Japanese Earthquake and Tsunami: Implications for the UK Nuclear Industry

Charles Temple[1] BSc MSc FSRP CRadP and
Mike Weightman[2] BSc MSc DPhil CEng CPhys MIOP MIMMM

1. HM Superintending Inspector, Radiological Protection and Emergency Preparedness and Response
2. HM Chief Inspector of Nuclear Installations

Office for Nuclear Regulation, Redgrave Court, Bootle, Liverpool L20 7HS UK

Abstract:

On 11 March 2011 Japan suffered its worst recorded earthquake, known as the Tokuhu event. The ensuing tsunami resulted in a serious nuclear accident at the Fukushima Dai-ichi reactor site. Governments around the world watched with concern. The accident has since been rated as 7 (the highest level) on the International and Radiological Nuclear Event Scale (INES).

In the United Kingdom the situation was kept under review at the highest level within Government with a focus on protecting UK citizens in Japan. The UK Government asked HM Chief Inspector of Nuclear Installations to co-operate and co-ordinate with international colleagues in examining the circumstances of the Fukushima accident to see what lessons could be learnt to enhance the safety of the UK nuclear industry. An interim report[1] of this review was published in May 2011 with a final report[2] in the autumn of 2011.

Key findings of these reports are summarised with particular emphasis on those relating to radiological protection and emergency preparedness and response.

Key Words: Fukushima, Nuclear, Regulation, Emergency Preparedness, Radiological Protection

1. INTRODUCTION

1.1 On 11 March 2011 Japan suffered its worst recorded earthquake. The epicentre was 110 miles east north east from the of the Fukushima Dai-ichi (Fukushima-1) nuclear power site which has 6 Boiling Water Reactors. Reactor Units 1, 2 and 3 on this site were operating at power before the event and on detection of the earthquake shut down safely. Initially 12 on-site back diesel generators were used to provide the alternating (AC) electrical supplies to power essential post-trip cooling. Within an hour a massive tsunami from the earthquake inundated the site. This resulted in the loss of all but one diesel generator, some direct current (DC) supplies and essential instrumentation, and created massive damage around the site. Despite the efforts of the operators eventually back-up cooling was lost. With the loss of cooling systems, Reactor Units 1 to 3 overheated. This resulted in several explosions and melting of the fuel in the reactors leading to major releases of radioactivity, initially to air but later by leakage of contaminated water to sea.

1.2 This was a serious nuclear accident, with an INES rating of Level 7 (the highest level). Tens of thousands of people were evacuated from a zone extending 20km from the site and remain so today. So far, the indications are that the public health effects from radiation exposure are not great.

1.3 The Secretary of State (SoS) for Energy and Climate Change requested on 14 March 2011 that Dr Weightman examine the circumstances of the Fukushima accident to see what lessons could be learnt to enhance the safety of the UK nuclear industry. He was asked to provide an Interim Report, which was published on 18 May 2011, and a Final Report, which was published in September 2011.

1.4 Information for these reports was obtained from sources including the International Atomic Energy Agency (IAEA), other nations' regulators and Japanese Government reports. In addition Dr Weightman gained insights from his leading an international mission of experts to Japan, during which he visited the Fukushima Dai-ichi (Fukushima-1), Fukushima Dai-ni (Fukushima-2) and Tokai sites.

1.5 The Final Report covers all types of nuclear installations in the UK. It links into other work underway or planned which seeks to learn lessons such as the European Council "Stress Tests" and the work of the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD) and the IAEA. Neither report sought to examine nuclear policy issues which are outside ONR's competence and role and are a matter for others. However, the report looks at the available evidence and facts to establish technically based issues that relate to possible improvements in nuclear safety and its regulation in the UK. The report provided a range of conclusions and recommendations. Recommendations were directed to a range of bodies including the UK Government, the UK's Nuclear Emergency Planning Liaison Group (NEPLG), ONR as the regulator and the nuclear industry as a whole.

1.6 It was important for us to seek to draw early lessons wherever we could and to ensure that those lessons are put into action in the UK as soon as possible. In doing so we have recognised that, to achieve sustained high standards of nuclear safety, we all need to adhere to the principle of "continuous improvement". This principle is embedded in UK law, where there is a continuing requirement for nuclear designers and operators to reduce risks "so far as is reasonably practicable" (SFAIRP), which for assessment purposes is termed "as low as reasonably practicable" (ALARP). This is underpinned by the requirement for detailed periodic reviews of safety to seek further improvements. This means that, no matter how high the standards of nuclear design and subsequent operation are, the quest for improvement should never stop. Seeking to learn from events, new knowledge and experience, both nationally and internationally, must be a fundamental feature of the safety culture of the UK nuclear industry.

1.7 The UK nuclear regulatory system is largely non-prescriptive. This means that the industry must demonstrate to the Regulator that it fully understands the hazards associated with its operations and knows how to control them. The Regulator challenges the safety and security of their designs and operations to ensure their provisions are robust and that they minimise any residual risks. So, we expect the industry to take the prime responsibility for learning lessons, rather than relying on the Regulator to tell it what to do. Whilst we have sought to identify areas for review where lessons may be learned to further improve safety, it is for industry to take ultimate responsibility for the safety of their nuclear facility designs and operations.

1.8 Clearly, as regulators ONR would not hesitate to take appropriate action were we to become dissatisfied with the on-going safety of any existing nuclear facilities. Whilst we believe that significant lessons have been identified, we intend to monitor closely any additional detailed information and research which may provide extra detailed insights in the longer term.

1.9 ONR will continue to seek improvements in nuclear safety and take these forward with the nuclear industry in line with our normal regulatory approach of challenge, influence and, where needed, enforcement.

2. GENERAL CONCLUSIONS

2.1 Our Final Report featured 6 conclusions and endorsed 11 conclusions that featured in the earlier Interim Report. Detailed discussion of the conclusions is beyond the scope of this paper but some of the key ones are listed below.

2.2 Conclusions from the Final Reports were as follows:

- FR-6: The Industry and others have responded constructively and responsibly to the recommendations made in our interim report and instigated, where necessary, significant programmes of work. This shows an on-going commitment to the principle of continuous improvement and the maintenance of a strong safety culture.

- IR-1 In considering the direct causes of the Fukushima accident we see no reason for curtailing the operation of nuclear power plants or other nuclear facilities in the UK. Once further work is completed any proposed improvements will be considered and implemented on a case by case basis, in line with our normal regulatory approach.

- IR-2: In response to the Fukushima accident, the UK nuclear power industry has reacted responsibly and appropriately displaying leadership for safety and a strong safety culture in its response to date.

- IR-3: The Government's intention to take forward proposals to create the Office for Nuclear Regulation, with the post and responsibilities of the Chief Inspector in statute, should enhance confidence in the UK's nuclear regulatory regime to more effectively face the challenges of the future.

- IR-4: To date, the consideration of the known circumstances of the Fukushima accident has not revealed any gaps in scope or depth of the Safety Assessment Principles for nuclear facilities in the UK.

- IR-5: Our considerations of the events in Japan, and the possible lessons for the UK, has not revealed any significant weaknesses in the UK nuclear licensing regime.

- IR-7: There is no need to change the present siting strategies for new nuclear power stations in the UK.

- IR-8: There is no reason to depart from a multi-plant site concept given the design measures in new reactors being considered for deployment in the UK given adequate demonstration in design and operational safety cases.

3. RECOMMENDATIONS FOR RADIOLOGICAL PROTECTION AND EMERGENCY PREPAREDNESS AND RESPONSE

3.1 In addition to the conclusions above, our reviews have given rise to 26 recommendations (Interim Report) and a further 12 recommendations (Final Report). Those with a particular bearing on radiological protection and/or emergency preparedness and response are listed and discussed in this section.

3.2 Recommendation IR-3: *The Nuclear Emergency Planning Liaison Group should instigate a review of the UK's national nuclear emergency arrangements in light of the experience of dealing with the prolonged Japanese event. This information should include the practicability and effectiveness of the arrangements or extending countermeasures beyond the Detailed Emergency Planning Zone (DEPZ) in the event of more serious accidents.*

3.2.1 In response to Recommendation IR-3 of the Interim Report, NEPLG conducted an initial review of emergency arrangements for dealing with a prolonged severe event at a nuclear site. This was followed by a series of workshops, to seek to learn the lessons from Fukushima. NEPLG currently has published "Consolidated Guidance"[3] that sets out the

response to emergencies at nuclear sites in the UK and overseas. NEPLG identified a number of opportunities to strengthen these arrangements, notably in the areas of radiation monitoring, central government response, emergency services' capacity and capabilities and extendability. These topics are considered below:

3.2.2 Radiation monitoring: NEPLG considered the adequacy of current radiation monitoring capabilities in the UK . Whilst the strengths of the existing arrangements were acknowledged, a number of areas of improvement were identified. In particular, although *Radiation Monitoring Co-ordination* (Consolidated Guidance Chapter 15) provided general information on the UK's radiation monitoring capabilities, it lacked detailed information about the UK's radiation monitoring capacity. NEPLG will improve this by addressing the need for a description of the UK's capability for hazard assessment and consider the UK's radiation monitoring arrangements more fully in guidance.

3.2.3 Central government response: Consolidated Guidance sets out the central government response to an emergency at a nuclear site based on the reference accident. NEPLG such arrangements to be fit for purpose, but it also identified a number of opportunities for strengthening arrangements. These include producing a common response framework for all types of event at nuclear sites; ensuring that the provision of science / technical advice for any event at a nuclear site is timely and lines up with best practice; and identifying further opportunities for working with local and national agencies to optimise the response to an event such as:

- reviewing the interfaces and roles of groups such as the Scientific and Technical Advice Cell (STAC) and the Scientific Advisory Group on Emergencies (SAGE); and centres such as the Nuclear Emergency Briefing Room (NEBR) and Scottish Government Resilience Room (SGRR); and

- reconciling key scientific roles including the Government Chief Scientific Adviser, Government Technical Adviser, Director of Public Health and HM Chief Inspector of Nuclear Installations.

3.2.4 Emergency Services' Capacity and Capabilities**:** Preparedness and response for the emergency services and how they work together, in any kind of emergency, have improved in recent years. Nevertheless, there are lessons to be learned from Fukushima and these will be taken forward, in part, through the Government's response to another recommendation (IR-2). NEPLG believes that within the UK there has been limited opportunity to test emergency service capacity and capability in the event of a prolonged radiation emergency at a nuclear site. Given the potential demand on current specialist responders, NEPLG has identified the need for a consistent radiation protection and intervention framework for all emergency services throughout the UK, and is currently developing a *Working Together Agreement* or *Memorandum of Understanding* between nuclear site operators and emergency services responders.

3.2.5 Extendibility: The Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR) require the Local Authority to maintain an off-site plan in the event that a reasonably foreseeable radiation emergency might lead a member of the public off the site to receive an unmitigated effective dose of 5 mSv in the year following the emergency (alternative criteria also apply). It is good practice for the off-site emergency plan to provide the basis for dealing with radiation emergencies that are not reasonably foreseeable through the concept of extendibility. The emergency plan should be extendible to provide rapid and effective mitigation for radiation emergencies which could occur, but the likelihood of which is so remote that detailed emergency planning is not justified. Further guidance on extendibility is available in NEPLG consolidated guidance[3] (see Chapter 3 on 'Emergency plans' and Chapter 8 on 'Early countermeasures beyond the detailed emergency planning zone') and 'Arrangements for responding to nuclear emergencies'[4]

3.2.6 It is good practice for the extendibility scenario (for a severe accident beyond the design basis) to consider sheltering and the taking of stable iodine tablets out to approximately 15km, and evacuation out to 4km. The guiding principle of extendibility was considered by the Inspectors for the Sizewell B and Hinkley Point C Public Enquiries, both of whom endorsed the "extendibility" principle. The Hinkley Point C Inspector also took account of the impact of the Chernobyl accident on emergency planning in his deliberations.

3.2.7 NEPLG concluded that the concept of extendibility is right, however it concluded that further work on the stress testing of these extendibility concepts will need to take place to ensure that the planning is appropriate for the full range of emergencies at nuclear sites. NEPLG also identified a need for consistent guidance on planning for the DEPZ (typically between 1 – 3km around a nuclear site) and the importance of ensuring effective and more-regular testing of extendibility arrangements. It is important to continue to determine emergency planning zones on a site-by-site basis. The UK Department of Energy and Climate Change (DECC) are currently taking forward detailed work (separate from, but complementary to, the Government's response to the Interim Report review) on the risk assessment, planning and response to potential emergencies of any scale at nuclear sites within the UK or abroad.

3.2.8 ONR and NEPLG are currently working with DECC to review current arrangements for emergency response to nuclear emergencies on nuclear licensed sites including on-site, off-site (near-field), off-site (far-field) and internationally. The DECC website provides a detailed record of the work of NEPLG and its sub-groups as this continues to evolve.

3.3 Recommendation IR-6: *ONR should consider to what extent long-term severe accidents can and should be covered by the programme of emergency exercises overseen by the regulator. This should include:*

a) evaluation of how changes to exercise scenarios supported by longer exercise duration will permit exercising in real time such matters as hand-over arrangements, etc.;

b) how automatic decisions taken to protect the public can be confirmed and supported by plant damage control data; and

c) recommendations on what should be included in an appropriate UK exercise programme for testing nuclear emergency plans, with relevant guidance provided to Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR) duty holders.

3.3.1 The Interim Report indicates that there is a need to consider extending some emergency exercises in the UK to include severe accident scenarios. The extensive and extended nature of the Fukushima accident highlighted areas where improvements may be made through exercising in real time such matters as handover arrangements, sustainability of resourcing, the provision of technical advice in short timescales (tailored to the needs of the different recipients) and the vital role of communications and the acquisition of reliable data.

3.3.2 As a result ONR has initiated a review of the existing programme of exercises to evaluate how changes to exercise scenarios supported by longer exercise duration will permit exercising in real time such matters as hand-over arrangements. To this end we are working closely with stakeholders including the Nuclear Emergency Arrangements Forum (NEAF) to develop the current exercise programme to ensure that the 3-year programme targets identified areas for improvement including Extendibility, Recovery, Communications, Security and Central Government response. The current programme is available at http://www.hse.gov.uk/nuclear/emergexeprog.htm

3.3.3 Extendability scenarios have previously been successfully tested in Exercise Madonna, based on an event at Heysham Power Station, in 1997 and in Exercise Isis, based on an event Bradwell Power Station, in 2002. This latter exercise tested a severe accident scenario, beyond the reasonably foreseeable (on which the DEPZ is based).

3.4 Recommendation IR-7: *ONR should review the arrangements for regulatory response to potential severe accidents in the UK to see whether more should be done to prepare for such very remote events. This should include:*

a) enhancing access during an accident to relevant, current plant data on the status of critical safety functions, i.e. the control of criticality, cooling and containment, and releases of radioactivity to the environment, as it would greatly improve ONR's capability to provide independent advice to the authorities in the event of a severe accident; and

b) review of the basic plant data needed by ONR – this has much in common with what we suggest should be held by an international organisation under Recommendation IR-1

3.4.1 ONR's response to the Fukushima accident is well reported within our Interim Report. Although stakeholders have fed-back positively regarding ONR's response to Fukushima, such as our provision of authoritative advice to Government, we are working to improve our internal arrangements to provide a more robust capability to respond, in particular, to prolonged events including those, very unlikely, events beyond the design basis.

3.5 Recommendation FR-6: *The nuclear industry with others should review available techniques for estimating radioactive source terms and undertake research to test the practicability of providing real-time information on the basic characteristics of radioactive releases to the environment to the responsible off-site authorities, taking account of the range of conditions that may exist on and off the site.*

3.5.1 The Fukushima event highlighted the need to establish an effective and efficient process by which timely dose consequence advice can be provided to Government during an Off-Site Nuclear Emergency either in the UK or overseas. For Fukushima, ONR provided estimated source term information on which to base dose consequence assessments which required collaboration between ONR, the Health Protection Agency (HPA) and the Government's Radioactive Incident Monitoring Network (RIMNET).

3.5.2 ONR is continuing liaison with these agencies and with licensees to enable a quicker, more authoritative, assessment of appropriate countermeasure advice to protect the public in the event of a nuclear accident in the UK. A phased approach has been adopted starting with the more hazardous nuclear licensed sites.

3.6 Recommendation FR-7: The Government should review the adequacy of arrangements for environmental dose measurements and for predicting dispersion and public doses and environmental impacts**,** and to ensure that adequate up to date information is available to support decisions on emergency countermeasures.

3.6.1 Following the Fukushima accident widespread environmental monitoring was implemented across Japan, including measurements of air concentrations, ground deposition, water and foodstuffs within a few days of the earthquake. Radiation monitoring during and after a nuclear emergency plays an important role in providing an input to decision-making and in the provision of information to the public and to official bodies. Monitoring undertaken might relate to the immediate impact of the accident on people and the potential future impact resulting from environmental contamination. Furthermore reliable monitoring results are likely to inform decisions on changes to countermeasure advice. Within the UK, responsibilities for radiation monitoring in the event of a nuclear emergency lie with a number of organisations. The licensee carries out monitoring of the area immediately surrounding the facility, out to a pre-determined radius. The HPA's Centre for Radiation, Chemical and

Environmental Hazards (CRCE) co-ordinates activities beyond this. During the Fukushima accident, international assistance was requested due to the widespread dispersal of the contamination.

3.6.2 ONR's response to date to this recommendation is based on work to improve off-site radioactive monitoring capability and arrangements for identifying and implementing improvements to national arrangements for dose consequence assessment (as discussed earlier in this paper).

3.7 Recommendation FR-9: *The UK Government, nuclear industry and ONR should support international efforts to improve the process of review and implementation of IAEA and other relevant nuclear safety standards and initiatives in the light of the Fukushima-1 (Fukushima Dai-ichi) accident.*

3.7.1 The UK has, for many years, enjoyed a good relationship with nuclear regulators worldwide and with various international nuclear bodies including:

- IAEA (www.iaea.org)
- The Organisation for Economic Co-operation and Development's (OECD) Nuclear Energy Agency (NEA) (www.oecd-nea.org)
- European Council's European Nuclear Safety Regulators Group (ENSREG) (www.ensreg.org)
- The Western European Nuclear Regulators' Association (WENRA) (www.wenra.org)

3.7.2 We have participated at the highest level in meetings with these agencies at which the Fukushima accident have been discussed and also in support of the Convention on Nuclear Safety (CNS www-ns.iaea.org/conventions/nuclear-safety).

3.7.3 Additionally, Dr Weightman was invited to lead an IAEA high-level team of international nuclear experts to conduct a fact-finding mission to Japan[5].

3.7.4 In addition, ONR has close bilateral links with other nuclear regulators, in particular the United States Nuclear Regulatory Commission (US NRC) and the French Autorité de Sûreté Nucléaire (ASN).

3.7.5 We have also participated in the European Council "Stress Tests" for nuclear facilities in Europe, based on the emerging issues (see WENRA website for details). The UK's national Final Report for UK nuclear power plants was published in December 2011 and is available at: http://www.hse.gov.uk/nuclear/fukushima/stress-tests-301211.pdf.

We are currently progressing a similar programme of Stress Tests in relation to UK licensed nuclear sites other than non-nuclear power plants and will publish our findings in due course.

3.7.6 ONR is supporting the IAEA in its reviews of safety standards in the light of Fukushima, notably their GS-R-2 Safety Requirements document 'Preparedness and Response for a nuclear or radiological Emergency'. We also take an active role in working groups including the NEA OECD's Working Party on Emergency Matters (WPNEM) and the Emergency Arrangements Working Group of the Heads of European Radiological protection Competent Authorities (HERCA).

3.7.6 Such international co-operation has greatly enhanced our ability to respond to the lessons learned from the Fukushima accident.

4. RADIOLOGICAL PROTECTION – SPECIFIC LESSONS LEARNED

4.1 A number of specific lessons can be learned from the Fukushima accident in the area of radiological protection. Some of these are specific to the UK's arrangements, others to wider international experience. These are discussed in this section.

4.2 Training for event mitigation and recovery: The IAEA has noted good practices relating to the Fukushima clean-up and recognised that there are lessons to be learned in this area. Generally, in the UK, there is no detailed consideration given to the resources and facilities required, and co-ordination and control of such activities. This is of particular importance in terms of the arrangements for radiological monitoring and protection of workers, and the potential need to train many contract workers who may have little or no familiarity with the hazards on a nuclear site.

4.3 Doses to Intervention Personnel: In responding to the nuclear emergency at the Fukushima-1 site it was necessary for some of the operator's staff and emergency services, in seeking to restore cooling, to incur authorised whole body doses up to 250 mSv. Such exposures are considerably in excess of the 100 mSv emergency dose limit that had previously been applied in Japan. Similar arrangements apply in the UK where, in the event of a radiation emergency, it is recognised that emergency exposures exceeding normal dose limits may need to be incurred provided that the likely benefits in terms of life saving clearly outweigh the risks to those carrying out the intervention. If interventions require emergency workers to receive a dose greater than the limits specified in the Ionising Radiation Regulations 1999 (IRR 99) , then arrangements under REPPIR can disapply the normal dose limit for the purposes of intervention. REPPIR requires operators to notify HSE in advance of the dose levels they have determined to be appropriate for intervention workers in the event of a radiation emergency. The UK and REPPIR framework applied to the determination of dose levels for intervention personnel is consistent with that declared by IAEA and ICRP.

4.4 Vulnerability of RP Equipment: The on-site emergency response at Fukushima was hampered by damage to a range of equipment including electronic personal dosimeters and readers and air contamination monitors. It is therefore important to review the vulnerability of accident response equipment and resources to those accidents for which they would be needed, and ensure that arrangements are robust.

4.5 Public Protection Countermeasure Zone: Initially, the Japanese implemented a 3km radius evacuation zone and a 10km radius shelter zone. This was quickly extended to 10km radius evacuation zone and 20km radius shelter zone, and then later to a 20km radius evacuation zone and 30km radius shelter zone. This is similar to the UK arrangements, where immediate countermeasures are implemented in accordance with the off-site emergency plan within the 'detailed emergency planning zone' (DEPZ), but can be extended in terms of distance or an escalation in countermeasures as the event unfolds.

4.6 Distribution of Potassium Iodate Tablets: The Japanese do not pre-distribute potassium iodate tablets to those within the predetermined emergency planning zone. In response to the Fukushima emergency, potassium iodate tablets were distributed to evacuation centres within three days. Tablets were not distributed to evacuees until nine days into the accident. The UK provided potassium iodate tablets to the British Embassy in Japan for distribution to UK nationals to take if they were likely to be exposed to a significant cloud of radioactive iodine. Potassium iodate tablets are only needed around sites where there are operating nuclear reactors. They provide the most effective protection from radioactive iodine if taken just before an exposure occurs. In the UK the tablets are pre-distributed to residents within the DEPZ including schools and hospitals.

4.7 Monitoring, Decontamination and Medical Assistance of Evacuees, Casualties and Intervention Personnel: Monitoring and decontamination units were employed at evacuation centres to identify those who may have been contaminated and to provide reassurance monitoring to those who were not. It is believed that contamination was identified on only a few evacuees, who were successfully decontaminated at the evacuation centre. Also a few intervention workers are believed to have received significant skin doses to their feet or lower legs (believed to be 2–3 Sv), taken to hospital for medical treatment and later discharged. UK arrangements include the provision of monitoring and decontamination units, and local hospitals are identified that have the facilities and trained, competent staff to receive irradiated or contaminated casualties.

4.8 Countermeasures Against Ingestion: In Japan, milk, leafy green vegetables and drinking water were found to exceed regulatory values in some localised areas and restrictions were implemented. Discharges to sea of contaminated water resulted in fishing bans within 30km of the Fukushima-1 site being implemented along with a change to the permitted level of iodine-131 in fishery products. Where radioactivity is released into the environment, the criteria for intervention in food safety in the UK (at least in the early phase of the emergency) will be the Council Food Intervention Levels (CFIL) laid down by the EU. These are based on the aversion of a dose of 1mSv, assuming contaminated food is being consumed at the indicated level of contamination for a whole year. In the UK the Food Standards Agency (FSA) is responsible for ensuring the public is protected from contaminated food, including taking action to ensure food contaminated to unacceptable levels does not enter the food chain and implementing, where necessary, restriction orders under the Food and Environment Protection Act 1985. If it is assessed that levels of radioactivity in any potential food products may exceed the CFILs as a result of an accident, the FSA will describe the area in which the relevant CFILs might be exceeded, name the food products affected and advise on the actions to be avoided (e.g. eating, collecting, harvesting or transporting).

4.9 Longer Term Protective Actions: In Japan significant quantities of contaminated water were discharged to sea, and continue to be held on-site, potentially threatening the marine environment. Furthermore, in seeking to remediate contaminated land it has become clear that careful optimisation is needed to prevent the generation of unmanageable volumes of very low level radioactive waste. In the UK the Department for Environment, Food and Rural Affairs has responsibility in a nuclear emergency to protect animal welfare and to minimise the impact of the emergency on food production, farming and fishing industries. The disposal of any radioactive waste arising from decontamination and clean-up following a nuclear emergency would be handled on the basis of advice from the Environment Agency (EA) or the Scottish Environment Protection Agency (SEPA). These environment agencies advise on the most appropriate means of dealing with the waste and, where necessary, arranging for its disposal. FSA would also help to advise on the disposal of contaminated foodstuffs.

6. THE WAY FORWARD

6.1 ONR will continue to work with a range of UK agencies in seeking to deliver improvements in response to lessons learned from the Fukushima accident. For emergency preparedness and response, this will include working with NEPLG and supporting DECC in their development of a National Strategic Framework for responding to nuclear emergencies. We are fully involved in the governance and delivery of this work.

6.2 We have decided to produce a further report in the autumn of 2012 to provide an update on progress in implementing the lessons for the UK's nuclear industry, including those involving radiological protection and emergency preparedness and response as discussed in this paper.

5. ACKNOWLEDGEMENTS

In preparing this paper we are indebted to many colleagues in the Office for Nuclear Regulation (ONR) and those outside of ONR who have contributed to Dr Weightman's Interim and Final Reports on this topic.

References

1. *Japanese earthquake and tsunami: Implications for the UK nuclear industry. Interim Report* ONR Report ONR-FR-REP-001 Revision 3 HM Chief Inspector of Nuclear Installations, 18 May 2011, www.hse.gov.uk/nuclear/fukushima/interim-report.pdf

2. *Japanese earthquake and tsunami: Implications for the UK nuclear industry. Final Report* ONR Report ONR-FR-REP-11-002 Revision 1 HM Chief Inspector of Nuclear Installations, September 2011, www.hse.gov.uk/nuclear/fukushima/final-report.pdf

3. *Nuclear Emergency Planning Liaison Group Consolidated Guidance*

http://www.decc.gov.uk/en/content/cms/meeting_energy/nuclear/safety_and_sec/emergency_plan/neplg/guidance/

4. *Arrangements for Responding to Nuclear Emergencies*, HSE Books, 1994, ISBN 9780717608287

5. *Mission report* IAEA International Fact Finding Expert Mission of the Fukushima Dai-chi NPP Accident Following the Great East Japan Earthquake and Tsunami Tokyo, Fukushima Dai-ichi NPP, Fukushima Dai-ni NPP and Tokai Dai-ni NPP, Japan 24 May–2 June 2011.