Rethinking our readiness for rapid response radiation monitoring in the face of nuclear incidents

Image: Mads Eneqvist

White Paper

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Foreword

I am honoured to declare my recognition and support for this publication which, unusually in these matters, encapsulates both the nature of a fundamental problem facing the world, alongside a proven technology to deal with the most essential part of it.

Nuclear danger is back near the top of the international security agenda. When the Cold War came to an end the possibility that nuclear weapons might be used somewhere, sometime, seemed to recede. 'Nuclear conflict' was regarded as a residual legacy of the old world. The declining interest in nuclear conflict was reinforced by the stuttering record of civil nuclear power generation across the developed world; it didn't seem as if civil nuclear power would play such a big part in the world's energy future after all. 'Nuclear dangers' seemed like yesterday's concerns, or else concerns that were just part of our societal baggage.

However, we have all been rudely awakened to the greater dangers mankind has faced over the last decade, and particularly in our most recent turbulent years. The 'big four' powers in the world – the US, China, Russia and India – are engaged in various levels of antagonistic competition with one another. Their mutual relationships set the political weather in which the rest of us, even within the prosperous 'post-modern' societies of Europe, have to exist. And the political weather at the moment is moving in favour of much greater nuclear weapons proliferation across the globe; just as it is moving in favour of greater moral tolerance for the use of other weapons of mass destruction, such as chemical, biological or radiological devices. We can see this clearly in the Middle East, in Central and East Asia, and across Pacific Asia – even perhaps now in Eastern Europe since the onset of the war in Ukraine. There is nothing in the current picture to suggest that global conflicts are declining, quite the opposite.

The cooperative international framework actively to discourage the resort to weapons of mass destruction during conflicts – through arms control, treaty regimes, international law, and the force of global opinion – has been weakening all the time since the beginning of this century. It is now weaker than at any period in my own lifetime.

Simultaneously, the manifest threats to human welfare posed by climate change and environmental stress are now abundantly self-evident. Humanity faces an urgent need to decarbonise and move away, as fast as possible, from burning fossil fuels. The world is turning urgently back towards the use of nuclear power as part of the international response to climate change. This is particularly the case for the developing world, whose energy outlook is otherwise frankly bleak. As civil nuclear energy generation grows – particularly under the urgent pressures of climate change targets – and as we *see the consequences of delay meeting those targets in ever more frequent extreme weather events, we have to accept that there will be a greater incidence of potential nuclear accidents. Whatever our safety protocols may be on paper, accident risks are statistically destined to grow in burning nuclear fuel, in processing it, in storage, transport, security, and so on, through a range of ancillary functions.*

So, we are living in a world in which the threat of accidents, or indeed of malign intent, in relation to nuclear, chemical, biological, and radiological dangers is already increasing and is certain to go on increasing. What are responsible governments to do?

The most important first step is to have some early warning of particular threats as they take shape. Early detection, monitoring and then mapping a threat must lie at the heart of any strategy that aims to get to grips with emergent challenges. Strategies have to be developed that can understand a threat properly and then triage available resources to deal with it. The aim must be to build infrastructural resilience so that medical, informational, data, public and private resources can be allocated at the most appropriate time and in the right order. That, of course, sounds obvious. But as the Covid crisis demonstrated yet again, it is remarkably difficult to achieve in the real world of politics and public administration.

The best chances governments and societal organisations have to get this sort of sequencing right is to have genuinely early warning, with details, of the safety challenges they might be facing. That depends on good technology. Fortunately, such technology now exists. It is no longer exquisitely complex, nor prohibitively expensive. Nor is it hard to apply and adapt. In a very short time such technologies, as outlined here, have become effectively ‘mature’. And from that baseline they are continuing to develop and expand quickly.

Time is of the essence; to monitor the new dangers of nuclear proliferation, to meet climate change targets, to replace fossil fuel energy sources, to mobilise global opinion effectively by showing that scientific and technological solutions are within our grasp – and therefore that our political priorities should embrace the opportunities now on offer.

This work deals with some daunting global problems facing humanity. But it is a report of genuinely good news. We should celebrate such good news, and act on it while we still have this opportunity.

Prof Michael Clarke
Visiting Professor, Strategy and Security Institute, University of Exeter and former Director General of the Royal United Services Institute.

Executive Summary

The UK Government, and indeed administrations the world over, must learn the lessons on preparedness that COVID-19 has brutally taught us. Events of the last few months have escalated the risk of a nuclear incident to levels not seen since the Cold War.

A combination of belligerent rhetoric and armed conflict within the Chernobyl Exclusion Zone and in close proximity to operational nuclear reactors, have awakened the public to the prospect of internationally significant fallout. In addition, the global drive for net zero will necessitate the construction of new nuclear reactors in developing nations, vulnerable to severe weather, natural disaster and civil unrest.

It is the UK Government's intent to embrace the "safe, clean, affordable new generation of nuclear reactors, taking the UK back to pre-eminence in a field where we once led the world". While this is a very sensible strategic move, we need to ensure that we have all supporting safety and security measures in place to respond to a nuclear incident in the UK.

With about 30 countries considering, planning, or starting nuclear power programmes, the expansion of civil nuclear reactors increases the potential for a nuclear incident to happen. We therefore need to make sure that our ability to respond to an international incident is as robust and up to date as possible. This also poses an opportunity for the UK to export its expertise in rapid response monitoring and to be the partner of choice for building indigenous capability.

The potential for nuclear incidents in the near future

Multiple nuclear disasters have been narrowly avoided in the early stages of the Ukrainian conflict.

The recent sinking of the Russian flagship Moskva was a potential nuclear disaster narrowly avoided, as the ship was reported to be carrying multiple nuclear munitions as part of its inventory of R1000 Vulkan missiles.

Nuclear incidents have been narrowly avoided at civil nuclear facilities including Chernobyl and Zaporizhzhia plants as well as waste storage and research facilities in Kharkiv and Kyiv.

Zaporizhzhia plant, consisting of 6 VVER-type pressurised water reactors, was at substantial risk of triggering a loss of coolant incident, which was the direct cause of the Fukushima disaster. There is still a substantial residual risk with this site, given the reactors are running again but under Russian control which prevents the site operating independently and as per regulatory requirements.

It is unclear whether nuclear facilities briefly held by the Russian forces in the Chernobyl area still have a full inventory of nuclear materials and sources. Reports indicate that nuclear materials, including sealed sources, have been taken by the Russian forces and a full facility inventory for the Chernobyl Exclusion Zone and its associated processing and storage facilities has yet to be defined. There are legitimate concerns about the nefarious reutilisation of materials for Radiological Dispersion Devices (RDD).

Three scenarios of deliberate release look increasingly viable as war in Ukraine seems to stretch the objectives of its aggressors. First, is a radiological dispersion incident. There are many permutations and combinations of this scenario but let us examine the most obvious.

A RDD event in Russian territory, focused in a major conurbation enacted by the Russians as a false-flag attack could be used to justify nuclear escalation. As already mentioned, it is still not clear what nuclear materials or other radiological materials may have been taken from Chernobyl, Zaporizhzhia or elsewhere within Ukraine. Any such materials could form the radiological component of an RDD.

As Russian frustrations over NATO support for Ukraine increase, it is plausible that an RDD event could be enacted by Russia in a NATO or other Ukraine-supporting country, badged as a reprisal by Ukrainian separatists. Many other permutations and combinations are considered possible.

In any case, in the event of a RDD event, there is a need for a local emergency response which is well trained and well equipped. Whilst a first responder might be able to identify elevated radioactivity with a simple Geiger-Muller (GM) counter, this technology is arguably unsuitable for the ensuing logistical response that is required. This is because a GM counter can only indicate that there is increased radioactivity but cannot define either the actual intensity. A dosimeter can measure the radiation levels but importantly, as with GM counters, cannot determine the radioisotopes present following an RDD event, yet this is one of the primary needs immediately after an event. Determining the isotopes responsible for the radiation defines the radiological, and to an extent, the associated chemical threat as some of these materials are poisonous even in miniscule quantities. This means that portable gamma spectrometers are needed from a very early stage.

Following an RDD event, there is an immediate need to delineate the area affected by radiation – this requires intelligent gamma mapping capability. Provided that suitable technology is quickly available, this can be achieved by rapidly establishing a network of spectroscopic monitoring units, some of them in fixed locations, some of them on mobile vehicles including drones or ground robots, but some also carried by specialists wearing suitable PPE. These specialists might also gather samples as nuclear forensic evidence to determine material provenance.

Subsequently, due to wind and rain this initial disposition of material might change and do so quickly, depending on weather patterns and hence there is a need for repeated and regular monitoring from the period of initial response and throughout clean-up and recovery. A quickly established radiation monitoring network would provide a means of mapping these dispositional changes as a function of time, thereby informing the best locations for clean-up and sampling as well as delineation of the hazard areas.

For example, rain will cause radiological run-off into sewer systems, whilst wind will carry radioactive fines downwind, potentially for significant distances and spreading the contamination to new areas. Whilst an RDD is designed to incite terror and fear, potentially even mass evacuation, the amount of radioactive material in such a device is typically expected to be small and hence the residual radiological threat is likely limited in extent. However, this does not mean they cannot be disruptive for long periods. Accumulation of radiological material in a municipal sewerage system may render it temporarily impossible to maintain, meaning that a city might have to be partially evacuated not because of radiation threat to the general population but simply because the toilets are backed up. This was clearly evidenced post-Fukushima in 2011.

Depending on the beta/gamma doses of the affected area, there may or may not be a need for surveying to be conducted remotely using ground and/or aerial robotics. This must be decided rapidly, but in any case, relies on the availability of gamma spectrometers and dosimeters to define the intensity of the radiological hazard. If the hazard is sufficiently high, then the option of a robotic deployment also needs to be available, and quickly.

Beyond an RDD, the next level of nuclear escalation, considered viable, is the utilisation of a short-range tactical nuclear weapon by Russia. It is not immediately clear what international response would be triggered by the use of such a device. The general expectation is that on balance it would be unlikely that western powers would respond with nuclear force.

This takes us to numerous different radiation fallout scenarios depending on the strike location of any device. There is a contrasting source term between detonations over the sea versus over urban versus rural areas. The fallout terms in each case are different because although the warhead materials are always the same, the material source term for neutron activation is different between the three basic scenarios.

This again invokes the need for a rapid response spectrometry capability and the need for repeat measurements and surveys for areas affected by fallout plumes in the hours or days following the detonation. Contamination would be spread over a larger area than an RDD up to several square kilometres, but again the need for rapid and repeat surveying would be acute.

The third, and worst-case, scenario, is the detonation of a high yield atomic bomb. The effects would be much greater that the short-range tactical detonation scenario, but the residual response and recovery issues would be similar but over a much larger scale.

Looking up momentarily from the immediate conflict in the Ukraine, there is a vigorous global agenda for achieving net zero carbon emissions. For most countries the aim is to achieve this by the middle of the century, perhaps even accelerating ahead of this driven by the current Ukraine crisis, which is ending Western European reliance on Russian gas supplies.

Many countries are once again looking at new nuclear stations, as a secure and reliable carbon-neutral electricity source. The UK has set nuclear firmly back on the agenda, but some countries are setting a civil nuclear energy agenda for the first time, especially in the Middle East with countries including Saudi Arabia, UAE, Egypt, Turkey and Jordan all with strong civil nuclear ambitions. Over the coming decades it is plausible that a major nuclear incident might occur in one of these countries, either due to inexperienced or negligent operation of civil plant, or due to terrorism, civil war or even invasion.

So, whilst these are numerous potential scenarios that could occur overseas in the coming months, there is also a smaller prospect of an incident directly affecting the UK both in the short and medium term. Hence, with all of these unpalatable scenarios being considered as possible, what should the UK and other western nations be doing in terms of preparedness and support?

What does preparedness look like?

Sufficient preparedness is almost certainly not a governmental memo to procurement to stockpile of iodine capsules and GM counters. Instead, a more holistic approach needs to be considered, including everything from developing plans for public messaging, plans and training for emergency responders, national recovery teams and healthcare providers, as well as provision of suitable PPE and modern detection, identification and mapping equipment.

The UK has not updated its publicly available thinking since 2015 [1]. A lot has changed in terms of global nuclear risk in the past 7 years and hence it is necessary that planning for preparedness is revised, which, following other international examples should be more readily available and easily digestible for the public.

The COVID pandemic has been a wakeup call on preparedness, especially when it comes to PPE and equipment.

Of course, there is an unavoidable cost to retaining any type of equipment stockpile. This is driven by the need to periodically check, maintain and eventually replace items. For any major risk scenario, from an influenza pandemic to nuclear disaster, there is a need for a country to consider the level of preparedness that they are willing to invest in, in proportion to the risk of not doing so. There were well documented preparedness challenges encountered at the outset of the COVID-19. Based on lessons learned from these and looking at the current likelihood of a major nuclear incident in Europe, it is logical to rethink the correct level of preparedness for a radiological event.

Evolving global nuclear risks

With global warming continuing to put pressure on essential resources such as food and water, forced or induced migration alongside religious or ideological radicalisation may lead to countries currently considered ‘stable’ becoming destabilised and subjected to armed conflict.

As part of a coordinated preparedness strategy, there is a requirement to consider the creation of an international response capability that can deploy to these locales.

Once again, having the necessary ‘readiness’ in terms of quickly available radiation mapping and portable gamma spectrometry technologies, will be universally important to respond adequately to any future incident. In some respects, proactively establishing and maintaining monitoring networks on and around nuclear sites, around critical infrastructure, key cities and even border crossings and ports, could provide an already active capability which has pre-recorded and well-defined baselines for the ‘normal’ levels of radioactivity prior to any nuclear incident. Without such baseline mapping it would be extremely challenging to know what levels any clean-up activity would have to work towards. This was, and still is, a major technical issue for TEPCO and the Japanese government in the wake of the Fukushima incident.

Whilst this position paper has focused on preparedness in terms of rapid response radiation monitoring, it should be acknowledged that a wider associated argument on preparedness for CBRN incidents can also be made. It is essential we get this right for the UK but equally it is also important that we can help our global friends and partners to develop their own thinking and capability around nuclear incident preparedness.

Conclusions

There is a heightened risk of a nuclear event in the short and medium term, both deliberate and accidental. With increasing use of nuclear power in the future, and likely geopolitical instability, it is necessary to be prepared for a rapid response to such an event. Constantly updated plans should include provision for training and response roles and ensure adequate stocks of equipment is readily available in sufficient quantities for immediate response.

A key part of this equipment base should be sufficient technology to detect, identify and monitor the radiation from an event, in order to optimally mitigate the effects. This technology needs to be easily deployable, able to quantify the radiation levels, and identify the isotopes involved.

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[1] https://www.gov.uk/government/publications/national-nuclear-emergency-planning-and-response-guidance

About the authors:

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Former Director-General of the Royal United Services Institute (RUSI) from 2007 to 2015 when he retired from that role. Until 2001 he was Deputy Vice-Principal and Director for Research Development at King's College London, where he remains a Visiting Professor of Defence Studies. From 1990 to 2001 he was the founding Director of the Centre for Defence Studies at King's. He was appointed Professor in 1995. He is now a Fellow of King's College London and of the Universities of Aberystwyth and of Exeter, where he is also Associate Director of the Strategic Studies Institute. He has been a specialist adviser to the House of Commons Defence Committee since 1997, having served previously with the House of Commons Foreign Affairs Committee 1995-6. In 2004 he was appointed as the UK's member of the UN Secretary General's Advisory Board on Disarmament Matters. In 2009 he was appointed to the Prime Minister's National Security Forum and in 2010 to the Chief of Defence Staff's Strategic Advisory Group. He also served on the Strategic Advisory Panel on Defence for UK Trade and Industry and in 2014 was Chairman of the Defence Communications Advisory panel for the Ministry of Defence. In January 2016 he was appointed a specialist adviser to the Joint National Committee on Security Strategy for the period of the current Parliament.

Prof Thomas Scott. Royal Academy of Engineering Research Chair and William Penney Fellow, University of Bristol

Tom is an academic co-funded by the Royal Academy of Engineering, UK Atomic Energy Authority (UKAEA) and the Atomic Weapons Establishment (AWE), with expertise in materials, devices and instrumentation applied to Nuclear Fission and Fusion Energy challenges. With extensive experience in radiation detection, fission and fusion materials and manufacturing, Tom runs a multi-million-pound programme of fundamental and applied research working closely and successfully with the nuclear industry, government, and international partners, especially AWE, UKAEA, Magnox, EDF and Sellafield. With a distinguished track record in research and innovation and as Director of the South West Nuclear Hub, a consortium of industry and academic bodies interested in research, skills and innovation in nuclear, he is an acknowledged expert in mapping and monitoring of nuclear sites and facilities using novel sensors and robotic platforms.

Mr Nick Tomkinson. Senior Partner, Global Nuclear Security Partners

Nick is a national and nuclear intelligence and security expert with over 20 years' experience in Government and the private sector. Nick has a thorough understanding of international nuclear sectors and their relevant fuel-cycles. He has worked extensively with overseas partners, including helping foreign governments to develop national level approaches on working between industry and government in protecting critical national infrastructure. He has led analytical and operational teams to understand and act on attempts by foreign countries to bypass safeguards, divert material and procure goods for nuclear weapons programmes. He has led on strategic policy and operational advice relating to Plutonium & Highly Enriched Uranium security & transportation, including consolidation of all UK holdings. He has supported multiple clients over the course of his consulting and works with clients across the civil and defence nuclear sectors. Nick is also a Certified Nuclear Security Professional through the World Institute for Nuclear Security (WINS).

Dr Arnab Basu. CEO, Kromek Group

Arnab is the founding CEO of Kromek Group plc, a leading developer of radiation detection and bio-detection technology solutions for the advanced imaging and CBRN detection segments. Headquartered in County Durham, UK, Kromek has manufacturing operations in the UK and US, delivering on the vision of enhancing the quality of life through innovative detection technology solutions. In CBRN detection, the Group provides nuclear radiation detection solutions to the global homeland defence and security market. Kromek's compact, handheld, high-performance radiation detectors, based on advanced scintillation technology, are primarily used to protect critical infrastructure and urban environments from the threat of 'dirty bombs'. The Group is also developing bio-security solutions which consist of fully automated and autonomous systems to detect a wide range of airborne pathogens.