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Considerations in relation to off-site emergency procedures and response for nuclear accidents

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ABSTRACT

The operation of nuclear facilities has, fortunately, not led to many accidents with off-site consequences. However, it is well-recognised that should a large release of radioactivity occur, the effects in the surrounding area and population will be significant. These effects can be mitigated by developing emergency preparedness and response plans prior to the operation of the nuclear facility that can be exercised regularly and implemented if an accident occurs. This review paper details the various stages of a nuclear accident and the corresponding aspects of an emergency preparedness plan that are relevant to these stages, both from a UK and international perspective. The paper also details how certain aspects of emergency preparedness have been affected by the accident at Fukushima Dai-ichi and as a point of comparison how emergency management plans were implemented following the accidents at Three Mile Island 2 and Chernobyl. In addition, the UK's economic costing model for nuclear accidents COCO-2, and the UK's Level-3 Probabilistic Safety Assessment code "PACE" are introduced. Finally, the factors that affect the economic impact of a nuclear accident, especially from a UK standpoint, are described.

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1. Introduction

Since the development of civil nuclear power in the 1950s, it is fortunate that relatively few accidents have occurred with off-site consequences. Such events are rare due to the effort expended to provide the necessary preventive, protective, and mitigative safety measures for all types of nuclear facility. These measures span structures, systems and components (SSC), along with the management of the facility. The potential for high-consequence accidents to occur, albeit with very low probability, motivates the high financial costs observed in nuclear safety.

However, it is impossible to eliminate the possibility of accidents with off-site consequences entirely. With each accident

that has occurred, our conception of what the overall impacts associated with the accident, along with the policies and practices that are put in place to mitigate the consequences of the accident, has been challenged. For instance, a recent analysis has posited that, from an economic perspective, large-scale permanent relocation of people within the evacuation zones of Chernobyl has proven significantly less optimal than an alternative policy that could have been adopted: short-term evacuation coupled with aggressive remediation followed by a later return of those displaced (Waddington et al., 2017a). Two examples of such challenges from the incident at the Fukushima Dai-ichi in 2011 are as follows: (a) in the instance of protracted radionuclide releases it has been suggested that short-term sheltering may be detrimental if later evacua-

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tion is required (due to the potential for increased radiation dose received whilst evacuating) (Gering et al., 2013); (b) that whilst there have been no radiation-induced deaths from the accident at Fukushima Dai-ichi, an estimated 1793 have lost their lives during the subsequent evacuation and relocation (The Reconstruction Agency, 2014), with a much greater number experiencing detrimental health effects (Yabe et al., 2014).

Nuclear safety in most countries is assessed against the five levels of the defence-in-depth philosophy (IAEA, 2012a) in which the first four levels rely mainly on SSC on the site. SSC can be costly and, particularly if they are only required for unlikely events, a decision has to be made on whether they are cost effective.¹ Off-site emergency preparedness is the main mitigative safety measures in Level 5. However, although such arrangements are generally benchmarked against international guidelines (e.g. IAEA, 2002a), significant variations are seen between different national policies depending on: (a) their political acceptance, (b) public perception and aversion to radiological risk, (c) public trust of the relevant authorities, and (d) national approaches to dealing with civil contingencies. Arrangements and approaches to emergency response have changed over time and a synopsis of lessons that have been learnt over the last 70 years can be found in IAEA (2012b).

This paper reviews international guidance on emergency preparedness and responses to accidents and provides a review of the UK's approach. Section 2 details current emergency preparedness and response procedures and the effect of events at Fukushima Dai-ichi on these guidelines. Section 3 details the UK's approach to performing economic assessments of nuclear accidents; whilst Section 4 outlines the factors that affect the severity of a nuclear accident from both health and economic perspectives and how these can be assessed by a Level-3 Probabilistic Safety Assessment. For a discussion surrounding the UK's nuclear liability regime post-Fukushima, the reader is referred to (Heffron et al., 2016).

This review considers the health and safety aspects during an accident as well as remediation to reduce radiation doses post-accident, paying due attention to economic factors. Aspects such as decommissioning and dismantling of the facility, replacing the facility and/or the lost electricity, are not included. Whilst these may be of significant concern to the licensee and/or government, they do not impact directly on the risks from ionising radiation to people and the environment (cf. the Safety Objective in IAEA, 2006). In line with this consideration, risks from conventional hazards have been considered only where they result from actions to prevent radiation doses.

This review article was prepared as a background paper for the study of the likely effects of a major nuclear reactor accident in the UK, where Public Health England's PACE program suite and COCO-2 economic costing model (Charnock et al., 2013; Higgins et al., 2008) was applied to assess the economic and health costs of a hypothetical release from a fictitious

nuclear power station with realistic demography (Ashley et al., 2017).

2. Phases of an accident

Emergency preparedness for a nuclear accident can be considered within three chronological phases: planning phase, response phase, and recovery phase. The phases are not entirely separate and the boundaries should not be viewed as definitive as overlap can occur.

2.1. Planning phase

2.1.1. Requirements

It is fundamental in all countries that there should be some form of emergency planning and preparedness around nuclear facilities in case an accident should happen. This requirement is generally enshrined in some form of legal enactment, though this varies between countries as does the responsibility for drawing up these plans, assessing their basis, exercising them and, if needed, implementing them. Internationally, this is underpinned by Article 16.1 of the Convention on Nuclear Safety (IAEA, 1994) which states: "Each Contracting Party shall take the appropriate steps to ensure that there are on-site and off-site emergency plans that are routinely tested for nuclear installations and cover the activities to be carried out in the event of an emergency. For any new nuclear installation, such plans shall be prepared and tested before it commences operation above a low power level agreed by the regulatory body." The Convention of Nuclear Safety has 77 contracting parties with 65 signatories, including the United Kingdom and European Union (under the auspices of EURATOM) (IAEA, 2014a).

In the UK, the Nuclear Installations Act 1965 (HM Government, 1965), as amended by the Energy Act 2013 (HM Government, 2013), refers to emergency preparedness within Section 4.3²:

"Conditions that may be attached to a licence by virtue of subsection (1) may in particular include provision—"

clause (c):

"with respect to preparations for dealing with, and measures to be taken on the happening of, any accident or other emergency on the site;"

The Office of Nuclear Regulation (ONR) is responsible for administering these Acts and the requirements regarding emergency preparedness are covered in standard Licence Condition 11 (Office of Nuclear Regulation, 2013a, p. 11). The ONR in its guidance document, "Licencing Nuclear Installations" (Office of Nuclear Regulation, 2014), states as part of the supporting evidence required when applying for a Nuclear Site Licence the applicant should include:

"details of appropriate emergency arrangements and a suitable emergency plan (this may be limited in extent for the period before nuclear fuel is brought onto the site);"

The ONR also requires that before the start of active commissioning, adequate emergency arrangements should be in place and exercised as appropriate.

¹ In the UK, the requirement for not implementing additional safety measures is the legal requirement to show that risks to the health and safety of employees and people not in the employer's employ have been reduced so far as is reasonably practicable (see e.g. Health and Safety Executive, 2001).

² Although the Nuclear Installations Act 1965 was amended by the Energy Act 2013, the sections regarding emergency preparedness remained unchanged.

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