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The Early Phase of a Radiation Accident: Revisiting Thinking on Evacuation and Exclusion Zones

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ABSTRACT

We are just beginning a two year research project on the management of nuclear risk issues, paying particular attention to environmental, financial and safety issues. One aspect that concerns us is to avoid the assumption that any future accident will be similar to a past accident. In the cases of Chernobyl and Fukushima, it was possible both to evacuate the local population to impose a substantial exclusion zone, and we recognize that for many potential accidents this would be the case. But for some nuclear plant, it may not be so because of the large number of local inhabitants or because of some key industrial or societal infrastructure. We would like to take the opportunity of the ISCRAM conference to discuss this issue with a wide audience.

Keywords

Exclusion zone; evacuation and relocation; multi-criteria decision analysis (MCDA); radiation accident.

INTRODUCTION

We are just embarking on a two-year research project, *Management of Nuclear Risk Issues: Environmental, Financial and Safety* (NREFS), funded as part of a UK-India Civil Nuclear Research Collaboration. Our overall aim is to look at some of the fundamental thinking about the emergency management of a radiation accident, particularly in the early phases, drawing in some recent developments in J-value theory to evaluate health consequences, financial mathematics including real options and the use of multi-criteria decision analysis (MCDA) within the context of multiple scenarios. The Indian dimension is important because inevitably they have to plan to deal with much greater population densities than has been common in much thinking on emergency planning.

Issues that need to be considered in post-accident mitigation include the justifiable levels of dose for first-response workers, the size and duration of the exclusion zone for the general public and desirable levels of land remediation. The choice of location for new nuclear power plant is a related subject, but our project will not address that directly. Without prejudging the outcome of the research, it seems probable that a precautionary approach has been taken when establishing criteria for population evacuation and exclusion both in emergency planning (Mossman and Marchant, 2002) and in relation to the Chernobyl and Fukushima Accidents. Once established such precautionary thresholds may be very difficult to overturn. The public may perceive them as relating to minimum levels of safety and any attempt to relax such levels can lead to reduced trust in the authorities and low public acceptance.

Many trade-offs are involved in deciding on post-accident response, e.g. balancing worker safety versus public safety, economic loss versus immediate public safety, and immediate safety versus long-term health. There are ethical issues to be considered as well as a host of economic, social and legal issues (Butler, et al., 2011; French, et al., 1997a; Oughton and Howard, 2012). One of the key learning points from many studies on decision making in relation to the Chernobyl Accident was that decision making needed to be based on many more criteria than simply a cost benefit trade-off between public health and the financial cost of a countermeasure (Papamichail and French, 2013).

A particular feature of any mitigation strategy adopted is that it will be subject to strict scrutiny and needs to be capable of rigorous justification, not only to experts in the field but also to politicians and the general public, who may have a particular concerns about exposures to radio-activity. This puts a premium on using scientific methods of appraisal, which should be as objective as possible to allow decisions to be made in a way that is demonstrably rational, but should also be amenable to being understood by a wide audience including technical and economic stakeholders and, above all, the lay public.

The NREFS project will explore all these issues and others; but the focus of this paper is more restricted. The intention is to engage in discussion with ISCRAM members of the issues and criteria that need be addressed in thinking on evacuation, relocation and the scale of any exclusion zone. We unashamedly want such input for our project. In the next section we briefly present the wider NREFS project, its objectives and its methods. However, this is purely for information and background. The following section provides the focus of the paper. What issues and concerns need be addressed in emergency planning and management in relation to evacuation and relocation of people in the vicinity of a radiation accident? What determines the size of any exclusion zone? There is no conclusions section, since we wish to stimulate not resolve discussion. We will report back to ISCRAM2015 on the findings from our project on these and other matters.

THE NREFS PROJECT

The project forms part of the on-going UK-India Civil Nuclear Collaboration between the RCUK Energy Programme and India's Department of Atomic Energy (DAE), with the institutes sponsored by DAE including the Bhabha Atomic Research Centre and the Indira Gandhi Centre for Atomic Research. The problem of managing nuclear risk issues is vitally important to and common to all countries with nuclear programmes, including, of course, the UK and India. Our concern is to revisit the principles underpinning the planning of early phase responses to a radiation accident, bringing to bear recent developments in three areas of decision and evaluation methods.

- Health issues will be examined using the J-value methodology (Collins, 2009; Thomas and Jones, 2009; Thomas, et al., 2010). J-values offer a way of exploring and evaluating detriments to health in the context of safety. Moreover they have recently been extended to evaluate environmental issues relating to accidental contamination (Thomas and Jones, 2010).
- Financial and economic issues will be considered in the light of developments in financial mathematics including real options and models of liability insurance (Cardin, et al., 2008; Neely and de Neufville, 2001; Smith and Nau, 1995). Issues considered will include business continuity including the effect of an exclusion zone on this.
- MCDA has been used in emergency planning for radiation accidents over the past quarter century (Papamichail and French, 2013). Recently there have been a number of applications of MCDA across a range of scenarios which span the deep uncertainties within a context (Comes, et al., 2011; Montibeller, et al., 2006; Stewart, et al., 2013; Wright and Goodwin, 1999). The project will explore if such approaches can be used in the context of a radiation accident to support decision makers facing huge uncertainties (see also French, et al., 1997b).

The above three areas were chosen by the partly serendipitous process of an RCUK 'ideas sandpit' in which researchers and problem-owners develop small research projects in a short workshop. However, they can be rationalised in that emergency planning and response for radiation accidents has been driven to date by rather dated approaches to evaluating health and financial impacts. MCDA provides a framework which can articulate and integrate the different criteria. Moreover, there is possibility of combining this with scenario-thinking, as noted in the third bullet, to address the many deep uncertainties that face emergency planners and managers, particularly in the threat and early phases of the accident.

The research will make use of the extensive data on post-accident contamination and doses from the Chernobyl accident as a guide to its evaluation of mitigation options following a possible large-scale accident in the future. New data from Fukushima will be used as it is reported. Post-accident mitigation will then be considered in the four national contexts: Ukraine and Byelorussia, Japan, India and the UK. The formal objectives of the NREFS project are given below.

Objectives of the NREFS project

1. Develop and apply the J-value framework to post-accident mitigation, particularly for a large nuclear accident.
2. Develop and apply the methods of financial mathematics to post-accident mitigation
 - 2.1. Use real options analysis as a tool for judging the cost of instituting an exclusion zone following a severe nuclear accident.
 - 2.2. Use objective methods to assess nuclear power plant siting and liability insurance.
3. Use scenario-based multi-criteria decision analysis to investigate differences between recommendations from the objective methods and decisions being taken on the ground.
4. Integrate the results from the various methods into recommendations to nuclear plant operators worldwide.

Towards the end of the project we will hold one or more workshops and seminars to discuss our results and help shape the process of integrating them into a coherent whole.

While the NREFS project will not itself develop software and decision support tools to aid emergency planners and managers, our familiarity with systems such as RODOS and Argos (Bertsch, et al., 2009; French, et al., 2000; French, et al., 2007) will ensure that any methods and frameworks that we develop will be compatible with their working and relatively easy to implement.

EVACUATION, RELOCATION AND EXCLUSION ZONES

One issue that always faces emergency planning is the need to anticipate future events and not just solve past events better. Obviously we should learn from past events, but we must not assume that the future will completely repeat the past. Thinking on major radiation releases at nuclear plant has inevitably been dominated by the consequences of the Windscale, Three-Mile Island, Chernobyl and now, the Fukushima accidents. Thankfully, these have been the only four major accidents at nuclear reactors, and only three of these led to significant off-site contamination. Given that the Windscale event happened at an experimental plant in a much earlier age, Chernobyl and Fukushima provide the only recent examples of accidents with major off-site consequences and health risks. Inevitably a sample of two past events will lead to considerable biases if allowed to dominate emergency planning. One aspect that concerns us is that in both cases it was feasible to evacuate the local population and create an exclusion zone. In the case of Chernobyl, Prypiat was a substantial town, but it was the only substantial town within 30km of the plant and, moreover, the majority of its economy revolved around the plant. The rest of the region was agricultural; there was no other significant infrastructure or economic activity within 30km of the plant. The creation of an exclusion zone was costly, but feasible. In the case of Fukushima, the radiation accident was a part of a much larger catastrophe in which the Tsunami had devastated large swathes of land and infrastructure and killed around 20,000 people. Evacuating the population and creating an exclusion zone was a dreadful consequence of the radiation release; but, in the context of the Tsunami's devastation, it would seem less dramatic and thus more feasible than it would have had the release had some other cause.

There are already nuclear plant operating in locations in which evacuating the local population would be difficult, if not impossible in the timescales of an event and which are close enough to major infrastructure and industrial centres that creating an exclusion zone of 20-30km around the plant would have huge economic and social costs, perhaps well in excess of the health risks to the population a few km from the plant. In the case of India, the high population densities combined with poverty and lack of personal transport mean that evacuation of the local population in any reasonable timeframe may be a logistical impossibility.

While we have no intention of criticising decisions made in the context of Chernobyl and Fukushima, our project will revisit previous thinking on exclusion zones, evacuation and relocation. How much has thinking along the lines of that underpinning the Precautionary Principle (Mossman and Marchant, 2002) in its many variants dominated our thinking on emergency planning? Would it be better to use an approach which seeks to *balance* the radiation risks and health effects with the wider costs of creating an exclusion zone and the long-term relocation of large populations? To do this it is important, of course, to ensure that all the potential costs and detriments of any mitigation policy with or without relocation and the establishment of an exclusion zone are included in any analysis.

Thus in the early months of the project we shall be examining the thinking that occurred around Chernobyl and

Fukushima, the development of thinking and advice within forums such as ICRP and IAEA, and above all using the opportunity of events such as ISCRAM conferences to gather views and perspectives on these matters.

We close by emphasising that we do have an open mind on these matters. We are genuinely seeking to stimulate and draw on a discussion. We would also emphasise that the NREFS project will consider many other aspects of emergency planning and management of a radiation aspect than those raised here: for more details of those please contact any of the authors.

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