unit

Contents

Abstract i

1 Introduction 1
- 1.1 Scope of report 2
- 1.2 Structure of report 3

2 Literature review 3
- 2.1 Aims of review 3
- 2.2 Literature searches 3
- 2.3 Results of literature searches 4
- 2.4 Extended searches 4

3 Non-radiological health impacts of evacuation 5
- 3.1 General population 5
  - 3.1.1 Road traffic accidents 6
  - 3.1.2 Risk of death other than from road traffic accidents 7
  - 3.1.3 Psychological impact 7
- 3.2 Vulnerable populations 8
  - 3.2.1 Patients in hospitals, and nursing/care homes 8
  - 3.2.2 Children 9
  - 3.2.3 People living independently with medical or care requirements 10
  - 3.2.4 People with socioeconomic constraints 10
  - 3.2.5 Pregnancy 11

4 Non-radiological health impacts of temporary relocation 11
- 4.1 General population 11
  - 4.1.1 Psychological impact 12
    - *4.1.1.1 Causes of psychological distress 13*
    - *4.1.1.2 Post-Traumatic Stress Disorder (PTSD) 14*
    - *4.1.1.3 Cognitive dysfunction 14*
    - *4.1.1.4 Stigma 15*
    - *4.1.1.5 Link between mental and physical health 15*
  - 4.1.2 Overweight and obesity 15
  - 4.1.3 Diabetes 16
  - 4.1.4 Cardiovascular disease, hypertension, and dyslipidemia 16
  - 4.1.5 Metabolic syndrome 17
  - 4.1.6 Chronic kidney disease 18
  - 4.1.7 Polycythaemia 18
  - 4.1.8 Other health problems 18
- 4.2 Vulnerable populations 19
  - 4.2.1 Patients in hospitals, and nursing/care homes 19
  - 4.2.2 Children 20
  - 4.2.3 Adults living independently with medical/care requirements 20

5 Non-radiological health impacts of sheltering-in-place 21
- 5.1 General population 21
- 5.2 Vulnerable populations 22

5.2.1 Patients in hospitals, and nursing/care homes 22
5.2.2 Children 23
5.2.3 Adults living independently with medical/care requirements 23
6 Discussion 23
6.1 Comparison of evacuation/temporary relocation and sheltering 23
6.1.1 General population 25
6.1.2 Patients in hospitals, and nursing/care homes 25
6.1.3 Children 26
6.1.4 Independent adults with medical needs 26
6.2 Justification of protective actions 27
6.3 Influences of different stressors 28
6.3.1 Radiation anxiety 29
6.4 Dependency between health impacts 30
6.5 Planning 30
6.6 Communication 31
6.7 Limitations of this review 32
7 Findings from the review 33
8 Glossary of terms 36
9 References 37

1 Introduction

In the event of a radiation emergency such as an accident at a nuclear power plant, urgent protective actions, such as sheltering-in-place, evacuation or administration of stable iodine, may be implemented quickly for periods of hours or days, to protect against exposures received over relatively short timescales. Such actions will protect against harmful effects of radiation exposure, both direct tissue damage (deterministic effects) such as radiation burns, radiation sickness, cataracts and fatalities, and an increased risk of health problems such as cancer incidence in the future (stochastic effects). In its advice on public health protection in the event of radiation emergencies (Nisbet, 2019), PHE outlines how the principles of justification and optimisation should be applied to urgent protective actions to ensure that they (a) do more good than harm in the broadest sense; and (b) maximise the benefit achieved. Justification and optimisation take account of all expected consequences, both beneficial and undesirable, including radiation and wider health risks (including psychological impact); consequential injuries; economic consequences; social and environmental factors.

Non-radiological risks of evacuation and relocation have been conceptually and qualitatively known since the Chornobyl accident but there has been a lack of quantitative assessment of these risks (Murakami et al, 2015) and the potential for non-radiological consequences, which may have more impact on society than the radiological consequence, is often underestimated (Martell et al, 2022). International safety standards such as IAEA (2014) and IAEA (2015a) give general instructions that non-radiological consequences should be taken into account when deciding on potential actions, however there is limited detail included (WHO, 2020). In particular until recently, there has been little guidance on how to explicitly address psychosocial impacts and the importance of planning to manage them, and few practical tools for including mental health issues in the response to radiation emergencies (WHO, 2020). Assessments of disasters have therefore tended not to take account of the psychosocial costs (OECD, 2018).

Evidence from the accident at the Fukushima Daiichi Nuclear Power Plant (Fukushima NPP) in 2011 has shown that a range of health effects, including some preventable deaths, occurred after evacuation orders were implemented (NEA, to be published; Oka, 2022; Tsubokura, 2018; US NRC, 2021; WHO, 2016). The evacuations were broadly in line with the IAEA recommendations at the time and were taken to also protect against potential further deterioration in the situation at the NPP. However, in retrospect, it is likely that the non-radiological health impacts of the protective actions implemented at Fukushima were not adequately considered at the time (Callen and McKenna, 2018). Evidence from Fukushima highlighted that there may have been severe problems for the most vulnerable groups such as hospital inpatients or residents at nursing homes for the elderly. These groups may be particularly vulnerable to the impacts of evacuation, temporary relocation, or sheltering-in-place. There was also a huge psychological impact following the Fukushima accident. Since then there has been increasing recognition of the importance of mental health and psychosocial support following radiation emergencies (Lagergren Lindberg et al, 2022). The World Health Organisation published a framework for mental health and psychosocial support in radiological and nuclear emergencies (WHO, 2020) and the Nuclear Energy Agency is developing practical guidance (NEA, to be published).

There is increasing recognition of the potential for health effects arising from protective actions (Ohba et al, 2021) with increased discussion on emergency evacuations during a nuclear accident (Thomas, 2017). The International Commission on Radiological Protection (ICRP) included sections on societal consequences and health impacts of changes in lifestyle associated with protective actions in one of its more recent reports (ICRP, 2020) and the US Nuclear Regulatory Commission published an analysis of non-radiological health impacts of evacuation and relocation (US NRC, 2021). However, there is still a risk that health impacts, including deaths, from the implementation of protective actions (particularly wide-scale evacuation or temporary relocation) could happen again in the event of another large-scale nuclear power plant accident. This review aims to look more closely at the non-radiological impacts on health from evacuation, temporary relocation, and sheltering-in-place.

1.1 Scope of report

Nisbet (2019), the most recent iteration of UKHSA advice regarding protective actions in a radiation emergency, considers urgent protective actions such as sheltering-in-place (hereafter generally referred to as sheltering) and evacuation to last only for hours and days. In this report, sheltering is assumed to last for hours and no more than day or two at most, and evacuations to last no more than about a week. Sometimes longer-term protective actions are also required. For example, temporary relocation lasts for an extended but limited period of time, weeks, months or years depending on the characteristics and extent of the contamination (Nisbet, 2019). This report considers the health effects of temporary relocation as well as the urgent protective measures of evacuation and sheltering, following a radiation emergency, such as an accident at a nuclear power plant. Effects related to other actions, including taking stable iodine, or restrictions on food and drink, are not considered in this report.

Physical and psychological health effects are considered, in line with the World Health Organisation definition of health which includes physical, mental and social wellbeing (WHO, 1948).

This report considers most radiological incidents, but nuclear detonations, including improvised nuclear devices, are not considered. It looks at the general population and vulnerable groups such as residents of hospitals or care homes; children; and adults living independently who have medical or care needs. The report does not consider the following groups:

- Groups who must remain in the affected area to deal with the emergency, to maintain essential infrastructure, or to attend to livestock.
- Impacts on a host community as a result of the influx of evacuees.
- Return of displaced populations, whether that is days, weeks, months or even years into the future.

Some of the data found provided quantitative data, for instance the risk of death, the risk of injury, the prevalence of a particular health effect, or the loss of life expectancy (LLE), which is the average lost lifetime, compared to the estimated average age at death. While such values are useful, papers that only gave qualitative information were not excluded.

In any disaster scenario the population may be affected by exposure to primary or secondary stressors, with radiation emergencies bringing unique stressors (WHO, 2020). Primary stressors arise directly from the disaster, for example the direct effects of radiation would be the primary stressor in a radiological event. Primary stressors may also be subjective (Moran, 2014), for example anxiety due to fear of radiation, which may be greater than anxiety caused by any other primary stressors. Secondary stressors are stressful consequences caused by the primary stressor (Moran, 2014) including the impacts of any measures, such as evacuation, temporary relocation or sheltering, implemented in response to the primary stressor. This review's aim was to identify and describe the health impacts of protective actions (ie secondary stressors). However, the literature did not always clearly differentiate between the effects of primary and secondary stressors. Such papers were included in the literature review as the information they provided was still considered to be useful. See Section 6.3 for discussion of the influences of different stressors.

1.2 Structure of report

This report describes the literature review used to obtain information (Section 2). Findings are presented on the non-radiological health impacts of evacuation (Section 3), temporary relocation (Section 4) and sheltering-in-place (Section 5), with each of these three sections distinguishing between general and vulnerable populations. Section 6 contains discussion that compares sheltering with evacuation and temporary relocation, as well as planning, communication and limitations of this review. Section 7 provides conclusions and key messages, with a glossary of terms given in Section 8.

2 Literature review

2.1 Aims of review

The literature review looked at harms, including psychosocial impacts, introduced by implementing evacuation, temporary relocation and sheltering-in-place, to provide a broader context to those involved in public health decisions following a radiation emergency. The impact of these actions on vulnerable populations was considered separately to reflect the different needs from the general population. The review aimed to focus on UK experience, though as this is limited, international experience was also considered.

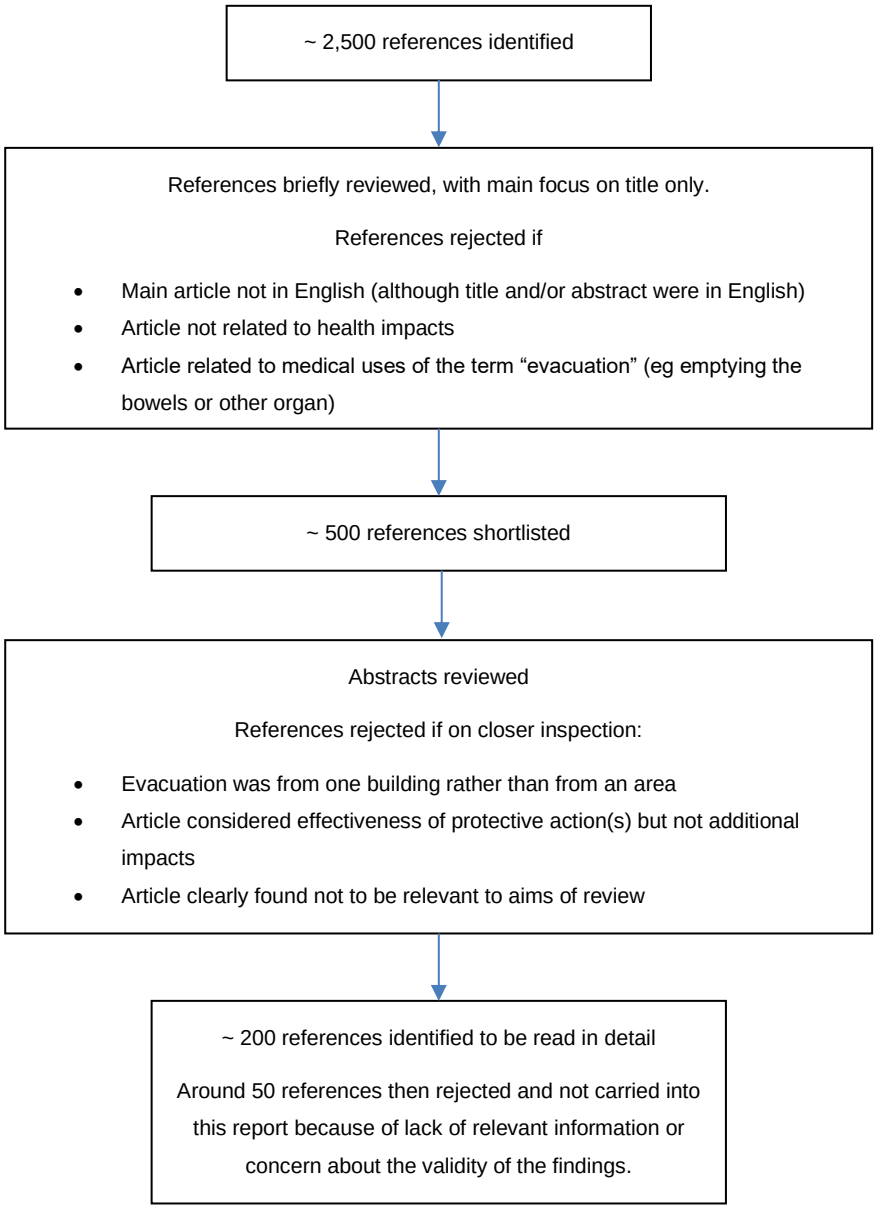
2.2 Literature searches

Initial literature searches were carried out using Scopus, Embase, Medline, Global Health and Web of Science. Search terms included "shelter", "sheltering", "shelter-in-place" "evacuation", "relocation", "radiation", "nuclear disaster", "chemical", "flood", and "health effect". The literature searches were restricted to material published since 2016, and these search results were added to those identified in earlier research by PHE (predecessor to UKHSA) on emergency countermeasures/urgent protective actions that included a literature review covering the period up to 2016.

2.3 Results of literature searches

Overall, around 2,500 potentially useful references were identified. A review process, as illustrated in Figure 1 was used to determine which were most relevant for this study.

Figure 1 Review process for shortlisting references



2.4 Extended searches

Some of the references cited within the articles read were followed up. It also became clear that some initial assumptions of the literature searches needed to be adapted or broadened. Therefore, some additional searches, using the Scopus database and internet searches, were carried out in three main areas as described below. Some references prior to 2016 were

identified during this process and considered in the review if they appeared to be particularly relevant.

- **Non-radiation emergencies -** Fortunately, there are relatively few cases where urgent protective actions have been required following a radiation emergency. Three notable examples are the accidents at Three Mile Island (1979), Chornobyl (1986) and Fukushima (2011). It was therefore decided to include literature relating to non-radiological emergencies, such as hurricanes, fires, flooding, or emergencies involving release of toxic chemicals, if evacuation, temporary relocation or sheltering-in-place were implemented. Other than a report about protective actions during chemical incidents and fires (PHE, 2020) and information on flooding or the COVID pandemic, relevant information on UK evacuations was sparse. Therefore, both UK and international experience were included, with particular attention given to locations considered as fairly similar to the UK, based on climate and demographics.
- **Vulnerable populations -** Before undertaking this literature review, only hospital patients were considered as “vulnerable populations”. As the literature review progressed this definition was extended to include residents of nursing homes; children; adults with medical or care requirements, for example the elderly, people with disabilities, or neurodiverse individuals; those affected by socioeconomic factors, and pregnant women.
- **Additional terms of interest** - New areas of interest emerged that required specific searches to be carried out. These included a wider range of health effects then was first anticipated, such as polycythemia, tuberculosis, liver dysfunction, and metabolic syndrome. Additionally, themes of traffic flow during mass evacuations, separation of families, communication methods, social isolation, stigma and self-abuse were investigated.

3 Non-radiological health impacts of evacuation

Despite perceptions of mass panic in emergencies, the general public tends to act rationally and cooperatively, showing altruism and mutual support (Carter et al, 2014; Government Communication Service, 2022; IASC, 2007). Even so, evacuations, especially if conducted without adequate preparation, can put psychological strain and physical burdens on evacuees. The health effects attributable to evacuation, as described in the following sub-sections are those that may occur within a few days of the accident, and certainly within a week or so. Effects that arise from longer-term displacement from home are included in the section on temporary relocation (Section 4).

3.1 General population

There is evidence that there are risks associated with the acts of preparation for evacuation, travel, or from living in the evacuation location, even for a relatively short time. Consequences of evacuation, including fatalities, have been seen following natural disasters. Information from county medical examiners and funeral homes following Hurricane Rita in 2005 indicate that of 111 deaths in Texas linked to the hurricane, 90 deaths (81%) were related to the evacuation process (Zachria and Patel, 2006). Although (Waite et al, 2017) shows flooding has a more

significant impact on mental health than evacuation, Menne and Murray (2013) report that evacuation and the disruption associated with it were the most significant stressors for victims of flooding in England and Wales. Evacuations following radiation accidents have also been linked to fatalities, with deaths not directly attributed to the primary stressor (eg radiation) but from related causes classes as disaster related deaths (DRDs). Following the Fukushima Daiichi Nuclear Power Plant (Fukushima NPP) accident, fatigue or exhaustion from travelling from the incident area to the evacuation area is reported to account for between 24% and 30% of DRDs, while fatigue or exhaustion from living in evacuation facilities accounts for between 34% and 41% (Hayakawa, 2016; Saji, 2013). These were the two largest causes of DRDs. In comparison, fatigue or stress from the Great East Japan Earthquake (GEJE) and tsunami were responsible for between 3% and 9% of all DRDs and stress from the Fukushima NPP accident was responsible for just 2% or 3% of DRDs. Within the first month after evacuation, it is estimated that 2,688 out of 460,000 evacuated people died at shelters (Hasegawa et al, 2016). This is equivalent to a daily death rate of 0.19 deaths per 1,000 evacuees, about seven times Japan's estimated 2011 general death rate of 9.4 deaths per 1,000 people per year (Macrotrends, 2023), equivalent to a daily death rate of 0.026 per 1,000 people.

3.1.1 Road traffic accidents

Many evacuations involve road transport, so there is a risk of death or injury from traffic accidents. There are extreme examples, such as a bus fire during the Hurricane Rita evacuations which killed 24 people (Regnier, 2008), though minor accidents and incidents are more common.

It is not straightforward to evaluate the risk of death from traffic accidents during evacuation compared to normal driving conditions. The amount of traffic may increase, for example some reports suggest poor traffic management (Dombroski et al, 2006) with severe traffic jams during evacuations after the Three Mile Island accident (Ohba et al, 2021) while others suggest that traffic was just a bit heavier than usual (Bastien et al, 1985). Major traffic jams were reported on main roads during evacuations following the Fukushima NPP accident (IAEA, 2015b). It could be hypothesised that a large-scale evacuation could lead to chaos and traffic congestion on the roads, resulting in more accidents than in normal driving conditions. An alternative theory is that largely unidirectional traffic flow, coupled with low driving speeds caused by heavy traffic during evacuation conditions, will lead to a lower likelihood of hazardous driving and a lower risk of death than during normal transport. A lower than usual number of accidents was reported during evacuations after the Three Mile Island accident (Bastien et al, 1985). It is therefore not unreasonable to assume that the risk, in terms of deaths per distance travelled, is about the same as for normal road transport. This is backed up by data on evacuations in the USA which showed that the death risk during evacuation of the public who do not need support is about the same as that during normal road travel (Callen-Kovtunova et al, 2022). The death rate for car occupants during normal road transport in the UK is 1.6 fatalities per billion passenger miles (Department for Transport, 2020), equivalent to a risk of death per person of around 2 10^{-7} per 100 miles travelled,

3.1.2 Risk of death other than from road traffic accidents

Non-radiological risks of death from evacuation, other than transport-related risk, include short-term risks of death due to accidents that occur either during the preparation for evacuation, or associated with residing at the evacuation centre. It was suggested (Aumonier and Morrey, 1990) that these risks are generally similar to everyday risks but may be slightly higher (by less than an order of magnitude) due to haste during evacuation and unfamiliarity with the evacuation centre. There is also an increased risk of disease associated with crowding in an evacuation centre, though this is hard to quantify. Conversely, analysis of evacuated and non-displaced groups found that evacuation was sometimes associated with slightly lower mortality (US NRC, 2021).

It is reported that around 6,000 deaths occur in the UK each year as a result of accidents in the home (RoSPA, 2023). This suggests a risk of death from an accident at home of about 1 in 11,300 per year, equivalent to a daily risk of death of 2.4×10^{-7}. Assuming the risk of death during emergency circumstances is similar to this, the estimated daily non-transport risk of death from preparation for evacuation and time in the relocation centre is roughly equal to, or slightly higher than, the transport related risk per person from making a total journey of 100 miles, as estimated in Section 3.1.1. This balance of risks will be different if evacuation distance or length of time at the evacuation centre changes, but it is likely that for the shorter evacuation distances typical in the UK the risk of death from transport will be the less significant element.

3.1.3 Psychological impact

Three of the most notable nuclear accidents (Three Mile Island, Chornobyl and Fukushima) have one common health effect for survivors: psychological impact. It is recognised that radiological or nuclear accidents have unique factors and that the perceived risks of radiation exposure can cause mental health issues (NEA, to be published). There are also mental health impacts linked to evacuations. Natural disasters have also resulted in psychological impacts linked to evacuation, with anxiety, depression and Post-Traumatic Stress Disorder (PTSD) reported following hurricanes (Blackburn and Shelke, 2022; Taioli et al, 2018), and flooding (Menne and Murray, 2013; Munro et al, 2017; Paranjothy et al, 2011; Waite et al, 2017) and depression reported following wildfires (Lalani et al, 2021). Evacuation following emergency scenarios can have acute psychological impacts which may undermine long-term health, both physical and psychological (IASC, 2007). Following the English floods of 2013 and 2014, Waite et al (2017) found that among the people whose homes were not flooded, there was higher prevalence, though not significant, of depression, anxiety, or PTSD among those who evacuated compared to those who remained within their home, while Munro et al (2017) found a link between evacuation or displacement and mental health even when the primary stressor of flooding was removed. Causes may be linked to conditions in an evacuation centre, including issues with security and privacy (Kett, 2005; Taioli et al, 2018). Minimisation of time spent in temporary evacuation are thought to be important as psychosocial impacts were found to be reduced when disruption to evacuees was minimized (Health Canada, 2020). In contrast, (Munro et al, 2017) found no association between the duration of displacement following flooding and mental health symptoms.

3.2 Vulnerable populations

Evacuation can be more challenging for certain groups of the population, leading to considerable health risks (WHO, 2016). For example, evacuation of institutionalised settings such as hospitals or nursing homes are complex, due to medical or care needs, particularly if intensive medical care is required (Bagaria et al, 2009; Stenke et al, 2016). Outside of institutions, some groups living independently at home may also be considered to have additional vulnerabilities. Examples include the elderly and people with disabilities or pre-existing conditions such as diabetes, and neurodiverse individuals. Children may also be more vulnerable to the impacts of evacuation, both physically and psychologically. If an emergency occurs during the school day this may lead to familial separation, which is likely to cause additional stress to both children and parents. Socioeconomic constraints may also make some groups or individuals more vulnerable (Renne, 2018) and any emergency may have an impact on pregnancies. Not all individuals in a population identified as vulnerable will require assistance during evacuation, and not all vulnerable populations will be vulnerable at the same time. However, the needs of vulnerable groups should be considered when developing plans for evacuation.

3.2.1 Patients in hospitals, and nursing/care homes

Studies of evacuations of nursing homes and hospitals following the Fukushima NPP accident and hurricanes in the United States, show an association between hasty evacuations and increased mortality rates. A review of 35 studies of relocated elderly residents between 1970 and 1992 (Castle, 2001) found that post-relocation mortality rates ranged between 0 and 43%. A study of effects of evacuation of nursing home residents concluded that evacuation significantly increased morbidity and mortality (Dosa et al, 2012).

Following the Fukushima NPP accident, evacuation of many elderly residents from hospital and nursing care facilities took place with the intention of protecting against radiation exposure. Many of these evacuations took place early in the response, in a hurry, and without planning. Hasegawa et al (2015) and Ohba et al (2021) reported that evacuees were often transported with no medical care, food or even water for many hours during the evacuation. Deaths during, or shortly after, evacuations of nursing home patients have been attributed to hypothermia, dehydration, the physical burdens of evacuation, interruptions in care, and worsening of existing conditions without adequate support (Hasegawa et al, 2015; NEA, to be published). In one case, hasty evacuation of 800 elderly hospitalised patients without medical personnel, medical supplies, or heating is reported to have caused 50 deaths (Hasegawa et al, 2016; Tanigawa et al, 2012). Without adequate support, the risk of death from evacuations of hospitals and nursing care facilities is estimated to be about 60 per 1000 (Callen-Kovtunova et al, 2022), with mortality rates among elderly, institutionalised people generally found to increase from between three times (Ohto et al, 2017) to nearly four times (Nomura et al, 2016c). In contrast, another hospital evacuation, which took place a little later in the response, and was carried out in an organised manner over a four day period with planned medical support, saw no lives lost among 509 inpatients and elderly people (Hasegawa et al, 2016). Separate from the findings related to evacuations following the Fukushima NPP accident, a review (Willoughby et al, 2017) of ten studies on evacuations of nursing homes found that only one study reported no deaths post-evacuation.

Following earthquakes in the Kumamoto prefecture in 2016, evacuations of 38 new-born infants from a hospital's neonatal intensive care unit considered the clinical backgrounds of the patients and managed to provide medical care throughout the evacuation. As a result of this there was only one adverse incident, a case of hypothermia in a low birth-weight infant, although risk factors were seen to be greater in those patients transported out of, rather than within, the prefecture (Iwata et al, 2017).

Increased mortality and morbidity[1] were also attributed to poor management of evacuations when hurricanes Katrina, Rita and Gustav hit the United States (Hyer et al, 2007; Nomura et al, 2016a). Florida, with extensive experience of disasters and evacuation, fared better than other areas. Emergency preparedness infrastructure and policies in Florida allowed 13,000 residents of nursing homes, assisted living facilities and continuing-care retirement facilities to be evacuated during hurricanes Katrina, Rita and six other hurricanes in 2004/2005 with no evacuation-related deaths (Hyer et al, 2007).

3.2.2 Children

Hazards of evacuation can of course affect children as well as adults. (Gu et al, 2016) studied videos of real emergency evacuations and analysed the emergency evacuation behaviour of school students in the event of earthquakes. The number of students departing from a classroom each second, and the cumulative curve of the number of departures was compared in normal and emergency conditions. Under normal conditions the number of departures per second was quite stable, with a linear cumulative departure curve, indicating uniform motion. In emergency situations an increased mean value and variance of departure numbers per second was seen, with the cumulative curve becoming non-linear. Increased reaction times were also observed in emergency conditions. Overall, students' emergency behaviour was seen to be more chaotic, suggesting that risks of falls, trips and other minor accidents would be elevated during emergency evacuation.

Evacuation centres themselves may contain physical hazards for children, for example playing on stairs. At best, centres may not offer adequate support, for example play opportunities or paediatric mental health resources, to families (Mace et al, 2010). Thienkrua et al (2006) reports a small occurrence of depression and PTSD symptoms among relocated children living in evacuation camps, that is associated with the experience of living in the camp, rather than the trauma of the tsunami that led to the relocation. There is also cause for concern that children living in evacuation centres may be particularly prone to infectious diseases.

Children can also be affected psychologically by evacuation, with the development of emotional problems having been seen in evacuated children. Children evacuated outside of the Fukushima prefecture after the GEJE, tsunami and NPP accident were seen to be at significant risk of developing emotional symptoms (Oe et al, 2018). If evacuation takes place during the school day, children may be evacuated separately from their families, and this can increase psychological distress experienced by both the children and the parents. It is also known that early childhood exposure to major stress is a well-established risk factor for adult mental health issues (Havenaar et al, 2016).

[1] morbidity is the condition of having a disease, or the amount of disease within a population.

3.2.3 People living independently with medical or care requirements

Whilst hospitals and nursing/care homes look after some of the elderly population and those with medical or additional needs, many individuals continue to live independently at home. Behr and Diaz (2013) noted that in cases of storm events, the elderly population tended to shelter-in-place rather than evacuate, suggesting that there are factors reducing their ability to evacuate. Problems with perception, cognition and physical mobility may occur with increasing age, suggesting that evacuation of this section of the population is likely to be more problematic and require assistance with evacuation, especially for those living alone. Older adults will generally have different needs to the younger population. Disruption of routine and unfamiliar environments while living in evacuation centres can make older adults vulnerable to depression (Holle et al, 2019). Older people have been seen to be vulnerable after major disasters, with people aged 66 years or older accounting for about 89% of DRDs following the Fukushima disaster (Tanaka, 2015). It has been shown (Lee et al, 2016; Malik et al, 2018) that there was an increase in attendance of adults aged 65 or over, or with diabetes, at the New York City Emergency Department in the first week after Hurricane Sandy, with the largest increase seen in the evacuation zone most vulnerable to flooding.

For those with physical disabilities, not only can the evacuation process be more difficult, if evacuation centres are not suitable this can not only cause practical difficulties, but can impose a psychological burden if an individual feels they are a nuisance to others (Sawano et al, 2019).

Another part of the population that is likely to need particular attention if forced to evacuate is neurodiverse individuals. The term neurodiverse refers to a variety of conditions including autism, dyslexia, dyscalculia, attention deficit hyperactivity disorder (ADHD), obsessive compulsive disorder (OCD) and Tourette's syndrome. Such conditions are natural variations in how the brain works and the term "neurodiverse" covers a range of abilities. It is likely however, that at least some of this group may find changes in routine difficult, may be unable to adapt to a widely different situation, may have problems understanding and following instructions, and may struggle with social interactions, possibly becoming overwhelmed meeting a lot of unfamiliar people. The evacuation process and time spent at evacuation centres are therefore likely to be more stressful for neurodiverse people than for neurotypical people.

3.2.4 People with socioeconomic constraints

The process of evacuation may be more challenging for certain groups (Chen and Li, 2017; IASC, 2007). For those without access to a car (eg tourists, young people who may rely on public transport rather than owning a car and elderly populations who may no longer drive) evacuation may be difficult. This may be less of an issue for evacuations following an accident at a UK nuclear power plant as these are likely to include provision for evacuation by bus or coach. However assumptions about availability of buses and drivers, and failure to incorporate non-car users into plans can all be barriers to effective evacuation planning (Renne, 2018). Evacuation may also be more difficult for those with limited finances, or with limited understanding of the English language.

Different populations may particularly show different resilience and responses, regarding mental health impacts. Non-medical factors, such as education, income, employment and job

security, food security, housing, and childhood development, influence health outcomes and can account for variations of 30% to 55% in health outcomes between different populations (NEA, to be published). Difficulties with evacuation are also likely to increase the psychological impacts of evacuation. Additionally, those who are less fluent in English may also find life in the evacuation centre especially isolating, which may impact their mental health.

3.2.5 Pregnancy

Some evidence was found in the literature about birth rates, abortions, and decisions to avoid pregnancy following radiological accidents, though no differences were reported between relocated and non-relocated populations. Following the Chornobyl accident, a drop in birth rates was seen in several European countries in the first quarter of 1987 (Körblein, 2021). An intentional decrease in the number of planned pregnancies in the first weeks after the accident, and an increase in induced abortions was reported in Italy (Bertollini et al, 1990) and Greece (Trichopoulos et al, 1987) while Bromet and Havenaar (2007) reported set up of “abortion assembly lines” after the Chornobyl accident. These effects are thought to be linked to stress caused by the disaster and belief that there was a high risk of abnormalities in the embryos. Lower live birth rates have also been reported following the Fukushima NPP accident, with an observed 20% decrease in delivery rate in the Fukushima prefecture and a 9% decrease in live births in Fukushima and ten surrounding prefectures (Körblein, 2021). A highly significant association between decline in birth rate in December 2011 and mean effective dose in different areas was reported by Körblein (2021) who suggests that this reflects early deaths of the conceptus from high radiation exposure. However, Fujimori et al (2014) report that the incidences of miscarriage and induced abortions indicated no change after the Fukushima NPP accident and that the incidence of congenital malformation corresponded to the average rate over the whole of Japan. It is however possible that women from the areas with higher effective dose had increased concern over the risks of pregnancy and avoided pregnancy after the accident.

4 Non-radiological health impacts of temporary relocation

If evacuation extends beyond a few days, then people are considered to have been temporarily relocated. Health effects attributable to evacuation, occurring within the first week or so, are described in Section 3. This section concerns the effects seen when people are away from home for weeks, or possibly even up to years. The terms “displaced population” and “displaced residents” are used in this section to refer to people subject to temporary relocation.

4.1 General population

Relocation may affect health outcomes in a variety of ways, some of which can be long lasting. Health impacts include mental health issues, obesity, diabetes, cardiovascular disease, hypertension, kidney disease, metabolic changes, and other illness. A statistically significant increase in prevalence was seen for 9 out of 14 health effects studied (US NRC,

2021) with a positive odds ratio, indicating an association, seen for the other health effects. Eto et al (2019) reported that in the years following the Fukushima NPP accident, a number of statistically significant negative health effects were seen among the displaced population, despite the displaced population showing a significant increase in the amount of exercise compared to no such increase in the non-displaced population. It is thought that an overall shift to a sedentary lifestyle among the displaced population is more significant than any increase in exercise. “Disuse syndrome”, physical inactivity leading to deterioration of many aspects of physical health, is recognised by Oka (2022) as being linked to prolonged evacuations and causing cardiovascular and musculoskeletal health, obesity, depression and premature ageing.

There is an abundance of information available in the literature on a wide range of health impacts in the populations relocated following the accident at the Fukushima Daiichi Nuclear Power Plant (Fukushima NPP). Both physical and psychological effects were seen and are described in the following subsections. It is important to note that there is some dependency between physical and psychological health impacts. For example, depression may be linked to a lack of physical activity which can lead to weight gain and obesity which in turn is linked to other conditions such as diabetes or cardiovascular disease. It is also important to recognise that when considering the data from Fukushima, it can be difficult to separate the effects of the earthquake/tsunami and NPP accident (primary stressors) from the effects of relocation (secondary stressor). This is discussed in Section 6.3.

4.1.1 Psychological impact

Temporary relocation is associated with a number of psychological problems, which can be greater than the radiation-induced health impacts being avoided (Hasegawa et al, 2015; NEA, to be published; WHO, 2020). People may fear being separated from loved ones, being socially excluded and subject to stigma (see Section 4.1.1.4), not being able to work and losing their jobs (IASC, 2020). Relocation can interrupt the emotional support provided by the community that would normally help provide strength against both the primary stressor and the challenges of living in an unfamiliar environment, with associated lifestyle changes. Without adequate support networks mental disorders may develop, or pre-existing ones become amplified (Fussell and Lowe, 2014; IASC, 2007; Lyamzina, 2018). Increases in the incidence of psychological distress, depression and Post-Traumatic Stress Disorder (PTSD) among residents relocated from the Fukushima prefecture were reported by several authors (Hasegawa et al, 2016; Kunii et al, 2016; Lagergren Lindberg et al, 2022; Oe et al, 2016a; Oe et al, 2018; Ohto et al, 2017; Tsujiuchi et al, 2016; WHO, 2016). Studies of natural disasters also found increased frequencies of anxiety and depression among displaced populations (US NRC, 2021).

It is noted that psychosocial experiences can oscillate between distress and recovery (Stanke et al, 2012). This is seen in a three year study of relocated residents (Oe et al, 2017) where 19.3% of the study population showed signs of PTSD in the first two years, but none by the end of the study. Conversely another part of the study population, 17.7%, showed worsening of symptoms, with PTSD at the end of the study despite showing no definite symptoms earlier. Lagergren Lindberg et al (2022) reported that data from the Mental Health and Lifetime Survey (MHLS), following the GEJE and Fukushima NPP accident showed that in 2012 there was a prevalence for probable depression of 14.6% among the adult displaced population. This

showed a slow decrease to 9.7% in 2014. In comparison the prevalence of depression in the general population in Japan is around 3%.

Psychological stress can lead to self-medication of alcohol or drugs, with displaced populations seen as being at greater risk of substance abuse (Hanna, 2017). This can in turn cause a range of health problems associated with substance abuse.

In extreme cases psychological effects may lead to loss of life through suicide. In the five years following the GEJE and Fukushima NPP accident, 83 deaths were classified as disaster related suicides, with more of these occurring in Fukushima than in the neighbouring prefectures of Iwate and Miyagi (Maeda and Oe, 2017). It is not certain whether these suicides had more association with relocation or radiation (actual or perceived exposure) though it is suggested (Maeda et al, 2016) that difficulties faced by the population including stigma about radiation, uncertainties and distrust in authorities contributed to PTSD and depression, known to be risk factors for suicide. Certainly, comparison of the suicide rate in each prefecture with the average suicide rate in the Japanese population for the period 2010 to 2014, shows the same pattern over time seen in all three prefectures. Callen-Kovtunova et al (2022) reported that the standardised suicide mortality ratio decreased in Fukushima Prefecture during the first 2 years after the Fukushima NPP accident compared with 2010 but exceeded the pre-accident level in 2014, despite suicide prevalence declining slightly in Japan. This is the same pattern as seen following some natural disasters (Kõlves et al, 2013) and is known to be associated with a weakening of social ties, a known effect of relocation.

4.1.1.1 Causes of psychological distress

Psychological distress among displaced residents has been associated with a number of aspects of relocation. Housing stability has been shown to play an important role (Fussell and Lowe, 2014). Elements of this include:

- Satisfaction with accommodation. This was one of the most significant elements, with psychological distress seen in 44% of displaced residents who reported being dissatisfied with their accommodation and only 24% of those who reported satisfaction (Horikoshi et al, 2016).
- Type of accommodation. More psychological impacts were seen among displaced residents living in rented accommodation, evacuation shelters or temporary housing compared to those living in a relatives' home or to residents remaining in their own home (Kunii et al, 2016). Fussell and Lowe (2014) found higher levels of mental health problems among displaced populations staying in a hotel or with friends compared to those staying with relatives. Some positive impacts have been seen from temporary relocation with strangers; following the earthquake in Canterbury, New Zealand, both displaced residents and hosts reported feelings of increased emotional support and safety (Burton et al, 2013).
- Number of relocations. Following the GEJE and Fukushima NPP accident, several displaced residents were subject to multiple relocations, with more than 20% obliged to relocate more than six times (Hasegawa et al, 2016). Psychological distress was found in 36% of those who relocated four or more times, compared to only 24% of those who relocated less than four times (Horikoshi et al, 2016).

- Separation of families. Breakup of households occurred in 39% of families relocating from Fukushima (Maeda et al, 2016) with separated families being reported as one of the main reasons for psychological distress following the Fukushima disaster (Oe et al, 2016b).

Along with changes in living environment, job losses and inactivity are known to contribute to mental stress (Ochi et al, 2018). Some of the people who had to relocate from evacuation areas following the Fukushima NPP accident were allowed to temporarily return to the area for work each day. For these workers, longer commutes and increased work burdens and amounts of overtime could have resulted in increased mental stresses. However the protective factors of maintaining work satisfaction, physical activity and a social network helped the majority (52%) of them balance the increased work burdens and increased stresses linked to relocation and maintain their overall mental health (Orui et al, 2018).

4.1.1.2 Post-Traumatic Stress Disorder (PTSD)

Post-Traumatic Stress Disorder (PTSD), a form of anxiety disorder, is a recognised form of mental health illness, with higher incidence of PTSD seen among displaced populations following the Fukushima accident than in other parts of Japan (WHO, 2016). Reported rates of PTSD within one year of the Fukushima NPP accident were between 21.6% (Ohto et al, 2017) and 59.4% (Tsujiuchi et al, 2016) among displaced populations compared with normal levels of around 4% in other parts of Japan (Oe et al, 2016a; Ohto et al, 2017). Possible causes of this PTSD are the earthquake and tsunami, relocation, or anxiety about radiation. From the literature, it is not obvious which of these has the biggest influence. Other earthquakes in Japan that led to large scale displacements, but had no radiological element, were associated with lower levels of PTSD than seen in Fukushima (Tsujiuchi et al, 2016). Analysis of a number of studies of health effects following a range of natural disasters found a significant relationship between PTSD and relocation, with a large disparity in the prevalence of PTSD between displaced and non-displaced populations. No significant association was found between psychological distress and environmental radiation levels (Fukasawa et al, 2017), suggesting that any link with radiation is due to radiation anxiety rather than actual radiation exposure. Miura et al (2017) found a significant association between psychological distress and perception of radiation risk.

4.1.1.3 Cognitive dysfunction

Cognitive dysfunction refers to deficits in mental abilities such as reasoning, problem solving, decision making, and attention. A paper by Collett et al (2020) reviewed the psychological consequences of actual or perceived ionizing radiation exposure on cognitive dysfunction. High doses (>1.0 Gy) of ionising radiation can cause cognitive dysfunction via inflammation of the nervous tissues and the effects at these doses are fairly well understood. However, at low (<0.1 Gy) and moderate (0.1–1.0 Gy) doses of ionising radiation, the evidence is inconsistent. At these levels, any observed associations with cognitive dysfunction may be attributed to radiation or psychological stress caused by perceived exposure, which can also cause inflammation of the nervous tissues. Temporary relocation and loss of housing has been associated with risk of cognitive impairment, with reported evidence of such a link in older adults affected by the GEJE and Tsunami (Ishiki et al, 2016).

4.1.1.4 Stigma

Other psychological impacts from relocation are stigma (negative attitudes, prejudice and discrimination associated with a particular circumstance, quality, or person) and self-stigma (internalisation of negative attitudes and resulting self-discrimination such as self-imposed isolation). Those who experienced stigma and discrimination were two to three times more likely to show adverse psychological impacts at two to three months post emergency than those who did not (Hasegawa et al, 2015). Displaced populations can be subjected to stigma. This may be partly because of fear of radiation and contamination, but may also be because of perceptions and resentment related to compensation and free housing (van der List, 2018). Displaced populations from Chornobyl were known as “victims”, a label which is believed to have to contributed to poor mental health (Havenaar et al, 2016).

4.1.1.5 Link between mental and physical health

Psychological impacts are not only detrimental to health in themselves, but there are several physical health conditions that are seen to be linked to mental health issues in displaced populations. These include obesity, diabetes and cardiovascular disease. Additionally, mental health impacts can manifest as unexplained physical symptoms (Havenaar et al, 2016), although the interdependence between psychological and physical impacts is not completely understood (OECD, 2018).

4.1.2 Overweight and obesity

Analysis of a number of studies of health effects following a range of natural disasters found a statistically significant association between weight problems, including both increase and decrease in weight, and relocation. All but one of the individual papers analysed showed a significant association, indicating that changes in weight are very common during and after emergency events (US NRC, 2021). Significant increases in the numbers of people who were overweight (BMI[2] between 25 kg m^{-2} and 29.9 kg m^{-2}) or obese (BMI ≥ 30 kg m^{-2}) were commonly seen in adults displaced after the Fukushima disaster (Eto et al, 2019; Hasegawa et al, 2016; Ohira et al, 2016a; Ohira et al, 2016b; Ohira et al, 2017). Across these studies, the proportion of people classed as overweight or obese (BMI ≥ 25 kg m^{-2}) ranged between 21.9% - 34.7% before the disaster and 29.2% - 42.6% after the disaster for displaced adults. The values for non-displaced adults were between 18.2% - 30.5% before and 20.7% - 31.9% afterwards. The proportion of people with BMI above 25 kg m^{-2} increased more in the displaced populations then in those who were not displaced.

Not all studies reached this conclusion. One study (Ebner et al, 2016) showed no significant change in the prevalence of people with BMI ≥25 kg m^{-2} before and after the disaster, and another (Nomura et al, 2016b) showed that displaced residents were significantly more likely to have gained or lost more than 3 kg of their weight over a year following the disaster than those who were not displaced.

People living in difficult conditions are likely to have unhealthy dietary patterns and lower intake frequency of certain foods. Living in evacuation shelters or temporary housing was

[2] Body Mass Index (BMI) is calculated as an adult’s weight (in kilograms) divided by the square of their height (in metres) and is a measure of whether they are a healthy weight for their height.

found to be associated with lower intake of whole fruit and vegetables than for those living in their own or relatives' homes (Zhang et al, 2017a). This is thought to be a cause of the increased intake of fruit juices among those living in shelters or temporary housing, which may be a reason for weight gain among these subjects. Psychological distress may affect diet and also impact on physical activity, and can therefore be linked to being overweight or obese. There is a known link between low intake frequency for certain foods, including rice and bread, fish, meat, vegetables and fruit (other than-juice) and dairy products, and psychological distress (Uemura et al, 2016).

There are also obvious links between obesity/overweight and other aspects of physical health including diabetes and cardiovascular disease.

4.1.3 Diabetes

Analysis of a number of studies of health effects following a range of natural disasters found a small but significant increase of diabetes among displaced groups, though it was not clear whether there is a causal link or just correlation between displacement and diabetes (US NRC, 2021). Several studies (Ebner et al, 2016; Eto et al, 2019; Hasegawa et al, 2016; Satoh et al, 2015) showed increased incidence of diabetes among displaced adult residents after the Fukushima NPP accident. Ebner et al (2016) found an increased age-adjusted prevalence of diabetes from 11.3% before the GEJE to 14.7% in 2012 and 17% in 2013. The study by Eto et al (2019) reported that the prevalence of diabetes was increased after the accident in both displaced and non-displaced groups, but in the displaced group the increase was from 9.7% to 17.5%, a greater rise than the rise from 8.7% to 13.1% in the non-displaced group. Hasegawa et al (2016) found that the prevalence of diabetes in displaced populations was between 1.3 and 1.6 times higher than for non-displaced populations. Satoh et al (2015) found an increased prevalence of diabetes in displaced populations compared to non-displaced populations in 12 municipalities around Fukushima. However, while Leppold et al (2016) found an overall deterioration in glycaemic control following the accident, this study did not show evacuation/displacement status to be a significant predictor. One study (Murakami et al, 2017) estimated the additional incidence of diabetes following the accident and the associated estimated loss of life expectancy (LLE). This was compared with the estimated LLE from the estimated cancer risk from radiation exposure following the accident. The estimated average LLE to the whole population associated with diabetes was between 2.6 10^{-2} and 4.1 10^{-2} years, compared to an estimated average LLE of 0.69 10^{-2} years associated with radiation exposure if temporary relocations had not taken place.

4.1.4 Cardiovascular disease, hypertension, and dyslipidemia

Cardiovascular disease (CVD) is a disease that involves the heart or blood vessels. It is related to a number of risk factors including hypertension (high blood pressure) and dyslipidemia (an imbalance of fats (lipids) circulating in the blood stream which increases the risk of heart disease, heart attack, and stroke). Results of longer-term studies looking at CVD and associated risk factors were not entirely conclusive. Analysis of a number of studies of health effects following a range of natural disasters found a small, but not statistically significant, increase in heart disease amongst displaced populations. In the 2 years following the earthquake and Fukushima NPP accident, relocation was generally associated with an

increased likelihood of developing CVD or risk factors. Zhang et al (2017b) found that after one year living in evacuation shelters or temporary housing, cardiovascular related symptoms of headache, dizziness, and shortness of breath were exacerbated compared to those of people living in their own home. These results were statistically more robust in women than in men. These results may be linked to the psychological impact of relocation.

Ohira et al (2016a) reported significant increases in systolic and diastolic blood pressures after the earthquake and Fukushima NPP accident, in both displaced and non-displaced populations, with greater increases seen in displaced populations, A significantly increased prevalence in hypertension among the displaced population was also observed by Hasegawa et al (2016), with an increase from 53.9% to 60.1% after the evacuations. Hasegawa et al (2016) also reported a significant increase (1.5% to 2.4%) in atrial fibrillation (a common abnormal heart rhythm where electrical impulses fire off in a disorganised way in the top chambers of the heart) among the displaced population.

Relocation following the Fukushima NPP accident was also associated with dyslipidemia at least one year after the accident. One study (Nomura et al, 2016b) looked at the relative risk of hyperlipidemia compared to baseline measurements in 2008-2010. The relative risk was significantly different between displaced and non-displaced populations in 2012 and 2013, and remained after adjustment for confounding factors. Satoh et al (2016b) also reported a significant increase (from 6.0% to 7.2%) in the prevalence of hyperlipidemia following the disaster, with a significant correlation with evacuation.

4.1.5 Metabolic syndrome

Metabolic syndrome (METS) is a cluster of the conditions discussed above including blood pressure, high blood sugar, and abnormal cholesterol or triglyceride levels. When these all occur together there is an increased chance of developing heart disease, stroke or diabetes. One study (Hashimoto et al, 2017) looked at residents aged 40 to 74 living in evacuation designated areas who did not have METS at the time of the Fukushima NPP accident. A significant association was found between relocation and METS, with an incidence in displaced populations of 19.2% for males and 6.6% for females, compared to 11% (males) and 4.6% (female) for non-displaced populations.

Tsubokura et al (2013) studied metabolic measurements (body weight, waist circumference, blood sugar levels, blood pressure) in people living in temporary housing in Soma and compared results before and after the earthquake in those who were relocated because of the tsunami and those who were relocated because of high radiation levels. A significant difference was found in metabolic measurements (body weight, waist circumference, blood sugar levels, blood pressure) taken before and after the earthquake. Differences were also seen between the two groups. Notably, a significant increase in levels of glycated haemoglobin (HbA1c), which provides a measure of what average blood sugar levels have been over a period of weeks/months, in the post-earthquake results for the tsunami-relocated group, while no difference was seen for the radiation-relocated group. This difference may be related to changes in exercise and diet before and after the earthquake, and underlying differences between the two groups, but not enough information is available to be certain. These results suggest that chronic metabolic health problems should be monitored and treated after a disaster.

4.1.6 Chronic kidney disease

Chronic kidney disease (CKD) is a long-term condition with gradual loss of kidney function over time. This reduces the ability of the kidneys to carry out their normal functions, including maintenance of blood pressure and levels of chemicals that help the heart function. CKD is most often caused by damage to the kidneys from other conditions, most commonly diabetes and high blood pressure. People with CKD have an increased risk of developing other problems such as cardiovascular disease.

One study (Satoh et al, 2016a) looking at the prevalence of renal dysfunction at three to nine months following the Fukushima disaster did not find that relocation elevated the risk of chronic kidney disease (CKD), though it reported that there may be increased incidence of CKD complications in the future. Later studies (Ebner et al, 2016; Hayashi et al, 2017) found a significantly higher incidence of CKD about two years after the disaster, with Hayashi et al (2017) reporting evacuation as a significant risk factor for CKD. It is possible that CKD does not manifest in the short term but is seen after conditions such as diabetes and high blood pressure have had time to develop.

4.1.7 Polycythaemia

Polycythaemia is a condition with an elevated volume percentage of red blood cells in the blood. Red blood cell levels, haemoglobin levels and the prevalence of polycythaemia have all been found to be raised following the GEJE and Fukushima NPP accident. Eto et al (2019) found that the prevalence of polycythaemia increased from 23.7% to 36.4% in the relocated population but did not change in the non-relocated group. Another study (Sakai et al, 2014) found an increased prevalence of polycythaemia in both relocated and non-relocated groups with the increase in the relocated population (0.89% to 1.54%, $p<0.001$) being statistically significant. This study noted that among the relocated group, statistically significant increases in the prevalence of polycythaemia were seen in both smokers and non-smokers and in obese and non-obese, suggesting relocation is an independent factor for polycythaemia. A further study by Sakai et al (2017) also showed a higher prevalence of polycythaemia in both the relocated and non-relocated populations, with the relocated population showing a greater, statistically significant, increase from before the GEJE and NPP accident to afterwards. Even for smokers or those with obesity or hypertension there was increased prevalence of polycythaemia in relocated groups, though these increases were not as significant. Polycythaemia among relocated populations is believed to be caused by increased psychological stress, though the exact mechanism is unknown. As previously discussed, it is not clear whether the most significant cause of stress is the earthquake/tsunami, radiation anxiety, or relocation.

4.1.8 Other health problems

Cramped and overcrowded living conditions in evacuation centres can increase the incidence of communicable diseases. A significant increase in the incidence of tuberculosis (TB) was seen among evacuees in coastal regions of Northern Miyagi at two years after the Fukushima NPP accident (Sakurai et al, 2016), while inland regions showed the same incidence rate before and after the disaster. Results suggest that the coastal region evacuation shelters had overcrowding, and this is thought to have affected the incidence of TB.

A significant association was found (Takahashi et al, 2017) between relocation and an increase in liver dysfunction after the Fukushima accident. This was seen in non-drinkers, as well as light and heavy drinkers, allowing for age, sex, BMI, smoking and alcohol intake. It is thought that the increase was due to an increase in fatty liver disease via an increased BMI.

Social isolation, resulting from relocation, has been seen to contribute to delays in patients seeking medical attention for potentially serious health issues. One man with rectal cancer (Ozaki et al, 2017a) delayed seeking attention for over one year and the delayed diagnosis resulted in his early death. A study (Ozaki et al, 2017b) of women with symptomatic breast cancer in an area affected by the Fukushima disaster and subject to evacuations, found an increased risk of patient delay among post-disaster patients compared with pre-disaster.

4.2 Vulnerable populations

Some of the vulnerable groups considered for evacuation (see Section 3.2) also need special consideration in the longer term. Vulnerable populations may be more sensitive to changes in their living environment and to psychological burdens after a disaster, compared to the general population. The elderly and those with pre-existing health conditions can be particularly hard hit by temporary relocation and are more likely to experience difficulties in responding to rapidly changing post-disaster conditions.

A number of health effects have been discussed in Sections 4.1.1 to 4.1.8, with it being seen that sometimes the increased risk of health impacts related to relocation may be greater than the increased cancer risk associated with radiation exposure if relocation had not taken place. This is particularly true for residents of nursing homes and people with underlying conditions such as diabetes (Tsubokura, 2018).

4.2.1 Patients in hospitals, and nursing/care homes

Factors, such as relocation teams, assessment tools, and the environment of the receiving facility, have been identified as being associated with successful relocations of the elderly from one care home to another (Castle, 2001). However, following the Fukushima NPP accident, the mortality rate among relocated elderly people requiring nursing care was seen to rise by up to a factor of four (Nomura et al, 2016c; Ohto et al, 2017). There is evidence that mortality of relocated long-term care residents increased in the six-months after the Fukushima NPP accident compared to the mortality rate pre-accident or for residents who sheltered-in-place (Smith and Swacina, 2017). Although mortality rates did reduce after the first three months, they remained elevated in the longer term at 1.5 times the pre-accident level (Hasegawa et al, 2016; Ohto et al, 2017). Problems with medical records, disruption to supply of resources, staff availability and familiarity with residents, and an increased potential for errors when staff have had their own lives and routines disrupted are all thought to contribute to the increased mortality rates (Smith and Swacina, 2017). In particular, problems can occur with handover of patient information during transfer between medical facilities, leading to detrimental health effects (Sonoda et al, 2019). The increase in mortality can be contrasted with risks of radiation exposure, which were likely to be limited (Nomura et al, 2016a) and suggests that sheltering should be considered as an alternative strategy for emergency planning, especially if movement of patients is not well planned and carried out in haste.

4.2.2 Children

Children can experience stress and anxiety through evacuation and, if it turns into longer-term relocation, they can suffer through loss of friends and familiar spaces. Problems have been reported in displaced children from Fukushima (WHO, 2016). Restrictions, for example limits on outdoor play, may be placed on children after a radiation emergency because of parental fear of radiation (Maeda and Oe, 2017). This can also have a negative impact on children's mental health as well as levels of obesity. Increases in BMI and the proportion of overweight/obese have been seen in children (Ohto et al, 2017; Zheng et al, 2017). One study of health effects following the Chornobyl disaster (Bromet and Havenaar, 2007) reported that mothers of displaced children reported significantly more anxiety, depression, somatic symptoms, and memory impairment in their children, though nothing was found in school performance or in the children's self-reported mental health.

A link has been found between sleep time and mental health of children, with both short and long sleep durations contributing to increases in depressive symptoms. Itagaki et al (2018) studied sleep patterns and mental health issues in children aged 4–15 years living inside the government-designated evacuation zone as of 11 March 2011. Within the 4 to 6-year-old group, shorter sleep time (< 9 hours) was associated with a higher risk of mental health disorders. On the other hand, oversleeping (≥ 10 hours) was associated with a high risk of mental health disorders in 7 to 12-year-olds. In the group aged 13 to 15 years, both short (< 6 hours) and long (≥ 9 hours) sleep times were associated with a high risk of mental health disorders. The study also looked for correlations between sleep patterns and experience of either the tsunami or NPP accident, as well as whether participants were relocated within or outside of the Fukushima prefecture. There was no significant link between sleep patterns and experience of the tsunami in either the 4 to 6, 7 to 12, or 13 to 15-year-old groups. There was some correlation with experience of the NPP accident in the 7 to 12-year-old group, but none in the other age groups. In both the 4 to 6 and 7 to 12-year-old groups, those that were relocated outside of the Fukushima prefecture were found to sleep for longer times. No explanation was given for this, but as a greater correlation is seen between sleep patterns and evacuation than experience of either the tsunami or NPP accident, this may suggest that evacuation is the most stressful of these experiences.

Perceptions of others can also add to stress on children; nearly 200 children evacuated and temporarily relocated from the Fukushima prefecture were bullied, including verbal abuse such as being called "germ" or "radioactive" (Lyamzina, 2018). On a practical level, disruptions in education caused by evacuation and/or closure of schools can affect life chances, especially for those students affected close to the time of examinations (Deeming and Otley, 2018). Overall it is recommended (Mort et al, 2018) that sustained attention is required to address children's ongoing needs following relocation.

4.2.3 Adults living independently with medical/care requirements

Temporary relocation of individuals with physical impairments to facilities with unsuitable accommodation may lead to significant health impacts, and even premature death, through the deterioration of daily life activities because of physical and psychological burdens (Sawano et al, 2019). Chronic conditions can be exacerbated either by lifestyle changes or mental stress, both of which can be caused by temporary relocation. For example, rheumatoid arthritis, an autoimmune disease that causes joint inflammation with pain and stiffness, is

affected by living conditions and eating habits, as well as mental stress. The number of swollen joints, a clinical parameter used to score rheumatoid arthritis, was found to be significantly higher after the GEJE and Fukushima NPP accident than before, while the scores for this and other clinical parameters were seen to show significantly greater deterioration in the period after the disaster than before (Ochi et al, 2018). The low levels of radiation exposure arising from the accident would not cause this deterioration of clinical parameters; this is more likely to be mental stress and lifestyle changes resulting from the disaster. In a study of older people relocated from economically deprived areas following Hurricane Andrew, it was found that physical and mental health problems were exacerbated by relocation and only 28% had their physical health care needs met following relocation (Sanders et al, 2004).

Relocation can also result in impaired access to health care and access to medical facilities may remain difficult for some time after a disaster. An extreme case saw a 66 year old man forced to undertake several relocations to maintain dialysis treatment when facilities were moved after the GEJE and Fukushima NPP accident (Nishikawa et al, 2018). Continuity of care and treatment to prevent exacerbation of pre-existing disease should be considered in emergency arrangements.

5 Non-radiological health impacts of sheltering-in-place

Sheltering-in-place (generally referred to as sheltering in this report) is less disruptive than evacuation or temporary relocation but may also lead to mental stress linked to fear, confusion, or isolation. This is likely to be increased if individuals are sheltering at an unfamiliar location or are separated from family members. Sheltering may also be associated with the perception, true or false, that not enough is being done to protect the population.

5.1 General population

Sheltering is not a long-term option. Its use should ideally only be planned to last hours, and, at most, one or two days (Nisbet, 2019). A study of four French national-level radiological exercises (Domeneghetti et al, 2018) showed that actions implemented rapidly in the first hours of the event could last some time. In one case, initial sheltering lasted up to seven hours. This is long enough for potential problems, such as sheltering of ill people, the comfort afforded by the shelter, possible overcrowding, and availability of food, water and sanitation, to become real problems. The emotional impacts of confinement and separation from family members may be challenging, or people may struggle with the social interactions of sheltering with co-workers, extended family members or strangers (Dailey and Jungersen, 2013).

There are some relevant lessons to be drawn from experiences of quarantines related to infectious diseases, although such quarantines typically last much longer than would be expected with sheltering following a radiological incident. A review of literature concerning the psychological impact of quarantine for infectious diseases, particularly SARS and Ebola (Brooks et al, 2020) found that most studies reported negative psychological effects from quarantine, which could be wide ranging and long-lasting. It was found that many adverse effects came from having restrictions imposed, while voluntary quarantine with an altruistic approach lessened the impact. The duration of quarantine, health concerns (eg fear of

infection), inadequate supplies and inadequate information were all seen to be important factors for mental health. A review looking at the impact of the COVID-19 pandemic on adult mental health in the UK (Batteux et al, 2021) reported increasing levels of depression and anxiety since the start of the pandemic, with self-isolation identified as a risk factor for declining mental health. The amount of time spent watching pandemic related news was also identified as a risk factor for mental health issues in this review, contrasting with the study by Brooks et al (2020), which found lack of information to be a risk factor.

5.2 Vulnerable populations

The significant impacts of evacuation on vulnerable populations have been highlighted (Hasegawa et al, 2016; Tsubokura, 2018), with Murakami et al (2015) in particular suggesting that the loss of life expectancy (LLE) associated with receiving a radiation dose during sheltering (1,100 person-days for a 20 mSv dose up to 5,800 for a 100 mSv dose) is much lower than the estimated 11,000 person-days LLE associated with rapid evacuation. While elevated risks of mortality from evacuation have been well documented, gaps in knowledge on safe sheltering for vulnerable people have been noted (Shimada et al, 2018). The review of the impact of the COVID-19 pandemic on adult mental health in the UK (Batteux et al, 2021) reported that different populations were unequally affected, with women, young adults, ethnic minorities, those from lower socio-economic backgrounds and with pre-existing conditions most affected.

5.2.1 Patients in hospitals, and nursing/care homes

For patients and care home residents to shelter safely, resources such as power, medicines, food and caregivers are necessary. Sheltering without electrical power can be fatal for those dependent on medical technology such as ventilators (Mace and Doyle, 2017). If electrical power is lost, evacuation will be essential. If caregivers are evacuated away from the hospital, or access to medications or other supplies is limited, then patients become especially vulnerable with an increased risk of harm or death (Davis et al, 2017; Mace and Doyle, 2017). Therefore if the decision to implement sheltering is made, an adequate number of caregivers will be required to remain in the shelter (Smith and Swacina, 2017). Ohba et al (2021) report that people suffered when medical personnel left medical facilities near the Fukushima Daiichi NPP, because of concern about radiation.

If managed well, with consideration of requirements to shelter safely, sheltering can be a good option, particularly compared to unplanned evacuations. Following the Fukushima NPP accident, a nursing care facility in the Deliberate Evacuation Area considered that evacuation would be riskier than sheltering for the elderly residents. Plans were made to maintain care at the facility with staff visiting from outside the evacuation zone, and deaths related to evacuation were avoided (Ohba et al, 2021). However, Shimada et al (2018) indicate that sheltering in a “harsh” environment with inadequate resources can cause a mortality rate that is comparable with unplanned evacuations. The risk of sheltering in hospitals has been estimated as two to three times higher than for those who were evacuated with the needed support (Callen-Kovtunova et al, 2022). Mortality rates (number of deaths per person days in the hospital) among patients in a Fukushima hospital before the GEJE and Fukushima Daiichi Nuclear Power Plant (Fukushima NPP) accident were compared with mortality rates after the

accident. Post-accident mortality rates were calculated separately for three patient groups: patients who were evacuated (about 90% of these evacuations were on or after March 19th, 2011, allowing a reasonable amount of preparation time), patients who sheltered, and patients who were newly admitted after the emergency (Shimada et al, 2018). After adjusting for covariates (gender, primary disease and medical condition) the group that sheltered had a higher post-emergency mortality risk than pre-emergency, with no significant rise in mortality rate seen in the other two groups. This agrees with the suggestion that sheltering can lead to higher mortality rates than well planned evacuation of patients, especially if there are problems with resources such as heating, power, communication or supplies.

5.2.2 Children

If an incident occurs during school time, children may be sheltered at school rather than with their families. The emotional impacts of confinement and separation from family members may be challenging and lead to anxiety. It is recognised (Lasker et al, 2007) that anguish about separation from people you care about is a source of stress. The US Institute of Medicine (now the National Academy of Medicine) specifically recommend minimising parent-child separation (Committee on Homeland Security, 2006).

5.2.3 Adults living independently with medical/care requirements

The elderly, or those with medical conditions, may have particular requirements that cannot be met while sheltering. An increased mortality rate was seen among the elderly who were unable to safely shelter for extended periods following the Fukushima NPP accident (Callen and McKenna, 2018). Around one third of deaths in areas flooded by Hurricanes Katrina and Rita were in residences spared from flooding. These were due to dehydration, heart attack, stroke or other causes associated with lack of medical supplies during sheltering (Alderman et al, 2012).

6 Discussion

6.1 Comparison of evacuation/temporary relocation and sheltering

The literature review has shown that there are a wide number of non-radiological health impacts associated with evacuation, sheltering and temporary relocation. The most significant physical and psychological effects are summarised in Table 1. As there may be different concerns for the general population and vulnerable groups, Table 1 presents information for these populations separately and these are discussed in subsections 6.1.1 to 6.1.4. Because of these differences, it can be difficult to find a “one size fits all” solution; if decisions on urgent protective actions, intended to be in the best interest of the majority, are applied in a generic way across the whole population, those decisions may not be in the best interest of everyone.

For some protective actions and categories of individuals, there are no reported non-radiological health impacts. In such cases, there may be a genuine absence of health impacts or it may be because of gaps in the results that have been reported or picked up by the

literature review. Further work, ideally using a fully systematic review, is needed to establish a definitive position.

Table 1 Summary of non-radiological health effects for protective actions and population groups

	Evacuation	Temporary relocation	Sheltering-in-place
General population			
Physical effects	Small risk of transport related injury or death, likely to be the same as normal transport risks. Non-transport risks of injury may be slightly increased compared to everyday life, when unplanned or hurried.	Although not all studies agree, significant associations have been seen between relocation and overweight/obesity, diabetes, metabolic syndrome and polycythaemia. Some evidence exists for increase in cardiovascular disease and chronic kidney disease but are less conclusive.	Risk of problems with availability of food, water, and sanitation, especially as duration of sheltering increases.
Psychological effects	Some risk of psychological issues such as depression and anxiety disorders, including PTSD, arising, especially if evacuation is unplanned.	Increased incidence of psychological distress, depression and PTSD associated with relocation. This may be due to breakdown in communities, problems with accommodation and job loss but may also be caused by radiation anxiety. Disaster-related suicides may occur; evidence suggests there may be stronger link to relocation than radiation anxiety. Relocated communities may be subject to stigma.	Potential psychological impacts, due to family separation, and stress from sheltering with co-workers or strangers. Negative psychological impacts seen following quarantine situations, for infectious diseases, particularly when restrictions imposed. Lack of information, or too much focus on situation (eg watching TV news) can be risk factors for worsening mental health.
Vulnerable group – residents of hospitals/nursing homes:			
Physical effects	None reported in well planned evacuations, though deaths and increased morbidity can occur during unplanned evacuations. Problems can occur with handover of patient information during transfer between medical facilities, leading to detrimental health effects.	Elevated mortality rates. Problems with transfer of patient information may have impacts on health care.	Deaths or increased morbidity may occur, especially as duration of sheltering increases, or if there is a loss of power.
Psychological effects	None reported.	None reported.	None reported.
Vulnerable group – children:			
Physical effects	Higher risk of slips, trips and falls. Possibly more prone to infectious diseases.	Risk of obesity due to limited outdoor play.	None reported.
Psychological effects	Stress and risk of PTSD, especially if evacuation takes place during the school day, resulting in separation from family.	Risk of developing mental health disorders due to loss of friends and familiar spaces and disruption to sleep patterns. Risk of stigma and bullying from locals. Disruption to education.	Potential for anxiety disorders or other mental health issues if sheltered separately from family members. Young adults among population groups seen to be affected disproportionately by quarantine.

	Evacuation	Temporary relocation	Sheltering-in-place
Vulnerable group - independent adults with medical needs:			
Physical effects	Deaths may occur in elderly populations, especially if evacuations are not well planned. Increased morbidity may occur in the elderly or those with existing conditions, such as diabetes. If evacuation centres are not suitable for physical disabilities this can lead to significant health impacts because of physical burdens	Exacerbation of pre-existing conditions. If accommodation is not suitable for physical disabilities this can lead to significant health impacts because of physical burdens.	Deaths or increased morbidity may occur from dehydration, heart attacks and strokes, especially as duration of sheltering increases, due to lack of medical supplies
Psychological effects	If evacuation centres are not suitable for physical disabilities this can lead to significant health impacts because of psychological burdens.	If accommodation is not suitable for physical disabilities this can lead to significant health impacts because of psychological burdens.	None reported. Adults with pre-existing conditions among population groups seen to be affected disproportionately by quarantine.

6.1.1 General population

Evacuation is very effective at protecting small communities from radiation exposures, provided it is implemented before a release occurs and is well planned. For large numbers of people, or without adequate prior planning, evacuation can lead to serious physical and psychological health risks. Therefore, while the precautionary principle may suggest that evacuation of an area larger than required would be sensible, it is suggested that evacuation should not be carried out only to be cautious (US NRC, 2021). If the longer-term protective action of temporary relocation is required, physical and psychological health risks increase. Psychosocial effects may be among the most significant and costly non-radiological impacts resulting from an accident (Health Canada, 2020) and can exceed the direct health effects associated with radiation exposure that would have been received if the population had remained in situ (WHO, 2020). Chronic health problems such as diabetes should therefore be monitored and treated after a disaster. Sheltering-in-place can also offer effective protection from radiation exposures, and is often less disruptive, though health and wellbeing can be affected, particularly psychological health.

6.1.2 Patients in hospitals, and nursing/care homes

The decision whether to evacuate a hospital or nursing home or shelter-in-place is reported as being one of the hardest decisions that managers will have to make in their career, with some believing that there could be “no positive outcome” (McGinty et al, 2017). Evacuation of elderly or sick patients is a challenging and resource intensive task. Accessing appropriate modes of transport for transferring patients from one hospital site to another can be complicated. This is particularly true when caring for sick infants (Iwata et al, 2017). Evacuation decisions are time sensitive (Ricci et al, 2015). Early evacuation may subject patients to unnecessary risks, while delays in evacuation may lead to other problems. A complex evacuation may also take away resources from other parts of the response to an emergency and may be confusing and distressing to those being evacuated (Deeming and Otley, 2018). The difficulty of sharing

patient information following a disaster is recognised as a further complication (Sonoda et al, 2019), which can have adverse health impacts on vulnerable patients.

A major concern following the Fukushima Daiichi Nuclear Power Plant (Fukushima NPP) accident was whether or not to evacuate hospitals and nursing homes. The most influential factors considered when determining whether to evacuate a hospital or shelter-in-place included patient safety and maintaining continuity of operations, though cost was also cited as an influential factor (McGinty et al, 2017). Deaths and increased morbidity can occur as a result of evacuation, especially if this is unplanned. An evacuated population will need access to medical care and resources, which may in turn impact on the health care of the population in the receiving area. However, sheltering is not without problems for hospitals and nursing homes; a sheltered hospital population will require staff to remain at the facility and access to power, water and other resources. If nursing home residents are sheltered without adequate care, vulnerable residents may go long periods without adequate movement, teeth brushing, or even drinking water (some choose to do this in order to avoid needing the bathroom), increasing the risks of developing additional medical conditions subsequent to existing disease (Maeda et al, 2017).

The total loss of life expectancy (LLE) associated with rapid evacuations from a nursing home following the Fukushima NPP accident was estimated at around 11,000 person-days. This is many orders of magnitude higher than the estimated total radiation-related LLE of around 28 person-days that would have been incurred if evacuation had been delayed for 90 days (Murakami et al, 2015). Comparison of mortality risk before and after the Fukushima NPP accident, in sheltered patients and those who evacuated in a planned, unrushed manner suggested that sheltering can lead to higher mortality rates than well-planned movements of patients. It is therefore suggested that sheltering should be considered as an alternative strategy, especially if movement of patients would not be well planned but carried out in haste. An initial period of sheltering may be beneficial while evacuation is arranged. It is also suggested that more information is needed on the decision processes employed when deciding whether or not to evacuate and that the decision to evacuate nursing homes should be made with a transparent, evidence-based process rather than being the default position.

6.1.3 Children

Evacuation, temporary relocation or sheltering all bring a risk of mental health disorders, such as stress or anxiety disorders, including PTSD, in children. This is especially true if protective actions take place during the school day and result in separation of children from their families. Review of mental health following quarantine suggests that young adults' mental health may be affected differently to the general population. The literature contains some reports of the impacts of evacuation and temporary relocation on children's' physical health, though nothing was reported as a result of sheltering. Further research should investigate if any such effects have been reported.

6.1.4 Independent adults with medical needs

There is a risk that evacuation will be delayed when individuals have to wait for assistance. There is also a risk that people, especially the elderly, may be reluctant to leave their homes (Alderman et al, 2012). Either of these situations may result in last minute, hurried

evacuations. If essential supplies such as medicines, mobility aids, glasses, or hearing aids are left behind during a hasty evacuation, this is likely to make life in an evacuation centre, or alternative accommodation, even more challenging, and may put these people at increased risk of physical injury, or psychological impacts if they feel isolated.

An increased mortality rate was seen among the elderly who were unable to safely shelter-in-place for extended periods following the Fukushima NPP accident. Following Hurricanes Katrina and Rita, around one third of deaths in areas flooded were due to dehydration, heart attack, stroke or other causes associated with lack of medical supplies during sheltering.

6.2 Justification of protective actions

It is recognised in previous sections of this report that protective actions taken following the Fukushima NPP accident contributed to unnecessary deaths, morbidity, and in particular, psychological problems. In retrospect, it is likely that decisions concerning protective actions after the Fukushima NPP accident may have assumed an exaggerated health risk of radiation exposure and not have given adequate consideration of the non-radiological health impacts of protective actions (Callen and McKenna, 2018).

It is suggested (Callen-Kovtunova et al, 2022) that the number of deaths among the general population that were associated with protective actions is comparable to the estimated number of deaths that would be caused by radiation exposure of about 100 mSv. The off-site effective doses during the Fukushima accident were much lower than this so that the number of deaths associated with protective actions was greater than that prevented by the protective actions. The United Nations Scientific Committee of Effect of Atomic Radiation (UNSCEAR) reported no increase in health effects due to radiation exposure after the accident (Oka, 2022) However, survivors of the accident have suffered from long-term impaired mental health as a consequence of this disaster (Lagergren Lindberg et al, 2022). One source claims evacuation was ordered to avoid exposure that might shorten the average life expectancy by just 10 days (Yanovskiy et al, 2020). Oka (2022) reports that risk of the evacuation from Fukushima was 2.8 times the risk avoided by the evacuation. Hence protective actions implemented after the Fukushima NPP accident were possibly not properly justified (Callen-Kovtunova et al, 2022; Callen and McKenna, 2018). This agrees with Saji (2013), who reported that the risks and disaster related deaths (DRDs) imposed upon the evacuees outweighed the radiation risk that was potentially averted. A report of the United States Nuclear Regulatory Commission (US NRC, 2021) also says that a study of the protective actions taken at Chornobyl and Fukushima showed that most public relocations were not justified on the grounds of radiological health benefit. Particular problems were seen during evacuation of hospitals, where risks from evacuation often clearly outweighed the potential long-term health benefits of reducing the radiation dose from the accident.

It is also estimated that at least one third of the 116,000 relocations that took place in 1986 following the accident at Chornobyl were not appropriate, based on comparison of the expected loss of life expectancy (LLE) associated with the relocation to the expected LLE due to radiation exposure that would have occurred had people remained in situ (Thomas, 2017). Similarly, it is estimated that none of the 220,000 relocations carried out during a second evacuation in 1990 were appropriate. Therefore, it is possible that only less than 22% of

335,000 total relocations were fully justified with at least a quarter of a million people potentially moved away from the Chornobyl area without proper justification.

Adverse health effects occurred even though the actions were consistent with international recommendations to reduce radiation-induced health effects (Callen-Kovtunova et al, 2022). This is partly because although international safety standards such as (IAEA, 2014; IAEA, 2015a) give general instructions that non-radiological consequences should be taken into account when deciding on potential actions, there is little guidance on how to address psychosocial impacts and few or no practical tools provided (Callen-Kovtunova et al, 2022; WHO, 2020). It has also been suggested (Callen and McKenna, 2018; Yanovskiy et al, 2020) that the present guidelines published by IAEA are probably based on averting radiation risk only and that the reference levels do not properly consider the health impacts of taking protective actions and the psychological and other effects linked to exaggerated fear of radiation exposure. It is recognised that it is easy to re-evaluate previous decisions with the benefit of hindsight, and that some decisions made in Chornobyl and Fukushima were made when there was uncertainty and the potential for the situation to become much worse. Such decisions must be made under pressure, taking account of contradictory factors and much uncertainty. However, a study by Thomas (2017) concluded that governments tend to overreact if a large scale nuclear accident occurs, and that this can contradict the principle of justification. There is a need to prevent the same problems occurring should there be another severe NPP emergency, and radiation protection for emergency response should have the objective of taking better justified protective actions in the event of an emergency (Callen and McKenna, 2018).

6.3 Influences of different stressors

Section 1.1 described the differences between primary and secondary stressors, noting that the literature did not always clearly differentiate between the effects of primary and secondary stressors. In particular, it can be difficult to identify which is the main stressor when considering effects on mental health.

Much of the literature concerned the triple disaster of the GEJE and subsequent tsunami and Fukushima NPP accident, giving multiple primary stressors as well as the secondary stressor of protective actions implemented. The three prefectures of Fukushima, Miyagi and Iwate, which had similar cultures prior to the disaster, were all affected by the earthquake and tsunami, and evacuations/relocations were required from each of these prefectures. The Fukushima prefecture was also affected by the NPP accident, which increased the number of evacuations/relocations from this area. People leaving Fukushima also tended to be moved over greater distances than in the other two prefectures. It can therefore be tempting to attribute the relocations, rather than the primary stressors, as the reason why disaster-related deaths (DRDs) accounted for more than 50% of the Fukushima prefecture's total death toll, while in Iwate and Miyagi, DRDs accounted for less than 10% of the total death toll in these prefectures (Hayakawa, 2016) in the four years following the disaster. However, it must also be remembered that the radiological aspects (both physical effects of exposure and anxiety about real or perceived exposure, see Section 6.3.1) will likely have been more acute in the Fukushima prefecture (Hasegawa et al, 2016; Oe et al, 2018; Ohto et al, 2017). It was therefore not always clear to what extent health effects could be attributed to relocation rather than to the NPP accident, and for some health effects (particularly overweight/obesity,

diabetes, cardiovascular disease and chronic kidney disease) conflicting evidence was found in the literature. One study (Tanaka, 2015) noted that the areas with higher rates of DRDs coincided with areas subject to Evacuation Orders because of radiation levels, suggesting that the increased levels of DRDs were linked with radiation levels. However, the same study suggests that the high rates of DRDs, combined with high levels of displacement near the Fukushima NPP, implies that psychological stress associated with displacement may be underestimated.

Some studies following the Fukushima NPP accident do suggest that the secondary stressors of evacuation and relocation lead to more health effects than the primary stressors. Travelling to and living in an evacuation area are reported as being the two largest causes of DRDs following the Fukushima NPP accident, leading to considerably more DRDs than the earthquake, tsunami, or NPP accident (Hayakawa, 2016; Saji, 2013). Although the data was not straightforward to interpret, a study (Itagaki et al, 2018) of sleep patterns in young people following the GEJE, tsunami and NPP accident tended to show a greater correlation between sleep patterns and evacuation than experience of either the tsunami or NPP accident, suggesting that evacuation may be the most stressful of these experiences, see Section 4.2.2. Other earthquakes in Japan that led to large scale displacements, but had no radiological element, were associated with lower levels of PTSD than seen in Fukushima, see Section 4.1.1.2. This suggests that at least some of the PTSD is likely to be due to displacement, rather than any primary stressors. Another area where separation between the primary and secondary stressors is seen is disaster related suicides following the GEJE earthquake and Fukushima accident, as discussed in Section 4.1.1. The pattern over time in the ratio of suicide rate in individual prefectures to the average rate for the Japanese population was the same as seen following natural disasters and is known to be associated with a weakening of social ties, suggesting that relocation had a greater effect than radiation.

Some other studies, not related to Fukushima, also suggest the importance of the secondary stressors of evacuation and relocation. For example, studies following flooding (see Section 3.1.3) showed that evacuation is linked to increased levels of depression, anxiety, and PTSD. Additionally, analysis of a number of studies of health effects following a range of natural disasters found a significant relationship between PTSD and relocation, with a large disparity in the prevalence of PTSD between displaced and non-displaced populations (US NRC, 2021) and (Wu et al, 2019) indicate that evacuees have been seen to suffer up to twice the rate of illness of others affected by a disaster but who are not subject to displacement.

6.3.1 Radiation anxiety

Radiological accidents are further complicated by the presence of radiation anxiety/phobia. This is fear about radiation-induced harmful health effects, that can be significant and long lasting (Lagergren Lindberg et al, 2022), and acts as a subjective primary stressor. Not only can radiation anxiety cause health effects, particularly regarding mental health, but it may impact the number of evacuations. It is thought that consideration of radiation phobia influenced both the number of people who self-evacuated after the Fukushima NPP accident and the government's enforcement of prolonged evacuations (Saji, 2013).

Studies have found an association between people perceiving that health was affected by a nuclear power plant accident and poorer psychological well-being (Adams et al, 2011; Bromet, 2014; Bromet and Havenaar, 2007). The study of women displaced following the Chornobyl

accident (Adams et al, 2011) reported that this was largely explained by their continued concerns about the physical health risks stemming from the accident and knowing there is even a very small possibility that at some point in the future health problems related to radiation exposure could occur. Miura et al (2017) found a significant association between psychological distress and perception of radiation risk. Psychological stress caused by perceived exposure, can cause inflammation of the nervous tissues, giving a possible link between radiation anxiety and physical health impacts (Collett et al, 2020). Lagergren Lindberg et al (2022) reported that those with higher socioeconomic status tended to report lower levels of radiation anxiety than those with lower socioeconomic status.

Only low levels of radiation exposure were seen following the Fukushima NPP accident, and it is unlikely that radiation exposure will be directly responsible for the health effects seen. No significant association was found between psychological distress and environmental radiation levels (Fukasawa et al, 2017), but some studies found a significant association between psychological distress and radiation anxiety. Links between psychological distress and radiation anxiety have been seen following both the Chornobyl and Fukushima accidents (Bromet, 2014; Gresko and Perchuk, 2021; Kuroda et al, 2018; Lagergren Lindberg et al, 2022; Miura et al, 2017; Ochi et al, 2018; Oishi et al, 2021)

6.4 Dependency between health impacts

Health impacts of protective actions can be far reaching and may endure for a long time. In particular, changes of lifestyle, following temporary relocation can have a significant impact on physical and mental health, with strong links between the two. For example, poor mental health may lead to lack of physical activity, causing weight gain or obesity, and an increased BMI. This increases the risk of developing diabetes, cardiovascular disease or hypertension. Diabetes and hypertension can in turn impact on the kidneys. Conversely, changes in diet and physical activity may lead to weight gain which may cause mental health issues such as depression. It can be difficult to determine what causes each health effect observed – whether it is a direct result of either the protective action or the impact of the accident or is associated with another health effect. Careful monitoring of both psychological and physical health of displaced populations is recommended (Hashimoto et al, 2017; Lyamzina, 2018).

6.5 Planning

Preparedness is crucial in minimising the non-radiological impacts of urgent protective actions, especially for different population groups. Callen-Kovtunova et al (2022) suggests that around 60% of deaths among the general population relocated after the Fukushima NPP accident were caused by conditions that could have been eased by prior emergency preparedness provision. Plans should be tailored to the needs of each group, and should be reviewed and updated regularly (Ohba et al, 2021). Well planned evacuations tend to run more smoothly and cause less harm than those that are unplanned. Unplanned evacuations can lead to an alarming rise in morbidity and mortality. It is important to note that some residents in mandatory evacuation zones may remain in place despite evacuation orders, as seen after both the Chornobyl and Fukushima accidents. Mass evacuations can adversely affect the delivery of healthcare and other public health services, leaving any people remaining behind subjected to health risks arising from inadequate services, for example difficulties accessing

GP or hospital care (Morita et al, 2018). It is therefore important to adequately prepare and respond to their needs, including preparation for mental health and psychosocial support.

The NEA advises that it will be beneficial if experts in mental health involved in planning response to a radiological incident are given a basic understanding of radiation exposure and protection (NEA, to be published).

The benefits of planning are particularly important when considering vulnerable populations, who may have different needs to the general population. It has been shown that deaths and increased morbidity can occur as a result of evacuating hospital residents, but that good planning can prevent this.

Good preparation and planning by schools is recommended for a range of scenarios, ie not specifically radiation emergencies (Cabinet Office, 2014). It is left to individual schools to develop their own emergency plans according to local circumstances. Such plans will allow them to respond appropriately and in a timely fashion if an emergency occurs during the school day, reducing the immediate risks to students if evacuation is ordered. Additionally, plans should address how to mitigate the stress of separation from families if evacuation or sheltering-in-place occurs with or within the school, for example how to ensure communication with families to minimise uncertainty and provide reassurance.

People with disabilities, and elderly people with medical needs or mobility problems may live independently but need assistance in an emergency. These groups should be considered in planning, with plans considering how such groups can be identified (Cabinet Office, 2014). Such efforts would of course benefit the plans for any type of emergency, not just for radiation ones.

In the UK, a detailed off-site emergency plan is required for the area around a site/facility/mobile site (Detailed Emergency Planning Zone, DEPZ), while outlying areas only require less detailed outline planning. While outlying areas that are at low risk may not require detailed emergency plans, it was found that in areas beyond a 10 km radius of the Fukushima NPP there was insufficient information in evacuation plans about the process, how to prepare, how to vacate homes, how to protect oneself from radiation exposure, and how long evacuation may last. Only one hospital within the 10 km radius had prepared an evacuation manual for a nuclear emergency, while hospitals and nursing care facilities beyond a radius of 10 km were not prepared at all (Ohba et al, 2021). This is felt to have impeded the evacuation process (Hasegawa et al, 2016) once the evacuation zone expanded beyond 10 km of the Fukushima NPP. In particular, sub-populations where implementation of urgent protective actions may be difficult, will benefit from more detailed planning. There may therefore be a need for small areas, such as a school or hospital where evacuation is particularly challenging, within an outlying area that would normally only require outline planning, to have more detailed emergency plans.

6.6 Communication

The ability to manage effective communication has a significant impact on the success of measures such as evacuation and sheltering-in-place. If communication can be managed well, adverse health impacts may be reduced. The logistics of evacuation are complex and difficult to manage, especially without adequate communication. Following the Three Mile Island accident there were confused communications between various agencies, leading to

misunderstandings (WNA, 2001). As a result, although no official evacuation instruction was issued reports in the media about these “garbled communications” resulted in a loss of control and 140,000 people voluntarily evacuating with poor traffic management. Unclear information has the potential to increase the number of people seeking help unnecessarily, which can have an impact on healthcare to those most in need of it. Traditionally, television is the home-based way of receiving communications, while radio can be received at home or in the car. This was supported by Wray et al (2008). Advances in technology with improvements in mobile communication mean that communication methods are changing, and messages can be sent more easily to people on the move. A survey in 2014 (Nyaku et al, 2014) looked at which data sources US households would use as their main information source during a radiation emergency. Television and radio were still the main sources (55.8% and 18.4%), followed by the internet (13.6%). Only 1% of households gave social media as their main source of information. Social media has become increasingly important in recent years, with around 60% of the public relying on social media as a source for scientific information in a non-emergency situation, and can be useful to obtain and spread necessary information and ask for help in case of a disaster (Tsubokura et al, 2018). These communications can reach large groups of people almost instantaneously, though there is a need to ensure that information is accurate (OECD, 2018).

6.7 Limitations of this review

- Although efforts were made to be comprehensive with the literature search and to evaluate the quality of data sources found, it is recognised that this review has not been systematic. This is in part due to lack of definition for the review questions and methodology, and partly from being carried out over a prolonged period.
- It has been described in Section 6.3 that there can be difficulties determining the cause of health effects, that it can be hard to distinguish between primary and secondary stressors. More work is required on this.
- Although the literature reviewed ranged far beyond the experiences in Japan, there have been many studies following the 2011 Fukushima NPP accident. These have been important in highlighting the importance of non-radiation-related health issues, but it must be recognised that cultural differences, possibly including the perception of radiation resulting from the experiences at Hiroshima and Nagasaki, exist that may affect the extrapolation of Japanese experience to other countries.
- Many of the studies found in the literature are post-disaster studies, that do not take account of the pre-disaster status. Fussell and Lowe (2014) note that pre-disaster functioning is a strong predictor of post-disaster mental health and that without accounting for pre-disaster status the influence of evacuation or relocation on psychological outcomes may be over-estimated. While some studies do account for pre-accident mental health issues this is not a common occurrence. However, if the post-disaster prevalence of a mental health condition is compared between displaced and non-displaced populations, this should help negate such over-estimation as it can be expected that the pre-accident level of mental health issues would be the same in both populations

- There are inconclusive findings particularly regarding groups such as children, young people and the elderly. Additionally, gaps in knowledge have been noted for safe sheltering-in-place for vulnerable people (Shimada et al, 2018) and more information is needed on decision making for the evacuation or sheltering of hospitals.
- The review considers the current circumstances. Future changes in technology or society, coupled with an increasing awareness of the implications on mental health and the need for psychosocial support are likely to change the situation. It is important to consider demographic trends such as the increasing age of the population, for example the proportion of the population aged 85 and over in the UK is growing at a faster rate than other age groups (Office for National Statistics, 2018). Advancements in communication technology, such as the development of systems to send emergency alerts (*https://www.gov.uk/alerts*) will also impact on emergency preparedness and response.

7 Findings from the review

The decision as to whether to evacuate, relocate or shelter-in-place can be complex. This report reviewed a range of literature and collated the findings. Evacuation, relocation, and sheltering-in-place are all shown to be effective protective actions in response to a radiation emergency. However, they can all also result in non-radiological health impacts, both physical and psychological, including fatalities. Studies show several associations of health effects with evacuation and relocation. In some cases, studies suggest that displacement causes health effects and there is a potential for the risks from evacuation or relocation to exceed the risk to individuals from radiation exposure that would have been incurred if they had not been moved. However, it is not always clear whether displacement directly causes the health effects or if other factors are involved. For example, radiation anxiety can cause some of the health effects observed, particularly psychological issues, making it difficult to determine the extent to which a protective action, rather than radiation anxiety, is responsible for health effects.

Different population groups may require different protective actions, according to the prevailing circumstances. It can be difficult to find a ‘one size fits all’ solution. Specific areas outside the detailed emergency planning zone may require more detailed emergency plans. An example of this would be a hospital, where evacuation is particularly challenging.

Preparedness is crucial. In all cases considered in the review the risks of evacuation were greater if evacuations were unplanned and/or carried out in haste. For example, evacuation of hospitals or nursing homes following the Fukushima NPP accident, which were often rushed or carried out without adequate planning, led to increased mortality rates. It has been reported (Ohba et al, 2021) that in some cases where evacuation was carried out in a rush some people subsequently returned to the evacuation zone to collect important items that were left behind, thus reducing the radiation dose that was averted.

Psychological impacts are known to be very important, and it is known that links exist between physical and psychological health. Planning should therefore include preparation for mental health and psychosocial support. An important association has been shown between psychological distress among displaced populations and issues with accommodation. If the mental health of displaced populations can be given more consideration at an early stage and

actions taken to reduce psychological impacts, then this is likely to have a beneficial effect on physical health as well as mental health.

It is hoped that consideration of non-radiological health impacts will provide a broader context within which decision makers can plan and implement protective actions in the event of a radiation emergency. Key messages are presented below, grouped into four areas: general prevention of adverse health effects; prevention of adverse health effects in vulnerable populations; mental health; and gaps in knowledge. Full identification of the non-radiological health risks associated with protective actions is required, along with research to fill in identified knowledge gaps.

General prevention of adverse health effects

- The risks of radiation exposure and the risk of actions taken to reduce radiation risks need to be presented in an understandable way and balanced with a holistic approach to ensure justification.
- Evacuation of population groups is more efficacious when well-planned and not carried out in haste.
- Monitoring of health impacts (both physical and psychological) in displaced populations, with appropriate treatment offered as required, will help mitigate against non-radiological health effects such as diabetes.
- Emergency planning would benefit from considering demographic trends such as the increasing age of the population and advancements in communication technology.

Prevention of adverse health effects in vulnerable populations

- The needs of vulnerable groups may be different to the general population. It is therefore beneficial to consider the harms and benefits of protective actions, particularly urgent protective actions, separately for vulnerable population groups and the general population.
- It is preferable for decisions about whether or not to evacuate hospitals/nursing homes to be transparent and evidence-based, rather than evacuation being the default.
- Sheltering-in-place can be a successful alternative to evacuation of hospital patients/nursing home residents, especially if evacuations would be unplanned or in haste.
- Establishment of patient information sharing systems that can function after a radiation emergency will allow health care providers at any medical facility to understand the health conditions of displaced people as easily as possible.
- Whenever evacuation or shelter-in-place is being implemented, continuity of care in treatment of pre-existing conditions will lead to the best outcomes.
- For facilities where vulnerable groups are found, such as hospitals or schools, more in-depth planning will be beneficial, even if the facility is in an outlying area where detailed planning of urgent protective actions are not normally required.

- Following relocation, children are particularly likely to face both physical and social challenges, with ongoing needs to manage new routines.

Mental health

- Psychosocial support is likely to be needed for those with mental health issues, whether these are pre-existing or developed after the emergency. Temporary relocation may lead to more severe mental health effects than evacuation. Provision of psychosocial assistance should be provided through all stages of emergency response and may potentially be needed in the long term.
- Planning and action preferably in advance of any radiation emergency will support actions taken should such an event occur. This may include a review of capabilities for provision of mental health diagnosis, treatment and support among those subjected to evacuation, temporary relocation or sheltering-in-place, and recruitment and training of staff to provide co-ordinated mental health services.
- Ideally, actions to reduce stigma (negative attitudes, prejudice and discrimination) and self-stigma (internalisation of negative attitudes) should be developed as a priority.

Gaps in knowledge

- It is difficult to separate the effects of primary and secondary stressors on health. Additionally, although significant associations have been seen between relocation and a range of health effects, some results were inconclusive or conflicting. Further research, using prospective studies where possible, could help address these issues and fully understand the health risks.
- In particular, further research into vulnerability to mental health issues following a radiation emergency would help understand the risks.
- Study of the decision processes employed when deciding whether or not to evacuate hospitals and nursing homes would improve outcomes.
- There are areas where little or no evidence has been found in the literature to date and further investigation may be required. These include psychological effects in hospital or nursing home residents following evacuation or relocation; sheltering-in-place for vulnerable groups, particularly physical effects in children and psychological effects in hospital or nursing home residents or in adults with additional needs. However, this does not indicate a definite lack of health impacts, and a fully systematic review is recommended to establish a definitive position.
- Research into the types of support that can reduce impacts on people with physical disabilities could improve their prognosis in evacuation centres and other temporary accommodation.

8 Glossary of terms

Term or abbreviation	Definition
Anxiety disorder	Anxiety is a feeling of unease, worry or fear which, when persistent and impacting on daily life may be a sign of an anxiety disorder (Mental Health Foundation https://www.mentalhealth.org.uk/a-to-z/a/anxiety). Generalised Anxiety Disorder and Post-Traumatic Stress Disorder are two common types of anxiety disorder. Anxiety disorders can cause both psychological (mental) and physical symptoms.
BMI	Body Mass Index (BMI) is calculated as an adult's weight (in kilograms) divided by the square of their height (in metres) and is a measure of whether they are a healthy weight for their height.
Depression	Depression is a common mental health problem that causes people to experience low mood, loss of interest or pleasure, feelings of guilt or low self-worth, disturbed sleep or appetite, low energy, and poor concentration (Mental Health Foundation, https://www.mentalhealth.org.uk/a-to-z/d/depression) Depression can last for weeks or months, with psychological and physical symptoms.
Detailed Emergency Planning Zone (DEPZ)	A detailed emergency planning zone is a defined zone around premises where it is proportionate to pre-define protective actions which would be implemented without delay (eg within a few hours) to mitigate the most likely consequences of a radiation emergency. The protective action taken should provide prompt protection to those who may be affected, maximising effectiveness which would be reduced if time was taken to consider and implement appropriate action. (Health and Safety Executive, 2020)
Deterministic effects	Deterministic (health) effects are direct tissue damage, for example radiation burns, radiation sickness, cataracts, hair loss, sterility and the potential for fatalities, that occur if radiation exposure is sufficiently high, above a threshold dose. The threshold dose is usually defined as the dose above which signs and symptoms of the effect on a specific organ or tissue can be detected. Both the incidence and the severity increase with increasing dose above the threshold dose.
Disaster related death (DRD)	Death not directly attributed to the primary stressor (eg radiation) but from related causes, eg deaths caused by the deterioration of underlying medical problems due to poor medical access or illnesses arising from poor living environments, such as temporary shelters, in a disaster.
Displaced population	Displaced population refers to a group forced to leave their homes, usually due to a sudden event, such as war, a natural disaster (eg earthquake or flood) or a technological disaster (eg radiation accident). There is usually an intention to return home. (https://www.ifrc.org/en/what-we-do/disaster-management/about-disasters/definition-of-hazard/displaced-populations/)
Dyslipidemia	An imbalance of fats (lipids) circulating in the blood stream which increases the risk of heart disease, heart attack, and stroke. Levels of triglycerides and low-density-lipoproteins (LDLs, "bad" cholesterol) tend to be higher, while high-density lipoproteins (HDLs, "good" cholesterol) levels tend to be lower.
Hypertension	Also known as high blood pressure, this is a health condition in which the blood pressure in the arteries is persistently elevated. Long-term high blood pressure is a major risk factor for cardiovascular disease, stroke, vision loss, chronic kidney disease and dementia.
Polycythaemia	A medical condition with an increased volume percentage of red blood cells in the blood, either due to an increase in the number of red blood cells, or a decrease in the volume of blood plasma.
Post-traumatic stress disorder (PTSD)	A type of anxiety disorder that can develop after exposure to extremely stressful and traumatising events including severe accidents, sudden destruction of home or community, or harm to close relatives or friends. Feelings of distress may be severe and negatively affect an individual's quality of life. (Mental health Foundation, https://www.mentalhealth.org.uk/a-to-z/p/post-traumatic-stress-disorder-ptsd) Symptoms are generally long-term, lasting for at least a month after the event. A person with PTSD is at a higher risk for suicide and intentional self-harm.
Psychological impact	Psychological refers to things affecting to the mind, mental activity, or emotional state of a person. Psychological impacts therefore are those that affect the mental, rather than physical health.

Term or abbreviation	Definition
Psychosocial	Psychosocial refers to a combination of psychological and social aspects, related to impacts on mental health and/or social factors such as housing, education, health care or income, that impact on health (*https://www.cdc.gov/socialdeterminants/*)
Stigma, self stigma	Stigma is a negative association applied to a person or group who have had a specific disease or based on certain characteristics. People can be stereotyped and discriminated against because of a perceived link with disease or ill-health. (WHO, 2020) Self-stigma is awareness and internalisation of stigma. Self-stigma can cause feelings of shame and guilt often come with self-stigma, which can cause negative consequences, such as reduced self-esteem in an individual (Mental Health Foundation of New Zealand, *https://www.mentalhealth.org.nz/assets/ResourceFinder/individual-self-stigma-resource-card-4.pdf*)
Stochastic effects	Radiation exposures below those capable of causing deterministic effects may lead to an increased risk of health problems, such as cancer incidence, in the future. These are known as stochastic (health) effects and are chance events that are assumed to have no threshold. The probability of the effect increases with dose. With low doses of radiation, the increase in risk is likely to be very small and in practice may only be detectable using statistical methods. The severity of the effect is independent of the dose received.
Vulnerable populations	Specific groups with characteristics that distinguish them from the general population, and that make protective actions particularly difficult or hazardous, requiring separate consideration from the general population. Vulnerable populations may be more sensitive to changes in their living environment and to psychological burdens after a disaster, compared to the general population. Examples include hospital patients, residents of institutional settings such as nursing homes, children, the elderly, or adults who live independently but have particular medical or care needs.

9 References

Adams RE, Guey LT, Gluzman SF and Bromet EJ (2011). Psychological well-being and risk perceptions of mothers in Kyiv, Ukraine, 19 years after the Chornobyl disaster. *International Journal of Social Psychiatry* **57**(6), 637-645.

Alderman K, Turner LR and Tong S (2012). Floods and human health: A systematic review. *Environment International* **47**, 37-47.

Aumonier S and Morrey M (1990). Non-radiological risks of evacuation. *Journal of Radiological Protection* **10**(4), 287-290.

Bagaria J, Heggie C, Abrahams J and Murray V (2009). Evacuation and Sheltering of Hospitals in Emergencies: A Review of International Experience. *Prehospital and Disaster Medicine* **24**(5), 461-467.

Bastien MC, Dumas M, Laporte J and Parmentier N (1985). Evacuation Risks: A Tentative Approach for Quantification. *Risk Analysis* **5**(1), 53-61.

Batteux E, Taylor J and Carter H (2021). The impact of the COVID-19 pandemic on adult mental health in the UK: A rapid systematic review. *medRxiv*, 2021.2008.2023.21262469.

Behr JG and Diaz R (2013). Disparate Health Implications Stemming From the Propensity of Elderly and Medically Fragile Populations to Shelter in Place During Severe Storm Events. *Journal of Public Health Management and Practice* **19**(5), S55-S62.

Bertollini R, Di Lallo D, Mastroiacovo P and Perucci CA (1990). Reduction of births in Italy after the Chernobyl accident. *Scandinavian Journal of Work, Environment & Health* **16**(2), 96-101.

Blackburn CC and Shelke S (2022). The lingering impact of Hurricane Katrina: Examining the physical health, mental health, and racial equity impacts of disaster response. *Journal of Emergency Management* **20**(1), 9-15.

Bromet EJ (2014). Emotional Consequences of Nuclear Power Plant Disasters. *Health Physics* **106**(2), 206-210.

Bromet EJ and Havenaar JM (2007). Psychological and Perceived Health Effects of the Chernobyl Disaster: A 20-Year Review. *Health Physics* **93**(5), 516-521.

Brooks SK, Webster RK, Smith LE, Woodland L, Wessely S, Greenberg N and Rubin GJ (2020). The psychological impact of quarantine and how to reduce it: rapid review of the evidence. *The Lancet* **395**(10227), 912-920.

Burton JRA, Mora K, Rive GC and Thomas JA (2013). Billeting Post 2011 Canterbury Earthquakes – Research highlights and Billeting recommendations. Research summary fact sheet. Natural Hazards Research Platform. New Zealand.

Cabinet Office (2014). *Evacuation and shelter guidance. Non-statutory guidance to complement Emergency preparedness and Emergency response and recovery.* C. Office, London.

Callen-Kovtunova J, McKenna T and Steinhauser G (2022). What's better for our health? Conducting protective actions during a nuclear emergency or accepting a certain radiation dose? *Journal of Radiological Protection* **42**(2), 021516.

Callen J and McKenna T (2018). Saving Lives and Preventing Injuries From Unjustified Protective Actions—Method for Developing a Comprehensive Public Protective Action Strategy for a Severe NPP Emergency. *Health Physics* **114**(5), 511-526.

Carter H, Drury J, Amlôt R, Rubin GJ and Williams R (2014). Effective Responder Communication Improves Efficiency and Psychological Outcomes in a Mass Decontamination Field Experiment: Implications for Public Behaviour in the Event of a Chemical Incident. *PLOS ONE* **9**(3), e89846.

Castle NG (2001). Relocation of the Elderly. *Medical Care Research and Review* **58**(3), 291-333.

Chen X and Li Q (2017). Modeling Road Network Vulnerability for Evacuees and First Responders in No-Notice Evacuation. *Journal of Advanced Transportation* **2017**, 6193127.

Collett G, Craenen K, Young W, Gilhooly M and Anderson RM (2020). The psychological consequences of (perceived) ionizing radiation exposure: a review on its role in radiation-induced cognitive dysfunction. *International Journal of Radiation Biology* **96**(9), 1104-1118.

Committee on Homeland Security (2006). *Emergency Care Crisis: A Nation Unprepared for Public Disasters.* Subcommittee on Emergency Preparedness Science and Technology, Washington.

Dailey SF and Jungersen TS (2013) "The mental health effects of sheltering-in-place: What counselors need to know." Counseling Today.

Davis KJ, O'Shea G and Beach M (2017). Assessment of Risks Posed to VAD Patients During Disasters. *Prehospital and Disaster Medicine* **32**(4), 457-461.

Deeming H and Otley C (2018). *A review of recovery processes following Storm Desmond's impacts on Cumbria (5th/6th Dec 2015).*

Department for Transport (2020). *Reported road casualties in Great Britain: 2019 annual report.*

Dombroski M, Fischhoff B and Fischbeck P (2006). Predicting Emergency Evacuation and Sheltering Behavior: A Structured Analytical Approach. *Risk Analysis* **26**(6), 1675-1688.

Domeneghetti B, Benamrane Y and Wybo J-L (2018). Analyzing nuclear expertise support to population protection decision making process during nuclear emergencies. *Safety Science* **101**, 155-163.

Dosa D, Hyer K, Thomas K, Swaminathan S, Feng Z, Brown L and Mor V (2012). To Evacuate or Shelter in Place: Implications of Universal Hurricane Evacuation Policies on Nursing Home Residents. *JAMDA* **13**(2), 190.e191-190.e197.

Ebner DK, Ohsawa M, Igari K, Harada KH and Koizumi A (2016). Lifestyle-related diseases following the evacuation after the Fukushima Daiichi nuclear power plant accident: a retrospective study of Kawauchi Village with long-term follow-up. *BMJ Open* **6**(7), e011641.

Eto T, Chung Y-s, Ebner DK, Harada KH, Ishizuka J, Igari K and Koizumi A (2019). Impact of Evacuation on Lifestyle Activity and Metabolic Status Following the Fukushima Daiichi Nuclear Power Plant Accident: Preliminary Findings. *Nuclear Emergencies: A Holistic Approach to Preparedness and Response*. G. Steinhauser, A. Koizumi and K. Shozugawa. Singapore, Springer**:** 77-84.

Fujimori K, Nomura Y and Hata K (2014). Pregnant and Birth Survey After the Great East Japan Earthquake and Fukushima Daiichi Nuclear Power Plant Accident in Fukushima Prefecture. *Fukushima Journal of Medical Science* **60**(1), 106-107.

Fukasawa M, Kawakami N, Umeda M, Miyamoto K, Akiyama T, Horikoshi N, Yasumura S, Yabe H and Bromet EJ (2017). Environmental radiation level, radiation anxiety, and psychological

distress of non-evacuee residents in Fukushima five years after the Great East Japan Earthquake: Multilevel analyses. *SSM - Population Health* **3**, 740-748.

Fussell E and Lowe SR (2014). The impact of housing displacement on the mental health of low-income parents after Hurricane Katrina. *Social Science & Medicine* **113**, 137-144.

Government Communication Service (2022). *Crisis communication: A behavioural approach.* Cabinet Office.

Gresko MV and Perchuk IV (2021). Psychophysiological Features of Radiation Risk Perception. *Problems of Radiation Medicine and Radiobiology* **26**, 371-397.

Gu Z, Liu Z, Shiwakoti N and Yang M (2016). Video-based analysis of school students' emergency evacuation behavior in earthquakes. *International Journal of Disaster Risk Reduction* **18**, 1-11.

Hanna FB (2017). Alcohol and substance use in humanitarian and post-conflict situations. *Eastern Mediterranean Health Journal* **23**(3), 231-235.

Hasegawa A, Ohira T, Maeda M, Yasumura S and Tanigawa K (2016). Emergency Responses and Health Consequences after the Fukushima Accident; Evacuation and Relocation. *Clinical Oncology* **28**(4), 237-244.

Hasegawa A, Tanigawa K, Ohtsuru A, Yabe H, Maeda M, Shigemura J, Ohira T, Tominaga T, Akashi M, Hirohashi N, Ishikawa T, Kamiya K, Shibuya K, Yamashita S and Chhem RK (2015). Health effects of radiation and other health problems in the aftermath of nuclear accidents, with an emphasis on Fukushima. *The Lancet* **386**(9992), 479-488.

Hashimoto S, Nagai M, Fukuma S, Ohira T, Hosoya M, Yasumura S, Satoh H, Suzuki H, Sakai A, Ohtsuru A, Kawasaki Y, Takahashi A, Ozasa K, Kobashi G, Kamiya K, Yamashita S, Fukuhara S-i, Ohto H and Abe M (2017). Influence of Post-disaster Evacuation on Incidence of Metabolic Syndrome. *Journal of Atherosclerosis and Thrombosis* **24**(3), 327-337.

Havenaar JM, Bromet EJ and Gluzman S (2016). The 30-year mental health legacy of the Chernobyl disaster. *World Psychiatry* **15**(2), 181-182.

Hayakawa M (2016). Increase in disaster-related deaths: risks and social impacts of evacuation. *Annals of the ICRP* **45**(Suppl. 2), 123-128.

Hayashi Y, Nagai M, Ohira T, Satoh H, Sakai A, Ohtsuru A, Hosoya M, Kawasaki Y, Suzuki H, Takahashi A, Sugiura Y, Shishido H, Takahashi H, Yasumura S, Kazama JJ, Hashimoto S, Kobashi G, Ozasa K and Abe M (2017). The impact of evacuation on the incidence of chronic kidney disease after the Great East Japan Earthquake: The Fukushima Health Management Survey. *Clinical and Experimental Nephrology* **21**(6), 995-1002.

Health and Safety Executive (2020). *The Radiation (Emergency Preparedness and Public Information) Regulations Approved Code of Practice and guidance.* TSO.

Health Canada (2020). *Guidance on Planning for Recovery Following a Nuclear or Radiological Emergency.* Ottowa.

Holle CL, Turnquist MA and Rudolph JL (2019). Safeguarding older adults with dementia, depression, and delirium in a temporary disaster shelter. *Nursing Forum* **54**(2), 157-164.

Horikoshi N, Iwasa H, Kawakami N, Suzuki Y and Yasumura S (2016). Residence-related factors and psychological distress among evacuees after the Fukushima Daiichi nuclear power plant accident: a cross-sectional study. *BMC Psychiatry* **16**(420).

Hyer K, Polivka-West L and Brown LM (2007). Nursing Homes and Assisted Living Facilities: Planning and Decision Making for Sheltering in Place or Evacuation. Generations, American Society on Aging. **31:** 29-33.

IAEA (2014). *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards.* International Atomic Energy Agency, Vienna (Austria), General Safety Requirements Part 3 (GSR Part 3).

IAEA (2015a). *Preparedness and Response for a Nuclear or Radiological Emergency.* International Atomic Energy Agency, Vienna (Austria), General Safety Requirements No. GSR part 7.

IAEA (2015b). *The Fukushima Daiichi Accident, Technical Volume 3/5 Emergency Preparedness and Response.* Vienna.

IASC (2007). *IASC Guidelines on Mental Health and Psychosocial Support in Emergency Settings.* Inter-Agency Standing Committee, Geneva.

IASC (2020). *Briefing note on addressing mental health and psychosocial aspects of COVID-19 Outbreak-Version 1.0.* Inter-Agency Standing Committee.

ICRP (2020). Radiological Protection of People and the Environment in the Event of a Large Nuclear Accident. ICRP Publication 146. *Annals of the ICRP* **49**(4), 11-135.

Ishiki A, Okinaga S, Tomita N, Kawahara R, Tsuji I, Nagatomi R, Taki Y, Takahashi T, Kuzuya M, Morimoto S, Iijima K, Koseki T, Arai H and Furukawa K (2016). Changes in Cognitive Functions in the Elderly Living in Temporary Housing after the Great East Japan Earthquake. *PLOS ONE* **11**(1), e0147025.

Itagaki S, Ohira T, Nagai M, Yasumura S, Maeda M, Suzuki Y, Mashiko H, Shiga T, Miura I and Yabe H (2018). The Relationship between Sleep Time and Mental Health Problems According to the Strengths and Difficulties Questionnaire in Children after an Earthquake Disaster: The Fukushima Health Management Survey. *International Journal of Environmental Research and Public Health* **15**(4), 633-641.

Iwata O, Kawase A, Iwai M and Wada K (2017). Evacuation of a Tertiary Neonatal Centre: Lessons from the 2016 Kumamoto Earthquakes. *Neonatology* **112**(1), 92-96.

Kett ME (2005). Internally Displaced Peoples in Bosnia-Herzegovina: Impacts of Long-term Displacement on Health and Well-being. *Medicine, Conflict and Survival* **21**(3), 199-215.

Kõlves K, Kõlves KE and De Leo D (2013). Natural disasters and suicidal behaviours: A systematic literature review. *Journal of Affective Disorders* **146**(1), 1-14.

Körblein A (2021). Reduction in live births in Japan nine months after the Fukushima nuclear accident: An observational study. *PLOS ONE* **16**(2), e0242938.

Kunii Y, Suzuki Y, Shiga T, Yabe H, Yasumura S, Maeda M, Niwa S-i, Otsuru A, Mashiko H and Abe M (2016). Severe Psychological Distress of Evacuees in Evacuation Zone Caused by the Fukushima Daiichi Nuclear Power Plant Accident: The Fukushima Health Management Survey. *PLOS ONE* **11**(7), e0158821.

Kuroda Y, Iwasa H, Orui M, Moriyama N, Nakayama C and Yasumura S (2018). Association between Health Literacy and Radiation Anxiety among Residents after a Nuclear Accident: Comparison between Evacuated and Non-Evacuated Areas. *International Journal of Environmental Research and Public Health* **15**(7), 1463-1474.

Lagergren Lindberg M, Hedman C, Lindberg K, Valentin J and Stenke L (2022). Mental health and psychosocial consequences linked to radiation emergencies—increasingly recognised concerns. *Journal of Radiological Protection* **42**(3), 031001.

Lalani N, Drolet JL, McDonald-Harker C, Brown MRG, Brett-MacLean P, Agyapong VIO, Greenshaw AJ and Silverstone PH (2021). Nurturing Spiritual Resilience to Promote Post-disaster Community Recovery: The 2016 Alberta Wildfire in Canada. *Frontiers in Public Health* **9**.

Lasker RD, Hunter ND and Francis SE (2007). *With the Public's Knowledge, We Can Make Sheltering in Place Possible.* New York, NY: The New York Academy of Medicine.

Lee DC, Gupta VK, Carr BG, Malik S, Ferguson B, Wall SP, Smith SW and Goldfrank LR (2016). Acute post-disaster medical needs of patients with diabetes: emergency department use in New York City by diabetic adults after Hurricane Sandy. *BMJ Open Diabetes Research and Care* **4**(1), e000248.

Leppold C, Tsubokura M, Ozaki A, Nomura S, Shimada Y, Morita T, Ochi S, Tanimoto T, Kami M, Kanazawa Y, Oikawa T and Hill S (2016). Sociodemographic patterning of long-term diabetes mellitus control following Japan's 3.11 triple disaster: a retrospective cohort study. *BMJ Open* **6**(7), e011455.

Lyamzina Y (2018). Indirect health effects consequent to the Fukushima nuclear accident of 11 March 2011. *Ecological integrity, Law and Governance*. L. Westra, K. Bosselmann, J. Gray and Gwiazdon. Abingdon, Routledge.

Mace SE and Doyle CJ (2017). Patients with Access and Functional Needs in a Disaster. *Southern Medical Journal* **110**(8), 509-515.

Mace SE, Sharieff G, Bern A, Benjamin L, Burbulys D, Johnson R and Schreiber M (2010). Pediatric issues in disaster management, Part 2: Evacuation centers and family separation/reunification. *American Journal of Disaster Medicine* **5**(3), 149-161.

Macrotrends (2023). *Japan Death Rate 1950-2023.* [Online] Available at https://www.macrotrends.net/countries/JPN/japan/death-rate [accessed 28/03/2023]

Maeda K, Shamoto H and Furuya S (2017). Feeding Support Team for Frail, Disabled, or Elderly People during the Early Phase of a Disaster. *The Tohoku Journal of Experimental Medicine* **242**(4), 259-261.

Maeda M and Oe M (2017). Mental Health Consequences and Social Issues After the Fukushima Disaster. *Asia Pacific Journal of Public Health* **29**(2_suppl), 36S-46S.

Maeda M, Oe M, Bromet E, Yasumura S and Ohto H (2016). Fukushima, mental health and suicide. *Journal of Epidemiology and Community Health* **70**(9), 843-844.

Malik S, Lee DC, Doran KM, Grudzen CR, Worthing J, Portelli I, Goldfrank LR and Smith SW (2018). Vulnerability of Older Adults in Disasters: Emergency Department Utilization by Geriatric Patients After Hurricane Sandy. *Disaster Medicine and Public Health Preparedness* **12**(2), 184-193.

Martell M, Perko T, Zeleznik N and Molyneux-Hodgson S (2022). Lessons being learned from the Covid-19 pandemic for radiological emergencies and vice versa: report from expert discussions. *Journal of Radiological Protection* **42**(1), 011518.

McGinty MD, Burke TA, Resnick B, Barnett DJ, Smith KC and Rutkow L (2017). Decision Processes and Determinants of Hospital Evacuation and Shelter-in-Place During Hurricane Sandy. *Journal of Public Health Management and Practice* **23**(1), 29-36.

Menne B and Murray V (2013). *Floods in the WHO European Region: health effects and their prevention.* Copenhagen: WHO Regional Office for Europe.

Miura I, Nagai M, Maeda M, Harigane M, Fujii S, Oe M, Yabe H, Suzuki Y, Takahashi H, Ohira T, Yasumura S and Abe M (2017). Perception of Radiation Risk as a Predictor of Mid-Term Mental Health after a Nuclear Disaster: The Fukushima Health Management Survey. *International Journal of Environmental Research and Public Health* **14**(9), 1067-1079.

Moran CL (2014). Stressors, Primary and Secondary. *The Wiley Blackwell Encyclopedia of Health, Illness, Behaviour, and Society*. W. C. Cockerham, R. Dingwall and S. Quah, John Wiley and Sons.

Morita T, Nomura S, Furutani T, Leppold C, Tsubokura M, Ozaki A, Ochi S, Kami M, Kato S and Oikawa T (2018). Demographic transition and factors associated with remaining in place after the 2011 Fukushima nuclear disaster and related evacuation orders. *PLOS ONE* **13**(3), e0194134.

Mort M, Walker M, Williams AL and Bingley A (2018). Displacement: Critical insights from flood-affected children. *Health & Place* **52**, 148-154.

Munro A, Kovats RS, Rubin GJ, Waite TD, Bone A, Armstrong B, Waite TD, Beck CR, Bone A, Amlôt R, Kovats RS, Armstrong B, Leonardi G, Rubin GJ and Oliver I (2017). Effect of evacuation and displacement on the association between flooding and mental health outcomes: a cross-sectional analysis of UK survey data. *The Lancet Planetary Health* **1**(4), e134-e141.

Murakami M, Ono K, Tsubokura M, Nomura S, Oikawa T, Oka T, Kami M and Oki T (2015). Was the Risk from Nursing-Home Evacuation after the Fukushima Accident Higher than the Radiation Risk? *PLOS ONE* **10**(9), e0137906.

Murakami M, Tsubokura M, Ono K, Nomura S and Oikawa T (2017). Additional risk of diabetes exceeds the increased risk of cancer caused by radiation exposure after the Fukushima disaster. *PLOS ONE* **12**(9), e0185259.

NEA (to be published). *Practical guidance for mental health and psychosocial support in radiological and nuclear emergencies.* NEA.

Nisbet AF (2019). *Public Health Protection in Radiation Emergencies.* Public Health England, Chilton (UK), PHE-CRCE-049.

Nishikawa Y, Ozawa Y, Tsubokura M, Ozaki A, Sawano T, Morita T, Yoshida N and Fujii F (2018). Long-term vulnerability of access to hemodialysis facilities in repopulated areas after the Fukushima Nuclear Disaster: a case report. *Oxford Medical Case Reports* **2018**(7), 228-230.

Nomura S, Blangiardo M, Tsubokura M, Nishikawa Y, Gilmour S, Kami M and Hodgson S (2016a). Post-nuclear disaster evacuation and survival amongst elderly people in Fukushima: A comparative analysis between evacuees and non-evacuees. *Preventive Medicine* **82**, 77-82.

Nomura S, Blangiardo M, Tsubokura M, Ozaki A, Morita T and Hodgson S (2016b). Postnuclear disaster evacuation and chronic health in adults in Fukushima, Japan: a long-term retrospective analysis. *BMJ Open* **6**(2), e010080.

Nomura S, Tsubokura M, Gilmour S, Hayano RS, Watanabe YN, Kami M, Kanazawa Y and Oikawa T (2016c). An evaluation of early countermeasures to reduce the risk of internal radiation exposure after the Fukushima nuclear incident in Japan. *Health Policy and Planning* **31**(4), 425-433.

Nyaku MK, Wolkin AF, McFadden J, Collins J, Murti M, Schnall A, Bies S, Stanbury M, Beggs J and Bayleyegn TM (2014). Assessing Radiation Emergency Preparedness Planning by Using Community Assessment for Public Health Emergency Response (CASPER) Methodology. *Prehospital and Disaster Medicine* **29**(3), 262-269.

Ochi S, Kato S, Leppold C, Morita T, Tsubokura M, Oikawa T, Shineha R, Kanazawa Y and Fujiwara M (2018). Can a disaster affect rheumatoid arthritis status? A retrospective cohort study after

the 2011 triple disaster in Fukushima, Japan. *International Journal of Rheumatic Diseases* **21**(6), 1254-1262.

Oe M, Fujii S, Maeda M, Nagai M, Harigane M, Miura I, Yabe H, Ohira T, Takahashi H, Suzuki Y, Yasumura S and Abe M (2016a). Three-year trend survey of psychological distress, post-traumatic stress, and problem drinking among residents in the evacuation zone after the Fukushima Daiichi Nuclear Power Plant accident [The Fukushima Health Management Survey]. *Psychiatry and Clinical Neurosciences* **70**(6), 245-252.

Oe M, Maeda M, Nagai M, Yasumura S, Yabe H, Suzuki Y, Harigane M, Ohira T and Abe M (2016b). Predictors of severe psychological distress trajectory after nuclear disaster: evidence from the Fukushima Health Management Survey. *BMJ Open* **6**(10), e013400.

Oe M, Maeda M, Ohira T, Itagaki S, Harigane M, Suzuki Y, Yabe H, Yasumura S, Kamiya K and Ohto H (2018). Trajectories of Emotional Symptoms and Peer Relationship Problems in Children after Nuclear Disaster: Evidence from the Fukushima Health Management Survey. *International Journal of Environmental Research and Public Health* **15**(1), 82-91.

Oe M, Takahashi H, Maeda M, Harigane M, Fujii S, Miura I, Nagai M, Yabe H, Ohira T, Suzuki Y, Yasumura S and Abe M (2017). Changes of Posttraumatic Stress Responses in Evacuated Residents and Their Related Factors: A 3-Year Follow-up Study From the Fukushima Health Management Survey. *Asia Pacific Journal of Public Health* **29**(2_suppl), 182S-192S.

OECD (2018). *Towards an All-Hazards Approach to Emergency Preparedness and Response. Lessons Learnt from Non-Nuclear Events.* Organisation for Economic Cooperation and Development.

Office for National Statistics (2018). *Living longer - how our population is changing and why it matters (August 2018).*

Ohba T, Tanigawa K and Liutsko L (2021). Evacuation after a nuclear accident: Critical reviews of past nuclear accidents and proposal for future planning. *Environment International* **148**, 106379.

Ohira T, Hosoya M, Yasumura S, Satoh H, Suzuki H, Sakai A, Ohtsuru A, Kawasaki Y, Takahashi A, Ozasa K, Kobashi G, Hashimoto S, Kamiya K, Yamashita S, Abe M, Ohto H, Suzuki S, Yabe H, Maeda M, Matsui S, Fujimori K, Ishikawa T, Watanabe T, Suzuki S, Fukushima T, Midorikawa S, Shimura H, Mashiko H, Goto A, Nollet KE, Niwa S, Takahashi H and Shibata Y (2016a). Evacuation and Risk of Hypertension After the Great East Japan Earthquake. The Fukushima Health Management Survey. *Hypertension* **68**(3), 558-564.

Ohira T, Hosoya M, Yasumura S, Satoh H, Suzuki H, Sakai A, Ohtsuru A, Kawasaki Y, Takahashi A, Ozasa K, Kobashi G, Kamiya K, Yamashita S and Abe M (2016b). Effect of Evacuation on Body Weight After the Great East Japan Earthquake. *American Journal of Preventive Medicine* **50**(5), 553-560.

Ohira T, Nakano H, Nagai M, Yumiya Y, Zhang W, Uemura M, Sakai A and Hashimoto S (2017). Changes in Cardiovascular Risk Factors After the Great East Japan Earthquake: A Review of the Comprehensive Health Check in the Fukushima Health Management Survey. *Asia Pacific Journal of Public Health* **29**(2_suppl), 47S-55S.

Ohto H, Yasumura S, Maeda M, Kainuma H, Fujimori K and Nollet KE (2017). From Devastation to Recovery and Revival in the Aftermath of Fukushima's Nuclear Power Plants Accident. *Asia Pacific Journal of Public Health* **29**(2_suppl), 10S-17S.

Oishi K, Orita M, Taira Y, Kashiwazaki Y, Matsunaga H and Takamura N (2021). Risk Perception of Health Risks Associated with Radiation Exposure among Residents of Okuma, Fukushima Prefecture. *International Journal of Environmental Research and Public Health* **18**(24), 13208-13215.

Oka Y (2022). Risks and benefits of evacuation in TEPCO's Fukushima Daiichi nuclear power station accident. *Progress in Nuclear Energy* **148**, 104222.

Orui M, Suzuki Y, Goto A and Yasumura S (2018). Factors Associated with Maintaining the Mental Health of Employees after the Fukushima Nuclear Disaster: Findings from Companies Located in the Evacuation Area. *International Journal of Environmental Research and Public Health* **15**(1), 53-67.

Ozaki A, Leppold C, Sawano T, Tsubokura M, Tsukada M, Tanimoto T, Kami M and Ohira H (2017a). Social isolation and cancer management – advanced rectal cancer with patient delay following the 2011 triple disaster in Fukushima, Japan: a case report. *Journal of Medical Case Reports* **11**(1), 138.

Ozaki A, Nomura S, Leppold C, Tsubokura M, Tanimoto T, Yokota T, Saji S, Sawano T, Tsukada M, Morita T, Ochi S, Kato S, Kami M, Nemoto T, Kanazawa Y and Ohira H (2017b). Breast

cancer patient delay in Fukushima, Japan following the 2011 triple disaster: a long-term retrospective study. *BMC Cancer* **17**(423).

Paranjothy S, Gallacher J, Amlôt R, Rubin GJ, Page L, Baxter T, Wight J, Kirrage D, McNaught R and Palmer SR (2011). Psychosocial impact of the summer 2007 floods in England. *BMC Public Health* **11**(1), 145.

PHE (2020). *Chemical Hazards and Poisons Report Issue 27 - September 2020 Protective actions during chemical incidents and fires: evacuate or shelter-in-place?* PHE.

Regnier E (2008). Public Evacuation Decisions and Hurricane Track Uncertainty. *Management Science* **54**(1), 16-28.

Renne JL (2018). Emergency evacuation planning policy for carless and vulnerable populations in the United States and United Kingdom. *International Journal of Disaster Risk Reduction* **31**, 1254-1261.

Ricci KA, Griffin AR, Heslin KC, Kranke D and Dobalian A (2015). Evacuate or Shelter-in-place? The Role of Corporate Memory and Political Environment in Hospital-evacuation Decision Making. *Prehospital and Disaster Medicine* **30**(3), 233-238.

RoSPA (2023). *General Home Safety, Facts and Figures.* [Online] Available at *https://www.rospa.com/home-safety/advice/general/facts-and-figures* [accessed 04/05/23]

Saji G (2013). *A post accident safety analysis report of the Fukushima accident—future direction of evacuation: Lessons learned* IN 21st International Conference on Nuclear Engineering, ICONE21. Chengdu, China, 2013.

Sakai A, Nakano H, Ohira T, Hosoya M, Yasumura S, Ohtsuru A, Satoh H, Kawasaki Y, Suzuki H, Takahashi A, Sugiura Y, Shishido H, Hayashi Y, Takahashi H, Kobashi G, Ozasa K, Hashimoto S, Ohto H and Abe M (2017). Persistent prevalence of polycythemia among evacuees 4 years after the Great East Japan Earthquake: A follow-up study. *Preventive Medicine Reports* **5**, 251-256.

Sakai A, Ohira T, Hosoya M, Ohtsuru A, Satoh H, Kawasaki Y, Suzuki H, Takahashi A, Kobashi G, Ozasa K, Yasumura S, Yamashita S, Kamiya K and Abe M (2014). Life as an evacuee after the Fukushima Daiichi nuclear power plant accident is a cause of polycythemia: the Fukushima Health Management Survey. *BMC Public Health* **14**(1), 1318.

Sakurai M, Takahashi T, Ohuchi M, Terui Y, Kiryu K and Shikano K (2016). Increasing Incidence of Tuberculosis Infection in the Coastal Region of Northern Miyagi after the Great East Japan Earthquake. *The Tohoku Journal of Experimental Medicine* **238**(3), 187-195.

Sanders S, Bowie SL and Bowie YD (2004). Lessons Learned on Forced Relocation of Older Adults: The Impact of Hurricane Andrew on Health, Mental Health, and Social Support of Public Housing Residents. *Journal of Gerontological Social Work* **40**(4), 23-35.

Satoh H, Ohira T, Hosoya M, Sakai A, Watanabe T, Ohtsuru A, Kawasaki Y, Suzuki H, Takahashi A, Kobashi G, Ozasa K, Yasumura S, Yamashita S, Kamiya K and Abe M (2015). Evacuation after the Fukushima Daiichi Nuclear Power Plant Accident Is a Cause of Diabetes: Results from the Fukushima Health Management Survey. *Journal of Diabetes Research* **2015**, 627390.

Satoh H, Ohira T, Nagai M, Hosoya M, Sakai A, Watanabe T, Ohtsuru A, Kawasaki Y, Suzuki H, Takahashi A, Kobashi G, Ozasa K, Yasumura S, Yamashita S, Kamiya K and Abe M (2016a). Prevalence of Renal Dysfunction among Evacuees and Non-evacuees after the Great East Earthquake: Results from the Fukushima Health Management Survey. *Internal Medicine* **55**(18), 2563-2569.

Satoh H, Ohira T, Nagai M, Hosoya M, Sakai A, Watanabe T, Ohtsuru A, Kawasaki Y, Suzuki H, Takahashi A, Kobashi G, Ozasa K, Yasumura S, Yamashita S, Kamiya K and Abe M (2016b). Hypo-high-density Lipoprotein Cholesterolemia Caused by Evacuation after the Fukushima Daiichi Nuclear Power Plant Accident: Results from the Fukushima Health Management Survey. *Internal Medicine* **55**(15), 1967-1976.

Sawano T, Nishikawa Y, Ozaki A, Leppold C, Takiguchi M, Saito H, Shimada Y, Morita T, Tsukada M, Ohira H and Tsubokura M (2019). Premature death associated with long-term evacuation among a vulnerable population after the Fukushima nuclear disaster: A case report. *Medicine* **98**(27).

Shimada Y, Nomura S, Ozaki A, Higuchi A, Hori A, Sonoda Y, Yamamoto K, Yoshida I and Tsubokura M (2018). Balancing the risk of the evacuation and sheltering-in-place options: a survival study following Japan's 2011 Fukushima nuclear incident. *BMJ Open* **8**(7), e021482.

Smith DA and Swacina PJ (2017). The Disaster Evacuation or Shelter-in-Place Decision: Who Will Decide? *JAMDA* **18**(8), 646-647.

Sonoda Y, Ozaki A, Hori A, Higuchi A, Shimada Y, Yamamoto K, Morita T, Sawano T, Leppold C and Tsubokura M (2019). Premature Death of a Schizophrenic Patient due to Evacuation after a Nuclear Disaster in Fukushima. *Case Reports in Psychiatry* **2019**, 3284153.

Stanke C, Murray V, Amlôt R, Nurse J and Williams R (2012). The Effects of Flooding on Mental health: Outcomes and Recommendations from a Review of the Literature. *PLoS Currents: Disasters* **4**, e4f9f1fa9c3cae.

Stenke L, von Schreeb J, Simonsson M, Johansson J, Postgård P, Sigurdsson S, Ljungquist Å and Lagergren Lindberg M (2016). Lessons Learnt from the Fukushima Accident—A Swedish Medical Preparedness Perspective. *Radiation Protection Dosimetry* **171**(1), 134-138.

Taioli E, Tuminello S, Lieberman-Cribbin W, Bevilacqua K, Schneider S, Guzman M, Kerath S and Schwartz RM (2018). Mental health challenges and experiences in displaced populations following Hurricane Sandy and Hurricane Harvey: the need for more comprehensive interventions in temporary shelters. *Journal of Epidemiology and Community Health* **72**(10), 867-870.

Takahashi A, Ohira T, Hosoya M, Yasumura S, Nagai M, Ohira H, Hashimoto S, Satoh H, Sakai A, Ohtsuru A, Kawasaki Y, Suzuki H, Kobashi G, Ozasa K, Yamashita S, Kamiya K and Abe M (2017). Effect of evacuation on liver function after the Fukushima Daiichi Nuclear Power Plant accident: The Fukushima Health Management Survey. *Journal of Epidemiology* **27**(4), 180-185.

Tanaka R (2015). Prolonged Living as a Refugee from the Area Around a Stricken Nuclear Power Plant Increases the Risk of Death. *Prehospital and Disaster Medicine* **30**(4), 425-430.

Tanigawa K, Hosoi Y, Hirohashi N, Iwasaki Y and Kamiya K (2012). Loss of life after evacuation: lessons learned from the Fukushima accident. *The Lancet* **379**(9819), 889-891.

Thienkrua W, Cardozo BL, Chakkraband MLS, Guadamuz TE, Pengjuntr W, Tantipiwatanaskul P, Sakornsatian S, Ekassawin S, Panyayong B, Varangrat A, Tappero JW, Schreiber M and van Griensven F (2006). Symptoms of Posttraumatic Stress Disorder and Depression Among Children in Tsunami-Affected Areas in Southern Thailand. *JAMA* **296**(5), 549-559.

Thomas PJ (2017). Quantitative guidance on how best to respond to a big nuclear accident. *Process Safety and Environmental Protection* **112**, 4-15.

Trichopoulos D, Zavitsanos X, Koutis C, Drogari P, Proukakis C and Petridou E (1987). The victims of Chernobyl in Greece: induced abortions after the accident. *British Medical Journal (Clinical research ed.)* **295**(6606), 1100.

Tsubokura M (2018). Secondary health issues associated with the Fukushima Daiichi nuclear accident, based on the experiences of Soma and Minamisoma Cities. *Journal of the National Institute of Public Health* **67**(1), 71-83.

Tsubokura M, Onoue Y, Torii HA, Suda S, Mori K, Nishikawa Y, Ozaki A and Uno K (2018). Twitter use in scientific communication revealed by visualization of information spreading by influencers within half a year after the Fukushima Daiichi nuclear power plant accident. *PLOS ONE* **13**(9), e0203594.

Tsubokura M, Takita M, Matsumura T, Hara K, Tanimoto T, Kobayashi K, Hamaki T, Oiso G, Kami M, Okawada T and Tachiya H (2013). Changes in metabolic profiles after the Great East Japan Earthquake: a retrospective observational study. *BMC Public Health* **13**(1), 267.

Tsujiuchi T, Yamaguchi M, Masuda K, Tsuchida M, Inomata T, Kumano H, Kikuchi Y, Augusterfer EF and Mollica RF (2016). High Prevalence of Post-Traumatic Stress Symptoms in Relation to Social Factors in Affected Population One Year after the Fukushima Nuclear Disaster. *PLOS ONE* **11**(3), e0151807.

Uemura M, Ohira T, Yasumura S, Otsuru A, Maeda M, Harigane M, Horikoshi N, Suzuki Y, Yabe H, Takahashi H, Nagai M, Nakano H, Zhang W, Hirosaki M and Abe M (2016). Association between psychological distress and dietary intake among evacuees after the Great East Japan Earthquake in a cross-sectional study: the Fukushima Health Management Survey. *BMJ Open* **6**(7), e011534.

US NRC (2021). *Nonradiological Health Consequences from Evacuation and Relocation.* United States Nuclear Regulatory Commission, Washington, DC, NUREG/CR-7285.

van der List B (2018). *'You're Contaminated': The Stigma Against Japan's Fukushima Survivors.* [Online] Available at *https://www.vice.com/en/article/mb5zny/japan-fukushima-earthquake-survivors-stigma* [accessed 23 November 2021]

Waite TD, Chaintarli K, Beck CR, Bone A, Amlôt R, Kovats S, Reacher M, Armstrong B, Leonardi G, Rubin GJ and Oliver I (2017). The English national cohort study of flooding and health: cross-sectional analysis of mental health outcomes at year one. *BMC Public Health* **17**(1), 129.

WHO (1948). *Preamble to the Constitution of the World Health Organisation as adopted by the international health conference. New York, 19-22 June, 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948.* World Health Organization, Geneva.

WHO (2016). *Radiation: Health consequences of the Fukushima nuclear accident.* [Online] Available at *https://www.who.int/news-room/questions-and-answers/item/health-consequences-of-fukushima-nuclear-accident* [accessed 09/01/2023]

WHO (2020). *A framework for mental health and psychosocial support in radiological and nuclear emergencies.* World Health Organization, Geneva.

Willoughby M, Kipsaina C, Ferrah N, Blau S, Bugeja L, Ranson D and Ibrahim JE (2017). Mortality in Nursing Homes Following Emergency Evacuation: A Systematic Review. *JAMDA* **18**(8), 664-670.

WNA (2001). *Three Mile Island Accident.* [Online] Available at *http://www.world-nuclear.org/information-library/safety-and-security/safety-of-plants/three-mile-island-accident.aspx* [accessed 26/04/18]

Wray RJ, Becker SM, Henderson N, Glik D, Jupka K, Middleton S, Henderson C, Drury A and Mitchell EW (2008). Communicating With the Public About Emerging Health Threats: Lessons From the Pre-Event Message Development Project. *American Journal of Public Health* **98**(12), 2214-2222.

Wu J, Huang C, Pang M, Wang Z, Yang L, FitzGerald G and Zhong S (2019). Planned sheltering as an adaptation strategy to climate change: Lessons learned from the severe flooding in Anhui Province of China in 2016. *Science of The Total Environment* **694**, 133586.

Yanovskiy M, Levi ON, Shaki YY and Socol Y (2020). Consequences of a large-scale nuclear accident and guidelines for evacuation: a cost-effectiveness analysis. *International Journal of Radiation Biology* **96**(11), 1382-1389.

Zachria A and Patel B (2006). Deaths Related to Hurricane Rita and Mass Evacuation. *Chest* **130**(4, Supplement), 124S.

Zhang W, Ohira T, Abe M, Kamiya K, Yamashita S, Yasumura S, Ohtsuru A, Masaharu M, Harigane M, Horikoshi N, Suzuki Y, Yabe H, Yuuki M, Nagai M, Takahashi H and Nakano H (2017a). Evacuation after the Great East Japan Earthquake was associated with poor dietary intake: The Fukushima Health Management Survey. *Journal of Epidemiology* **27**(1), 14-23.

Zhang W, Ohira T, Yasumura S, Maeda M, Otsuru A, Harigane M, Horikoshi N, Suzuki Y, Yabe H, Nagai M, Nakano H, Hirosaki M, Uemura M, Takahashi H, Kamiya K, Yamashita S and Abe M (2017b). Effects of socioeconomic factors on cardiovascular-related symptoms among residents in Fukushima after the Great East Japan Earthquake: a cross-sectional study using data from the Fukushima Health Management Survey. *BMJ Open* **7**(6), e014077.

Zheng W, Yokomichi H, Matsubara H, Ishikuro M, Kikuya M, Isojima T, Yokoya S, Tanaka T, Kato N, Chida S, Ono A, Hosoya M, Tanaka S, Kuriyama S, Kure S and Yamagata Z (2017). Longitudinal changes in body mass index of children affected by the Great East Japan Earthquake. *International Journal of Obesity* **41**(4), 606-612.

About the UK Health Security Agency

The UK Health Security Agency is an executive agency, sponsored by the Department of Health and Social Care.

www.gov.uk/government/organisations/uk-health-security-agency

Published: November 2023
Version 1